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# Minto Mine Constructed Wetland Treatment Research Program - Site Assessment

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## 1. Abbreviations and Definitions

**CWTS(s)** – Constructed Wetland Treatment System(s)

**DNA (deoxyribonucleic acid)** – is the hereditary material in humans and almost all other organisms. This can be used to identify organisms.

**DO** – dissolved oxygen

**DSTSF** – Dry Stack Tailings Storage Facility

**Heterotroph** – an organism deriving its nutritional requirements from complex organic substances.

**Metagenomics** – the study of genetic material recovered directly from environmental samples, related to a community rather than an individual organism.

**Microbes** – microscopic organisms which may be uni- or multi-cellular. This includes algae, bacteria, fungi, viruses, and yeast.

**MPN (Most Probable Number Method)** – a statistical value representing the viable population of microbes in a sample through use of dilution and multiple inoculations.

**MVFE** – Mill Valley Fill Extension

**Oxidation** – is the loss of electrons or increase in oxidation state by a molecule, atom, or ion. Can be catalyzed by microbes.

**Redox** – Oxidation-reduction potential, measured in millivolts

**Reduction (chemical)** – is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion. Can be catalyzed by microbes.

**SeIV broth or agar** – laboratory growth medium that contains selenite (SeIV) and indicates reduction of selenite to elemental selenium through a visible colour change.

**Species** – one of the basic units of biological classification and a taxonomic rank. Rank in the classification of organisms below genus and above strain.

**SWD** – Southwest Waste Dump

**Taxonomy** – classification, identification, and naming of organisms.

**TSS** – total suspended solids

**YTS250 (Yeast, Tryptone, Starch, 250g each)** – a type of laboratory growth medium used for environmental microbes.

## 2. Introduction

Constructed Wetland Treatment Systems (CWTSs) have been identified as a contingency method for improvement of the quality of site runoff water in the post-closure period for the Minto Mine (Minto Phase V/VI Expansion Project, YOR Project Number 2013-0100). Once established, wetlands can become self-sustaining ecosystems with the plants providing yearly renewal of carbon to fuel microbial activity. As such, they possess the desirable potential to remediate contaminated mine drainage for as long as it is generated. In order for the CWTS to be effective, they must be designed, piloted, optimized, implemented, and maintained in a site-specific manner.

At the request of Minto Explorations Ltd, Contango Strategies has undertaken a site assessment to inform the design of site-specific passive treatment technologies for the Minto site during post-closure. The overriding goal of the study was to identify natural water treatment processes that are currently occurring at the Minto site in areas receiving impacted waters, and how these could be optimized for passive water treatment in closure. As such, the focus of the research program reported here was on areas that currently receive impacted waters (Figure 1), with emphasis on the W15 monitoring station and upstream creek and wetland area that receive seepage and runoff from the Southwest Waste Dump (SWD). Additionally, preliminary information was gathered for the W37 area receiving seepage and runoff from the Dry Stack Tailings Storage Facility (DSTSF) and Mill Valley Fill Extension (MVFE) toe area. As was outlined in Appendix W – Preliminary Reclamation and Closure Plan Phase V-VI of the Phase V-VI expansion plan, the focus of work at this point is on the W15 area and SWD. At a future date, additional work will occur in the future down gradient of the DSTSF and within the footprint of the current water storage pond. The site assessment included two visits to the Minto Mine to gather information and samples. Sampling consisted of in situ measurements, collection of samples for physiochemical, geochemical, and microbiological analyses. General

feasibility of implementing passive treatment was also evaluated during the site visits.

It is our understanding that before this site assessment of the natural wetland area, there has been no monitoring of water quality along the creek between the W10 and W15 monitoring points, of the creek entering the W15 monitoring point, or the W15 runoff area entering the W15 monitoring point. Therefore, this study provides new information to inform decisions regarding the plausibility of water treatment by constructed wetlands at the Minto Site.

Copper is of greatest interest in this study, however, there are a number of other elements and parameters that can influence the biogeochemistry of a system and overall treatability of the copper. These include the presence of iron and sulphur, as well as the pH and oxygen content of the environment. Additionally, there are a few other elements (e.g., selenium) that will require some treatment in order to achieve discharge goals.

# 3. Site Visits

## 3.1. Information Gathering

Two site visits were conducted as part of the site assessment for the CWTS. Prior to the first site visit, preparations included gathering site-specific historical and predicted closure information including:

- Rates of seepage for known seeps (and interpretation as a function of dump area and catchments)
- References to analytical results about the site
- Rate of flow for W15 and W37 based on existing data
- Aerial photo interpretation or site personnel knowledge of areas with potentially acceptable granular soil materials, peat, limestone, and organic soils for subsequent on-site materials investigation, inspection and testing.
- Use of site-wide vegetation map to identify areas for possible vegetation borrow sources for the CWTS.
- Determine water quality parameters to be monitored and concentrations that will be used for pilot tests.

## 3.2. First Site Visit

The first site visit was conducted mid-August 2013 and had a primary goal of familiarizing Contango personnel with the site layout and water flows in order

to properly design sampling plans for assessment of existing natural treatment mechanisms occurring on site. Specific information gathered in the first site visit included:

- Visual inspection along the toe of SWD, Main Dump, DSTSF, and area down-gradient of W37 to identify and document primary seeps that have the potential to be intercepted along with an assessment of current fate of seepage surface flows.
- Identify conceptual options for intercepting and routing seepage into the CWTS.
- Selection of a significant seep(s) for further test work based on initial site reconnaissance. Evaluate potential path of seepage interception trench in comparison to seep location(s).
- Identify probable locations for CWTS. Investigation and evaluation of natural remediation processes that may be occurring on site as identified by redox and pH changes between surface water and plant roots, and choice of plant types to be tested in Contango's pilot CWTS tests.
- Identification of borrow sites for CWTS substrate (limestone, coarse sand/gravel, peat, plant sources for much, etc.)
- Identify ideal CWTS plant species based on site observations of vegetation.

Information collected prior to and during the first site investigation were reviewed and then used to refine the scope and direction of data collection in the follow up site visit. The refinement of scope and testing locations was conducted in consultation with ACG and staff from the Minto Mine.

### 3.3. Second Site Visit

A second site visit took place September 20-23, 2013 based on observations from the first site visit and historical and modeling data compiled to date. The purpose of the second site visit was to collect water, soil, plant, and microbiological samples from the natural wetland and creek area flowing between the W10 to W15 monitoring stations. This area begins with a creek that flows from off site through the W10 area and subsequently receives seepage and surface runoff from the SWD, surface runoff from the catchment area (including non-contact waters), and road runoff from a culvert entering the W15 collection pond. Samples were taken from potential borrow sources to assess suitability of the materials for constructing soils for the CWTS. Additionally, *Carex aquatilis* (Water Sedge) and *Sphagnum* (moss) plants were collected at the W10 site and transported back to Contango's CWTS research facilities in Saskatoon for use in the pilot-scale systems to be built specifically for testing and optimization of designs for the Minto site.

# 4. Experimental Setup

## 4.1. Sample and Analytical Data Collection

During the second site visit, fourteen different locations were sampled at the Minto Mine Site (Table 1 and Figure 2). Samples were collected starting at the most downstream location (W15) and progressing upstream to the W10 area over a period of 2 days. In all cases, water samples were collected first, then soil and plant samples. Water and soil samples were collected by grab sample, with soil sampled to a maximum depth of 5-7 cm. Water, sediment, and plant samples were submitted to Maxxam Analytics and analyzed for parameters listed in Table 2. For plants, only the above water (or above ground) portion was analyzed. For *Carex aquatilis*, *Equisetum* sp. and *Sphagnum* sp., the entire above ground (or water) portion was analyzed. For *Salix* sp., only the recent year's growth was collected. All micro samples were processed according to Sections 4.2 and 4.3.

## 4.2. Growth-based analyses (MPN)

The most-probable number (MPN) of bacteria was determined for all micro samples (Table 1). The test allows for estimation of the number of bacteria that can grow in a specific laboratory medium. The mediums tested for in this project were specific for bacteria that can reduce nitrate, selenite, and sulfate, respectively, as well as the total number of heterotrophic bacteria for comparative purposes (i.e., a growth-permissive test for all bacteria capable of growing on organic carbon as an energy source). MPN tests for sulphate (Active Standard ASTM D4412) were performed under anaerobic conditions, whereas selenite (Siddique et al., 2006) and nitrate (Nitrate Reduction Test, supplied by Sigma-Aldrich) were tested under aerobic conditions. Total heterotrophs (grown with YTS250 medium; Lefrançois et al., 2010) were tested for in both aerobic and anaerobic conditions. In brief, sediment samples were diluted 1:10 with a 0.1% peptone solution. This dilution was then used to perform a serial dilution along a sterile 96-microwell round-bottom plate containing the respective growth media. Sediment dilutions tested in the MPN plate ranged from 1/400 to 1/419,430,400. At a minimum, all tests were performed in duplicate. Wells were incubated at +30°C in a dark incubator and assessed for visible growth (formation of a bacterial pellet) and/or colour change specific to the type of media after 16 (aerobic) or 28 (anaerobic) days. A colour change to black or red/orange indicated sulphate or selenite reduction, respectively. Nitrate reduction was tested as per the kit manufacturer's protocol by addition of reagents to differentiate between reduction to nitrite or nitrogen gas. The most probable number of bacteria capable of each metabolism was then calculated as

described in the FDA Bacteriological Analytical Manual, Appendix 2: Most Probable Number from Serial Dilutions: (http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm109656.htm).

### 4.3. DNA-based analyses

DNA was extracted from all samples using the MO BIO Powersoil Powerlyzer DNA extraction kit. To identify the bacteria present in each sample, we performed targeted sequencing. The gene that is targeted by polymerase chain reaction (PCR) for bacteria is the v4 region of the 16S ribosomal RNA gene (Caporaso et al., 2011). Because the same gene is sequenced for all targeted organisms in a community, the relatedness of different microbes can be inferred based on sequence similarity. As such, the first step in the analysis of targeted metagenomics is clustering similar sequences into groups which are called Operational Taxonomic Units (OTUs). An OTU can essentially be described as a "species cluster", where all sequences present in an OTU are similar and presumed to represent the same or very closely related organisms. The threshold for choosing what is or is not considered the same organism is dependent on the region that is being targeted for sequencing. For example, bacteria are clustered together at 97% identity, as the v4 16S rRNA region that is targeted is known to have ~3% intra-species variation. Once the sequences have been clustered together, each OTU is assigned a taxonomy based on similarity with sequences from known organisms (using databases specific for each targeted region). The taxonomy classification is very dependent on the presence of that organism in the databases that are being used. For example, if a novel bacterium is sequenced, no taxonomy is assigned because no representative would be present in the database. Furthermore, different levels of taxonomy can be assigned based on how confident or similar the sequence is to known organisms. An OTU can therefore sometimes be classified as "Bacteria", or a second OTU as "Bacteria;Proteobacteria" as the software pipeline is not confident in the assignment of lower taxonomy levels, while a third OTU may be classified as "Bacteria;Proteobacteria;Epsilonproteobacteria;Campylobacterales; Helicobacteraceae;Sulfurimonas" based on high similarity with other *Sulfurimonas* sequences found in the database. While we cannot always confidently assign names to each of these OTUs, we can be confident that they are different from one another, as we have already compared their sequences. Hence, even though in this example both the second and third OTUs belong to the *Proteobacteria* phylum, we are confident that they are in fact different organisms. Once taxonomy has been assigned, the abundance

of each OTU in each sample is determined. To compare the community profile of different samples, a multitude of statistical analyses were performed.

# 5. Results and Discussion

## 5.1. Site Assessment

The sections below correspond to results and discussion specific to each of the objectives that are reiterated here for ease of reference.

- Visual inspection along the toe of SWD, Main Dump, DSTSF, and area down-gradient of W37 to identify and document primary seeps that have the potential to be intercepted along with an assessment of current fate of seepage surface flows.
- Selection of a significant seep(s) for further test work based on initial site reconnaissance. Evaluate potential path of seepage interception trench in comparison to seep location(s).

Fourteen sites at the area receiving water from the SWD were selected for further testing (Table 1, Figure 2) and assessed for the parameters listed in Table 2. These include 3 seeps that are part of Minto's routine monitoring program (W32, W38, W39) as well as areas of the creek parallel to the seep (W38 Creek, W39 Creek, W32 Creek). Additionally, the W32 area had visible seepage between the seep and creek, and there were two distinctly different branches of the creek itself. Therefore, a total of four samples were collected at the W32 location. These are the W32 Seep, W32 Creek, W32 Mid (further seep between the toe seep and creek), and W32 Creek Red. The W32 Creek Red sample is a distinct branch of the W32 creek that was covered in red foam in August, and red precipitate on the soil in September (Figure 3). It should be noted that due to the parallel selection of sites and the direction of flow in the area between the seeps and creek, the water from seep W38 would never be present in W38 creek. We realize it is not possible to know the exact areas of entry of the seeps into the creek unless detailed hydrological studies and use of tracers were used; however, the purpose of this site assessment was to determine overall trends in water chemistry through the site and not a thorough hydrological investigation. During the first site assessment to locate priority sampling areas, the weather was hot (>+30°C daytime temperature) and dry, and therefore the seeps marked for routine monitoring (including W32, W38 and W39) were mostly dry with no visible standing or flowing water. However, these sites are routinely monitored and have a wealth of historical data relating to toe seepage from the SWD, and so they were identified as high priority areas. During the second site visit, snowmelt was causing a greater volume of seepage than in

the first visit. Water pools were present at all marked monitoring seepage points along the SWD toe, some with visible flows.

Runoff was observed directly from the road above via a culvert entering into the W15 collection pond, bypassing the creek and natural wetland area entirely (Figure 2). This "culvert runoff into W15" was sometimes clear, but at other times muddy, seemingly when the grader passed over the road on its routine schedule. While flow volumes and periodicity would need to be determined in order to calculate actual contribution to loading and concentrations, it is likely that water from the culvert (runoff into W15) is contributing to elevated concentrations of constituents of concern that have been observed to coincide with high total suspended solids (TSS) events at the W15 monitoring station at the far end of the pond (Figure 2).

Further geotechnical and hydrological assessments of the W15 area are planned to determine the depth of seepage, to ensure that the interception trench is adequately built such that seepage does not pass below it, and to delineate the extent of permafrost. This will be conducted under a separate scope of work.

The W37 area was inspected during the first site visit. However, as noted in the Phase V/VI project proposal, this area and the MVFE are likely to change with further development prior to closure. As such, they were not targeted as a key area for research at this time.

- Identify conceptual options for intercepting and routing seepage into the CWTS.

The W15 and W37 (Figure 1) areas are both in natural depressions and likely suitable for implementation of a CWTS, although this will also cause the depressions to receive non-contact runoff water from the general catchment area. Due to the multiple seeps along the toe of the SWD, an interception trench would be needed to collect the seepage and direct it towards the entry of the CWTS. Alternatively, it may be possible to construct several smaller CWTSs, each with their own entry point for seepage. These two options will be evaluated as information pertaining to flow rates and removal rates are refined through scientific testing and continued gathering of information from the site.

W37 area appeared to be amenable to future implementation of a CWTS. We recommend that studies be conducted on the sediments under the current water storage area behind the dam, in order to ensure there has been no accumulation of elements that might be released upon oxidation once the dam is breached upon closure.

- Identify probable locations for CWTSs. Investigation and evaluation of natural remediation processes that may be occurring on site as identified

by redox and pH changes between surface water and plant roots, and choice of plant types to be tested in Contango's pilot CWTS tests.

The W15, W37, and Main Pit have been identified as probable locations for CWTS in closure (Figure 1). The natural remediation processes occurring at the W15 site were investigated and evaluated in the second site assessment, with results and findings detailed in this report. We were unable to measure soil redox, however, as the water temperature was too cold for the reference probe, causing its internal buffer solution to crystalize (+0.5°C).

- Identification of borrow sites for CWTS substrate (limestone, coarse sand/gravel, peat, plant sources for much, etc.)

Overburden piles of sand and peat were located and tested for parameters relevant to their use as a soil in the CWTS. The samples of borrow material are suitable for use in a future CWTS. A source of slow release carbon (e.g., wood chips) is still yet to be identified.

- Identify ideal CWTS plant species based on site observations of vegetation.

Plant species and associated findings are discussed in section 5.3 below.

### 5.2. Water and Sediment Geochemistry

Dissolved chloride concentrations in the water can be used as a proxy to determine if concentration decreases in other elements can be attributed to dilution or putative treatment mechanisms. Comparison of changes in concentrations of elements of interest along the creek indicates fluctuations are similar to those of chloride, indicating dilution rather than treatment is occurring within the free flowing areas of the creek itself (Table 3). However, comparison of the water exiting and entering the W32 Creek Red site shows substantial treatment of copper and also some treatment of selenium and sulphur (Table 4). Comparison of the seeps with the creek also indicates significant treatment of copper, selenium and sulphur (Table 5). Overall, this indicates that active treatment of elements is occurring in the vegetated areas between the seep and the creek, but little or no treatment occurs in the creek itself. In this case, averages were used for the creek as the actual flow of seeps, and entry points into the creek are not known. More refined calculations cannot be made without detailed hydrological information for the area. Figures 4 and 5 show only small changes in chloride concentration through the system, yet large fluctuations in concentrations of other elements occur, especially near the seeps. Moreover, the chemistry of each seep varies greatly from one another, while the concentrations of elements in

the creek show more consistency (Figures 5-7), supporting the notion of treatment between the seep and creek, which evens out these fluctuations in chemistry by the time the water reaches the creek.

At the furthest upstream location sampled in this assessment, the W10 site has some of the highest copper concentrations in sediment (Figure 8), yet some of the lowest concentrations of copper in the water (Figure 6). This could reflect that the W10 site has been accumulating copper for a longer time span (i.e., in existence for more years, as it is a background location, upstream of the SWD), or perhaps the materials used to build the access road near the W10 contained copper and spread further than is currently visible due to overgrowth. This could also be caused by removal of copper from the water and into the sediment by binding to oxidized iron as suggested by the ratios of total vs. dissolved iron at that sampling area, with further stabilization (retention) of the copper promoted by conditions (redox, pH) in the sediment created by the combination of plants, microbes, and chemistry in the area.

The culvert runoff into W15 area has the highest copper concentrations in both sediment and water (Figures 6 and 8). The W15 runoff area has a separate and independent flow than the creek, entering the W15 collection pond via a culvert from the road above, bypassing the creek and natural wetland entirely (Figure 2). The culvert runoff into W15 appears to only flow during melt and rain events. This W15 runoff was sometimes clear (as in the time the sample for this study was taken), but at other times is muddy, seemingly when the grader passed over the road on its routine schedule. While flow volumes and periodicity would need to be determined in order to calculate actual contribution to loading and concentrations, it is likely that water from the culvert (W15 runoff) is contributing to elevated concentrations of constituents of concern that have been observed to coincide with high TSS events at the W15 monitoring station at the far end of the pond. This can be seen in Figure 9 as the W15 inflow (from creek) has a lower concentration of key elements (e.g., copper, selenium) than is routinely measured at the W15 monitoring point. The only visible source for this loading is the culvert runoff into W15. This is a key finding of this site assessment, as the routine sampling performed at the set W10 and W15 monitoring points would indicate that there is less treatment ongoing in the natural wetland area than is truly occurring. This is because of the extra loading of contaminants contributed by the culvert runoff into W15 mixing in the collection pond with the cleaner water exiting the natural wetland area before reaching the W15 monitoring point (Figures 6 and 7).

The W32 Creek Red site is a location between the W10 (upstream) and W15 (downstream) areas where the creek briefly splits into two steams at the W32 clearing. The W32 Creek Red sample has a high concentration of oxidized iron, indicated by a visible red precipitate (Figure 3). At the first site visit in August, the red substance was fluffy and floating in the water and

also on the sediment. In September, the red substance was entirely at the sediment interface. Moreover, the water exiting the W32 Creek Red site has the lowest concentration of copper in the water (at 1.92 µg/L, the only site sampled in this study with copper concentration below CCME guidelines). This finding, paired with moderate concentrations of copper in the sediment at the W32 Creek Red site compared to other locations (Figure 8), suggests that copper removal may be occurring via binding to oxidized iron at the W32 Creek Red site. It would be useful in the future to monitor sediment redox at this and other sites; however, the water temperature (+0.5°C) was too cold for the reference probes to be used at the time of the September sampling event. There were several other smaller areas similar in appearance to the W32 Creek Red site found along the creek, always where water was shallow and *Equisetum* or *Carex* present.

The W32 Seep has low ammonia (9.4 µg/L) and high nitrate (39.9 mg/L) concentrations in the water relative to other samples (Figure 7). It appears that the ammonia is being oxidized to nitrate as it seeps through the waste rock pile, which is consistent with the peaks of sulphur and selenium concentrations in the water at the W32 site, both of which could be released from the waste rock under oxidizing conditions. In contrast, the W32 Creek and W32 Creek Red water samples have higher concentrations of ammonia and lower concentrations of nitrate than other samples (measured as N, 0.11 and 0.18 mg/L ammonia and 3.02 mg/L and below detection limit (<0.02 mg/L) for nitrate, respectively; Figure 7). It is possible that there are greater concentrations of ammonia seeping from the SWD between the W10 site and W32 creek sampling point, or that the ammonia is being produced within the creek from decaying organic material. It is also possible that the ammonia is being produced by the abundant *Geobacter* bacteria at the W32 Creek Red site (see section 5.4), as it is a known iron-reducing organism that feeds on electrons from oxidized iron and can also respire nitrate to ammonia (Lovley & Phillips, 1988; Senko & Stolz, 2001).

As would be supported by redox and biogeochemical theory, there is a strong correlation between ammonia and total iron concentrations in water (Figure 10), while iron and nitrate show a negative correlation. This makes sense from a theoretical oxidation-reduction chemistry perspective, as ammonia will oxidize into nitrate, increasing nitrate concentration while the same oxidizing environment will cause iron to oxidize and precipitate from solution. Conversely, the sulphur, selenium, and copper concentrations in water are positively correlated to the nitrate concentration in water (Figure 10), as would be expected since sulphur and selenium are normally present as soluble compounds in oxidizing environments. Likewise, at increasingly

negative redox nitrate will be reduced to nitrogen gas, followed by selenate/selenite to elemental selenium and at an even lower redox, sulphate is reduced.

### 5.3. Plants

*Sphagnum* (Moss) was found to grow in nearly all areas of the site, except directly at the outlet of the creek to the W15 pond. *Salix sp.* (Willow) was found at all sites, except at sites in the W32 area, which appeared to have been cleared at some point. *Carex aquatilis* (Water Sedge) was dominant within the W32 area that was recently cleared (Figure 11), and also within the W10 area where the water was deeper. *C. aquatilis* was found to be spreading through the W10 area access road, being the first plant to colonize the road and even recent tire ruts (Figure 12), indicating that it will be a potentially good choice for quickly establishing the CWTS. However, at locations with shallower water, *C. aquatilis* and *Sphagnum* coexisted, and *Equisetum* was also present, growing through the *Sphagnum.* This suggests that if water depth is not maintained, *Sphagnum* and *Equisetum* will grow in succession.

Compared to the other plant species tested, *Sphagnum* showed significantly greater uptake of elements such as copper, uranium, and iron at all sites that *Sphagnum* was available (Figures 13 and 14). No detectable selenium was found in any of the plants except for *C. aquatilis* and *Sphagnum* at the W32 Seep site (0.7 mg/kg) and *Sphagnum* at the W32 Mid site (0.3 mg/kg). This is presumably due to higher amounts of selenium being present in water at the W32 Seep site (Figure 6). Uptake of copper and iron in all plants was negatively correlated with copper concentration (-0.904) or iron concentration (-0.994) in sediment at each location, respectively. These findings suggest varying bioavailability of copper at the different sites sampled, and when elements are being deposited into the soils, they are in forms (species) that are less bioavailable to the plants than when in aqueous form.

All cases of water channeling through the natural wetland area were in association with *Salix* plants (Figure 15). *Salix* species had the least uptake of elements compared to other plant species at most of the sites (Figure 13). The root structure of these plants appears to contribute to the creation of channelized creeks, which also corresponds with little or no treatment occurring in the creek area. *Salix* has not regrown in the W32 area that was previously cleared, and it is recommended that this area be surveyed yearly

to assess whether they will begin to reestablish in this area. It should also be determined when the W32 area was cleared. This information will be used to establish a maintenance schedule for the wetlands, as young *Salix* plants should be removed before becoming well established.

Although a greater water depth is one parameter that can be used in CWTS to create an anaerobic redox and decrease dissolved oxygen concentration in the water, the research conducted here has shown that *Sphagnum* can be an effective means of removing elements from the seepage through uptake, a finding supported by literature. As such, this potential succession of plants may occur, but is not expected to significantly impact the performance of the CWTS, and may even improve the performance via plant uptake in the *Sphagnum*.

### 5.4. Microbiology

Genetic profiling of the microbial communities indicate great diversity with hundreds of species, but for the purpose of discussion in this section, the top ten most abundant organisms are focused upon (Appendix I). When assessing the microbial genetic profiles of all sites, most samples have a very similar distribution of organisms (Figure 16). The outflow of the W15 creek was sampled in triplicate as a control for microbial variability within a given sampled site. All of the creek samples receiving seepage (W32, W38, W39, and the three W15 sites) cluster together, which indicates similar microbial profiles. All three W15 sites show nearly identical microbial distributions (Appendix I and II), while strong similarities are found for all creek sites. One common trend in all creek sites is the presence of the *Intrasporangiaceae* organism group (yellow in Appendix I). This group appears to be closely related to *Tetrasphaera,* which are known to be involved in phosphorus removal from wastewater. Conversely, the W10 and W10 *Carex* Root samples show distributions more similar to one another than to the downstream creek locations. A large distribution of the organisms at W10 and W10 *Carex* Root locations represents the order *Bacteroidales*, which are ubiquitous colonizers of a wide range of environments (e.g., soil, activated sludge, decaying plant material, compost, fresh water and marine samples, dairy products). However, the W10 *Carex* Root had a denser population of organisms than the W10 sample taken away from plants in the area (i.e., # of organisms per gram of sample; Figure 17).

Laboratory growth-based assays also tested for total heterotrophic, selenite-, sulphate-, and nitrate-reducing organisms at different sites (Figures 17 and 18). The population of total heterotrophs grown under aerobic conditions was

significantly greater than under anaerobic conditions (Figure 18). Interestingly, both the laboratory- and genetic profiling-based methods showed very few sulphate-reducing organisms at most of the sites, with the highest amounts found at the W10 *Carex* Root and W15 inflow sites (Figure 17). The W10 *Carex* Root sampling location also showed interesting sediment features with black color and smell at deeper depths, characteristic of sulphate-reducing organisms, but with red iron oxides visible at the water interface (Figure 19). Selenite-reducing organisms were found at all tested locations, while nitrate-reduction only occurred to completion at the W10 *Carex* Root, W10, W32 Creek Red, W38 Creek and W15 inflow locations (Figure 17). No correlation was found between the number of selenite-, sulphate-, or nitrate-reducing organisms and the water concentration of nitrate, selenium, and sulphate at each location. This is potentially due to the correlation analysis being performed on water concentrations instead of sediment concentrations for these compounds (which is where the reducing organisms would be found), as non-detectable selenium and nitrogen levels were found in most of the sediment samples. In the case of sulphur, the laboratory (Maxxam Analytics) did not perform the requested analysis on the soils, and discussions are ongoing to determine if new samples could be collected and analyzed at their cost to fill in this data gap.

In addition to the red precipitate at the W32 Creek Red site, this location has a unique microbiological profile (Figure 16 and Appendix I). A very dominant percentage of the microbial population at W32 Creek Red is a bacterium called *Geobacter*. This organism is known to seek out insoluble iron oxides, and establish direct contact and reduce them as part of its metabolism. As such, it is likely that the high abundance of *Geobacter* bacteria found at W32 Creek Red is actively reducing Fe(III) to Fe(II), which then reduces Cu(II) to Cu(I) through a coupled biogeochemical reaction. In addition to the interplay between iron-reduction and other elements, the W32 Creek Red site has much lower available phosphorus in the soil and total phosphorus in the water in comparison to the W32 Creek site which is water flowing just adjacent to the red precipitate area, also suggesting that increased microbial activity may be playing a role.

## 6. Summary and Conclusions

Collectively, these findings contribute greatly to the ability to design and operate a CWTS for effective treatment of waters at the site. The geochemical data indicate that substantial treatment of seepage is occurring on site within the natural wetland, validating the concept that a constructed wetland could be designed to function in the long-term closure condition at

the site, but with optimized treatment performance. Mechanisms for treatment of copper and selenium were identified in the natural wetlands receiving seepage from the SWD, including dissimilatory sulfate reduction followed by sulfide precipitation, dissimilatory selenium reduction, and iron co-precipitation.

It is clear that there is greater and faster treatment occurring within the natural wetland than would have been evident if calculated only using data collected by previously existing routine sampling programs. The additional loading of elements at the runoff/culvert into the W15 collection pond is likely a significant contributor to loading during rainfall and melt events, masking the treatment that is occurring through the wetland for seepage that is originating from the SWD toe.

It is evident that the seepage chemistry varies greatly, both between seeps and over time (this study and historical data gathered). This will need to be taken into consideration when evaluating options of constructing a seepage diversion trench compared with building multiple smaller wetlands. The sources and amounts (frequency and range in flows) can be coalesced or treated as separate flows with individual specifically designed wetlands. Collection of seepage by a diversion trench would allow mixing of the various seepage chemistries and more uniform composition and volume of inflow water to the wetlands, but individual wetlands may be favoured in the W15 area due to topography and seepage locations.

There appears to be sufficient soil on site for both hydrosoil and berms for the CWTS. Analysis indicated that the chemistry of overburden soils is amenable to use as soil in the CWTS and to support plant growth, although slightly elevated in copper as is the entire background area. The overburden peat on site is also amenable to use in the soil as an amendment to the CWTS. However, additional sources of organic matter to create anaerobic conditions in the sediment and improve dissimilatory reduction pathways for sulfur and selenium will still need to be identified (such as wood chips, straw, and/or compost). Additionally, when an onsite demonstration-scale CWTS is built, there should be a mechanism developed to deliver seepage water to the CWTS rather than creek water, as substantial treatment is currently occurring between the seeps and the creek.

There is suitable vegetation present that is well adapted to the site conditions. The plants at site show a robust ability to grow in the range of water chemistries present in the area. Moreover, all sites sampled are host to a wide diversity of microbes with known capability of performing

favourable biogeochemical reactions, which will contribute to water treatment in a CWTS. This confirms that even at sites where no chemical evidence of treatment was found, there are microbes present that would be capable of these reactions if encouraged with the right environment (e.g., plant roots, shift in dissolved oxygen or redox, availability of electron donors). While organisms capable of favorable geochemical reactions were ubiquitous at the site, they were found in elevated numbers associated with *Carex* roots, enforcing our selection of this plant species for the CWTS.

CWTS designs are currently being piloted at Contango's year-round pilot facilities. These systems are planted with *C. aquatilis* from site, and peat from the selected borrow site is incorporated into the soils. Replicate pilot-scale CWTS experiments are in progress with and without *Sphagnum* added in order to assess whether the *Sphagnum* contributes positively or negatively to the treatment, and also whether succession from *C. aquatilis* to *Sphagnum* as the dominant plant can be prevented or enhanced through modification of water depth.

The pilot study will continue to integrate information and design decisions, as well as provide supplementary soil and water redox measurements to validate hypotheses about biogeochemical pathways in the CWTS. Further to this, pilot CWTS sediments will be subjected to leachabilty testing for elements of concern to confirm suitability and longevity of the designs. CWTS designs will continue to be optimized as closure water chemistry and volumes are refined.

## 7. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Respectfully submitted,

Contango Strategies Ltd

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## 9. Tables

**Table 1:** Summary of samples taken at the Minto Mine site

| Location | Water Sample | Sediment Sample | Micro Sample | Plant Sample |
|---|---|---|---|---|
| W10 * | Yes | Yes | Yes | Yes |
| W10 *Carex* Root | - | - | Yes | - |
| W32 Seep | Yes | - | - | Yes |
| W32 Mid | Yes | - | - | Yes |
| W32 Creek | Yes | Yes | Yes | Yes |
| W32 Creek Red | Yes | Yes | Yes | - |
| W39 Seep | Yes | - | - | - |
| W39 Creek | Yes | Yes | Yes | - |
| W38 Seep | Yes | - | - | - |
| W38 Creek | Yes | Yes | Yes | - |
| W15 Inflow 1 | Yes | Yes | Yes | Yes |
| W15 Inflow 2 | - | - | Yes | - |
| W15 Inflow 3 | - | - | Yes | - |
| Culvert runoff into W15 | Yes | Yes | Yes | - |

* *Carex aquatilis* and *Sphagnum* for the Minto Pilot 1 CWTS at Contango Strategies were obtained from this location

**Table 2**: Summary of water, soil, and plant analyses

| **Water Analysis** | **Soil Analysis** | **Plant Analysis** |
|---|---|---|
| Total Regulated Metals (Al, Sb, As, Ba, Be, Bi, B, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Ni, P, Se, Si, Ag, Sr, Tl, Sn, Ti, U, V, Zn, Zr, Ca, Mg, K, Na, S, Hg) | Assessment ICP Metals (Al, Sb, As, Ba, Be, Bi, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, P, K, Se, S, Ag, Na, Sr, Tl, Sn, Ti, U, V, Zn, Zr) | Metals (Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Ag, Na, Sr, Tl, Sn, Ti, U, V, Zn) |
| Routine Water (Alkalinity, $HCO_3$, Ion Balance, Dissolved ions, Hardness) | Available Nitrogen, Phosphorous, and Potassium (NPK) | |
| Total Suspended Solids (TSS) | Cation Exchange Capacity (CEC) | |
| Chemical Oxygen Demand (COD) | Sodium Adsorption Ratio (SAR) | |
| Biological Oxygen Demand (BOD) | Total Organic Carbon (TOC) | |
| Total Kjeldahl Nitrogen (TKN) | Electrical Conductivity (EC) | |
| Total Organic Carbon (TOC) | Texture Analysis (Physical properties) | |
| Ammonia | | |

**Table 3:** Copper, selenium, sulphur, and chloride concentrations along the creek. The approximate fold change in concentration along the creek is provided in grey in parentheses.

| | **W10** | **W32 Creek** | **W38 Creek** | **W39 Creek** | **W15 Inflow** |
|---|---|---|---|---|---|
| **Total Copper** (µg/L) | 5.92 | 32.5 (5.5) | 10.6 (0.3) | 11.5 (1.1) | 19.7 (1.7) |
| **Total Selenium** (µg/L) | <0.1 | 0.71 (7.1) | 2.64 (3.7) | 2.53 (1.0) | 2.10 (0.8) |
| **Total Sulphur** (mg/L) | <3 | 9.7 (3.2) | 24.7 (2.5) | 23.0 (0.9) | 23.1 (1.0) |
| **Dissolved Chloride** (mg/L) | 1.2 | 1.8 (1.5) | 3.0 (1.7) | 3.1 (1.0) | 2.9 (0.9) |

**Table 4:** Copper, selenium, sulphur, and chloride concentrations at W32 Creek compared to W32 Creek Red location, and W32 Mid compared to W32 Seep. Approximate fold concentration difference between the two sites is provided in grey parentheses.

| | **W32 Creek** | **W32 Creek Red** | **W32 Seep** | **W32 Mid** |
|---|---|---|---|---|
| **Total Copper** (µg/L) | 32.5 (0.06) | 1.93 | 10.1 (1.5) | 15.1 |
| **Total Selenium** (µg/L) | 0.71 (0.3) | 0.21 | 19.6 (0.01) | 0.24 |
| **Total Sulphur** (mg/L) | 9.7 (0.3) | <3 | 110 (0.1) | 11.9 |
| **Dissolved Chloride** (mg/L) | 1.8 (2) | 3.5 | 5.5 (1.2) | 6.8 |

**Table 5:** Average copper, selenium, sulphur, and chloride concentrations in the creek (W32, W38, W39, and W15; i.e., not including W10), compared to each seep. Approximate fold concentration difference between the seep and average creek is provided in grey parentheses.

| | **Avg. Creek** | **W32 Seep** | **W38 Seep** | **W39 Seep** |
|---|---|---|---|---|
| **Total Copper** (µg/L) | 18.6 | 10.1 (0.5) | 102 (5.5) | 71.4 (3.8) |
| **Total Selenium** (µg/L) | 2.0 | 19.6 (9.8) | 7.59 (3.8) | 0.94 (0.5) |
| **Total Sulphur** (mg/L) | 20.1 | 110 (5.5) | 45.8 (2.3) | 46.0 (2.3) |
| **Dissolved Chloride** (mg/L) | 2.7 | 5.5 (2.0) | 5.5 (2.0) | 3.8 (1.4) |

## 10. Figures




**Figure 1**: Conceptual closure diagram of Minto mine (Appendix A, Minto Phase V/VI Preliminary Reclamation and Closure Adaptive Management Plan), indicating potential wetland locations and routine monitoring sites.




**Figure 2**: Sampling locations at the Minto mine. All routine monitoring points are indicated in white, while sampling locations unique to this study are shown in yellow. The blue arrows indicate the direction of water flow. The W32 Creek label corresponds to the location of both the W32 Creek and W32 Creek Red.




**Figure 3**: Minto Site W32 Creek (bottom in A; left in B) and W32 Creek Red (top in A; right in B) in A) August 2013 and B) September 2013. The pictures show the same site at two different dates.

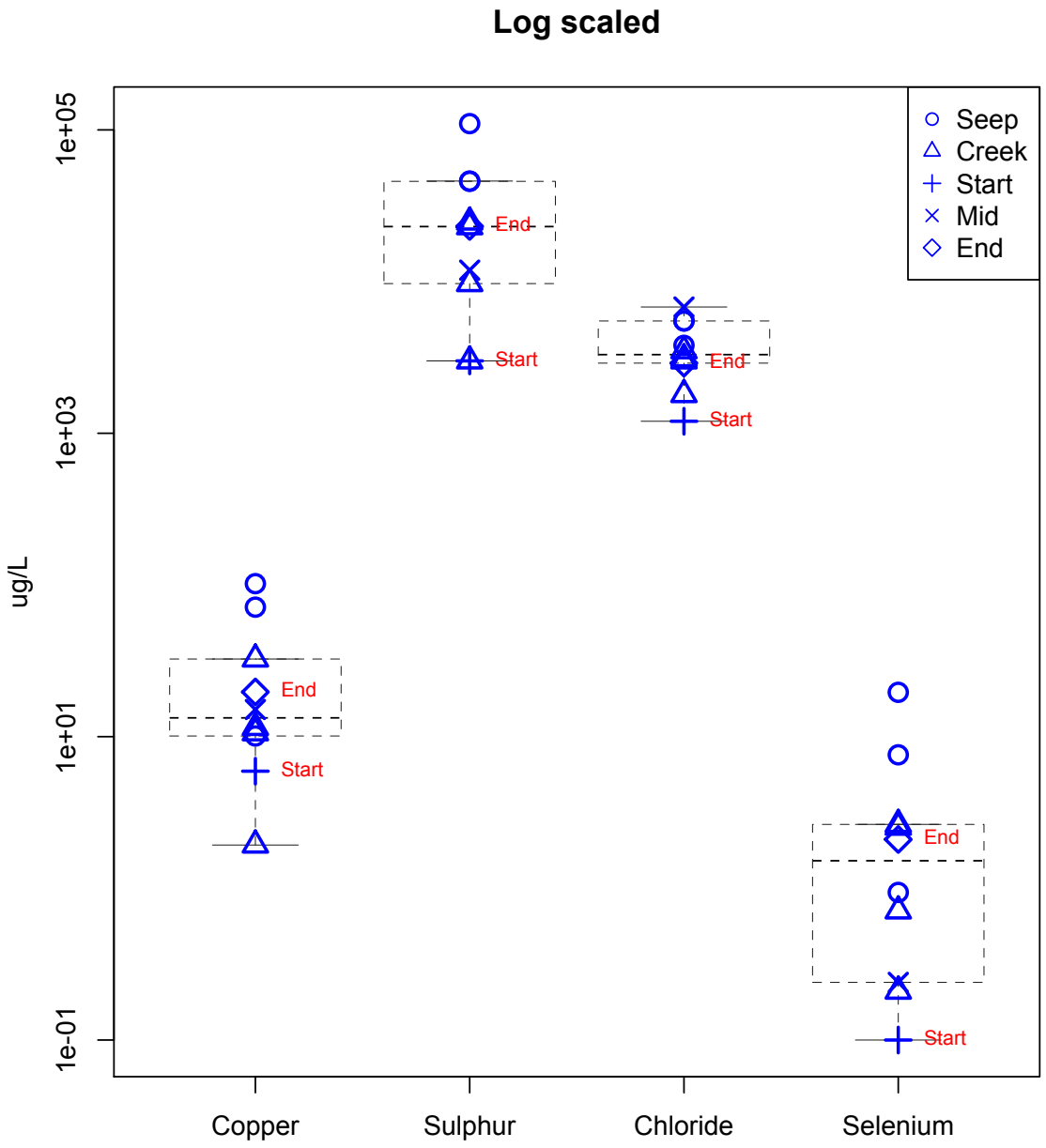



**Figure 4**: Comparison of copper, sulphur, chloride and selenium concentrations in the creek between the W10 and W15 areas, and seeps along the toe of the SWD. "Start" indicates the W10 location, while "End" indicates the W15 inflow. The W32, W38, and W39 Creek locations are shown as triangles, while all seeps are differentiated as circles. The W32 Mid site is depicted as a X. Note the spread of the copper, sulphur, and selenium plots is greater than that of chloride. The seeps demonstrate the highest concentration of copper, sulphur, and selenium, while chloride concentrations do not follow this trend.

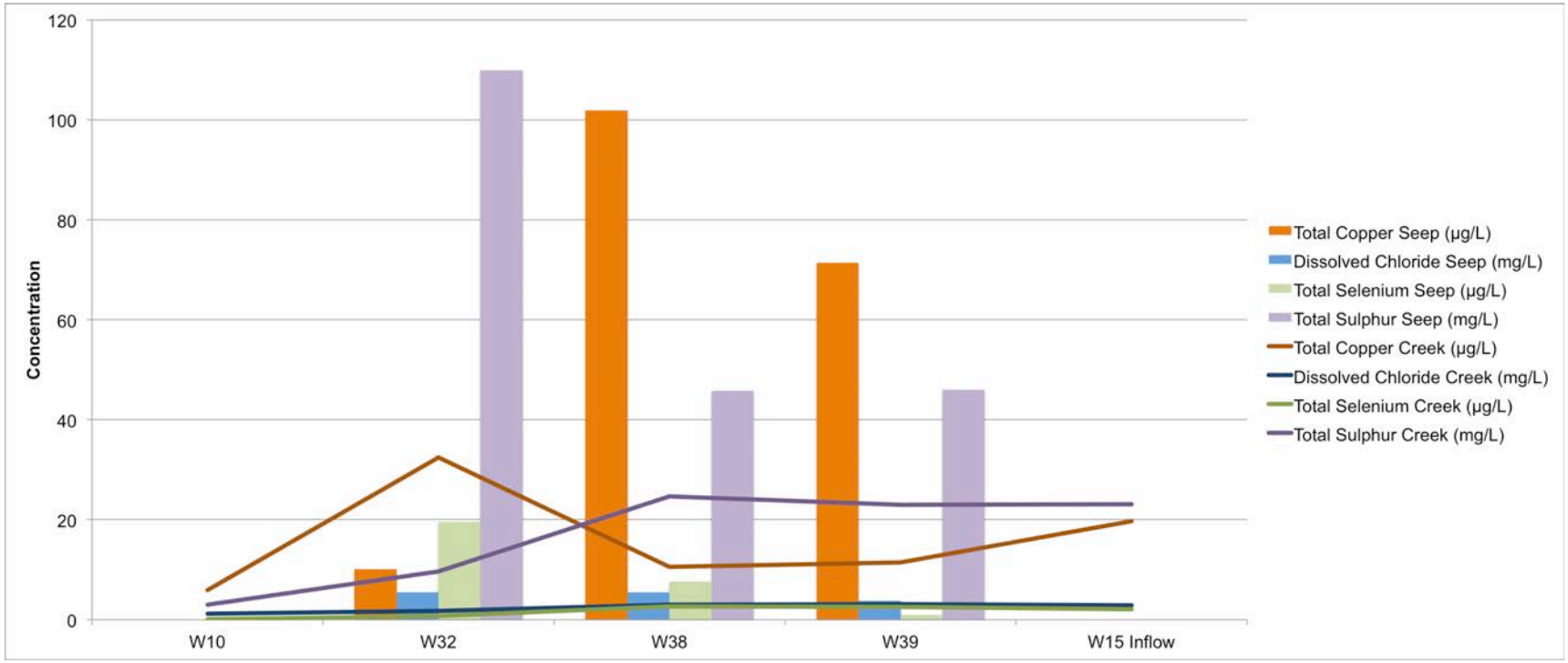



**Figure 5**: Copper, chloride, selenium, and sulphur concentrations in the creek and seep locations. Bars indicate seepage, while lines indicate the creek concentration of each element.

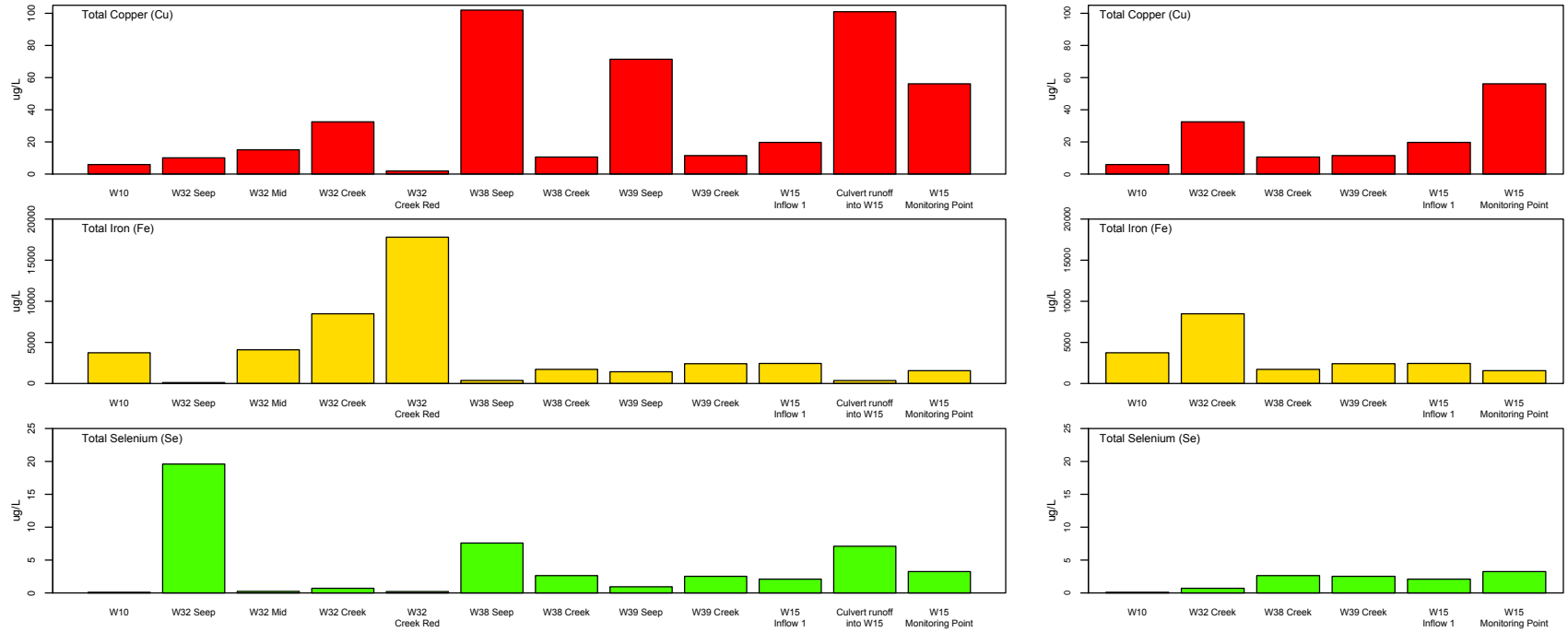



**Figure 6:** Copper, iron, and selenium concentration in water. The left plots show all sites, while the right plots show the distribution of elements along the creek. The W15 Monitoring Point represents the average of September 17th and September 28th, 2013, monitoring timepoints, which are the closest dates to the site visit when samples were obtained.

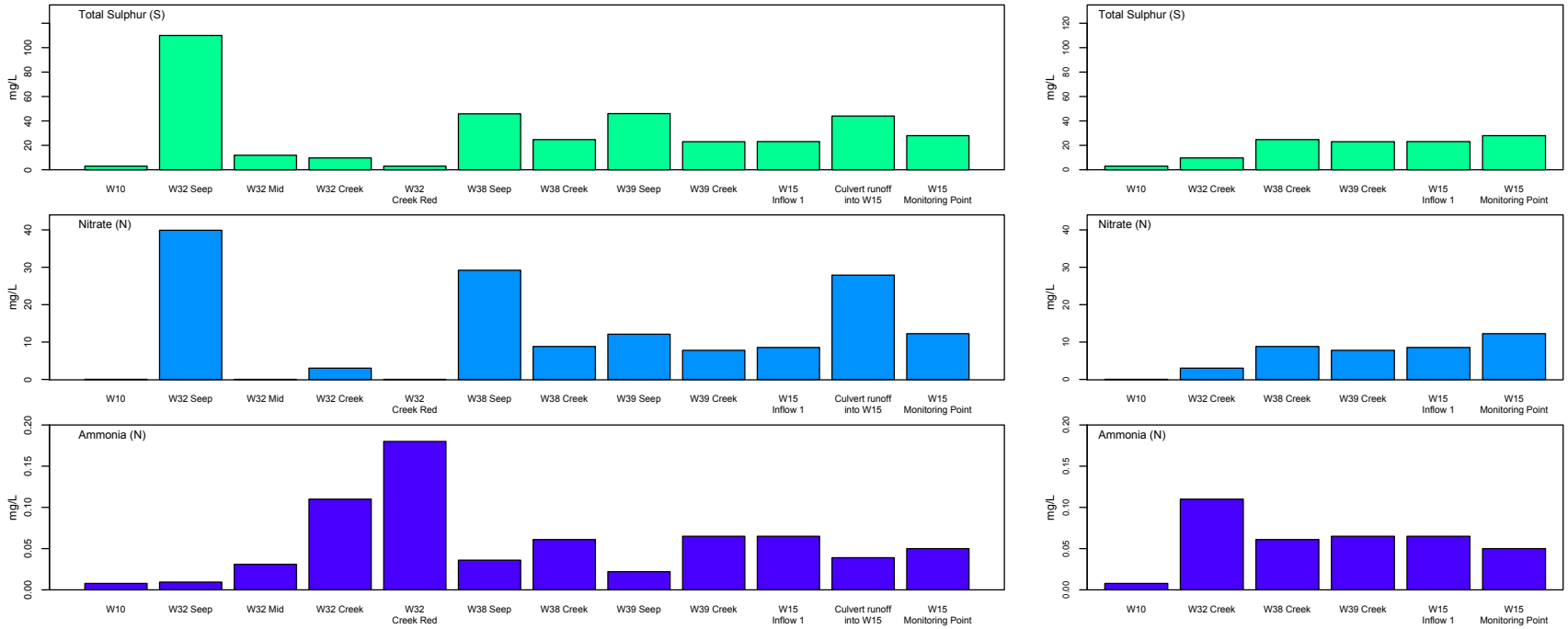



**Figure 7**: Sulphur, nitrate, and ammonia concentration in water. The left plots show all sites, while the right plots show the distribution of elements along the creek. The W15 Monitoring Point represents the average of September 17th and September 28th, 2013, monitoring timepoints, which are the closest dates to the site visit when samples were obtained.

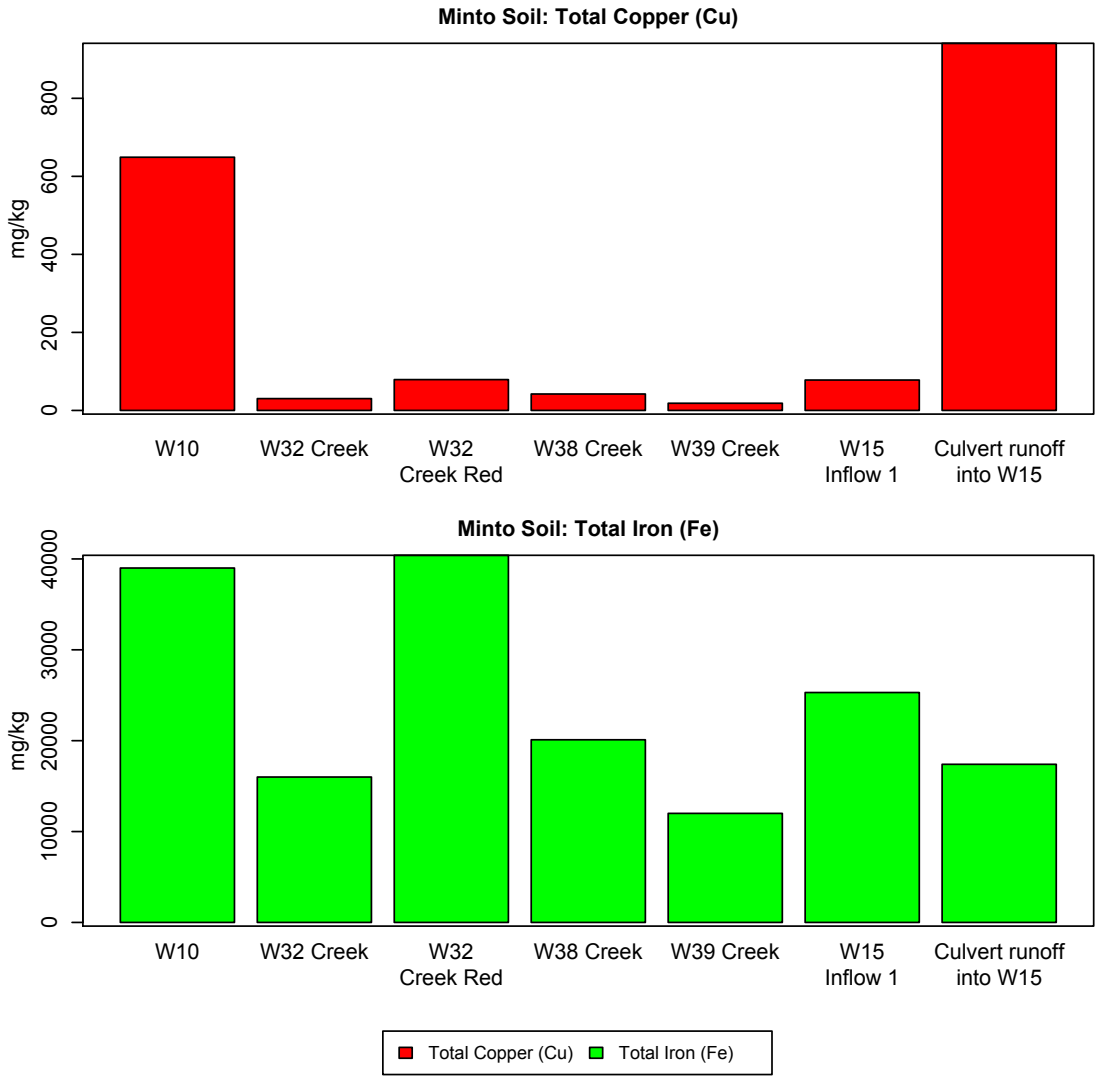



**Figure 8**: Copper and iron concentration in soil. Selenium was below the detection limit in sediment (<0.5 mg/kg), and is therefore not shown.

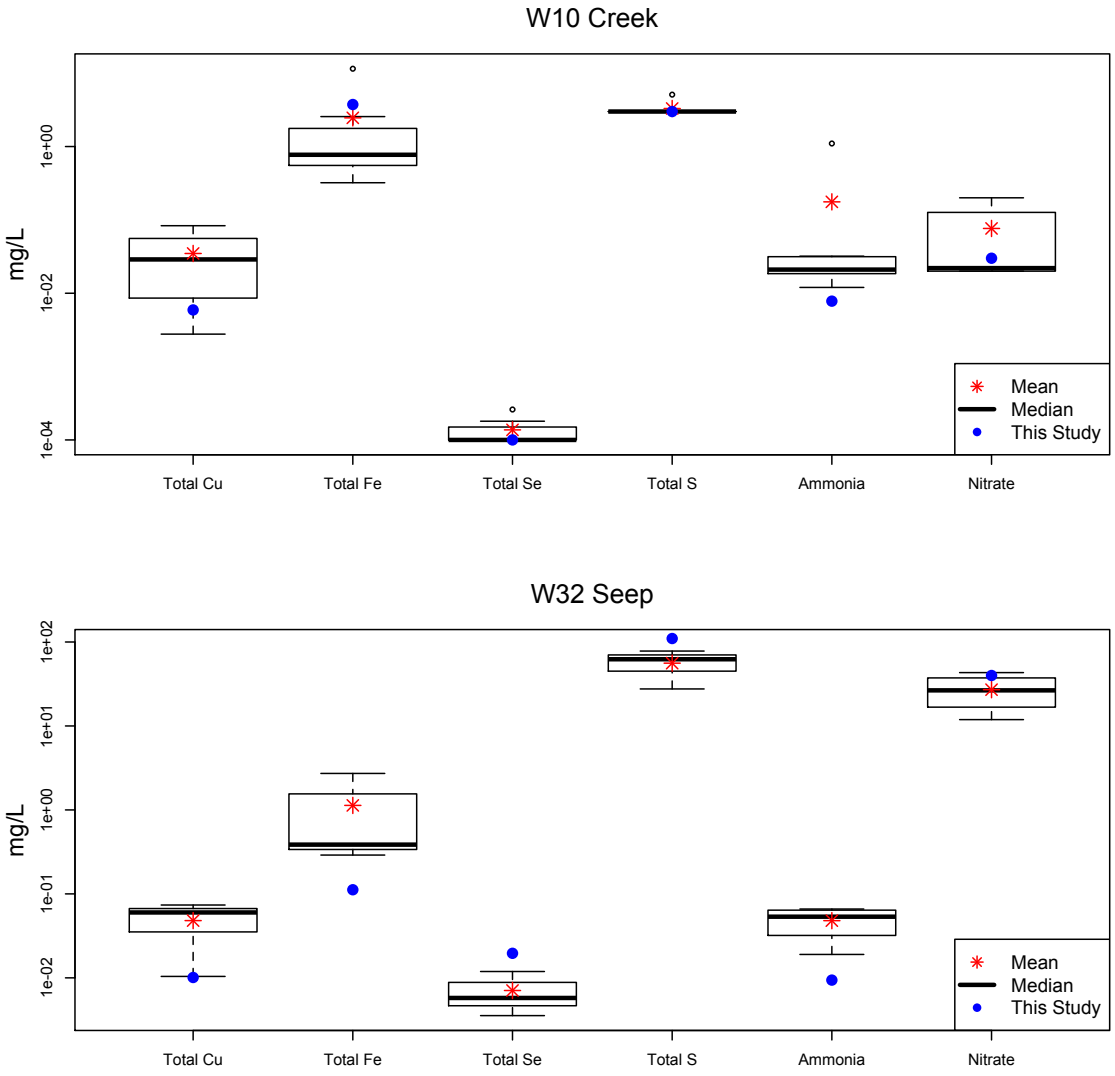



**Figure 9**: Concentration of select elements from all 2013 routine monitoring program measurements. Blue dot indicates concentration measured in samples collected as part of this study. Figure is continued on following page.

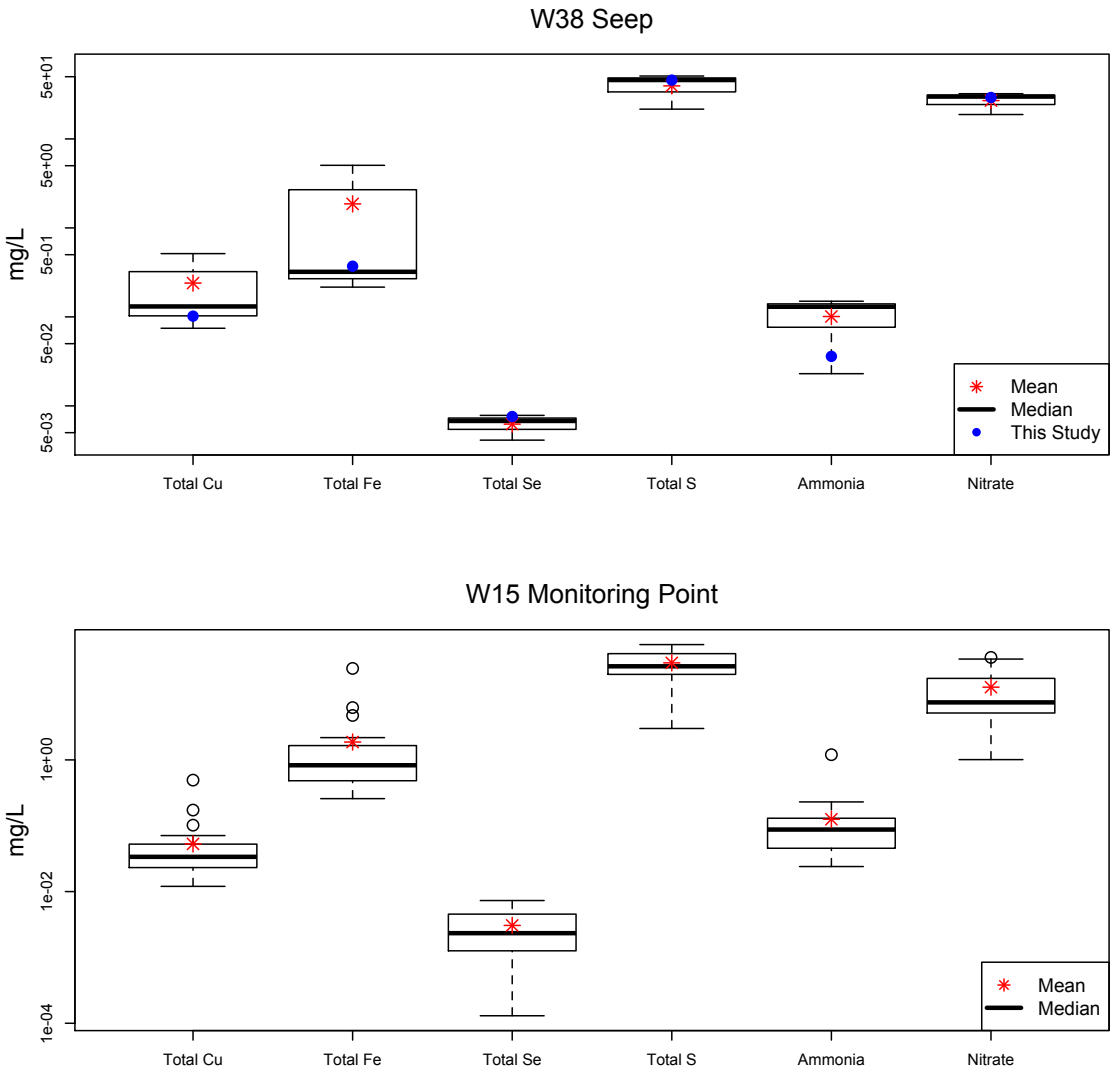



**Figure 9**: Concentration of select elements from all 2013 routine monitoring program measurements. Blue dot indicates concentration measured in samples collected as part of this study. Figure is continuation from previous page.

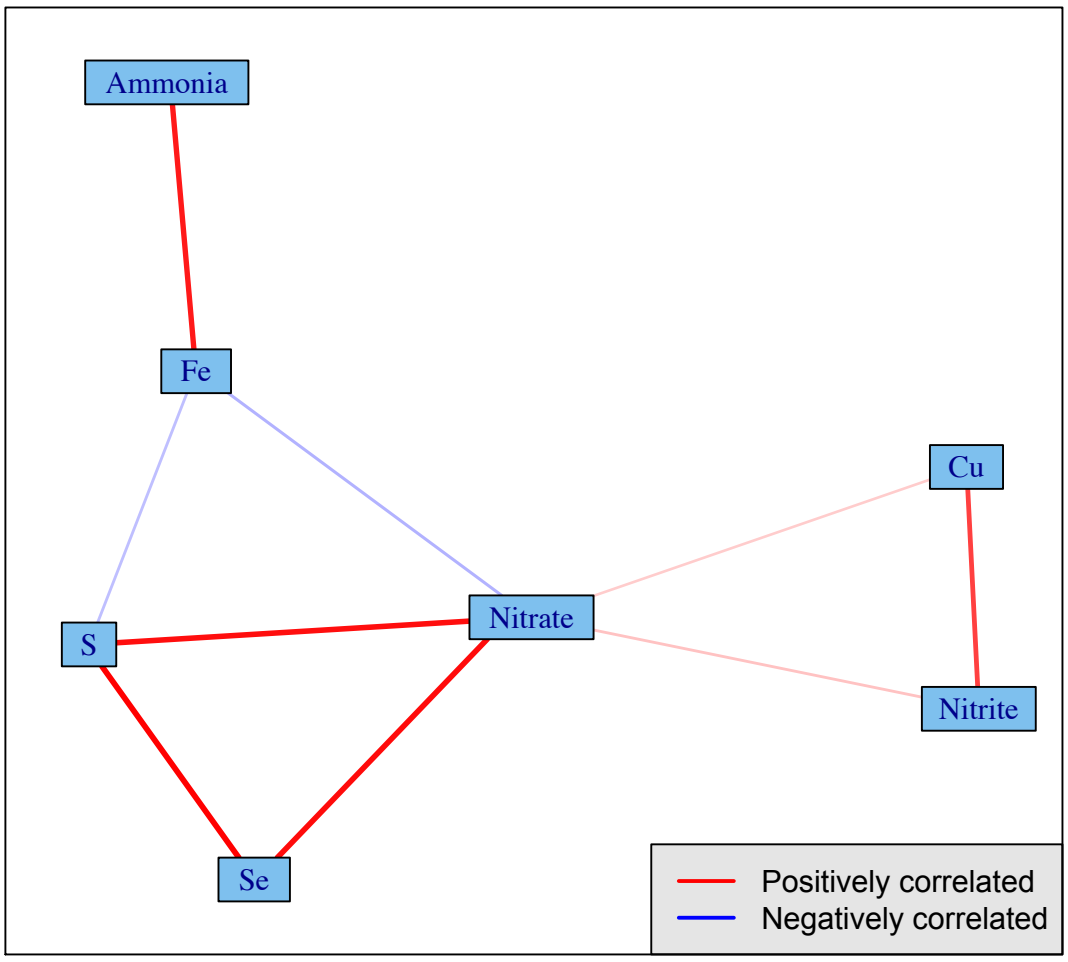



**Figure 10**: Correlation of various compounds in water. The strength of the line connecting different compounds indicates the strength of the correlation. For example, the thick line between Se and S corresponds to a Pearson correlation coefficient of 0.939, while the line connecting Cu, and Nitrate or Nitrite corresponds to a coefficient of 0.527 or 0.812, respectively. All Pearson correlations are significant at a level of P<0.1. Also of note, copper concentrations in soil were found to be significantly correlated with copper and nitrite concentrations in the water (not depicted in figure).



**Figure 11**: *C. aquatilis* and grasses are dominant at the W32 area that was recently cleared.



**Figure 12**: *C. aquatilis* spreading through the W10 area access road, being the first plant to colonize the road and recent tire ruts.

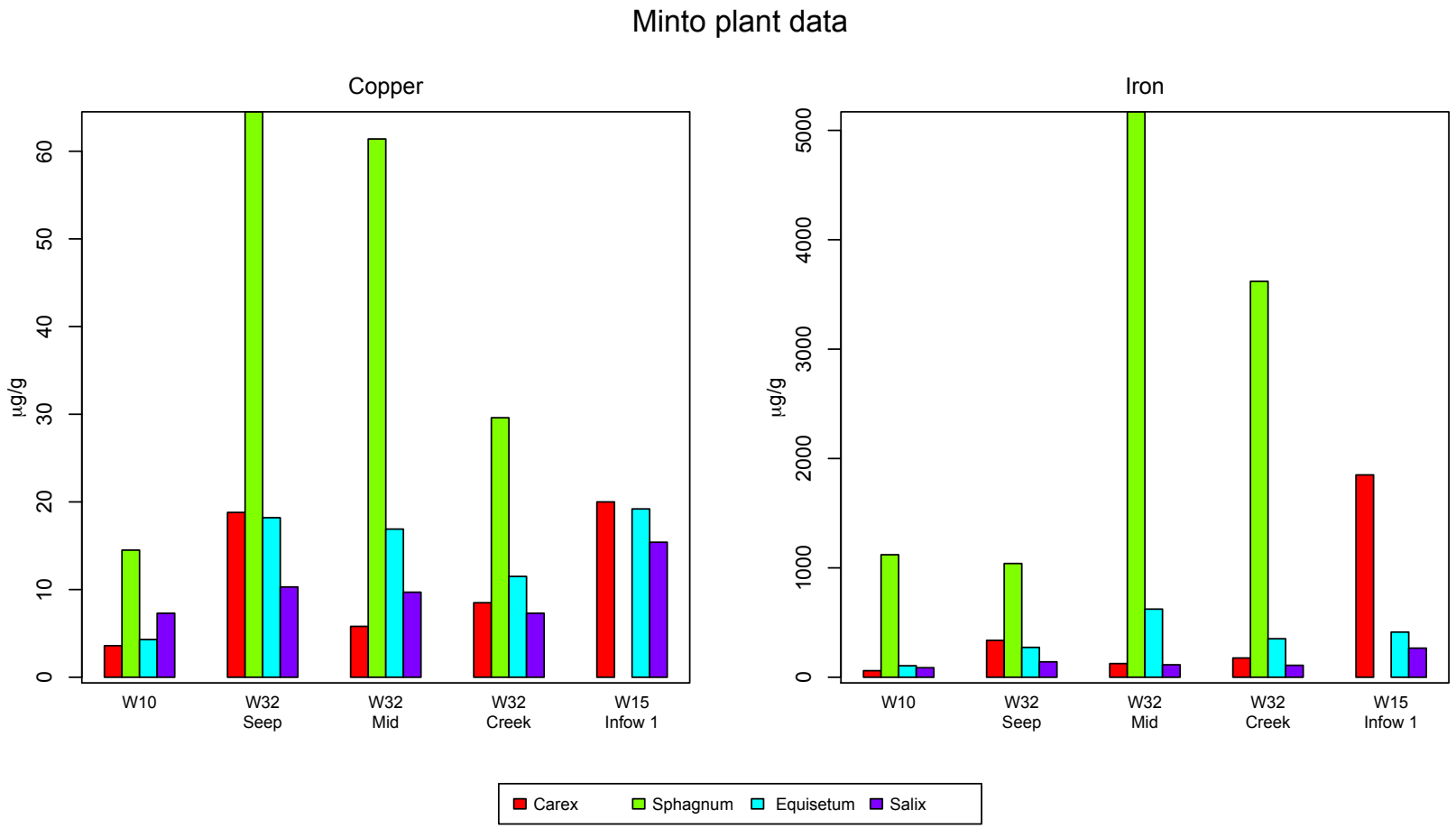



**Figure 13**: Concentration (µg/g) of dry plant matter for copper and iron in plants at the Minto Site. Note that there was no *Sphagnum* present at the W15 inflow site available for collection.

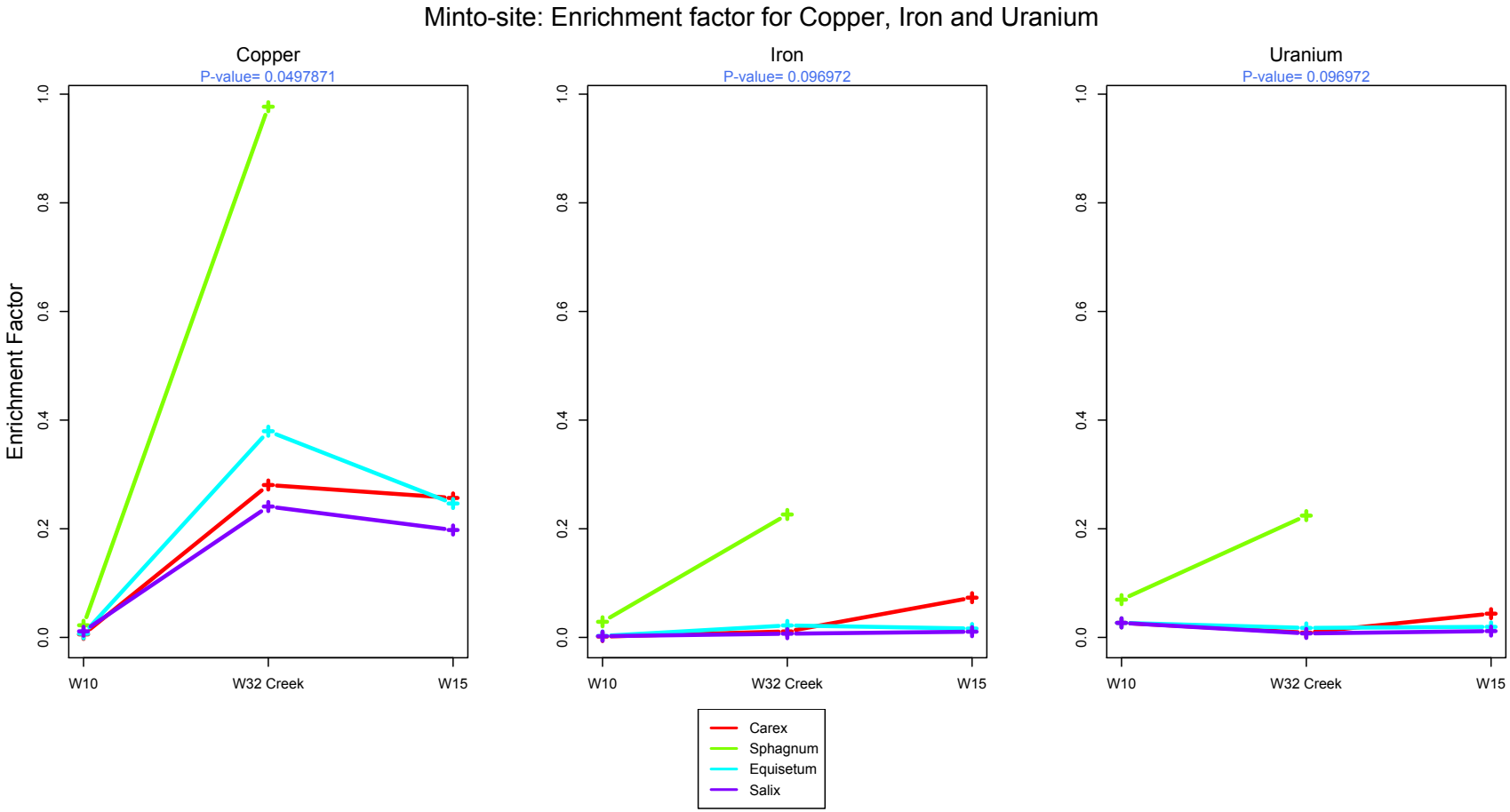



**Figure 14**: Enrichment factor for copper, iron, and uranium in *Carex, Sphagnum, Equisetum,* and *Salix.* A p-value <0.1 indicates there is a significant difference in the enrichment factor at different sites. Note that there was no *Sphagnum* present at the W15 inflow site available for collection.



**Figure 15**: Example of creek channeling through *Salix* plants.

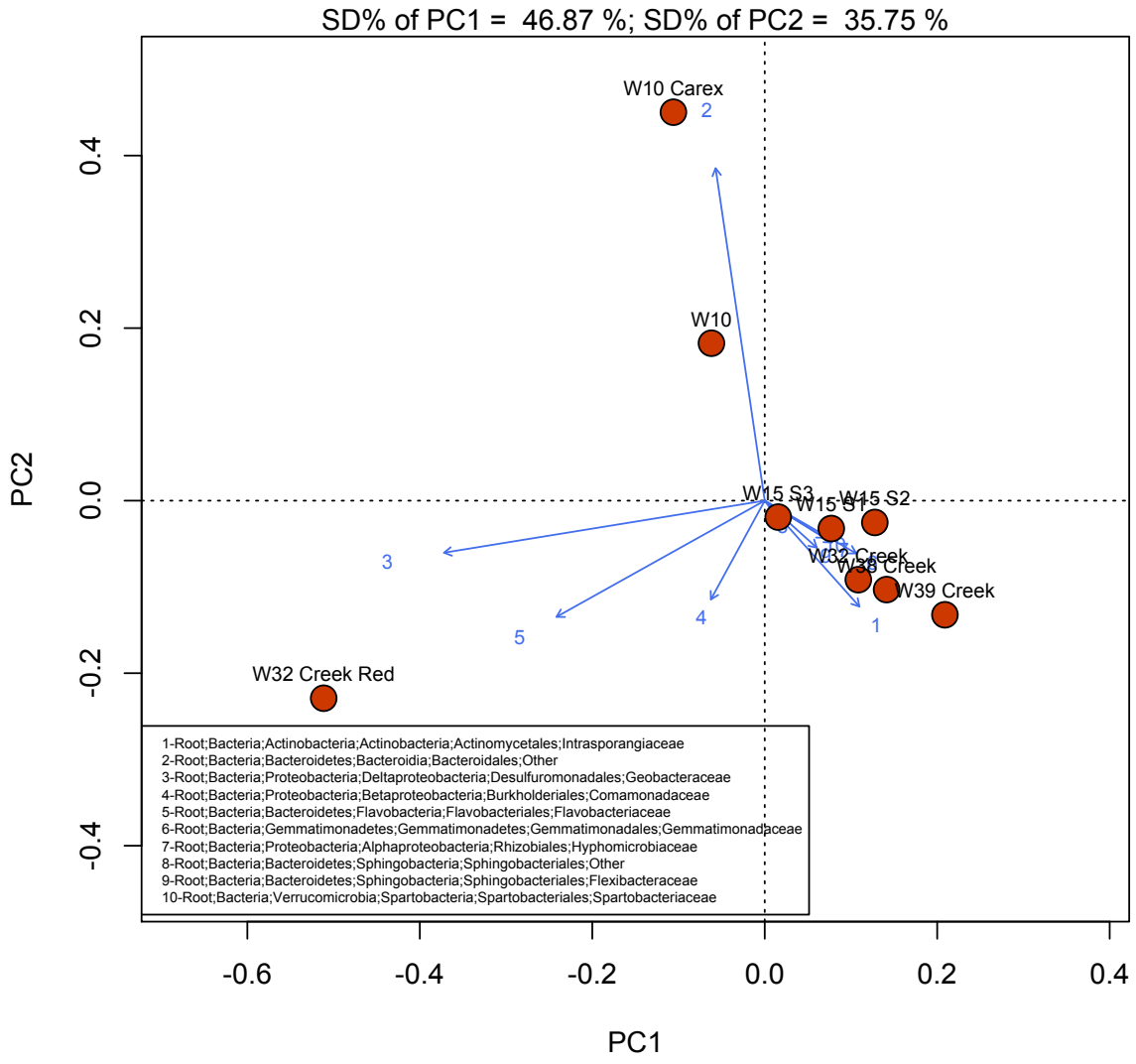



**Figure 16**: Principal component analysis of all sites based on microbial community profiles. All sites that cluster together have similar microbial profiles, while sites clustering on their own (e.g., W32 Creek Red) show a less similar profile. Each numbered arrow represents a group of microorganisms listed in the legend. Essentially, the direction and length of an arrow represents how abundant that group of microorganisms is in each sample. For example, W32 Creek Red would show a high abundance of *Geobacteraceae* (arrow #3) and *Flavobacteriaceae* (arrow #5), while W10 Carex shows a high abundance of *Bacteroidales* (arrow #2). All creek samples (W32, W38, W39, and W15) cluster together and show similar microbial profiles (high abundance of *Intrasporangiaceae,* arrow #1).

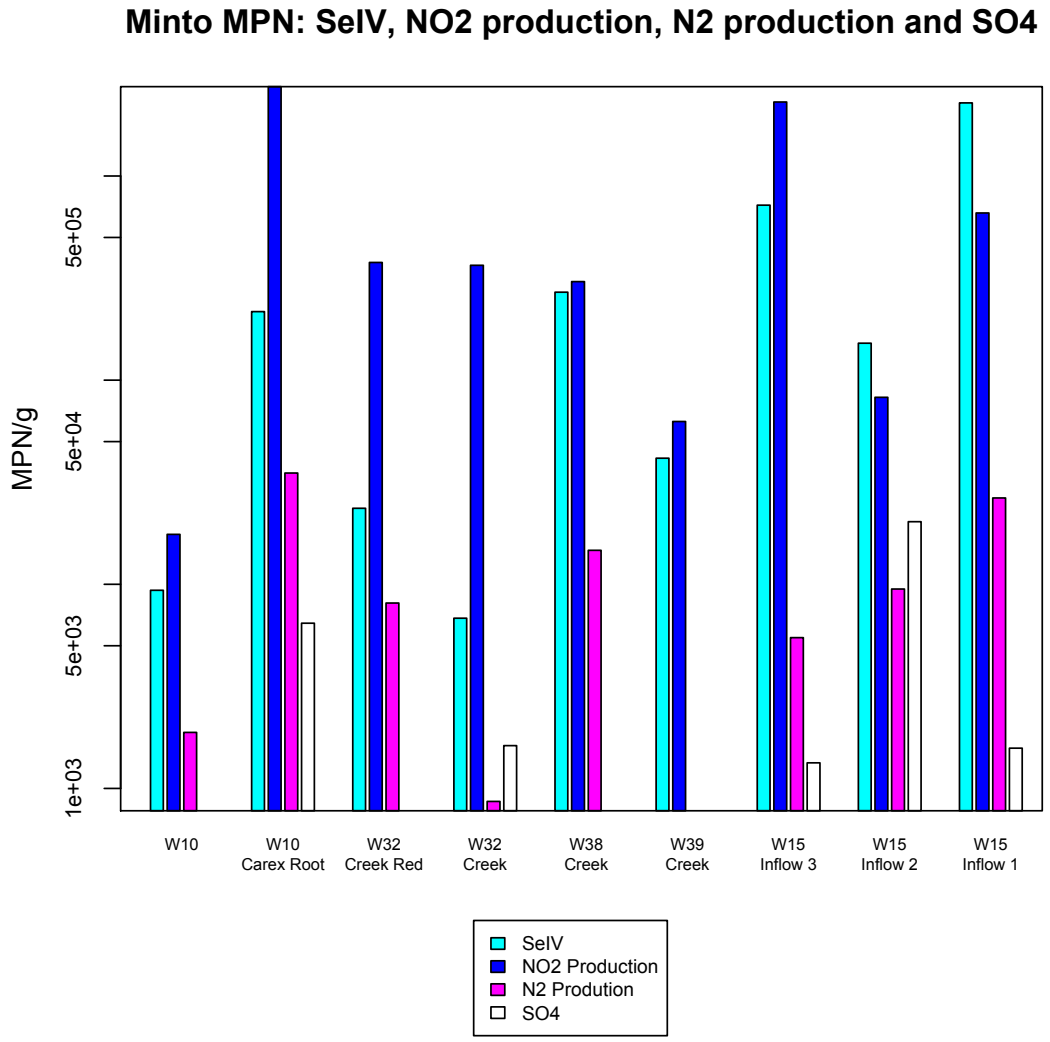



**Figure 17**: Predicted number of selenite, sulphate, and nitrate reducing bacteria found at various Minto sites, based on the most-probable number assay. The nitrate-reduction assay tests for microbes that can reduce nitrate to nitrite (i.e., $NO_2$ Production), as well as microbes that can further reduce nitrite to nitric oxide or nitrogen gas (i.e., $N_2$ Production).

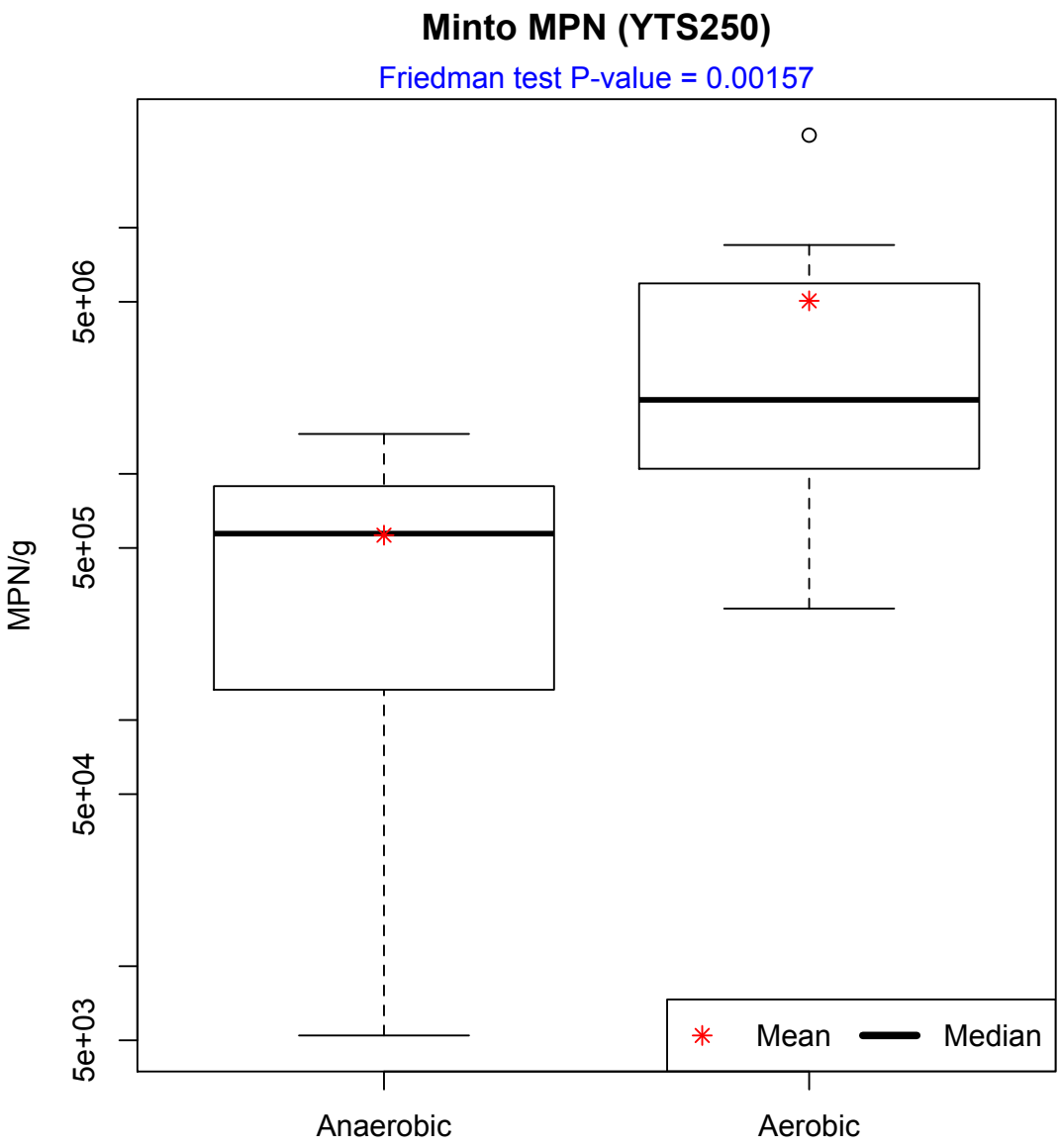
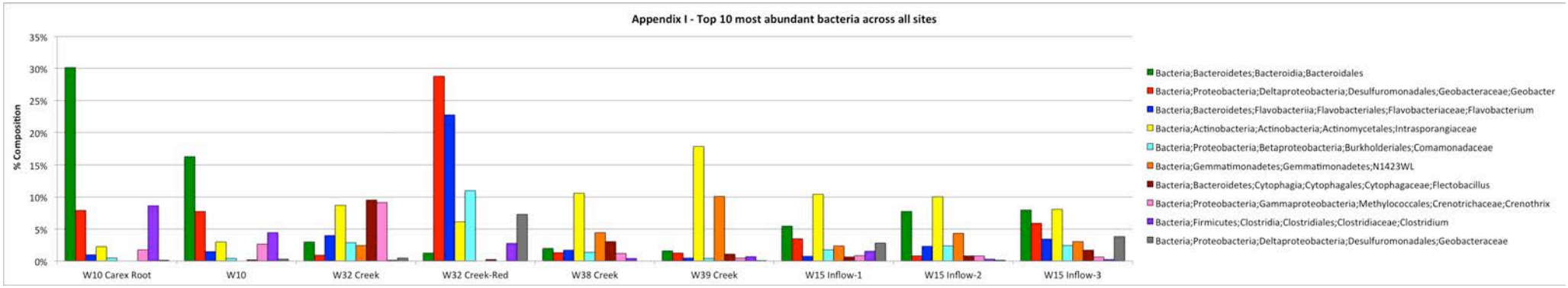


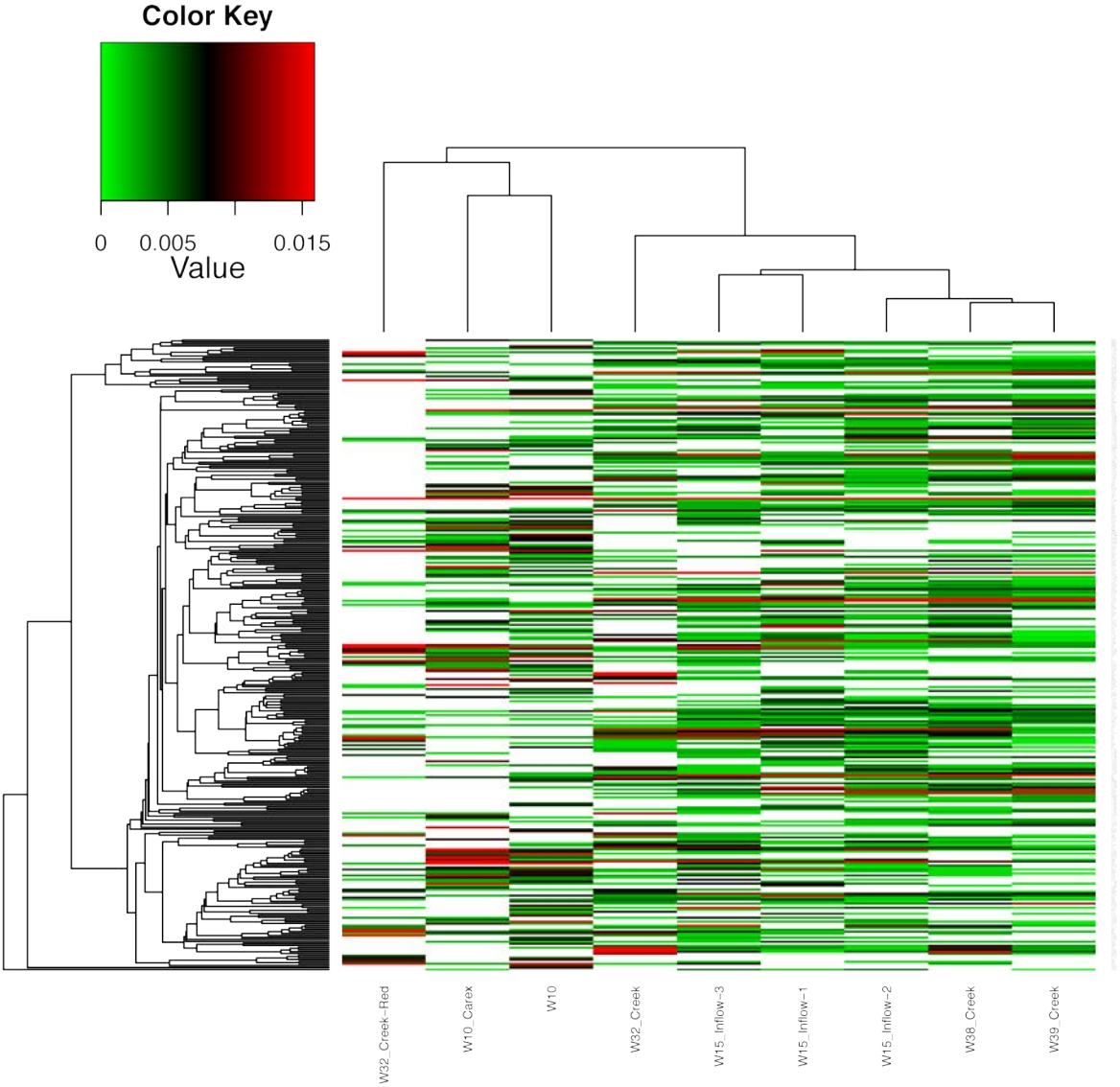

**Figure 18**: Most-probable number of total heterotrophic organisms at the Minto site. The number of heterotrophic organisms growing under aerobic (with oxygen) and anaerobic (no oxygen) conditions is shown. Significantly more total heterotrophs grew under aerobic conditions that under anaerobic, as demonstrated by a P-value < 0.05.



**Figure 19**: Color distribution of sediment surrounding *Carex* root at the W10 location.


Appendix I - Top 10 most abundant bacteria across all sites
% Composition
35%
30%
25%
20%
15%
10%
5%
0%
W10 Carex Root
W10
W32 Creek
W32 Creek-Red
W38 Creek
W39 Creek
W15 Inflow-1
W15 Inflow-2
W15 Inflow-3
Bacteria;Bacteroidetes;Bacteroidia;Bacteroidales
Bacteria;Proteobacteria;Deltaproteobacteria;Desulfuromonadales;Geobacteraceae;Geobacter
Bacteria;Bacteroidetes;Flavobacteriia;Flavobacteriales;Flavobacteriaceae;Flavobacterium
Bacteria;Actinobacteria;Actinobacteria;Actinomycetales;Intrasporangiaceae
Bacteria;Proteobacteria;Betaproteobacteria;Burkholderiales;Comamonadaceae
Bacteria;Gemmatimonadetes;Gemmatimonadetes;N1423WL
Bacteria;Bacteroidetes;Cytophagia;Cytophagales;Cytophagaceae;Flectobacillus
Bacteria;Proteobacteria;Gammaproteobacteria;Methylococcales;Crenotrichaceae;Crenothrix
Bacteria;Firmicutes;Clostridia;Clostridiales;Clostridiaceae;Clostridium
Bacteria;Proteobacteria;Deltaproteobacteria;Desulfuromonadales;Geobacteraceae

# Appendix II - Microbial Profile




Heatmap showing the distribution of bacteria at the Minto Mine. Each column represents a sampling location, while each row represents an OTU (group of bacteria). The abundance of each group of bacteria is depicted through a heatmap: white indicates absent, and green through red indicates increasing abundance. Samples are clustered together based on the similarity of microbial communities, and indicated by the dendrogram at the top of the heatmap. The dendrogram on the left represents a phylogenetic tree of all OTUs.



Contango STRATEGIES LTD.

*Forward looking.* Lateral thinking.

# Minto Mine Constructed Wetland Treatment Research Program – Pilot Scale

capstone MINTO MINE

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# 1. Abbreviations and Definitions

**CWTS(s)** – Constructed Wetland Treatment System(s).

**Dissimilatory reduction –** is a process utilized by specific types of bacteria where an electron donor material (e.g. organic carbon) is oxidized, producing energy for the bacteria and reducing another material (e.g. sulphate, or selenium) as part of the microbial metabolism.

**DNA (deoxyribonucleic acid)** – is the hereditary material in almost all living organisms. This can be used to identify organisms.

**DO** – Dissolved Oxygen.

**Heterotroph** – an organism deriving its nutritional requirements from complex organic substances.

**Metagenomics** – the study of genetic material recovered directly from environmental samples, related to a community rather than an individual organism.

**Microbes** – microscopic organisms which may be uni- or multi-cellular. This includes algae, bacteria, fungi, viruses, and yeast.

**MPN (Most Probable Number)** – a statistical value representing the viable population of microbes in a sample through use of dilution and multiple inoculations.

**Oxidation** – is the loss of electrons or increase in oxidation state by a molecule, atom, or ion. Can be driven by microbes. Process is complementary to chemical reduction.

**Redox** – Oxidation-reduction potential, measured in millivolts.

**Reduction (chemical)** – is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion. Can be catalyzed by microbes. Process is complementary to chemical oxidation.

**RRC (Removal Rate Coefficient)** - a numerical value, expressed as the variable *k,* representing a first order rate of removal, considering removal extent and the time required for removal.

**SeIV broth or agar** – laboratory growth medium that contains selenite (SeIV) and indicates reduction of selenite to elemental selenium through a visible colour change.

**Species** – one of the basic units of biological classification and a taxonomic rank. Rank in the classification of organisms below genus and above strain.

**Taxonomy** – classification, identification, and naming of organisms.

**TSS** – Total Suspended Solids.

**YTS250 (Yeast, Tryptone, Starch, 250g each)** – a type of laboratory growth medium used for environmental microbes.

## 2. Introduction

Constructed Wetland Treatment Systems (CWTSs) have been proposed as a method for improving the quality of site runoff water in the post-closure period for the Minto Mine (Minto Phase V/VI Expansion Project, YOR Project Number 2013-0100). Once established, wetlands can become self-sustaining ecosystems with the plants providing yearly renewal of carbon to fuel microbial activity. As such, they possess the desirable potential to remediate contaminated mine drainage for as long as it is generated. In order for CWTSs to be effective, however, they must be designed, piloted, optimized, implemented, and maintained in a site-specific manner.

Wetlands provide a natural environment in which unique biogeochemical reactions can occur. CWTSs can be designed to have desirable conditions similar to those in natural wetlands, and should be designed specifically for each site. Having a site-specific approach allows for the appropriate set of operational conditions to be achieved, where complex coupled reactions can take place for treatment of targeted constituents. This can be done with complex and challenging waters, where problematic constituents are transferred or transformed to less bioavailable forms. The benefits of CWTSs include:

- low operational cost,
- low maintenance,
- effective and robust treatment,
- increased effectiveness over time,
- aesthetically pleasing,
- tolerance to changes in flow rate and contaminant load, and
- simultaneous treatment of multiple constituents more effectively than chemical or physical treatment processes.

CWTSs have been used to mitigate risks to aquatic receiving environments from a variety of aqueous contaminants, including copper (Cu) and selenium (Se). The biogeochemical reactions that take place in a wetland environment are many, but there are specific reactions that may decrease the aqueous and more bioavailable concentrations of some contaminants (e.g. Cu, Se), thus lowering risk to the receiving environmental systems by decreasing exposure to contaminants. A process called dissimilatory sulphate reduction can chemically reduce available aqueous sulphate to sulphide through the metabolism of specific bacteria. Once dissimilatory sulphate reduction has occurred, it provides a mechanism to remove dissolved cations such as Cu from water by complexation with the sulphide ion to produce copper sulphide, an insoluble precipitate. Selenium treatment in a CWTS is a similar process, but with slightly different results. The mechanism for Se treatment is more direct, through dissimilatory selenium reduction that is also microbially mediated, often by some of the same bacteria that undergo dissimilatory sulphate reduction. The most common forms of aqueous Se are selenite and selenate, with valence states of IV and VI, respectively. When these are reduced in a wetland to an insoluble state, Se precipitates as elemental Se(0).

In both cases, the Cu and Se precipitates are removed from the water through filtration mechanisms inherent in wetlands and are sequestered into the sediments over time as an accretive process. Accretion is the naturally occurring process of accumulation of wetland

sedimentary material (soil, minerals, decaying plant material, etc.) over time. Once an accreting CWTS is established and mature, targeted constituents are sequestered into the sediment and covered over time by newly generated sediments and detritus. This essentially seals away the treated constituents under layers of sediment, rendering them less bioavailable and less susceptible to re-entry into the water column. There is therefore no need to dredge or harvest wetland plants for the Minto site; in fact, this type of activity would disrupt the treatment functions and re-expose the previously sequestered constituents. This process mimics what occurs in naturally created wetlands; therefore, this process is often the best option for long-term, low-maintenance and effective treatment.

## 3. Background

At the request of Minto Explorations Ltd, Contango Strategies has undertaken a pilot-scale study to inform the design of site-specific passive treatment technologies for the Minto site during post-closure. These pilot-scale trials build upon a site assessment that was conducted and reported on in 2013. The overriding goal of this pilot study is to develop, optimize, and test site-specific pilot-scale CWTSs for post-closure water treatment at the Minto site.

## 4. Pilot System Operations

### 4.1. **Design and assembly**

In October 2013 three pilot CWTSs were constructed, each in duplicate, to evaluate the performances of different designs for selenium and copper treatment (Figures 1 and 2). These were planted with either Sedge (*Carex aquatilis*), or Sedge and aquatic moss as follows:

- System 1 and 2: *Carex aquatilis*
- System 3 and 4: *Carex aquatilis* + Moss
- System 5 and 6: *Carex aquatilis* + Moss, with biochar amendment in soil

The pilot CWTS systems were built with two cells per series, each cell having a 41 cm diameter and a height of 57 cm. To establish the plants, soil was filled to a depth of 20 cm at the bottom of each cell, and submerged under 10 cm of tap water. The water depth was changed throughout the pilot testing to evaluate effects on performance, and develop strategies for optimization.

#### *4.1.1. Hydrosoil*

Hydrosoil is a specially selected soil blend to aid in achieving the targeted hydraulic conductivity required to meet the CWTS objectives. In this case, the hydrosoil mixture was the same for all pilots; sand amended with 2% woodchips (v/v) and 5% peat, except that the third system design (system 5 and 6) also included a 5% pine biochar amendment. The sand and amendments were tested for initial metal and nutrient contents (Table 5). This specific type of biochar was chosen as an amendment as previous studies conducted by Contango have demonstrated that addition of biochar to the hydrosoil can result in faster establishment and growth of newly planted wetland plants (SETAC Presentation #593, Haakensen 2013). The biochar selected

was low in soluble salts, had a high surface area, low metals content, and moderate available organic carbon and phosphorous (Appendix 1). The peat borrow site at the Minto Mine was selected as it provided a sufficient quantity for a full-scale wetland. It was tested for metals content and other relevant parameters such as nutrients (N, P, K), and total organic carbon before use in the pilot CWTS system.

#### *4.1.2. Plants*

Two plant species were of interest for the pilot CWTS based on data collected during the August/September 2013 site assessments (reports 2013-0100-256 and 2013-0100-257 on the YESAB registry). *Carex aquatilis* (sedge) was chosen, as it is readily available at the Minto site and was one of the first plants to colonize cleared areas, indicating that it may be a good candidate for quickly establishing the CWTS. Moss was also used in the second and third pilot CWTS designs (systems 3-6), as locations at Minto with shallower water had *Carex* and Moss coexisting. As such, we wanted to assess whether the Moss contributes positively or negatively to treatment, and also whether succession from *Carex* to Moss as the dominant plant can be prevented or enhanced through modification of water depth.

It is well known that Moss has a high uptake rate of cations (such as copper and selenium) and is also a relatively benign sink for these elements (i.e., is not a food source for invertebrates or higher animals and as such does not contribute greatly to bioaccumulation (Haines & Renwick, 2009; Longton, 1997; Suren & Winterbourn, 1991)). This was also confirmed in the site assessment in 2013, which produced data indicating that Moss at the Minto site has a high uptake of elements such as copper, and could therefore be an effective means of removing elements from seepage through uptake. During the September 2013 site visit, Moss and *Carex* were collected from the Minto site and these were subsequently used to vegetate all pilot CWTS in this study. A total of 10-12 *Carex* were planted per cell, with approximately a 250ml volume of Moss (compressed) added to systems 3-6.

#### *4.1.3. Water and Testing Periods*

The CWTS(s) were designed for treatment of water that would be present at the Minto site after closure. As such, this water does not yet exist and had to be synthesized as an approximation based on water quality modeling. The worst-case post-closure water chemistry was used based on the month of October, as it had the highest concentrations of key elements for any month with free-flowing water. The synthetic water underwent five iterations of design, testing, and optimization to ensure the composition and method of formulating the water resulted in analytical chemistry that matched the water quality predicted to exist after closure and reclamation of the Minto mine. The final recipe and resultant water chemistry is provided in Tables 1 and 2.

Design of the synthetic water chemistry focused on constituents requiring treatment and elements/compounds that are expected to affect treatment rates or capacity based on previous experience and scientific literature. For the first period (High N) of the pilot-phase work, the predicted maximum worst-case ammonia and nitrate concentrations were used, which reflected residuals of these compounds from blasting. The ammonia concentrations measured on site are

lower than would be expected based on the chemical composition of ammonia nitrate used for blasting, suggesting that the ammonia has already undergone oxidation to nitrate prior to the seepage exiting the waste rock pile. Nitrate can affect compounds such as selenium that are removed from water through coupled biogeochemical reactions and dissimilatory reduction, as nitrate has a high affinity for available electrons and is preferentially reduced before other compounds. However, it is known that over time in closure, the concentrations of ammonia and nitrate will decrease dramatically, and this may affect removal rates of other compounds. As such, the pilot-scale CWTSs were subjected to a 6-week trial of synthetic water of the same max worst-case post-closure water quality, but with depleted ammonia and nitrate concentrations to simulate the chemistry expected in long-term closure (Low N period).

It is possible to shift the functionality of a CWTS to stimulate additional microbial dissimilatory selenium reduction and enhance overall treatment of this element. The resultant CWTS would be a hybrid bioreactor-CWTS and is a "passive care" option. This means that the hybrid-CWTS would require more maintenance and operational intervention than a normal CWTS, with periodic dosing of an organic amendment needed (once or a few times annually) in order to achieve the targeted decreased dissolved oxygen and redox levels. However, depending on actual inflow and target outflow concentrations, this approach may be a necessary compromise.

The third and final stage of pilot testing therefore included the addition of an organic carbon amendment (alfalfa hay and straw) to stimulate reducing conditions for improved selenium treatment. Alfalfa hay and straw were chosen as they would provide both short and long-term carbon sources compared to a metered dosing of more available electron donors such as ethanol. This hybrid bioreactor-CWTS period was conducted as an 8-week trial to test how the CWTS functions once converted from conventional CWTS operation to the hybrid configuration. A total of 1.4 g of alfalfa pellets were added per liter of water in each A cell. Straw was added at 10 $cm^3$ per L to A cells, and 5 $cm^3$ per L to B cells. The alfalfa pellets and oat straw were tested to ensure suitability for use (Appendix 1). A summary of the periods and timelines is provided in Table 3.

Over the course of the study, a total of 45,000 L of synthetic water (influent) was received by the pilot CWTS (in 41 batches), approximately 1,200 L of synthetic water per week in a pilot CWTS footprint of 1.56 $m^2$. The system operated with a flow rate of 20 mL/min, resulting in a hydraulic retention time (HRT) ranging from 34 to 94.3 hours, depending on the period of testing and water depth (Table 3).

#### *4.1.4. Routine Monitoring of Explanatory Parameters*

Explanatory parameters are characteristics of a specific environment that describe conditions in the context of how these parameters can affect the chemical reactions taking place. These parameters, when within specific ranges of values, can be used to predict and/or promote certain reactions in the aforementioned environment. Accordingly, dissolved oxygen (DO; mg/L and %), temperature (°C), pH, conductivity (µS/cm), specific conductivity (SPC; µS/cm), and oxidation-reduction potential (ORP; mV) were measured on a routine schedule with a YSI Professional Plus handheld unit.

Hydrosoil reduction-oxidation (redox) potential was measured using inert electrodes (copper wire probes with platinum tips) that were permanently installed in the hydrosoil of the cells and remained there for the duration of the project to ensure accurate readings (Faulkner et al., 1989). On testing days, a reference electrode (Accumet Calomel) was suspended in the water column above the inert electrode. The redox potential was then measured in millivolts by a voltmeter.

#### *4.1.5. Flow Rates*

Constant flow metering pumps were used to set the flow rate of water into the system. To confirm flow rates, the influent to cell A was collected into a graduated cylinder over a timed period of several minutes allowing a flow rate to be calculated in milliliters per minute (mL/min). Flow rates were measured regularly (at minimum weekly) and adjusted as necessary to within +/-10% of the desired flow, to achieve the desired HRT. The rate of water outflow from a CWTS cell was measured using the same procedure. Outflow rates for a series were typically measured every 2 weeks.

#### *4.1.6. Water sampling*

Water samples were collected from the outflow port of each CWTS cell. Care was taken to avoid collecting plant matter, invertebrates, or other debris in the sample. Samples were collected from downstream to upstream to ensure the water sampling did not affect sample collection from the next cell (e.g., disrupting flow rates or suspending solids). All samples were collected according to the schedule in Table 4, with parameters outlined in Table 5.

#### *4.1.7. Stem Counts and Height Measurements*

*Carex aquatilis* stems were counted in each CWTS cell, and 10 stems were randomly chosen in each cell for height measurement. The height of the tallest leaf of each stem was measured to the nearest 0.5 cm from the soil surface to the tip of the leaf. Stem counts and heights were taken monthly during the High N period, as well at the end of the Low N and hybrid bioreactor-CWTS periods (Table 4).

#### *4.1.8. Sediment Sampling*

Sediment/hydrosoil samples were collected at key intervals as per Table 4. Sediment was collected by carefully taking a grab sample of a small section of the top 6 cm of hydrosoil in each CWTS cell into a 50 mL centrifuge tube, pouring off any excess water after collection. In addition to the analyses listed in Table 5, sediment was also collected for microbial profiling according to the schedule in Table 4 and as described in Section 4.3.

#### *4.1.9. Plant Sampling*

Both *Carex* and Moss were collected for metals analysis at the beginning of the study, as well as at end of the Low N period. This schedule was chosen as it was uncertain if the Moss would survive through the hybrid bioreactor-CWTS period. For sample collection at the end of the Low N period, 4 stems of *Carex* (~15% of total stems) were randomly selected from each cell and trimmed at the surface of the water. An approximate 250 ml volume of compressed Moss was

also collected from each cell in series 3-6. Plants from replicate series (e.g., series 1&2, 3&4, 5&6) were combined and sent for metals analysis as a representative sample for each system type. For the final sampling point (i.e., at pilot system takedown) all remaining *Carex* plants in each cell were trimmed at the soil level and rinsed with water prior to sending for metals analysis.

#### *4.1.10. Freeze-Thaw Trial*

In addition to routine analysis for metals in plants, a replicate of each plant sample collected at the end of the low N period was used in a freeze-thaw trial to determine if the plants will leach constituents of concern such as Cu and Se after freezing. In this trial, 200 mL of water from the corresponding CWTS cell was added to the plant sample to completely cover the plant material. The samples were frozen at -20°C for 5 days, and then thawed at room temperature (~22°C) overnight. The plant samples were removed and lightly squeezed to return residual water to the container, and the plant tissue was sent for metals analysis to compare with pre-freeze concentrations.

#### *4.1.11. Organic Carbon Leach Test*

To determine the constituents that could leach from the alfalfa and straw that were added for organic carbon during the hybrid bioreactor-CWTS period, a leach test was performed. In this test, 2 L of outflow from system 1 was collected and alfalfa and straw were added to mimic the concentrations that were added to the system. The water was tested for total metals 3 weeks after the organic carbon addition to determine if any metals had leached from the alfalfa and straw into the water.

### 4.2. **Methods for microbial analyses**

#### *4.2.1. Growth-based analyses (MPN)*

The most-probable number (MPN) of bacteria was determined for all micro samples. The MPN test allows for an estimation of the number of bacteria that can grow in a specific laboratory medium. The media tested in this project were specific for bacteria that can reduce nitrate, selenite, and sulfate, respectively, as well as the total number of heterotrophic bacteria for comparative purposes (i.e., a growth-permissive test for all bacteria capable of growing on organic carbon as an energy source). MPN tests for sulphate (Active Standard ASTM D4412) were conducted under anaerobic conditions, whereas selenite (Siddique et al., 2006) and nitrate (Nitrate Reduction Test, supplied by Sigma-Aldrich) were tested under aerobic conditions. Total heterotrophs (grown with YTS250 medium; (Lefrançois et al., 2010) were quantified in both aerobic and anaerobic conditions.

In brief, sediment samples were diluted 1:100 with a 0.1% peptone solution. This starting dilution was then used for a serial dilution along a sterile 96-microwell round-bottom plate containing the respective growth media. Sediment dilutions tested in the MPN plate ranged from 1/400 to 1/419,430,400. At minimum, all tests were conducted in duplicate. Wells were incubated at +30°C without light and assessed for visible growth (formation of a bacterial pellet) and/or colour change specific to the type of media after 27 days. A colour change to black or red/orange indicated sulphate or selenite reduction, respectively. Nitrate reduction was tested

as per the kit manufacturer's protocol by addition of reagents to differentiate between reduction to nitrite or nitrogen gas. The most probable number of bacteria capable of each metabolism was then calculated as described in the FDA Bacteriological Analytical Manual, Appendix 2: Most Probable Number from Serial Dilutions: (http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm109656.htm). The MPN of organisms in each pilot system was compared over time using the non-parametric Kruskal-Wallis test.

#### *4.2.2. DNA-based analyses*

DNA was extracted from all samples using the MO BIO Powersoil Powerlyzer DNA extraction kit, with the addition of phenol during cell lysis as per the manufacturer's alternative protocol. Targeted sequencing was used to identify bacteria present in each sample via polymerase chain reaction (PCR) amplification of the v3/v4 region of the 16S ribosomal RNA gene (Klindworth et al., 2013). Library preparation and sequencing was performed as per the manufacturer's instructions for MiSeq v3 paired-end 300 bp sequencing (Illumina). All raw sequences were filtered to remove low quality reads, and the forward and reverse primers were truncated. Bioinformatics pipelines consisting of internal scripts and selected QIIME scripts (Caporaso et al., 2010; Edgar, 2010) were used to process the reads. Similar sequences were clustered into groups called Operational Taxonomic Units (OTUs) using a 97% identity threshold. Taxonomic classification of the OTU's was performed according to the Greengenes database (DeSantis et al., 2006; McDonald et al., 2012). Non-metric multidimensional-scaling was used to compare microbial communities across samples using the Bray-Curtis dissimilarity metric. The percentage of the microbial community classified as organisms of interest (e.g., sulphate-reducing bacteria) was also compared across samples. The most abundant OTU's were compared to the Cu, Se, and S concentrations in the sediment to calculate the Spearman correlation coefficient and associated p-value.

## 5. Results and Discussion

#### *5.1.1. Outflow concentrations of copper and selenium*

The pilot systems were operated for 37 weeks with three distinct trial periods of High Nitrogen, Low Nitrogen, and Hybrid Bioreactor-CWTS, with the average influent and outflow water chemistry provided in Tables 6, 7, and 8, respectively. The minimum, maximum, and average measurements of selected parameters and copper and selenium concentrations are summarized in Table 9. While copper treatment was relatively stable through both the High N and Low N periods, selenium treatment improved during the High N period (Figure 3), and then stabilized through the Low N period. For both the High N and Low N periods, the systems that were planted with Moss and *Carex* had significantly better copper treatment than Moss only. There was no statistically significant difference found among the three pilot system designs for selenium removal (i.e., Moss or biochar did not show a significant effect on selenium treatment during these periods).

The hybrid bioreactor-CWTS configuration was effective for both copper and selenium treatment. The purpose of the bioreactor-CWTS configuration is to serve as a contingency in

case greater treatment is needed than is being achieved by the CWTS at a given point in time (e.g., the influent water quality or outflow objectives change). The tests here show that the CWTS can be repurposed as a hybrid bioreactor-CWTS with improved selenium and copper treatment within the same footprint, and without need for added construction. However, operating the system as a hybrid bioreactor-CWTS would require greater operational maintenance than it would in its original CWTS configuration.

In the case of selenium, the reconfiguration resulted in a statistically significant decrease in outflow concentration compared to that prior to the reconfiguration (Figure 3). This result for selenium was expected based on the design targeting more favourable conditions for selenium reduction, such as lower dissolved oxygen and ORP resulting from the additional electron donors from the microbial decomposition of the alfalfa and straw. In terms of copper, the lowest outflow concentration of the study was measured during the hybrid bioreactor-CWTS phase (7.5µg/L); however, prior to this there was a brief decrease in treatment effectiveness in all systems (Figure 3, June 19$^{th}$ data point). However, even during this brief disruption, 86% of the total copper entering the system was treated.

It is not known whether this brief change in treatment effectiveness was due to a short-term loss of treatment capacity during the transition, or if it might have been caused by a release of copper and other constituents that were sorbed to the moss or other organic matter during the transition. This decrease in treatment effectiveness coincided with low dissolved oxygen and moderately reducing conditions in the water column being attained in all cells (DO < 0.5 mg/L, ORP < -80 mV); however, it was not clear if the additional copper in the outflow was released from the alfalfa and straw that were added, or if constituents were briefly released from the sediment or moss and detritus after the system transitioned into more reducing conditions. As a result, a leach test was conducted on the alfalfa and straw and determined that there was no discernible release of copper from these organic materials. The origins of the decrease in treatment effectiveness could not be determined definitively, with the disturbance being registered during a single sampling point, with a maximum potential disturbance period of 4 weeks.

While the hybrid bioreactor-CWTS configuration improved selenium treatment, and demonstrated the lowest outflow concentration of copper of the entire trial, the short upset of treatment performance during the transition is meaningful in terms of monitoring during site implementation. It should be emphasized that if a transition from a typical CWTS design to a hybrid bioreactor-CWTS style is performed, careful monitoring of the CWTS is required as some elements may have decreased treatment effectiveness for a brief period. During this timeframe, if concentrations of elements exceed regulatory guidelines, water may need to be recycled through the wetland, or a contingency water treatment plan should be put in place for the outflow over the period of treatment disturbance.

#### *5.1.2. Removal Rate Coefficients*

An important factor for wetland design is the rate of treatment, also known as the removal rate coefficient (RRC). The RRC is based on treatability of a specific compound and the hydraulic retention time of the system. Once the RRC is known, the equation is rearranged and the RRC can be used to calculate the HRT needed to meet outflow objectives (and accordingly, the size of the wetland). It can also be used to predict the expected outflow concentrations of a specific element in a wetland of the same design based on inflow rates, concentrations, and footprint. RRCs vary with the concentrations of an element, and therefore, a sequential cell approach was used in this pilot study to allow for the RRC to be calculated over a broader range of inflow and outflow concentrations than if the system were only considered as a single treatment unit. Together these can then be used to estimate the size needed for a full-scale CWTS to meet outflow concentration performance objectives for a given influent concentration and flow rate. It should be noted that a RRC is specific to each given constituent respective to a particular wetland design, and can change based on the water chemistry and/or system design. The RRCs presented in this paper are a representative approximation of the Minto Mine site in a closure scenario and accounts for High N, Low N, and the use of a hybrid bioreactor-CWTS operational period (Figure 4, Table 10). When comparing the RRC of different designs of pilot systems in which the retention time and inflow concentrations are the same, a higher RRC indicates increased removal of the constituent. In the equation below, the first order RRC has been reconfigured to calculate *t* (hydraulic retention time), allowing the use of *Ci* (initial concentration), *Cf* (final, desired concentration), and *k* (removal rate constant, RRC) to be used to size the wetlands accordingly.

$$k = \frac{-ln(C_f/C_i)}{t}$$

$$t = \frac{-ln(C_f/C_i)}{k}$$

**Equation:** Removal rate coefficient (RRC) calculation, and rearranged to solve for HRT

When comparing the copper RRC of cells A and B within a series during the High N period, the RRC of the first cell is very high, while the RRC of the second cell is negligible (Figures 5 and 6). This phenomenon is frequently observed in treatment wetlands, where the treatment rate is faster at higher concentrations than at lower concentrations (Horner et al., 2012; Murray-Gulde et al., 2008; Spacil et al., 2011). As such, increasing the HRT of these systems by adding additional cells to the series would not result in a linear decrease in the final copper outflow concentration.

In contrast, the Low N and hybrid bioreactor-CWTS periods do not have this same degree of difference between copper RRC between cells A and B within a series (Figure 5). This change in cell-to-cell difference of RRC still results in similar or improved outflow concentrations. Generally speaking, the RRC of the first cell in the system has decreased, while that in the second cell has improved. This observation can be attributed to a variety of factors. Based on previous experience, the most likely explanation is that there was an abundance of sorption sites available in all cells at pilot initiation. As the study progressed, the sorption sites became

occupied and removal via this mechanism was no longer available. This same phenomenon is also often seen when setting up an on-site demonstration-scale or full-scale treatment wetland. As such, both pilot and demonstration scale studies should be conducted for a sufficiently long period of time so as to realize the actual treatment capacity of the system beyond this initial sorption phase. This phenomenon must also be taken in the context of the duration over which the system must operate within a year, and the knowledge that the reaction front will move downstream within a wetland through this time. Therefore, an increased wetland size might not significantly improve outflow concentrations, but will aid in maintaining treatment performance through the year, so long as the added size does not result in concentration of the elements due to evaporation of the water caused by increased size.

A second possibility is that since the High N conditions coincided with an algal bloom (both visible, but also confirmed by community profiling that there was an abundance of cyanobacteria; Figure 7), the greater concentrations of cyanobacteria and algae during the High N period could have also been responsible for increased sorption and uptake of copper in the A cells. In either case, it is not to say that the B cells were not capable of a high removal rate, but rather that the concentration of copper in the A cell effluent left very little copper available for treatment in the B cell, regardless of capacity for treatment.

It is important to note that the RRCs for copper decreased during the hybrid bioreactor-CWTS period (Figure 4). This can be attributed to the longer HRT created by the increased water depth in this period despite similar outflow concentrations. Through all periods, the outflow concentration of copper for any given system did not vary significantly, indicating that regardless of the cause of the difference in RRC at different points in the system operations (e.g., sorption, algal uptake, increased water depth), the thermodynamic minimum for copper removal has likely been approached within the system, with an average outflow concentration of 18 ± 5 µg/L (Figure 6). That is to say, making the wetland bigger using any of the tested designs would not result in a further significant decrease in outflow copper concentration, but rather, design alterations would need to be made in order to attempt to achieve lower outflow concentrations. During the High and Low N periods when the Moss was actively growing, copper removal rates were greater in systems containing Moss than in systems with only *Carex*. It is likely that as the Moss continues to grow over time and increase in total mass, the RRC would also improve in these systems. Finally, the addition of biochar did not have any significant effect on performance.

Selenium tells a different story than copper in regards to the RRC. Selenium had a fairly similar removal rate in both the A and B cells during the Low N period (Figures 5 and 6). This could be because the selenium treatment is microbially mediated, or because the inflow concentrations are already so low that both the inflow and outflow concentrations of all cells still fall within the same RRC range. A test of the metals composition in the plants and subsequent mass balance of the systems confirmed that the system was operating as designed to target selenium mineralization to the sediment, as plant uptake was responsible for only 1-3% of the total selenium that was removed from the water during the entire course of the study (Figure 10). Based on the RRCs for selenium in the Low and High N periods, an increased HRT is expected

to result in a lower outflow concentration of selenium (Figure 6). This could be achieved by increased footprint, or water depth, so long as the depth does not exceed that in which the *Carex* and Moss will grow.

Conversely, the hybrid bioreactor-CWTS time period had a significantly higher RRC for selenium in the A cells compared to the B cells (Figure 5). It should be noted that while the HRT is longer during the hybrid bioreactor-CWTS period than it was during the Low or High N periods due to an increase in water depth, it can be calculated using the RRC from the previous periods that this alone does not account for the degree of improvement in outflow concentration of the bioreactor-CWTS design. If the improvement in outflow concentration could be attributed solely to the increased HRT, the RRC would remain the same. Instead, we observe an improvement of not just the outflow concentration, but also in improvement in the RRC for selenium in all systems when converted to the bioreactor-CWTS configuration. This higher RRC is presumably due to the more favourable conditions that have been targeted for selenium reduction, including lower dissolved oxygen and a lower ORP resulting from the additional electron donors available through the microbial decomposition of alfalfa and straw. Through all time periods, there was no discernible benefit measured by the addition of biochar into the soils of the systems; rather, the systems that were planted with *Carex* and Moss performed similarly regardless of whether biochar had been included in the soil or not.

As would be expected based on the RRC data for systems containing *Carex* and Moss, the final sediment concentrations of copper are higher in the A cells than the B cells, with the B cells being only slightly higher in concentration than the starting levels (Figure 8). The same trend is evident for selenium; however, the starting concentration and concentrations in most of the B cells are below detection limits. It is of note that the copper and selenium sediment concentrations are positively correlated to an increase of sulphur in the sediment, while no discernible change was found in iron concentrations (Figure 8). This correlation is important to understand the long-term stability of copper within the system, as copper is highly stable when mineralized in a sulphide form and maintained under reducing conditions such as those in the wetland soils. In this case, the sulphides are being formed by microbes living in the soil and associated with the plant roots (see black areas in soil and around roots in Figures 14 and 15). This is supported by the finding of an initial increase of sulphate-reducing bacteria in the sediment, followed by stability over time at a most probable number of approximately 10,000-100,000 microbes per gram of sediment that are capable of reducing sulphate to sulphide (Figure 17). In the case of selenium, the correlation with sulphur in sediment is presumably due to the ranges of explanatory parameters found within the system (dissolved oxygen, ORP, soil redox, pH) which are favorable to both microbially-mediated selenium and sulphur reduction, suggesting the sedimentary selenium is likely in an elemental form, or sorbed to organic materials such as biofilms. While, the stability of the copper and selenium mineralizations were not tested in this study, it is planned for testing to be performed during the upcoming on-site demonstration-scale trial by using sequential extractions on the sediment paired with ICP analysis.

### *5.1.3. Fate and distribution of copper and selenium*

Mass balances were calculated for each pilot system to assess the fate and distribution of elements removed from the water during the course of testing (i.e., the full 37 week period). For systems that were planted with *Carex* and Moss, 64-75% of the copper removed from the water was sequestered into the top 6 cm of sediment (Figure 9). In contrast, systems with only *Carex* planted and no Moss had only 33% of the copper ending up in this top sediment fraction (Figure 9). For systems planted with both *Carex* and Moss, 68-83% of the treated selenium was sequestered to this top portion of the sediment, but less than 52% was in the sediment of the system planted with only *Carex* (actual percentage cannot be calculated as the selenium was below the sediment detection level; Figure 10). For both elements, only 1-3% of the total load removed from the water was found in the above water vegetation (*Carex*) at the end of pilot testing.

It was not possible to determine the concentrations of elements in Moss, as the majority did not survive in the hybrid bioreactor-CWTS period conditions. However, in anticipation of this potential issue, samples of Moss were sent for analysis prior to the start of the hybrid bioreactor-CWTS period, allowing for a bioconcentration factor (BCF) to be calculated.

### *5.1.4. Plant uptake and overall performance*

The bioconcentration factor (BCF) is the ratio of the amount of an element taken up into or sorbed onto the surface of a plant, compared to the amount of the element in the water, and is expressed as the ratio of mg of chemical per kg of organism to mg of chemical per liter of water. The amount of an element sorbed onto the surface of a plant was included in the BCF calculation to give a better representation of the amount that would be present in and on a plant in the wetland (i.e., for plant death/degradation as well as consumption perspectives). As would be expected based on samples collected during the site visit in 2013 and supported by scientific literature, we found in this study, and also in the site visit that *Carex* had a much lower BCF than Moss for both selenium and copper (Table 11). This finding is expected, as moss is known to have a high sorption capacity and therefore, high BCF (Aldrich & Feng, 2000; Gstoettner & Fisher, 1997). For some elements, bioconcentration factors within a plant species are higher when the element itself is at a lower concentration. This held true in the pilot systems when comparing cells A and B in a series, as the BCF for copper in *Carex* was significantly higher in B cells (which had lower aqueous concentrations) than in A cells (with higher influent concentrations) for all three pilot system designs tested (Figure 11). However, for selenium, the A cells had a similar BCF as B cells planted with both *Carex* and Moss (not statistically different), but a significantly higher BCF in the A cells planted with only *Carex* (Figure 11).

Selenium bioconcentration in *Carex* in the pilot systems was very low, resulting in average final tissue concentrations of only ~1.9 mg/kg wet weight. The BCF of selenium was greater in the Moss than the *Carex* in the pilot systems (Table 11). However the Moss BCF recorded here is still relatively low overall based on the United States Environmental Protection Agency Toxic Substances Control Act which considers BCF less than 1000 as non-bioaccumulative. It should also be noted that although selenium is generally known to bioaccumulate, Moss is not a food source for higher animals or invertebrates; as such, the selenium in the Moss should not be

contributing to bioaccumulating pathways (Haines & Renwick, 2009; Longton, 1997; Suren & Winterbourn, 1991).

It is important to the overall treatment system design to determine if elements may be released by the plants by freezing and thawing in the water, as would occur through natural seasonal progression. A freeze-thaw trial was conducted in which *Carex* and Moss were collected and sent for metals analysis both before and after being submerged in water from the wetland and freezing to -20°C followed by thawing to room temperature. It was promising to find that *Carex* released only a small percentage of the selenium (18-38%) and copper (0-13%) as noted by the decrease in tissue concentrations after freezing and thawing (Figure 12). Moreover, Moss was found to have a significant increase in concentration of these elements after being frozen and thawed (Figure 13). It appears that through the freeze-thaw process, the Moss has an enhanced sorption of these compounds, removing an additional amount from the water.

Based on the pilot system design and plant densities, *Carex* would theoretically release on average 0.14 mg of copper and 0.27 mg of selenium per square meter of wetland area, while Moss would theoretically bind 511 and 11.8 mg/m$^2$, respectively. This finding is important, as it demonstrates that despite some release of constituents by *Carex* through freeze-thaw, the Moss will provide uptake in excess of what is released by the *Carex* and also assist with treatment during initial spring thaw before biogeochemical processes are at full capacity.

During the pilot CWTS takedown, it was noted that the *Carex* had an extensive root structure throughout the entire hydrosoil (Figures 14 and 15), making it an ideal candidate for construction of stable wetlands on site. Additionally, it should be noted that no significant difference in plant health or growth (i.e., number of stems, plant height, weight, and percent moisture at end of pilot) was found for systems with or without biochar or Moss (Figure 16). Based on the data collected during the pilot-phase testing, we can conclude that the combination of *Carex* and Moss is the ideal CWTS design for long-term and sustainable copper and selenium treatment. In this design the *Carex* provides structure to soil and sediment of the wetland with extensive root structure, additional treatment capacity based on the roots drawing water down into the sediment, renews organic carbon in the sediment and contributes to accretion through detritus decomposition, and aids in the production of sulphate reducing zones (as indicated by black areas in Figure 15). Meanwhile, the Moss provides sorption and uptake of elements even through freeze-thaw events.

#### *5.1.5. Microbially-mediated treatment*

In order to fully understand the function of biogeochemical processes such as the mineralization of copper and selenium, it is critical that the microbial populations performing these functions are well characterized and understood. Therefore, the microbial communities populating the sediment of each pilot CWTS cell were analyzed by both genetic and growth-based methods. The genetic method identifies and comparatively quantifies all of the bacteria in a sample without requiring growth, which is very important because a large proportion of environmental organisms will not grow in a laboratory setting. The genetic-based profiling is therefore used to assess which microbes are present and at what abundance, giving an idea of the robustness of

the community and allowing for potential function to be inferred. The second method is called the most-probable number (MPN) assay, which is a dilution-based growth method that can determine the number of selenite-reducing, sulphate-reducing, and nitrate-reducing organisms per gram of sediment. The MPN method is therefore a means to evaluate the biogeochemical cycling potential of a sample; however, because the analysis is based on growth in laboratory media, it is presumed that not all organisms are able to grow and that only a partial profile of the microbial community is provided. Both methods allow for comparisons to be made of the microbial populations across samples, treatments, or time series.

With the microbial analyses, we were interested in three key questions:

- How does the microbial community adapt and change with different influent water chemistries and system designs?
- Are microbes that contribute to selenium, copper, or nitrate treatment present in the pilot wetland cells, and if so, are these same organisms present at the Minto site?
- Is selenium or copper treatment mediated by microbes present in the sediment?

As Figure 7 shows, the microbial population adapted rapidly and consistently to the changes in influent chemistry (i.e., High N, Low N), as well as the addition of organic matter. The nMDS plot of Figure 7 can be interpreted simply as samples that cluster together have more similar microbial communities, while those that are farther apart have distinct differences in their populations (such as identity or relative abundance). At the beginning of the pilot system operation, the microbial community had a proportionately high number of *Actinobacteria*, which then transitioned to *Cyanobacteria* during the High N period corresponding to a visible algal bloom. The Low N and hybrid bioreactor-CWTS phases had similar microbial populations, indicating that either the microbes present in the Low N phases were also well suited to the bioreactor-CWTS conditions, or that the community was still in flux at the final sampling, and treatment would have continued to improve over time in the hybrid system as more anaerobic organisms flourished. Overall, Figure 7 shows that as expected, the microbial populations were both adaptive and robust, shifting to respond to changes in the water chemistry and explanatory parameters such as dissolved oxygen and redox.

The results of the MPN testing indicate that the High N period had an abundance of organisms capable of denitrification including the reduction of nitrate to nitrite, and nitrate to $N_2$ gas (Figure 17). As expected based on the elevated water concentrations of nitrate, the High N period had a large number of organisms present that could reduce nitrate to $N_2$ gas. Although in decreased abundance, denitrifying bacteria were present through the Low N period and the hybrid bioreactor-CWTS period, despite having much lower nitrogen concentrations during this timeframe. As such, it is anticipated that fluctuations in ammonia and nitrate concentrations over time would be rapidly met with millions of microbes per gram of soil that are able to perform denitrification reactions.

Sulphate-reducing bacteria consistently increased in abundance over time in all system designs, starting out with a most probable number of approximately a thousand per gram of sediment and increasing by two orders of magnitude through the study (Figure 17). This increase is

consistent with trends observed in the soil redox measurements becoming more negative over time in this study. The presence and abundance of sulphate-reducing bacteria were positively correlated with final sulphur concentrations in sediment, according to both the genetic and growth-based profiling methods. Several groups of known sulphate-reducing bacteria (e.g., *Desulfobacterium, Desulfosarcina, Desulfotomaculum)* were found to also correlate with copper concentrations in the sediment, suggesting that their presence leads to reduction of sulphate to sulphide, which then binds to copper and precipitates into the sediment. This can also be demonstrated by the black areas surrounding the *Carex* roots and black precipitates on the sediment surface observed during system takedown (Figures 14 and 15). This copper-sulphide mineralization mechanism is ideal for treatment as it provides a non-bioavailable and stable form of copper in the sediment.

We can tell from the genetic sequencing that these same types of sulphate-reducing bacteria were found in samples that were collected during the August 2013 site visit, specifically associated with *Carex* roots and sediment at the W10 location, as well as in the sediment at W15. It is likely that these were brought to the pilot system along with the plant roots as these *Carex* were harvested from the Minto W10 area. This indicates that despite having different sediment and environmental conditions at the site in comparison to the pilot CWTS, these microbes are robust and can be further encouraged to thrive and perform beneficial functions by having the ecological niches that they prefer (e.g., *Carex* roots, low ORP and DO).

The most probable number of selenite-reducing bacteria ranged from hundreds of thousands to tens of millions per gram of soil and was similar between the different system designs, having similar variance through the three testing periods (Figure 17). There was a general increase in selenite-reducing bacteria during the High N and Low N periods, followed by a decrease in their numbers during the hybrid bioreactor-CWTS period similar to denitrifying organisms discussed above. It was not possible to calculate a correlation between the number of selenite-reducing bacteria and the selenium concentration in the sediment due to the generally low levels (i.e., non-detectable) of selenium in the sediment of most cells. An abundance of selenite-reducing organisms in the pilot systems as well as at the Minto site indicates that these organisms are a robust and diverse group, and are present with a latent capacity to perform microbially-mediated selenium treatment given the proper conditions (e.g., electron donors, targeted ORP and DO levels).

The importance of these microbial results is two-fold: first, the treatment of selenium, copper, or nitrate can be mediated and sustained in a very passive manner by microbes if provided the right environment. Second, this necessary environment can be targeted through system design and adjustments in operation as have been done through this study, resulting in stimulation of these microbes in abundance, diversity, and activity.

#### *5.1.6. Range of operational parameters*

In order to be able to effectively implement a full-scale passive treatment system such as a CWTS, the targeted explanatory parameters must be predefined. As such, one of the goals of this pilot-scale work was to confirm or optimize the ranges of these parameters from what can

be derived from publications and previous experience. These explanatory parameters can then be used to predict the functionality of a wetland and efficacy of treatment. Moreover, well-defined explanatory parameters allow for adaptive management plans to be developed in order to maintain optimal treatment effectiveness and predictability. The pilot systems tested here performed well not only across a variety of water chemistries and induced conditions, but also over a wide range of water pH, DO, ORP and soil redox. Table 9 includes the minimum, maximum and average recorded values of some selected explanatory parameters for the different periods of testing. Most importantly, this table shows that the range of conditions needed for effective copper and selenium treatment were achieved for this site-specific CWTS design, highlighting the robustness and adaptability of the design and providing a range of conditions under which the system will function.

## 6. Conclusions and Recommendations

When designed and implemented in a strategic and scientifically guided manner, CWTSs can mitigate risks posed by many contaminants. A treatment plan that includes processes that precipitate insoluble species of these constituents for sequestration into the sediments of the wetland are very desirable, as this mechanism captures the contaminant and stores it with stability in the sediments, rather than transferring the contaminant to an indeterminate fate (e.g., plant uptake or volatilization). This study has addressed several important design considerations regarding implementation of a CWTS at the full scale for the treatment of copper and selenium at the Minto Mine. A synopsis of the conclusions and recommendations are:

- An effective and robust pilot-scale CWTS design was demonstrated and optimized using plants from the Minto site and predicted closure water chemistries.

- The pilot-scale CWTSs provided much of the information needed to effectively size full-scale CWTS for treatment at the Minto site, but sizing will also be dependent on other factors (hydrology, available area, and constructability considerations).

- The recommended CWTS design for long-term passive treatment of copper and selenium at the Minto site is a combination of *Carex* and Moss planted in a sand substrate supplemented with woodchips and peat.

- The selected design achieved average outflow concentration of 12 µg Cu/L (average influent 146 µg Cu/L), and 6 µg Se/L (influent 10.2 µg Se/L).

- Conversion of the CWTS to a hybrid bioreactor-CWTS design resulted in the lowest copper (7.5 µg/L) and selenium (1.9 µg/L) concentrations of the study, but was preceded by a brief disruption of treatment capacity. This configuration would require greater maintenance than the basic CWTS, but could be implemented if any changes in influent water quality are predicted or if outflow objectives change.

- If transitioning from the CWTS design to hybrid bioreactor-CWTS, close monitoring of CWTS and potential consideration of contingency treatment is recommended during the

transition period, as there may be a brief and temporary disruption in treatment effectiveness.

- The majority of the copper and selenium treated by the system was sequestered to the top 6 cm of sediment, with only a small portion (1-3%) being taken up into the *Carex* (commonly known as sedge).

- After undergoing a freeze-thaw cycle, the *Carex* used in this study released only a small amount of copper and selenium; however, under the same trial the binding and sorption capacity of the Moss increased, resulting in a net removal of copper and selenium from the water through a freeze-thaw cycle.

- Fluctuations in nitrogen levels (as would be expected in early closure due to residue from blasting activities) are responded to by a diverse microbial community with a robust capacity to treat nitrate, but also continue to treat Cu and Se through this transition;

- There were thousands to billions of nitrate, sulphate, and selenium reducing bacteria present per gram of soil in the pilot CWTS, many of which were confirmed through genetic testing to be the same groups of organisms as found at the Minto site.

- It is recommended that the design be tested on-site at Minto with a demonstration-scale CWTS receiving seepage water.

## 7. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Respectfully submitted,

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## 9. Tables

**Table 1:** Synthetic water formulation.

| Element | Compound | Concentration (mg/L) |
|---|---|---|
| **Aluminum** | $Al_2(SO_4)_3 \cdot 18H2O$ | 0.929 |
| **Ammonium** | $NH_4HCO_3$ | 1.00[1] |
| **Arsenic** | $Na_2HAsO_4 \cdot 7H_2O$ | 0.012 |
| **Barium** | $BaCl_2 \cdot 2H_2O$ | 0.817 |
| **Cadmium** | $CdCl_2$ | 0.0005 |
| **Calcium** | $CaCl_2$ | 11.68 |
| | $Ca(NO_3)_2 \cdot 4H_2O$ | 197.59[1] |
| **Chromium** | $CrO_3$ | 0.013 |
| **Cobalt** | $CoCl_2 \cdot 6H_2O$ | 0.017 |
| **Copper** | $CuCl_2 \cdot 2H_2O$ | 0.239 |
| **Iron** | $FeSO_4 \cdot 7H_2O$ | 15.29 |
| **Lead** | $Pb(NO_3)_2$ | 0.0007 |
| **Magnesium** | $MgSO_4 \cdot 7H_2O$ | 324.77 |
| **Manganese** | $MnSO_4 \cdot H_2O$ | 8.10 |
| **Molybdenum** | $Na_2MoO_4 \cdot 2H_2O$ | 0.026 |
| **Nickel** | $NiCl_2 \cdot 6H_2O$ | 0.023 |
| **Potassium** | $KNO_3$ | 28.34[1] |
| | $KH_2PO_4$ | 0.298 |
| **Selenium** | $Na_2SeO_3 \cdot 5H_2O$ | 0.032 |
| **Silver** | $AgNO_3$ | 0.0005 |
| **Sodium** | $Na_2SO_4$ | 54.14 |
| **Strontium** | $SrCl_2 \cdot 6H_2O$ | 8.73 |
| **Vanadium** | $V_2O_5$ | 0.026 |
| **Zinc** | $ZnCl_2$ | 0.056 |

[1] During Low N and hybrid bioreactor-CWTS periods of testing, $NH_4HCO_3$ and $KNO_3$ were not added, and the $Ca(NO_3)_2 \cdot 4H_2O$ was decreased to 1.976 mg/L

**Table 2:** Influent chemistry for pilot CWTS.

| Element (total) | unit | Influent | | | | |
|---|---|---|---|---|---|---|
| | | Targeted | Acclimation Period | High N | Low N | Hybrid bioreactor-CWTS |
| **Aluminum (Al)** | mg/L | 0.100 | 0.089 | 0.085 | 0.080 | 0.098 |
| **Antimony (Sb)** | mg/L | 0.00160 | 0.00060 | 0.00065 | 0.00061 | 0.0006 |
| **Arsenic (As)** | mg/L | 0.0030 | 0.0031 | 0.0033 | 0.0033 | 0.0037 |
| **Barium (Ba)** | mg/L | 0.500 | 0.153 | 0.284 | 0.192 | 0.224 |
| **Beryllium (Be)** | mg/L | 0.00078 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Boron (B)** | mg/L | 0.315 | 0.0243 | 0.0262 | 0.0239 | 0.0243 |
| **Cadmium (Cd)** | µg/L | 0.3340 | 0.011 | 0.236 | 0.336 | 0.392 |
| **Calcium (Ca)** | mg/L | 82 | 70.33 | 73.90 | 40.73 | 48.22 |
| **Chromium (Cr)** | mg/L | 0.0065 | 0.0058 | 0.0064 | 0.0071 | 0.0075 |
| **Cobalt (Co)** | mg/L | 0.0039 | 0.0039 | 0.0042 | 0.0043 | 0.0044 |
| **Copper (Cu)** | mg/L | 0.13 | 0.14 | 0.15 | 0.15 | 0.18 |
| **Iron (Fe)** | mg/L | 3.1 | 3.1 | 3.1 | 3.2 | 3.5 |
| **Lead (Pb)** | mg/L | 0.00070 | 0.00044 | 0.00067 | 0.00059 | 0.00071 |
| **Magnesium (Mg)** | mg/L | 50 | 49 | 49 | 51 | 53 |
| **Manganese (Mn)** | mg/L | 2.6 | 2.5 | 2.5 | 2.6 | 2.7 |
| **Molybdenum (Mo)** | mg/L | 0.012 | 0.013 | 0.015 | 0.013 | 0.013 |
| **Nickel (Ni)** | mg/L | 0.0072 | 0.0077 | 0.0087 | 0.0076 | 0.0080 |
| **Phosphorus (P)** | mg/L | 0.082-0.27 [1] | 0.333 | 0.236 | 0.082 | 0.082 |
| **Potassium (K)** | mg/L | 14 | 14.3 | 14.6 | 3 | 3 |
| **Selenium (Se)** | mg/L | 0.010 | 0.010 | 0.011 | 0.010 | 0.011 |
| **Sodium (Na)** | mg/L | 44 | 40 | 41 | 42 | 43 |
| **Strontium (Sr)** | mg/L | 2.9 | 2.5 | 2.5 | 2.5 | 2.6 |
| **Sulphur (S)** | mg/L | 85 | 85 | 84 | 86 | 88 |
| **Uranium (U)** | mg/L | 0.0051 | 0.0012 | 0.0012 | 0.0012 | 0.0014 |
| **Vanadium (V)** | mg/L | 0.016 | 0.015 | 0.013 | 0.014 | 0.018 |
| **Zinc (Zn)** | mg/L | 0.032 | 0.0517 | 0.037 | 0.040 | 0.042 |
| Nutrients | | | | | | |
| **Total Ammonia (N)** | mg/L | 0.2-0.5 [2] | 0.61 | 0.50 | 0.29 | 0.05 |
| **Dissolved Nitrate (N)** | mg/L | 0.8-28 [2] | 29.33 | 29.67 | 0.86 | 0.84 |
| Misc. Inorganics | | | | | | |
| **pH** | pH | 7.5-8.0 | 7.89 | 8.16 | 7.96 | 8.01 |
| Anions | | | | | | |
| **Alkalinity (Total as CaCO3)** | mg/L | | 107.33 | 107.00 | 100 | 100 |
| **Bicarbonate (HCO3)** | mg/L | | 133.33 | 130.00 | 122 | 130 |

[1] Phosphorous was not modeled for closure, so the maximum concentration from W15 (2007-2012) was used (0.27mg/L), this was later decreased to 0.082mg/L (95$^{th}$ percentile).
[2] Ammonia and nitrate were not added to the synthetic water for the Low N and hybrid bioreactor-CWTS periods.

**Table 3:** Pilot CWTS testing periods.

| Period | Timeline | # Weeks | Water Depth | HRT (hr) ± Std. Dev. | Description/Purpose |
|---|---|---|---|---|---|
| **Pre-Influent** | Nov 4, 2013 – Dec 12, 2013 | 6 | 10 cm | N.D. | Plant establishment |
| **Acclimation** | Dec 13, 2013 – Feb 26, 2014 | 10 | 10cm | 37± 3 | Acclimation of system to influent |
| **High N** | Feb 27, 2014 – Apr 12, 2014 | 7 | 10 cm, 17 cm[1] | 37 ± 3 53 ± 3[1] | High ammonia and nitrate in influent (early closure) |
| **Low N** | Apr 13, 2014 – May 28, 2014 | 7 | 17 cm | 53 ± 2.5 | Low ammonia and nitrate (long-term closure) |
| **hybrid bioreactor-CWTS** | May 29, 2014 – Jul 16, 2014 | 7 | 30 cm | 87 ± 3 | Post alfalfa and straw addition (hybrid bioreactor-CWTS) |

[1] 17 cm from March 13 to Apr 12, 2014 to test higher water depth during High N Period. This therefore results in a longer HRT for this timeframe.

**Table 4:** Monitoring schedule.

| | |
|---|---|
| **Water** | |
| **Temperature** | Weekly |
| **pH** | |
| **Dissolved oxygen** | |
| **Regulated metals water package** [1] | Bi-weekly |
| **Phosphorus** | |
| **Ammonia** [2] | |
| **Nitrate** | |
| **Flow rate** | |
| **Alkalinity** [3] | Monthly |
| **Hardness** [3] | |
| **Conductivity** [3] | |
| **Chemical oxygen demand (COD)** [4] | |
| **Total organic carbon** [4] | |
| **Total Kjeldahl Nitrogen (TKN)** [4] | |
| **Sulphate** [3] | |
| **Biological oxygen demand (BOD)** [3] | Monthly (outflow only) |
| **Total suspended solids** [2] | |
| **Soil** | |
| **Eh (redox)** | weekly |
| **Available NPK** | Initial soil, beginning of influent, end of study |
| **Regulated metals package** | |
| **Total organic carbon** | Initial soil, end of study |
| **Particle size analysis** | |
| **Conductivity** | |
| **Cation exchange capacity (CEC)** | |
| **Sodium adsorption ratio** | |
| **Plant** | |
| **Regulated metals** | Start and end; Freeze-thaw trial |
| **Stem counts and heights** [4] | Monthly |
| **Microbial** | |
| **Most probable number (growth-based)** | Initial soil; beginning High N period; end Low N period; end of study |
| **Genetic microbial community profiles** | |

[1] Dissolved metals was tested in addition to total metals for the Low N and hybrid bioreactor-CWTS periods
[2] Not performed during hybrid bioreactor-CWTS period, except at takedown of pilot
[3] Bi-weekly during hybrid bioreactor-CWTS period
[4] Not performed during Low N and hybrid bioreactor-CWTS periods, except at takedown of pilot

**Table 5**: Summary of water, soil, and plant analyses.

| Water | Soil | Plant |
|---|---|---|
| ICP-MS Total or Dissolved (Al, Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Ni, P, Se, Si, Ag, Sr, Tl, Sn, Ti, U, V, Zn, Ca, Mg, K, Na, S) | ICP-MS (Al, B， Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Mo, Ni, P, K, Se, S, Ag, Na, Sr, Tl, Sn, U, V, Zn,) | ICP-MS (Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Ag, Na, Sr, Tl, Sn, Ti, U, V, Zn) |
| Routine Water (Alkalinity, $HCO_3$, Ion Balance, Dissolved ions, Hardness, Nitrate/Nitrite) | Available Nitrogen, Phosphorous, and Potassium (NPK) | |
| Total Suspended Solids (TSS) | Cation Exchange Capacity (CEC) | |
| Chemical Oxygen Demand (COD) | Sodium Adsorption Ratio (SAR) | |
| Biological Oxygen Demand (BOD) | Total Organic Carbon (TOC) | |
| Total Kjeldahl Nitrogen (TKN) | Electrical Conductivity (EC) | |
| Total Organic Carbon (TOC) | Texture Analysis (Physical properties) | |
| Ammonia | | |

**Table 6:** Performance of pilot CWTS during High N period.

| Elements (Total) | Unit | Influent | Outflow Average | | |
|---|---|---|---|---|---|
| | | Average | *Carex* only | *Carex* + *Sphagnum* | *Carex* + *Sphagnum* + Biochar |
| **Aluminum (Al)** | mg/L | 0.085 | 0.012 | 0.008 | 0.009 |
| **Arsenic (As)** | mg/L | 0.0033 | 0.0010 | 0.0008 | 0.0007 |
| **Barium (Ba)** | mg/L | 0.284 | 0.039 | 0.036 | 0.040 |
| **Boron (B)** | mg/L | 0.0262 | 0.025 | 0.027 | 0.055 |
| **Cadmium (Cd)** | µg/L | 0.236 | 0.038 | 0.023 | 0.017 |
| **Calcium (Ca)** | mg/L | 73.9 | 78 | 78 | 77 |
| **Chromium (Cr)** | mg/L | 0.0064 | 0.0024 | 0.0023 | 0.0024 |
| **Cobalt (Co)** | mg/L | 0.0042 | 0.0008 | 0.0004 | 0.0003 |
| **Copper (Cu)** | mg/L | 0.150 | 0.018 | 0.013 | 0.012 |
| **Iron (Fe)** | mg/L | 3.10 | 0.08 | 0.08 | 0.08 |
| **Magnesium (Mg)** | mg/L | 49 | 50 | 51 | 51 |
| **Manganese (Mn)** | mg/L | 2.5 | 1.1 | 0.37 | 0.2 |
| **Molybdenum (Mo)** | mg/L | 0.0150 | 0.0139 | 0.0130 | 0.0128 |
| **Nickel (Ni)** | mg/L | 0.0087 | 0.0042 | 0.0027 | 0.0020 |
| **Phosphorus (P)** | mg/L | 0.236 | <0.1 | <0.1 | <0.1 |
| **Potassium (K)** | mg/L | 14.6 | 14.9 | 15.3 | 15.1 |
| **Selenium (Se)** | mg/L | 0.0110 | 0.0076 | 0.0073 | 0.0067 |
| **Sodium (Na)** | mg/L | 41 | 43 | 45 | 42 |
| **Strontium (Sr)** | mg/L | 2.5 | 2.7 | 2.7 | 2.6 |
| **Sulphur (S)** | mg/L | 84 | 86 | 87 | 86 |
| **Uranium (U)** | mg/L | 0.0012 | 0.0011 | 0.0011 | 0.0011 |
| **Vanadium (V)** | mg/L | 0.0130 | 0.0023 | 0.0019 | 0.0017 |
| **Zinc (Zn)** | mg/L | 0.0370 | 0.0042 | 0.0044 | 0.0034 |
| Nutrients | | | | | |
| **Total Ammonia (N)** | mg/L | 0.50 | 0.05 | 0.05 | 0.05 |
| **Dissolved Nitrate (N)** | mg/L | 29.67 | 29.4 | 29.4 | 29.5 |
| Explanatory Parameters | | | | | |
| **pH** | pH | 8.16 | 7.47 | 7.61 | 7.80 |
| **DO (mg/L)** | | | 5.33 | 5.16 | 5.52 |
| **Water redox (mV)** | | | 154.5 | 144.2 | 136.0 |
| **Soil Redox (mV)** | | | -148 | -191 | -220 |

**Table 7:** Performance of pilot CWTS during Low N period.

| Elements (Total) | Unit | Influent | Outflow Average | | |
|---|---|---|---|---|---|
| | | Average | *Carex* only | *Carex* + Moss | *Carex* + Moss + Biochar |
| **Aluminum (Al)** | mg/L | 0.080 | 0.008 | 0.006 | 0.007 |
| **Arsenic (As)** | mg/L | 0.0033 | 0.0007 | 0.0006 | 0.0006 |
| **Barium (Ba)** | mg/L | 0.192 | 0.028 | 0.027 | 0.030 |
| **Boron (B)** | mg/L | 0.024 | 0.023 | 0.024 | 0.022 |
| **Cadmium (Cd)** | µg/L | 0.336 | 0.070 | 0.027 | 0.023 |
| **Calcium (Ca)** | mg/L | 41 | 47 | 47 | 47 |
| **Chromium (Cr)** | mg/L | 0.0071 | 0.0034 | 0.0029 | 0.0030 |
| **Cobalt (Co)** | mg/L | 0.0043 | 0.0006 | <0.0003 | <0.0003 |
| **Copper (Cu)** | mg/L | 0.150 | 0.0210 | 0.0113 | 0.0125 |
| **Copper (Cu) Dissolved** | mg/L | 0.037 | 0.0123 | 0.0086 | 0.0086 |
| **Iron (Fe)** | mg/L | 3.20 | 0.16 | 0.06 | 0.09 |
| **Magnesium (Mg)** | mg/L | 51 | 55 | 55 | 55 |
| **Manganese (Mn)** | mg/L | 2.6 | 0.9 | 0.2 | 0.2 |
| **Molybdenum (Mo)** | mg/L | 0.0130 | 0.0110 | 0.0104 | 0.0105 |
| **Nickel (Ni)** | mg/L | 0.0076 | 0.0035 | 0.0018 | 0.0015 |
| **Phosphorus (P)** | mg/L | 0.11 | <0.10 | <0.10 | <0.10 |
| **Potassium (K)** | mg/L | 3.0 | 3.2 | 3.4 | 3.4 |
| **Selenium (Se)** | mg/L | 0.0100 | 0.0061 | 0.0060 | 0.0063 |
| **Selenium (Se) Dissolved** | mg/L | 0.0080 | 0.0052 | 0.0053 | 0.0052 |
| **Sodium (Na)** | mg/L | 42 | 44 | 44 | 45 |
| **Strontium (Sr)** | mg/L | 2.5 | 2.7 | 2.7 | 2.7 |
| **Sulphur (S)** | mg/L | 86 | 93 | 94 | 93 |
| **Uranium (U)** | mg/L | 0.0012 | 0.0009 | 0.0010 | 0.0010 |
| **Vanadium (V)** | mg/L | 0.0140 | 0.0023 | 0.0016 | 0.0022 |
| **Zinc (Zn)** | mg/L | 0.0400 | 0.0082 | 0.0032 | 0.0031 |
| Nutrients | | | | | |
| **Total Ammonia (N)** | mg/L | 0.29 | <0.05 | <0.05 | <0.05 |
| **Dissolved Nitrate (N)** | mg/L | 0.86 | 0.26 | 0.25 | 0.25 |
| Explanatory Parameters | | | | | |
| **pH** | pH | 7.96 | 7.58 | 7.76 | 7.61 |
| **DO (mg/L)** | | | 5.69 | 6.05 | 5.42 |
| **Water redox (mV)** | | | 179 | 170 | 205 |
| **Soil Redox (mV)** | | | -148 | -183 | -209 |

**Table 8:** Performance of pilot CWTS during hybrid bioreactor-CWTS period.

| Elements (Total) | Unit | Influent | Outflow Average [1] | | |
|---|---|---|---|---|---|
| | | Average | *Carex* only | *Carex* + Moss | *Carex* + Moss + Biochar |
| **Aluminum (Al)** | mg/L | 0.098 | 0.010 | 0.013 | 0.009 |
| **Arsenic (As)** | mg/L | 0.0037 | 0.001 | 0.001 | 0.001 |
| **Barium (Ba)** | mg/L | 0.224 | 0.061 | 0.061 | 0.058 |
| **Boron (B)** | mg/L | 0.024 | 0.026 | 0.026 | 0.025 |
| **Cadmium (Cd)** | µg/L | 0.392 | 0.057 | 0.067 | 0.067 |
| **Calcium (Ca)** | mg/L | 48 | 49 | 48 | 48 |
| **Chromium (Cr)** | mg/L | 0.0075 | <0.001 | <0.001 | <0.001 |
| **Cobalt (Co)** | mg/L | 0.0044 | 0.003 | 0.002 | 0.002 |
| **Copper (Cu)** | mg/L | 0.180 | 0.021 | 0.023 | 0.026 |
| **Copper (Cu) Dissolved** | mg/L | 0.0350 | 0.0122 | 0.0134 | 0.0168 |
| **Iron (Fe)** | mg/L | 3.50 | 0.41 | 0.33 | 0.22 |
| **Magnesium (Mg)** | mg/L | 53 | 54 | 54 | 55 |
| **Manganese (Mn)** | mg/L | 2.7 | 5.2 | 5.1 | 5.7 |
| **Molybdenum (Mo)** | mg/L | 0.013 | 0.015 | 0.020 | 0.021 |
| **Nickel (Ni)** | mg/L | 0.008 | 0.006 | 0.006 | 0.007 |
| **Phosphorus (P)** | mg/L | 0.12 | 0.11 | 0.11 | 0.10 |
| **Potassium (K)** | mg/L | 3.0 | 6.4 | 6.1 | 6.3 |
| **Selenium (Se)** | mg/L | 0.0100 | 0.0040 | 0.0040 | 0.0040 |
| **Selenium (Se)** | mg/L | 0.0119 | 0.0038 | 0.0039 | 0.0041 |
| **Sodium (Na)** | mg/L | 43 | 44 | 44 | 44 |
| **Strontium (Sr)** | mg/L | 2.6 | 2.6 | 2.6 | 2.6 |
| **Sulphur (S)** | mg/L | 88 | 87 | 87 | 87 |
| **Uranium (U)** | mg/L | 0.0014 | 0.0010 | 0.0010 | 0.0010 |
| **Vanadium (V)** | mg/L | 0.018 | 0.002 | 0.002 | <0.001 |
| **Zinc (Zn)** | mg/L | 0.042 | 0.007 | 0.005 | 0.006 |
| Nutrients | | | | | |
| **Total Ammonia (N)** | mg/L | 0.05 | 0.06 | 0.05 | 0.05 |
| **Dissolved Nitrate (N)** | mg/L | 0.84 | 0.08 | 0.06 | 0.03 |
| Explanatory Parameters | | | | | |
| **pH** | pH | 8.01 | 7.16 | 7.20 | 7.19 |
| **DO (mg/L)** | | | 1.52 | 1.73 | 1.86 |
| **Water redox (mV)** | | | -34 | -91 | -134 |
| **Soil Redox (mV)** | | | -197 | -218 | -226 |

[1] The average outflow for the hybrid bioreactor-CWTS period includes data from June 19th, when there was a spike in several constituents when the system reached low dissolved oxygen and moderately reducing conditions in the water column.

**Table 9**: Summary of explanatory parameters and outflow concentrations of copper and selenium

| Period | Parameter | Influent | System | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Carex* | | | *Carex* + Moss | | | *Carex* + Moss + Biochar | | |
| | | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| **High Nitrogen** | Copper (µg/L) | 146.4 | 16 | 20 | 18 | 11 | 16 | 13 | 9 | 14 | 12 |
| | Selenium (µg/L) | 10.2 | 5.8 | 9.7 | 7.6 | 6.0 | 9.5 | 7.3 | 5.8 | 8.5 | 6.7 |
| | pH | 8.00 | 6.99 | 7.94 | 7.49 | 7.19 | 8.29 | 7.64 | 7.39 | 8.28 | 7.84 |
| | DO (mg/L) | - | 4.08 | 6.69 | 5.36 | 2.59 | 7.55 | 5.35 | 3.50 | 8.70 | 5.75 |
| | ORP (mV) | - | 82 | 215 | 157 | 104 | 215 | 247 | 84 | 205 | 140 |
| | Redox (soil,mV) | - | -229 | -51 | -144 | -273 | -177 | -190 | -301 | -135 | -218 |
| **Low Nitrogen** | Copper (µg/L) | 145.5 | 17 | 32 | 21 | 10 | 13 | 11.3 | 11 | 15 | 12.5 |
| | Selenium (µg/L) | 10.2 | 5.3 | 6.7 | 6.1 | 5.6 | 6.5 | 6.0 | 5.8 | 6.9 | 6.3 |
| | pH | 7.96 | 7.16 | 8.05 | 7.54 | 7.26 | 8.32 | 7.71 | 7.15 | 8.25 | 7.60 |
| | DO (mg/L) | - | 3.99 | 7.72 | 5.61 | 3.02 | 9.78 | 5.73 | 2.57 | 9.04 | 5.21 |
| | ORP (mV) | - | 126 | 220 | 168 | 113 | 188 | 159 | 106 | 374 | 182 |
| | Redox (soil,mV) | - | -249 | -39.5 | -150 | -246 | -88 | -185 | -264 | -123 | -211 |
| **Hybrid Bioreactor-CWTS** | Copper (µg/L) | 175.6 | 7.5 | 45 | 21 | 8.3 | 44 | 23 | 8.3 | 64 | 26 |
| | Selenium (µg/L) | 11.9 | 1.9 | 5.6 | 4.0 | 2.5 | 5.4 | 4.0 | 2.8 | 5.4 | 4.0 |
| | pH | 8.01 | 6.91 | 7.62 | 7.16 | 6.95 | 7.82 | 7.20 | 6.96 | 7.71 | 7.19 |
| | DO (mg/L) | - | 0.02 | 3.23 | 1.52 | 0.11 | 5.61 | 1.73 | 0.03 | 4.71 | 1.86 |
| | ORP (mV) | - | -175 | -79 | -129 | -212 | -101 | -150 | -195 | -30 | -134 |
| | Redox (soil,mV) | - | -232 | -170 | -197 | -268 | -159 | -218 | -290 | -150 | -226 |

**Table 10**: Removal rate coefficients for each system and period of testing.

| Element | System | Period RRC ($hr^{-1}$) | | |
|---|---|---|---|---|
| | | High N | Low N | hybrid bioreactor-CWTS [1] |
| **Copper** | *Carex* | 0.0465 | 0.0390 | 0.0250 |
| | *Carex* + Moss | 0.0519 | 0.0497 | 0.0236 |
| | *Carex* + Moss + Biochar | 0.0543 | 0.0462 | 0.0242 |
| **Selenium** | *Carex* | 0.0069 | 0.0103 | 0.0130 |
| | *Carex* + Moss | 0.0078 | 0.0102 | 0.0128 |
| | *Carex* + Moss + Biochar | 0.0095 | 0.0090 | 0.0123 |

[1] The calculation of RRC for the hybrid bioreactor-CWTS period included data from June 19th, when there was a spike in several constituents when the system reached low dissolved oxygen and moderately reducing conditions in the water column.

**Table 11**: Bioconcentration factor for each plant species at the end of the Low N period.

| Plant Species | Copper (L/kg) | Selenium (L/kg) |
|---|---|---|
| ***Carex*** | 23 | 113 |
| **Moss** | 1390 | 593 |

## 10. Figures

**Figure 1**: Pilot CWTS layout

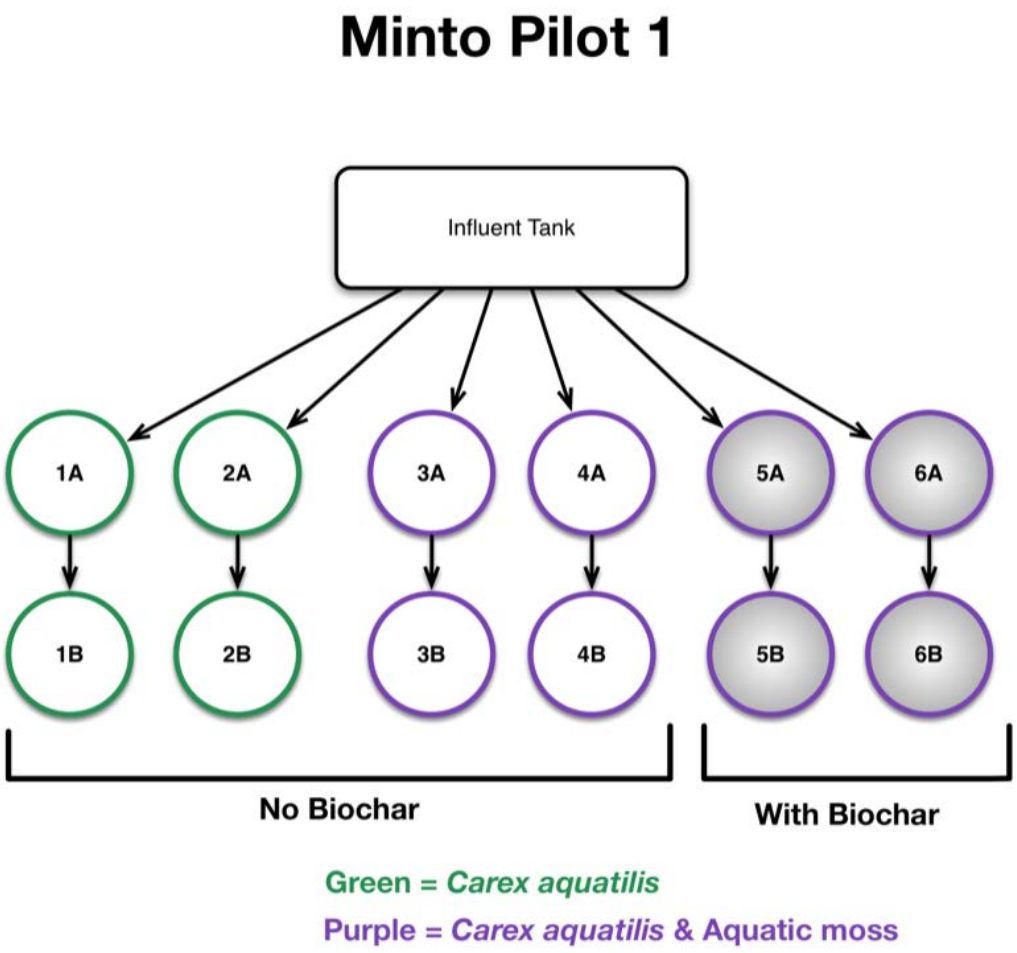


**Figure 2:** Photographs of pilot CWTS set up. Top is entire system, with 6 series of two cells; bottom is one cell.



**Figure 3:** Outflow copper and selenium water concentrations over time compared to influent.

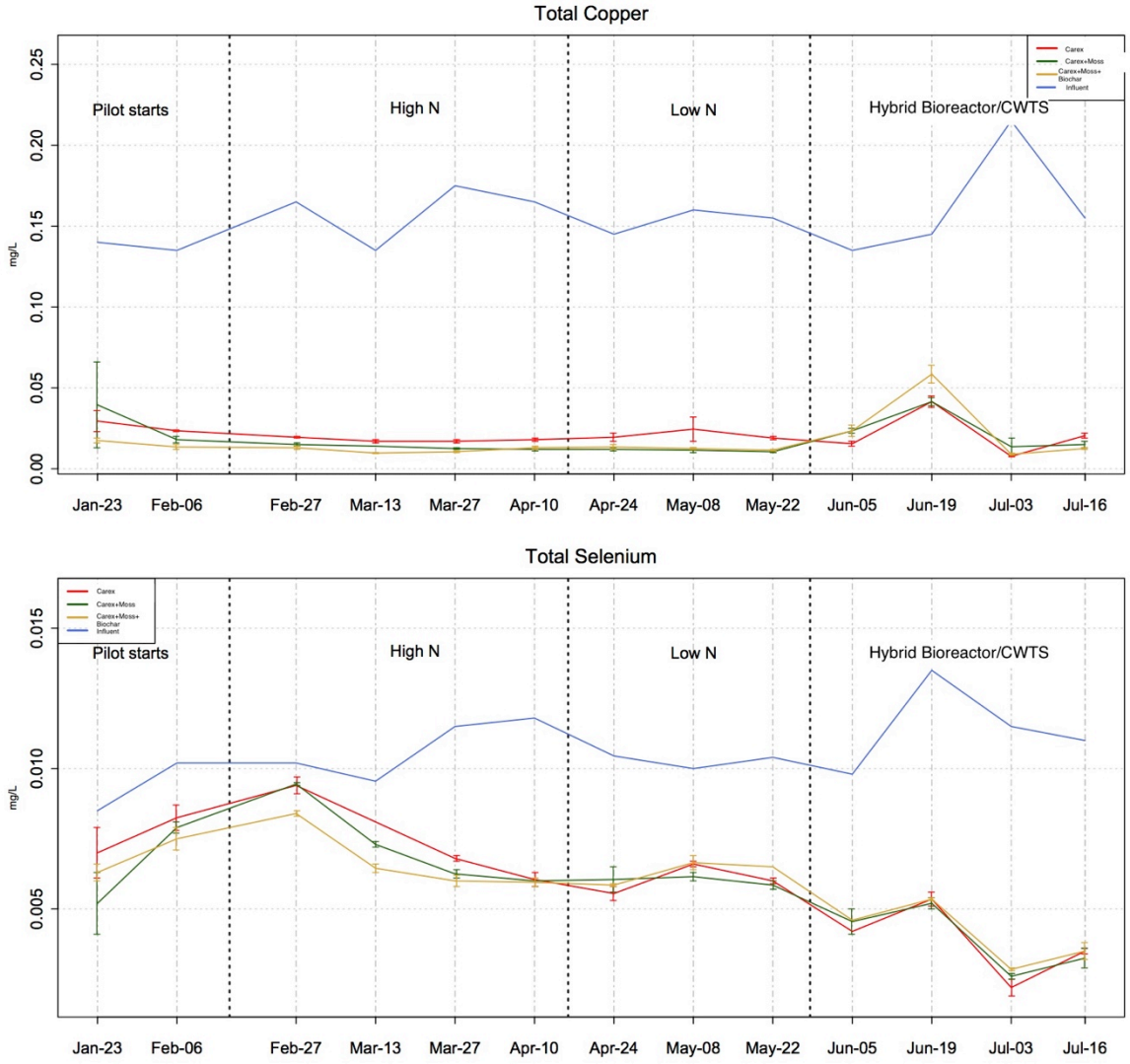


**Figure 4:** Copper and selenium removal rate coefficients during all periods of testing for the three system designs.

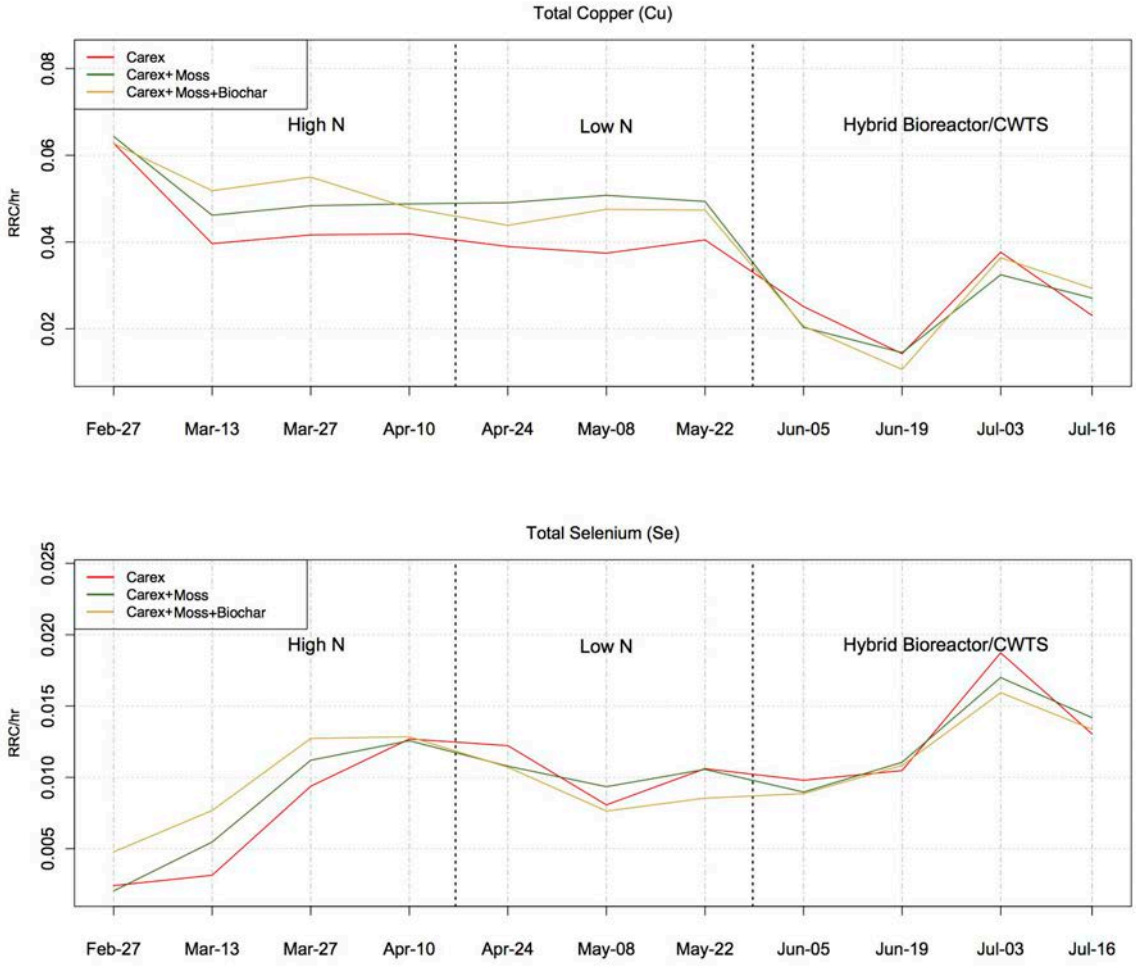


**Figure 5:** Copper (top) and selenium (bottom) removal rate coefficients for cells A and B in each system design. All three periods of testing are plotted separately (High N = Feb 27-April 12; Low N = April 13-May 28; hybrid bioreactor/CWTS = May 29-July 16). The average RRC is indicated with the bar chart, and error bars show the range. Note that the water depth was changed during the hybrid bioreactor/CWTS phase, which impacts the RRC.

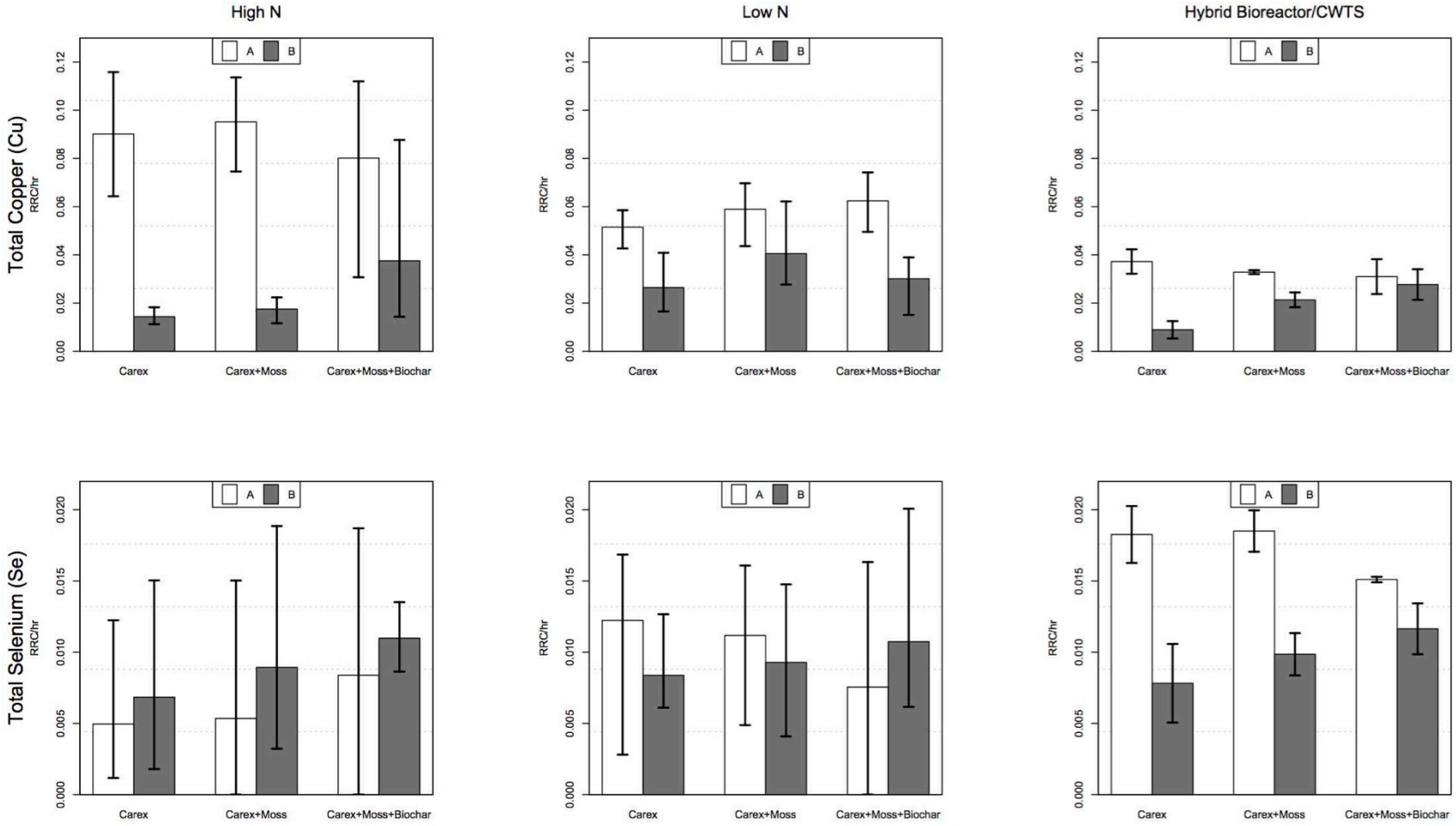


**Figure 6:** Outflow copper and selenium water concentrations from A and B cells over time compared to influent.

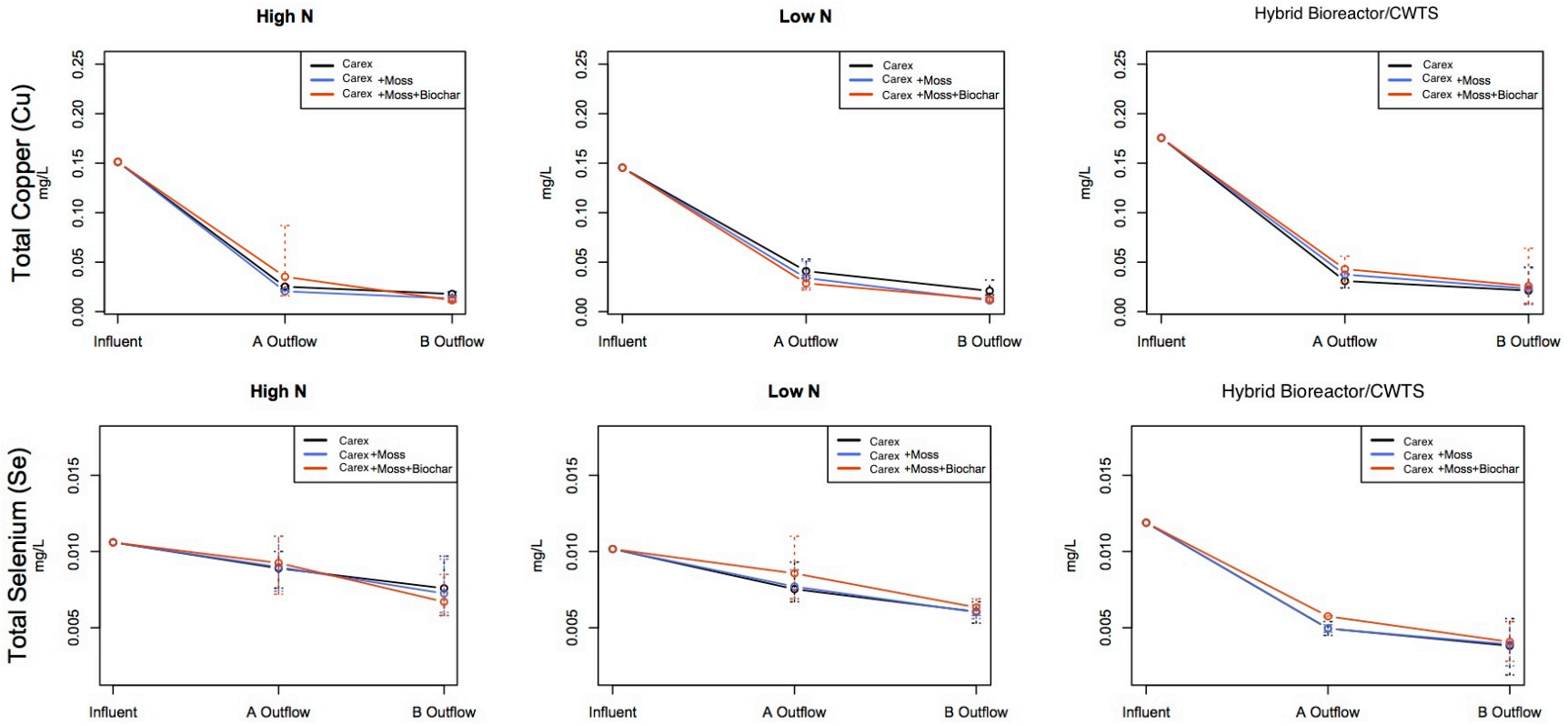


**Figure 7:** Non-metric multidimensional scaling (nMDS) analysis plot for bacterial community profiles of each pilot system design over time. Results are based on the genetic profiling method. Each time point during testing is shown with a different color, while the system design is indicated with shapes. All points that cluster together indicate similar bacterial communities. At the end of the pilot testing, we also determined the microbial population of the top root mass (orange outline), which was very similar to the microbial population in the sediment. The top 10 bacterial groups are indicated on the plot with dark blue numbers. The distance between a bacterial group label and a sample point depicts how high that group is in that sample.

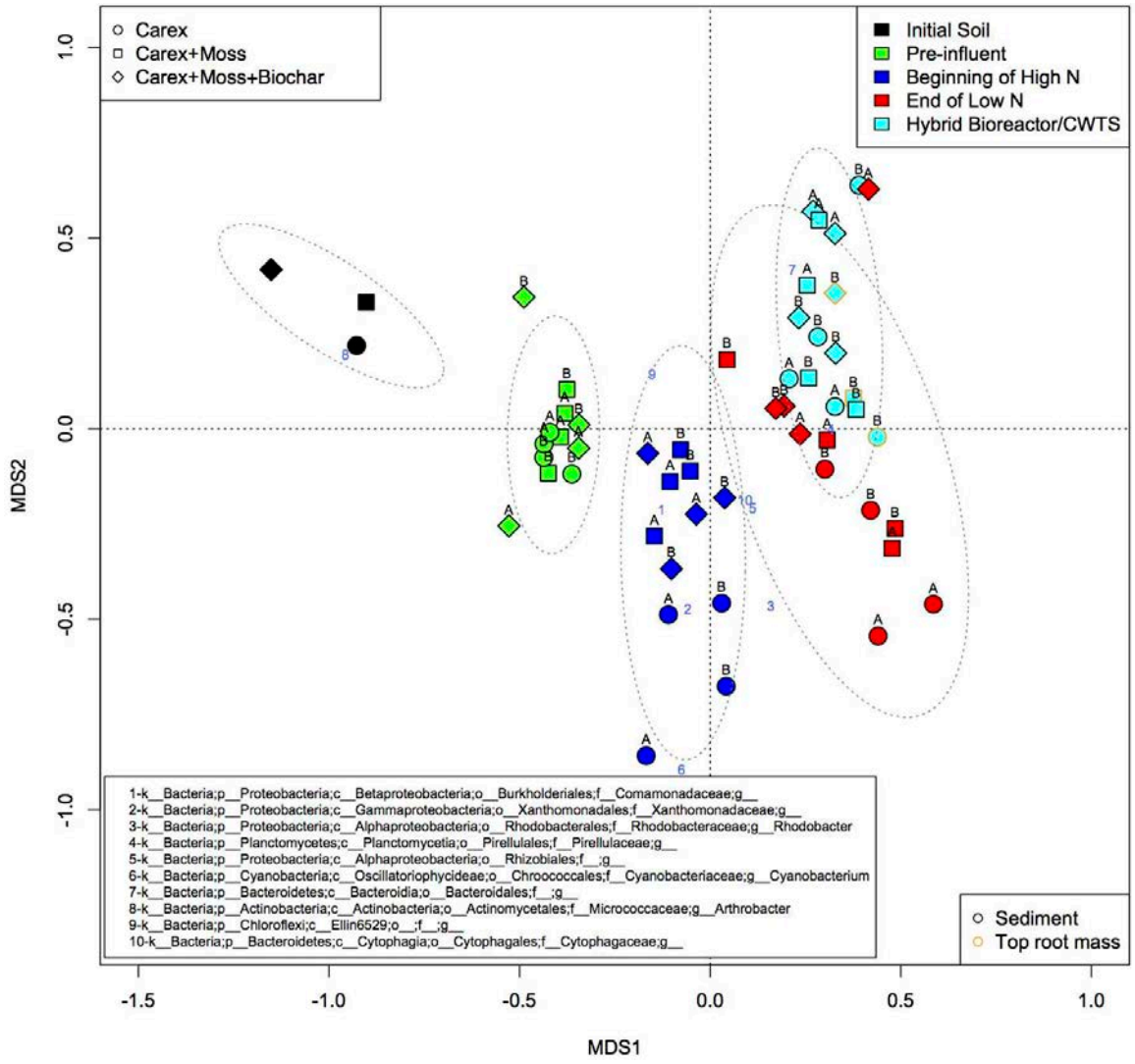
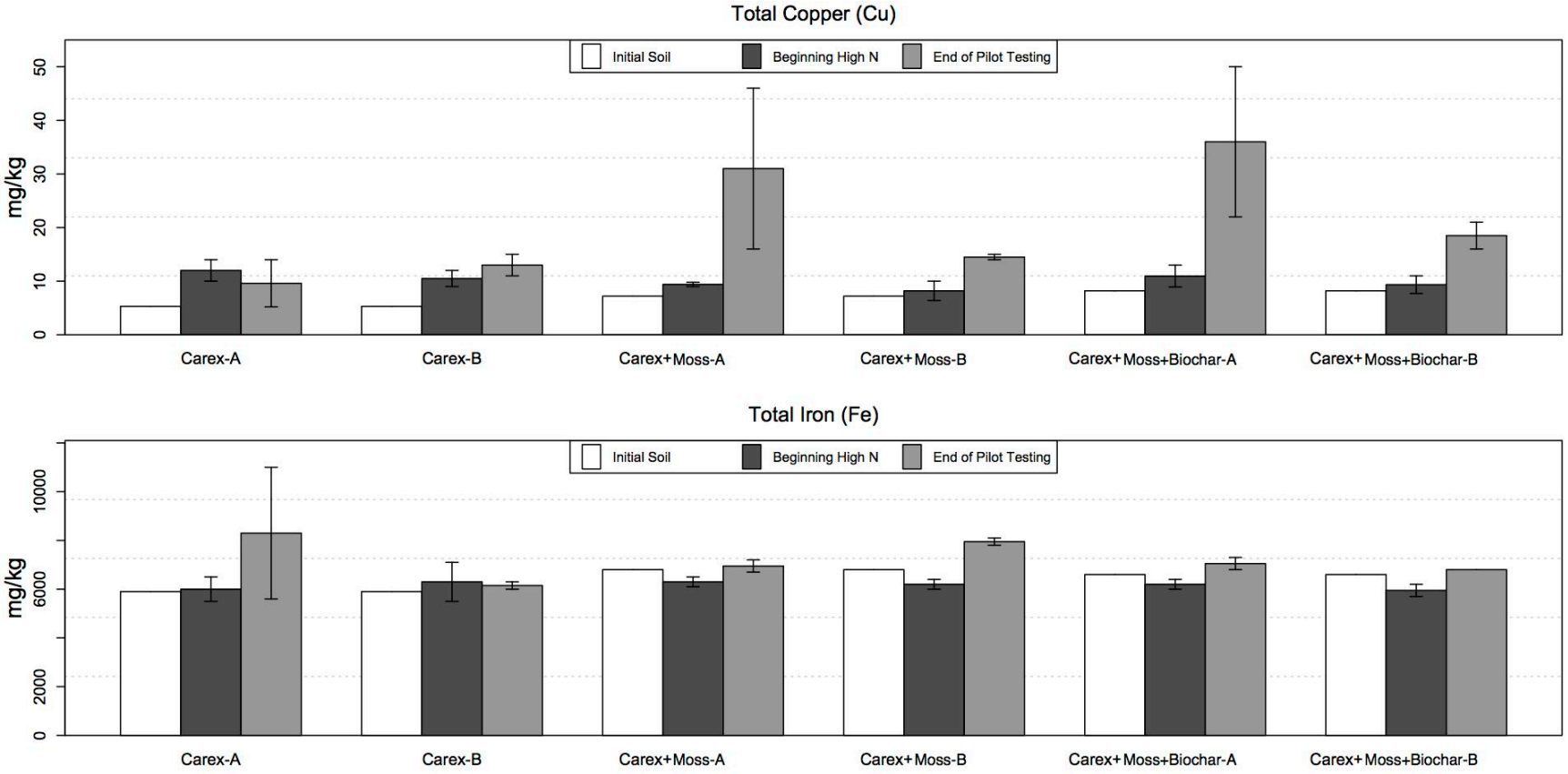


**Figure 8:** Copper, iron, selenium and sulphur concentrations in sediment throughout the pilot testing. Initial soil is the soil that was used to build the pilot systems, before any water was introduced. A and B cells for system designs are plotted separately, with error bars indicating the maximum and minimum values. The dotted red line indicates the selenium detection limit, as several samples were below this level. Selenium and sulphur plots are on the following page.



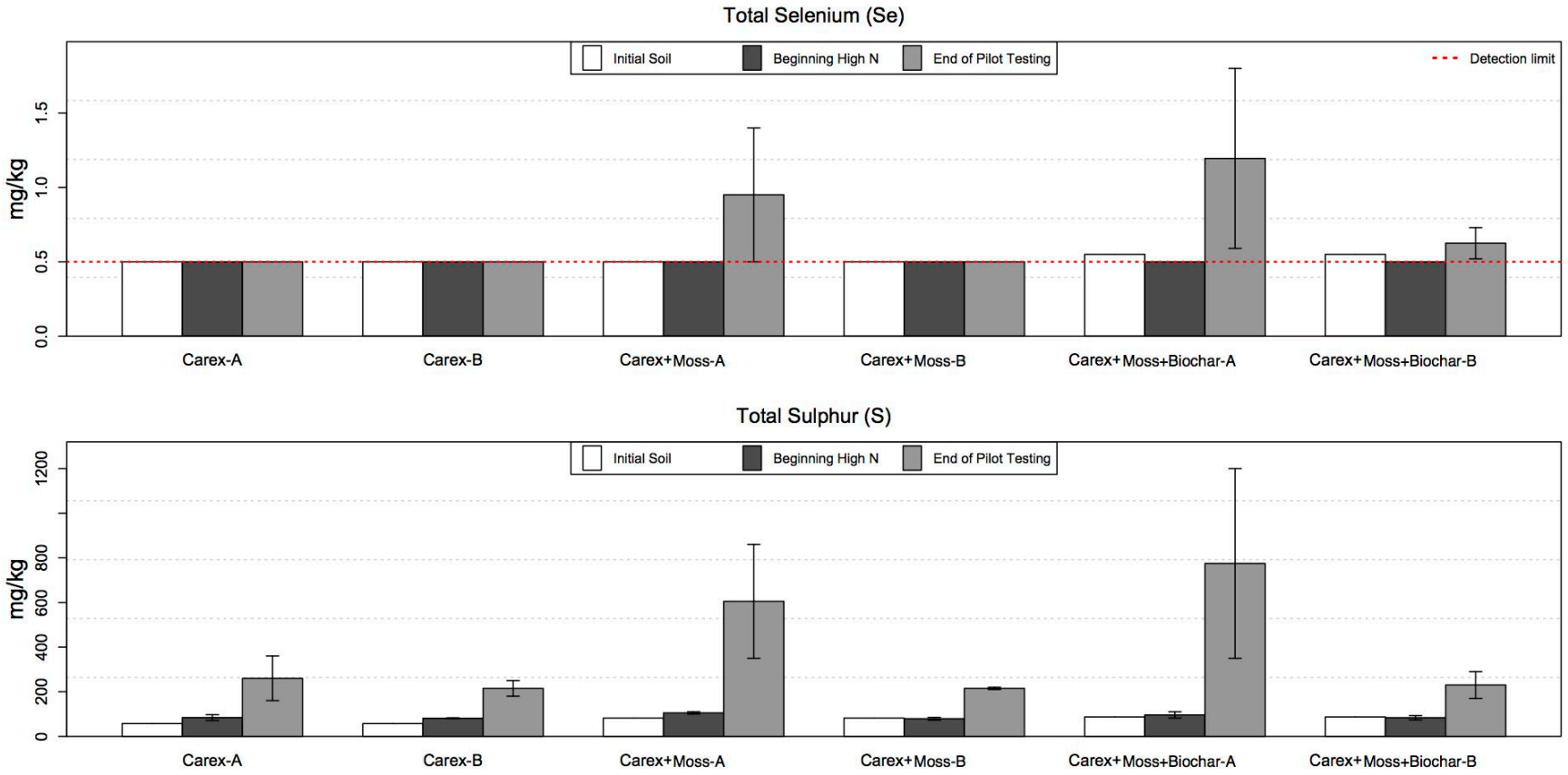

Total Selenium (Se)
Initial Soil
Beginning High N
End of Pilot Testing
Detection limit
mg/kg
0.0
0.5
1.0
1.5
Carex-A
Carex-B
Carex+Moss-A
Carex+Moss-B
Carex+Moss+Biochar-A
Carex+Moss+Biochar-B
Total Sulphur (S)
Initial Soil
Beginning High N
End of Pilot Testing
mg/kg
0
200
400
600
800
1200
Carex-A
Carex-B
Carex+Moss-A
Carex+Moss-B
Carex+Moss+Biochar-A
Carex+Moss+Biochar-B

**Figure 9:** Mass balance of copper in the pilot CWTS at the end of testing. The total amount of copper in the top 6 cm of sediment in A and B cells is shown for each system design, as well as the *Carex* in A and B cells. "Other" is the portion that was not analyzed for metals, and therefore cannot be differentiated. Examples of locations in the "Other" category would be plant roots, biofilms, and deeper sediment, as all of these were not analyzed. Additionally, it should be noted that the Moss did not survive the hybrid bioreactor-CWTS period, and therefore was not tested at the end of the pilot testing.

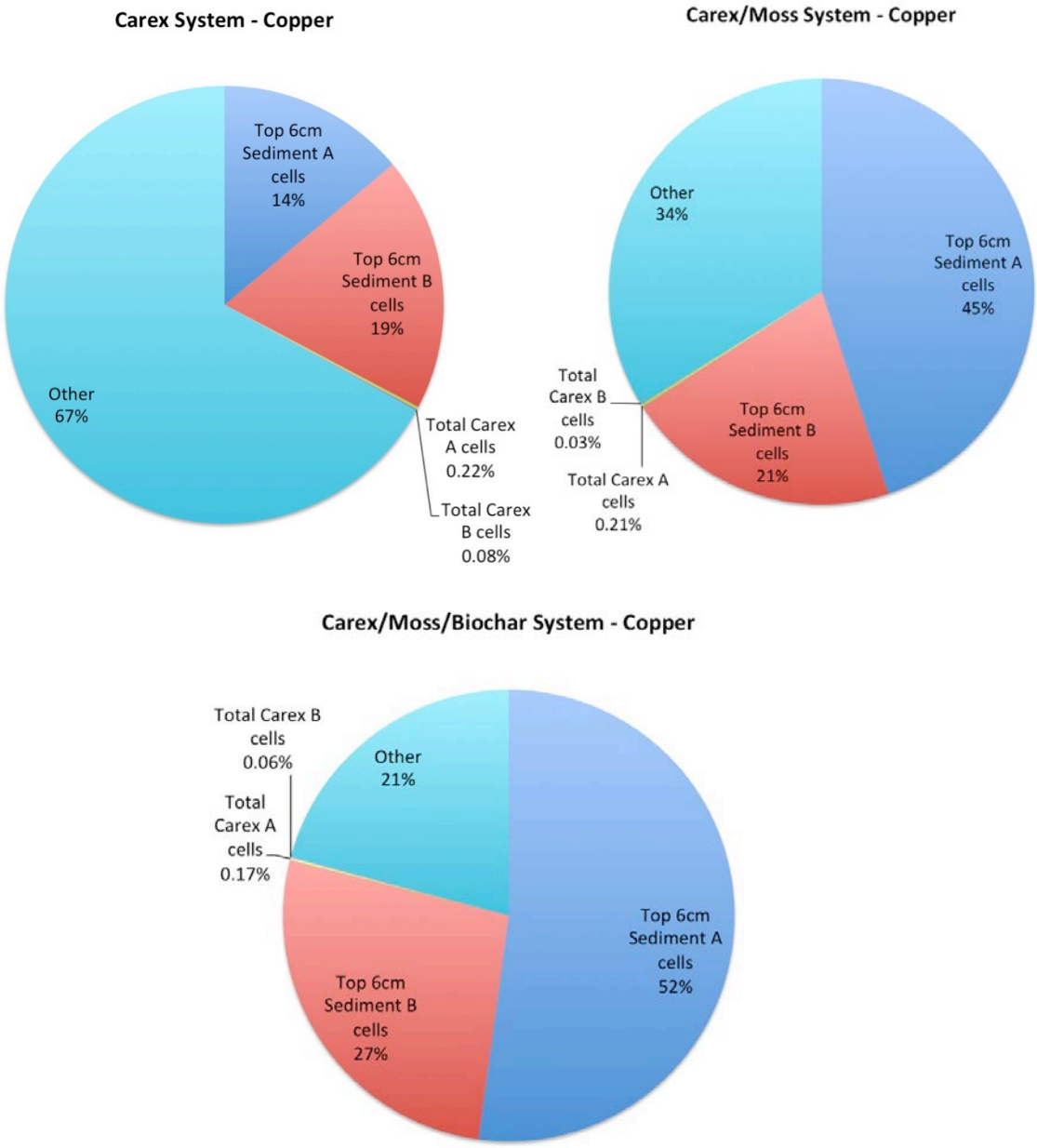


**Figure 10:** Mass balance of selenium in the pilot CWTS at the end of testing. The total amount of selenium in the top 6 cm of sediment in A and B cells is shown for each system design, as well as the *Carex* in A and B cells. "Other" is the portion that was not analyzed for metals, and therefore cannot be differentiated. Examples of locations in the "Other" category would be plant roots, biofilms, and deeper sediment, as all of these were not analyzed. Additionally, it should be noted that the Moss did not survive the hybrid bioreactor-CWTS period, and therefore was not tested at the end of the pilot testing.

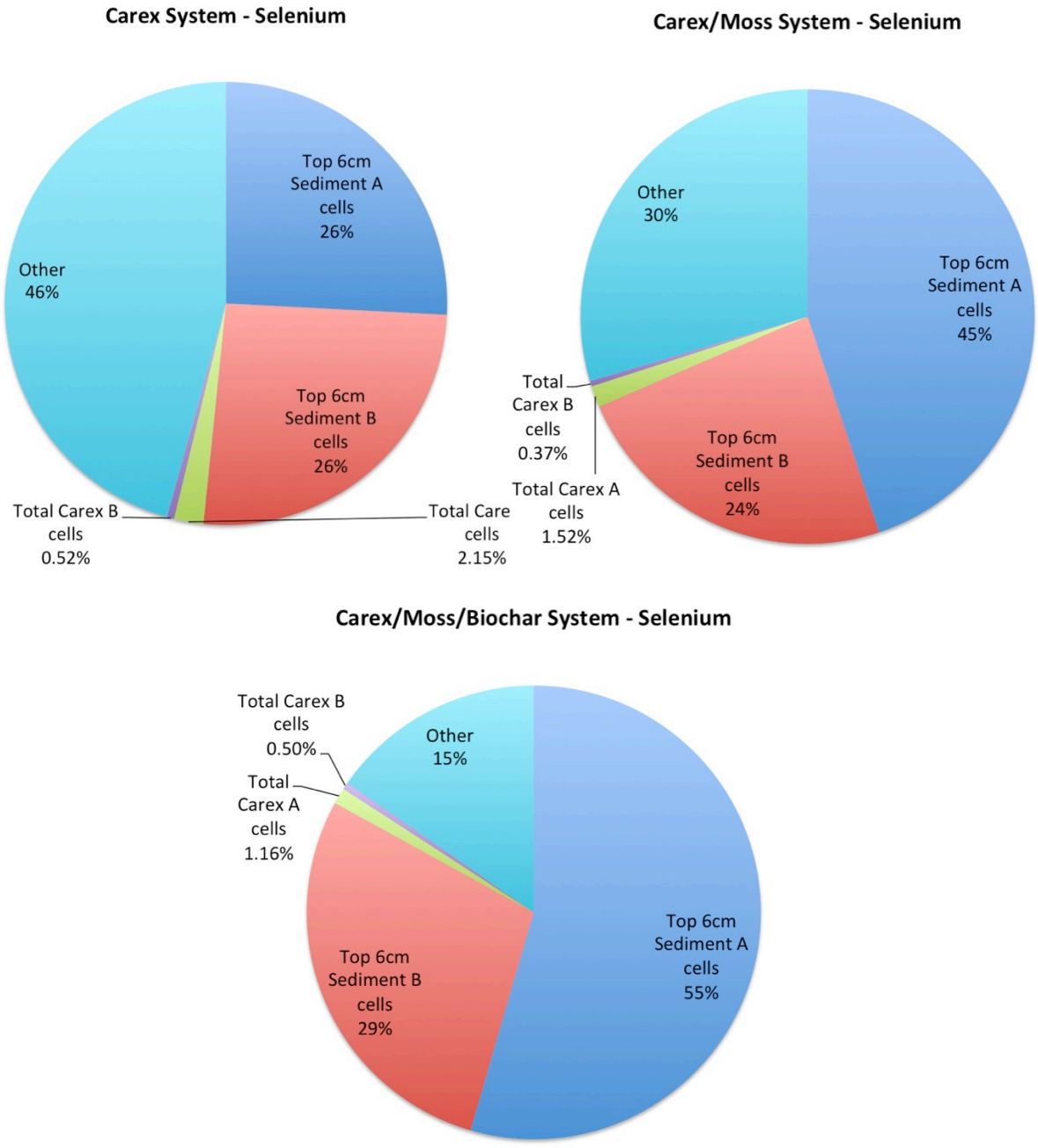


**Figure 11:** Comparison of bioconcentration factor for copper and selenium in *Carex* in A and B cells from each pilot system design. The p-value is calculated using Friedman test, with significant results shown in red. A significant test means that a difference between the BCF in A and B cells is found (e.g., A cells are always higher than B cells, or vice versa).

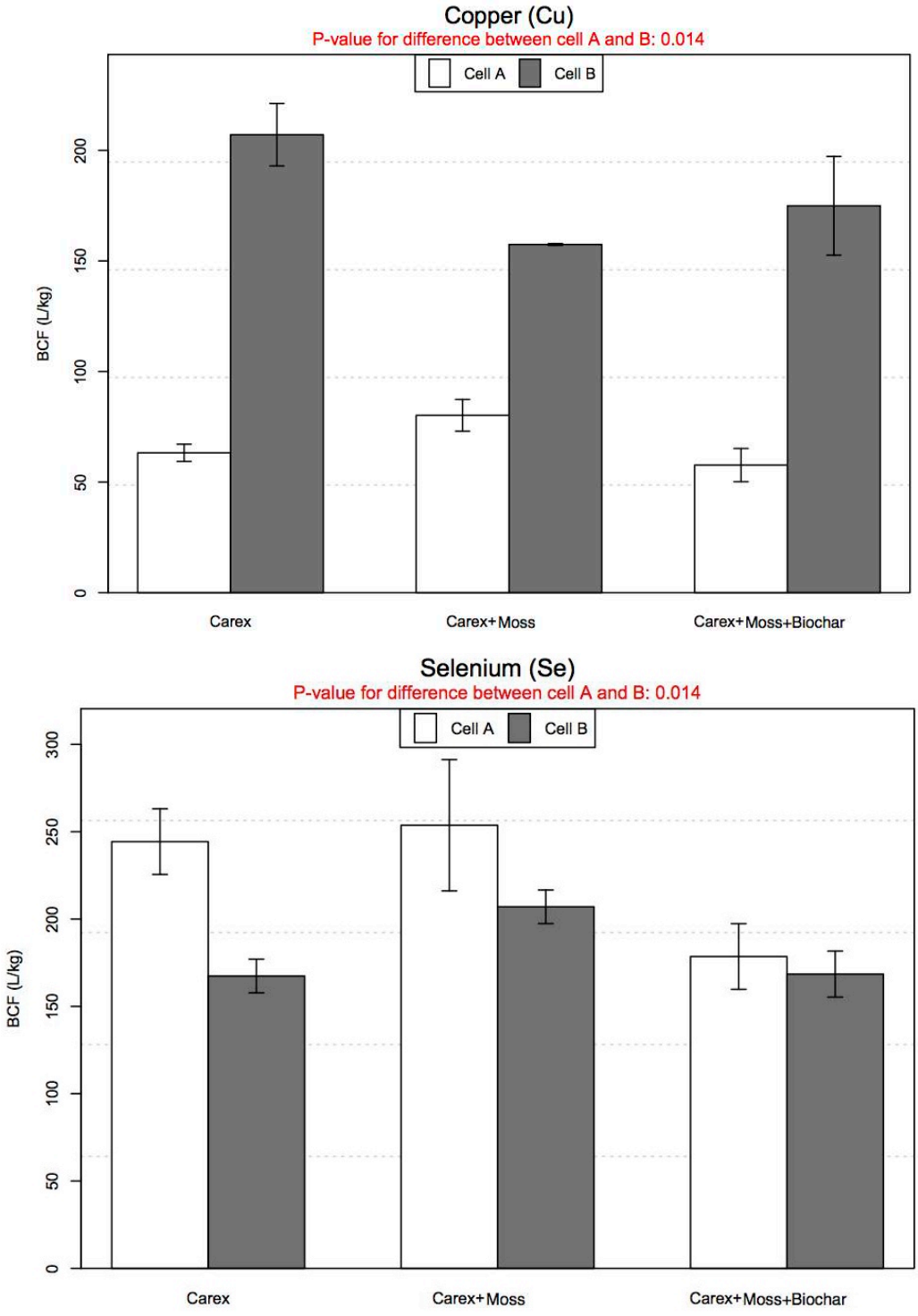


**Figure 12**: Copper and selenium concentrations in *Carex* before and after the freeze-thaw test, for all three system designs.

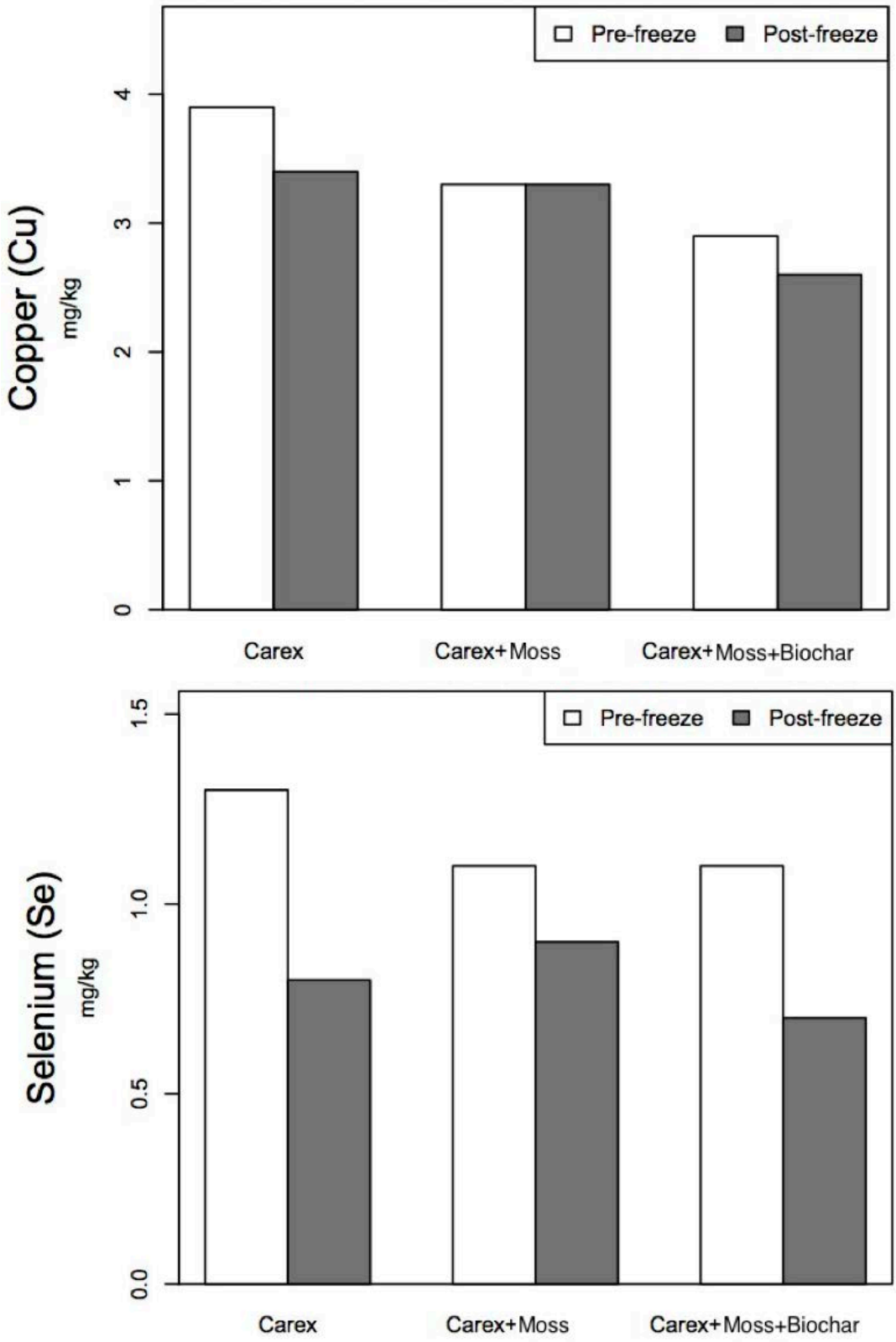


**Figure 13**: Copper and selenium concentrations in Moss before and after the freeze-thaw test, for the two system designs that had Moss.

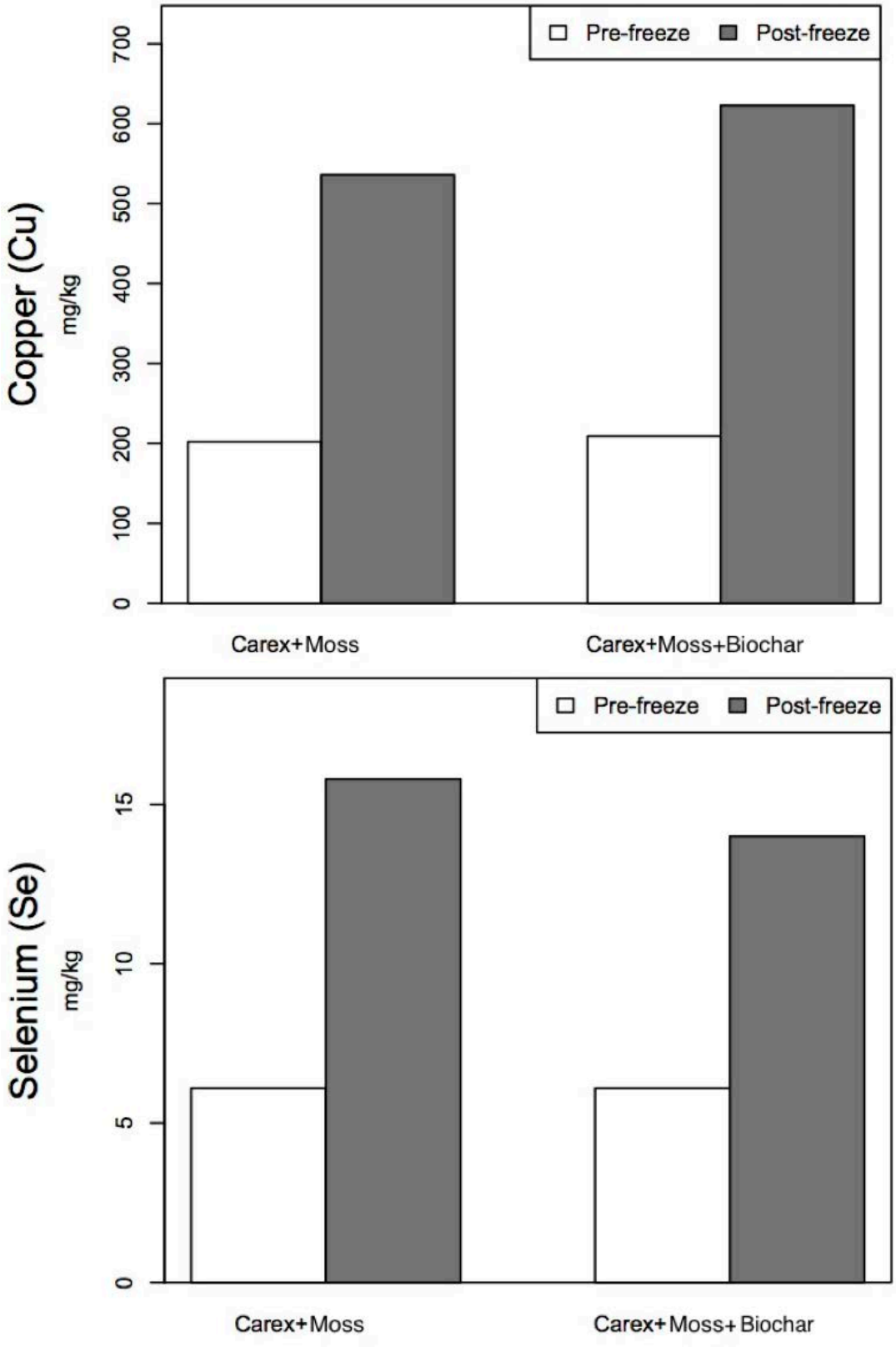


**Figure 14:** Photograph of *Carex aquatilis* (Sedge) roots at system takedown



**Figure 15:** Photograph of CWTS cell during takedown of the system. Orange-colored hydrosoil layer is approximately 18 cm, black detritus toproot zone is ~3 cm. Water depth was ~20 cm during the high and low nitrogen periods, and ~30 cm above the sediment during the hybrid bioreactor-CWTS period.



**Figure 16:** *Carex* stem counts (top) and height (bottom) of each system design, during all periods of testing.

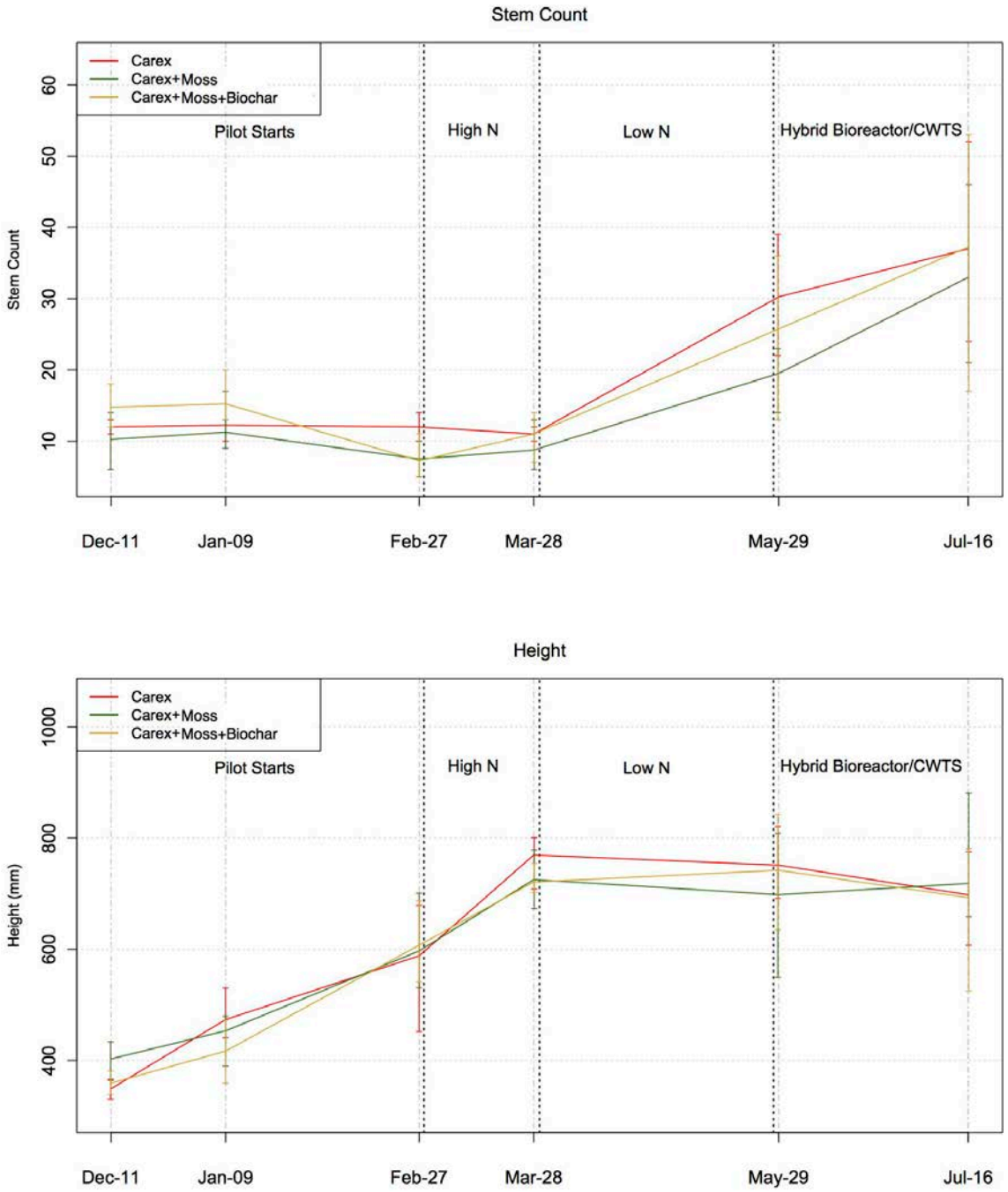
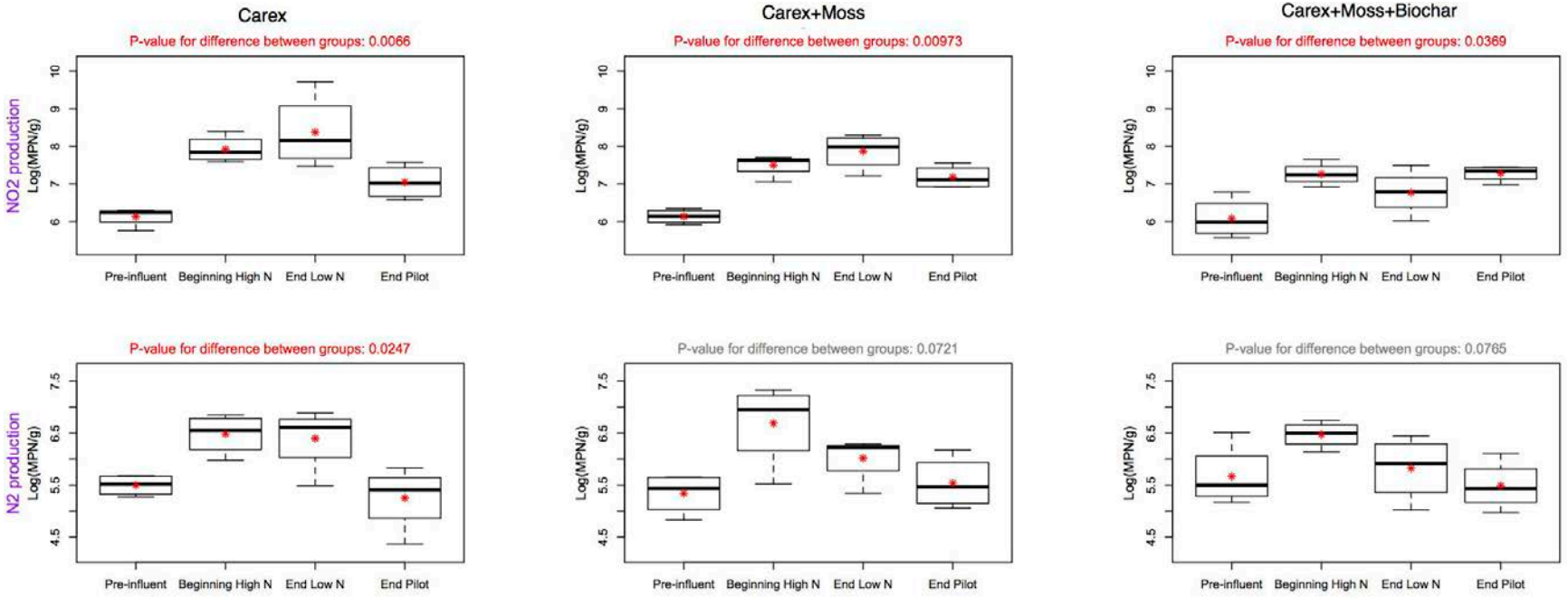
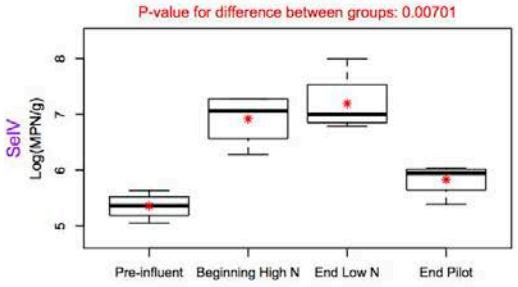
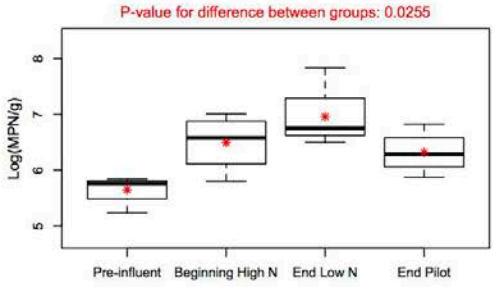


**Figure 17:** Comparison of the most probable number (MPN) of nitrate-, selenite-, and sulphate-reducing organisms in each system over time. $NO_2$ production indicates the MPN of organisms that are capable of reducing nitrate to nitrite. $N_2$ production shows the MPN of organisms that can reduce nitrate to nitrogen gas. The MPN was compared among the four time periods, and a P-value was calculated using the non-parametric Kruskal-Wallis test. The first plot represents systems with just *Carex*, the second plot is systems with *Carex* and Moss, while the third plot is systems with *Carex,* Moss, and biochar. Significant differences (P<0.05) are indicated in red, meaning a significant difference is found between the four testing periods in a given system design. Box plots are used to visualize the results; top and bottom edges of the box show the 25th and 75th percentile, respectively, while the thick black line depicts the median and the red asterisk shows the mean. The upper and lower whiskers provide the maximum and minimum non-outlier values. The remainder of the figure is provided on the following pages.




P-value for difference between groups: 0.00701
SeIV
Log(MPN/g)
5
6
7
8
Pre-influent
Beginning High N
End Low N
End Pilot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7
8
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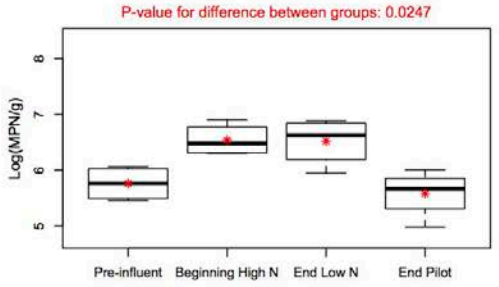
End Low N
End Pilot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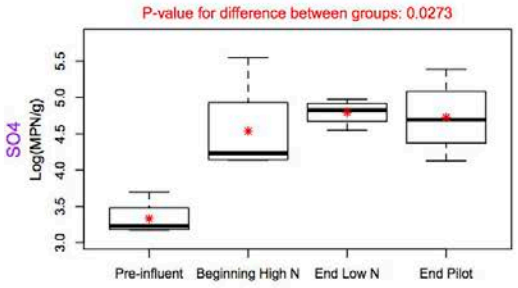
6
7
8
Pre-influent
Beginning High N
End Low N
End Pilot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SO4
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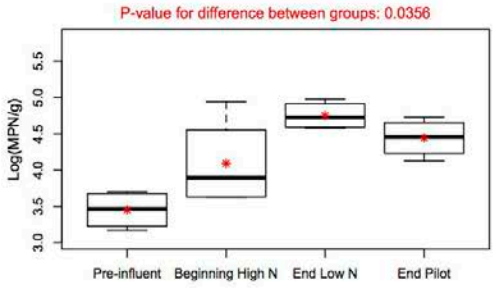
4.0
4.5
5.0
5.5
Pre-influent
Beginning High N
End Low N
End Pilot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3.5
4.0
4.5
5.0
5.5
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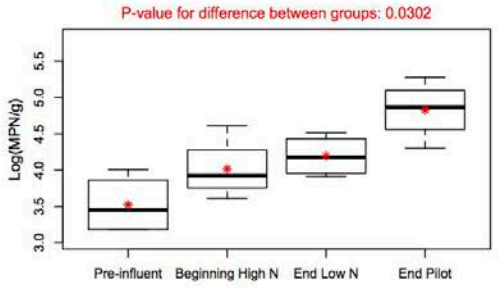
Beginning High N
End Low N
End Pilot


P-value for difference between groups: 0.0302
Log(MPN/g)
3.0
3.5
4.0
4.5
5.0
5.5
Pre-influent
Beginning High N
End Low N
End Pilot

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# Minto Mine Constructed Wetland Treatment Research Program – Demonstration Scale

Document – 011_0315_01A

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# 1. Introduction and Background

The Minto mine, operated by Capstone, is located 240 km northwest of Whitehorse on the west side of the Yukon River. The Minto property lies within the eastern part of the Dawson Range, with elevations from 700 to 1000 m; the landscape has rounded mountains intersected by broad valleys and drainages that are part of the Yukon River watershed.

The Minto mine has been in commercial operation since October 2007 and the deposits being mined are copper sulphide mineralized zones. Surface and groundwater water quality is a key consideration in the evaluation of potential effects of mining and mineral development projects and changes to water quality parameters have the potential to affect aquatic and human use of water resources. A Reclamation and Closure Plan (RCP) is required under both the Water Licence and the Quartz Mining Licence. The RCP is intended to address the long-term physical and chemical stability of the site and closure of the proposed features and disturbances associated with the mine. As a part of the RCP, a Constructed Wetland Treatment System (CWTS) is being designed, evaluated, and optimized for water treatment at closure through a phased program (Minto Phase V/VI Expansion Project, YOR Project Number 2013-0100).

Once established, wetlands can become self-sustaining ecosystems with plants providing yearly renewal of carbon to fuel microbial activity. As such, they possess the desirable potential to remediate contaminated mine drainage for as long as it is generated. In order for CWTSs to be effective, they must be designed, piloted, optimized, implemented, and maintained in a site-specific manner. A scaled approach for CWTS implementation allows for improvement, optimization, and flexibility for modifications along each step. Phases include: 1) site assessment and information gathering, 2) technology selection and conceptual design, 3) pilot-scale testing and optimization (controlled environment), 4) on-site demonstration-scale confirmation and optimization, and 5) full-scale implementation. Phases 1-3 have been completed (reports 2013-0100-256 and 2013-0100-257 on YESAB registry, and Contango, 2014) and confirmed plant amenability to transplantation and the CWTS design for further on-site testing. During pilot-scale trials, the selected CWTS design achieved 92% removal of copper (mean influent 146 µg/L, outflow 11.3 µg/L) and 41% removal of selenium (mean influent 10.2 µg/L, outflow 6 µg/L) using synthetic influent designed to mimic the worst-case water chemistry of a long-term closure scenario. Phase 4 of the project is now underway, with the on-site demonstration scale CWTS constructed at the Minto Mine during fall 2014. This document reports on the on-site demonstration scale CWTS design, construction, preliminary data, sampling schedule, and the long-term conceptual closure plan.

# 2. Design

## 2.1. System layout and dimensions

The demonstration-scale CWTS includes 2 systems in parallel with 2 cells in each series and a final catchment basin that both systems flow into (Figures 1-3). The location of the system in relation to the Minto site is provided in Figure 1. A stable foundation on waste

rock fill was selected for the CWTS and a base of residuum (sandy gravel) material was placed in compacted lifts to allow for shaping of the structure to design specifications. The two parallel systems serve as a replicate for data analysis, but as testing progresses, it is also possible that one of the two systems may be subjected to alternate conditions for comparative purposes.

The four planted cells ranged slightly in width and length. The as built sizing of the cells (at soil surface), after soil and amendments were added, ranged from 2.8 m to 3.8 m in width and 8.7 m to 9.8 m in length (Figure 4, Table 1). This was consistent with the submitted design of the cells being 3 to 4 times longer than wide.

The 4 cells and catchment basin were roughed in and large sharp rocks hand picked and removed prior to final grading and survey. The finished surface was lined with an impermeable 4030 Enviro Liner® that was welded together and sandwiched between two layers of 12 ounce geotextile fabric.

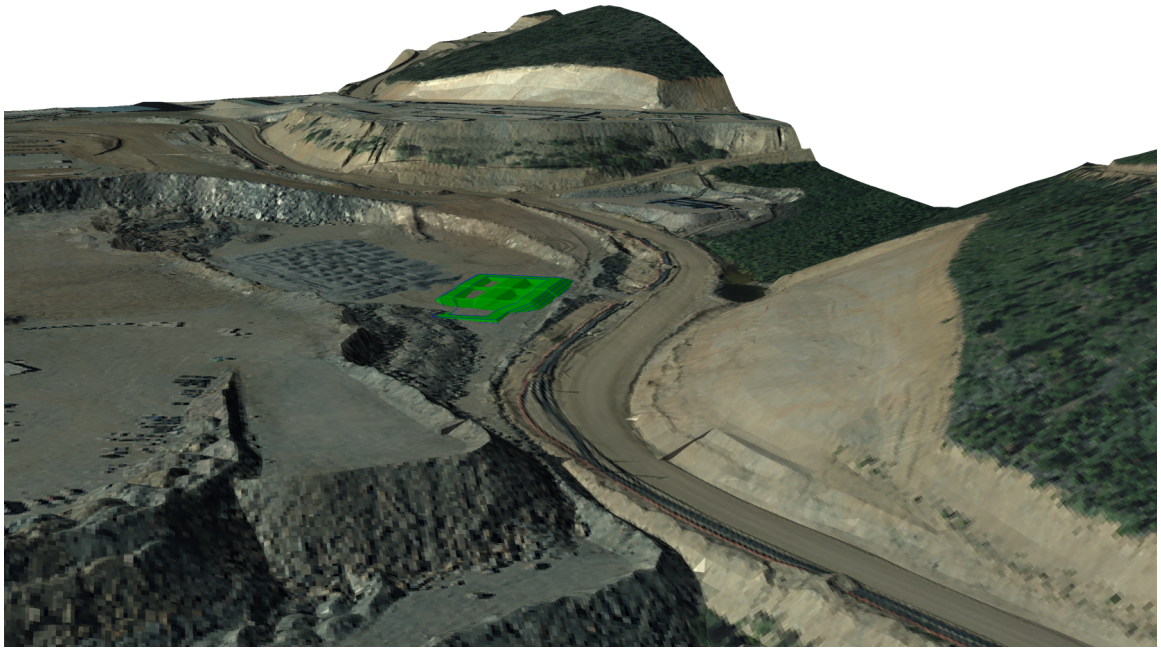

**Figure 1.** Location of demonstration-scale CWTS at Minto mine.

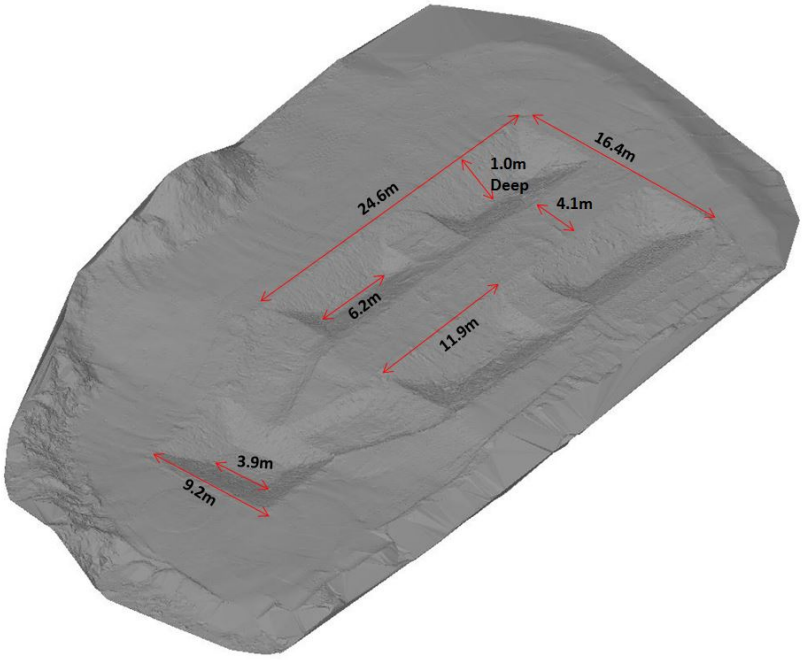


**Figure 2.** As built schematic of demonstration-scale CWTS.



**Figure 3.** Demonstration-scale CWTS prior to liner installation.

**Table 1.** Measurements of demonstration-scale CWTS cells at soil surface and resultant areas of treatment systems.

| Measurement | | 1A | 1B | 2A | 2B |
|---|---|---|---|---|---|
| Width (m) | Inflow | 3.6 | 3.8 | 3.6 | 2.8 |
| | Outflow | 3.3 | 3.8 | 3.3 | 3.6 |
| Length (m) | | 9.8 | 9.5 | 8.7 | 8.8 |
| Approximate surface area at soil ($m^2$) | | 33.8 | 36.1 | 30.0 | 28.2 |
| Total area of System at soil ($m^2$) | | 69.9 | | 58.2 | |

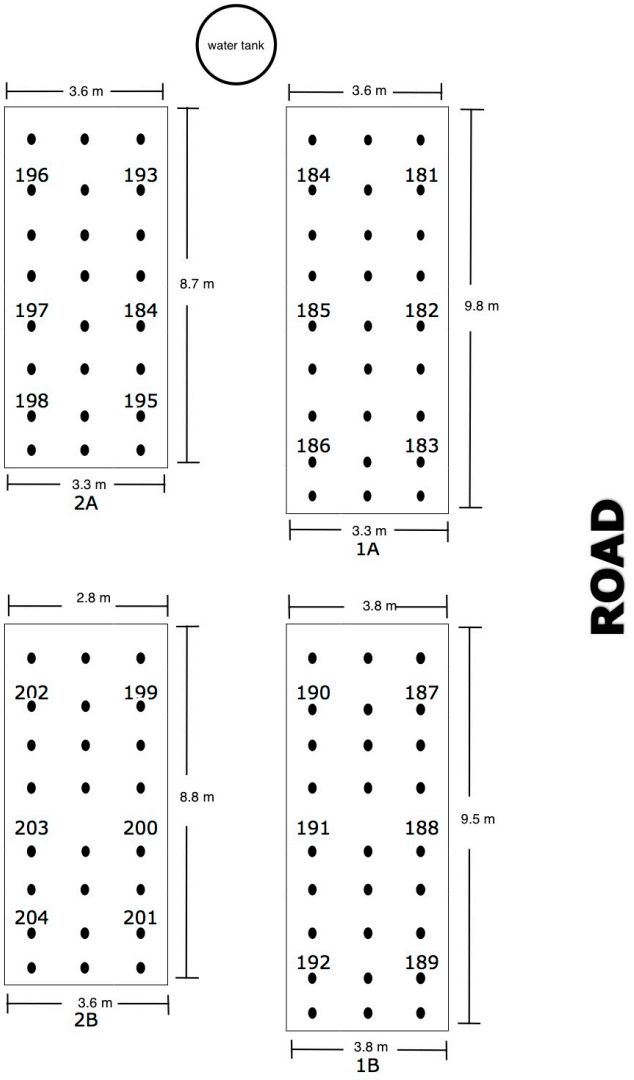


**Figure 4**. Diagram of demonstration-scale CWTS with dimension measurements at soil surface showing grid (by moss stakes; black dots) and locations of soil redox probes (with identifying numbers; Table 2).

### 2.2.Soil and Amendments

The recommended soil for the CWTS is sand, with 2-7% by volume as organic material (e.g., woodchips, peat). In the pilot-scale systems, this resulted in a total organic carbon (TOC) content of 0.2-0.6% (the sand itself was at 0.1% TOC prior to adding amendment). In this composition, the sand allows for circulation of water through the root zone of the plants, while the organic matter initiates reductive microbial processes that in future years will be sustained by decaying plant matter. In the case of this demonstration-scale system, the soil added to each of the 4 cells was from a local overburden site. The characteristics of this soil are provided in Appendix A. This borrow site was different than the site that was sampled during the Contango Strategies Ltd. (CSL) assessment in 2013, and also different than that tested in June 2014 (Appendix A, Table A1-A3).

The overburden soil used in the demonstration-scale CWTS was taken from stockpiled material that originated as richly organic soil from stripping of the Area 2 Pit. The calcium, magnesium and sulphate concentrations were higher than those of the pilot-scale tests, but this is not expected to negatively impact the performance of the CWTS. Owing to the general mineralization of the area, the concentration of copper was elevated in all soils tested as potential borrow sources. The synthetic precipitation leaching procedure (SPLP) analysis conducted on the soils used in the demonstration-scale wetland suggested there is between 148-608 µg/L of available copper and 0.35-0.69 µg/L of available selenium in the soil. This should be monitored and taken into consideration with wetland performance, and it may be necessary to investigate other sources of soil with lower copper concentration for final full-scale construction.

It was observed that the soil that was used for the demonstration-scale wetlands was higher in organic content and lower in sand than those used in the pilot-scale testing, or tested during the site assessment or June 2014 pre-construction sampling. This higher organic content was also associated with a more loamy texture. Due to the higher organics content in the soil being used for the demonstration-scale CWTS, there was less organic amendment added (by volume) than was initially planned. As the soil was added by the backhoe (Figure 5), there was 1 standard size straw bale (measuring 36 cm x 46 cm x 102 cm) and 50 rounded standard shovels of a 50:50 mix of spruce and pine wood shavings placed in each of the cells and mixed by hand with shovels and rakes (Figures 6 and 7). There was no biochar added as was proposed in the initial design as this was determined to not be required after the piloting phase at the CSL facilities (Contango, 2014).

The high organic content of this soil may actually be beneficial to the treatment of elements, through both sorption and increased microbial reductive processes. The drawback of using this organic material is that it may not facilitate the circulation of water in the root zone the way sand or gravel would, and it is also more difficult to work with for construction purposes. Specifically, the material used in the demonstration-scale CWTS did not support weight as a sandy soil would. For this reason, the wetland was planted while the soils were somewhat dry (before flooding), as the people planting the wetland would sink into the soil if it were wet. This should be taken into consideration if building the full-scale CWTS for the sake of ease of accessing monitoring points within the wetland, or if any revegetation

campaigns are needed. Over time, however, the plant roots and moss will grow and provide greater physical stability to the soils.

Upon inspection, there was too much soil placed in the cells by the mini-backhoe; some of the soil was therefore removed to bring the outflow depth to 20 cm and maintain a level grade in each of the 4 cells to a tolerance of +/- 5 cm in order to provide a uniform water depth. A uniform water depth is necessary to prevent future issues such as channeling of water, open water spots due to plants being unable to grow because of excessive water depth, or conversely, drying out.



**Figure 5.** Soil being added to demonstration-scale CWTS cells.



**Figure 6.** Organic soil amendments used in demonstration-scale CWTS. Left, wood shavings 50:50 pine and spruce mixture; Right, straw.



**Figure 7.** Mixing organic amendments into soil in demonstration-scale CWTS cell 2A.

### 2.3.Plants

The demonstration-scale CWTS was planted with *Carex aquatilis* (Sedge) and mosses, as was determined by pilot-scale testing as being the best design for this site and application (Contango, 2014). These plant species were harvested for the demonstration scale CWTS from a location that was identified during the August/September 2013 site assessments in the vicinity of the W10 monitoring point (reports 2013-0100-256 and 2013-0100-257 on the YESAB registry). This site had *C. aquatilis* and aquatic mosses growing together as is

desired for the CWTS design (Figures 8 and 9). Plant tissues were sent for analytical testing to determine initial concentrations (Appendix A, Table A4).

All 4 cells of the demonstration-scale CWTS were measured and the center of the width marked at both the inflow and outflow ends of each of the cells. The tape measure was then placed on the center axis down the length of each cell to start laying the center grid. The grid was created using wooden gardening stakes (50 cm in height), with aquatic moss tied to one end and inserted into the soil so that the moss was just above the soil (Figure 10; eventually to be submerged in the water). The grid for planting the *C. aquatilis* was created with these stakes, starting on the inflow end of each cell, with stake placement every 1 m progressing to the outflow (Figure 11). The final grid near the outflow of the cell was therefore sometimes less than 1 m of soil, but may look like a greater size due to the overlaying water. This was repeated moving outward from the center line, creating a grid of 1 m square areas for planting *C. aquatilis* to facilitate future monitoring of plant density. Depending on the varying width and length of the cells, along the sides of the length of the cells and the outflow of the cells the grids varied from 1 m squared to smaller than 1 m squared (Table 2).

**Table 2**. Number of planted grids in each demonstration-scale CWTS cell.

| Item | Cell | | | |
|---|---|---|---|---|
| | 1A | 1B | 2A | 2B |
| Moss stakes | 3*9=27 | 3*9=27 | 3*8=24 | 3*8=24 |
| 1 m squares | 18 | 18 | 16 | 16 |
| < 1 m squares (perimeter of CWTS cells) | 22 | 22 | 20 | 20 |

Using the 4 stakes marking the edges of the grid, 5 *C. aquatilis* were planted into the soil inside each 1 m by 1 m grids, with one in the middle and 4 others approximately equidistant from the stakes to create an even distribution of 5 sedge per square meter (Figure 12). This placement and grid system was used to ensure even distribution of plants through the demonstration-scale CWTS, with the foresight of future monitoring for plant establishment and density. As the grids at the perimeter of each wetland cell varied and were often smaller than 1 m by 1 m, it was estimated based on the size of the grid how many sedge should be planted to maintain a consistent density of plants.




**Figure 8.** Harvesting plants from W10 location (top), and transporting back to demonstration-scale CWTS (bottom).



**Figure 9.** Images of *Carex aquatilis* and aquatic mosses harvested at W10 for planting the demonstration-scale CWTS. Left, aquatic mosses growing at water surface at edge of *C. aquatilis*; top right, underwater photograph of aquatic moss; bottom right, *C. aquatilis* and aquatic mosses growing together.



**Figure 10.** Example of moss tide to stakes, which then were used to make grid in each demonstration-scale CWTS (Figure 4, 11, 12 and Table2).



**Figure 11.** Moss stakes placed in demonstration-scale CWTS cell 2A, looking towards cell 2B.



**Figure 12**. *C. aquatilis* planted within grid of moss stakes in demonstration-scale CWTS cell 2A, and influent perforated pipe being laid in place.

### 2.4.Water

Water from the W36 area receiving seepage from the toe of the MVFE (Figure 13) was selected for the demonstration-scale CWTS testing as the leachate is similar to that expected upon closure in the Mill Valley Fill Extension (MVFE) area. The chemistry of this water at the time of bringing the demonstration-scale CWTS online (September 18, 2014) is provided in Appendix A, Table A5. A Grundfos CR1S-6 stage pump was selected to maintain the appropriate head of water in the holding tank to provide a range of flows between 0.1-1.1 $m^3$/hr on a 4-inch line with 30 m of head (Figure 13). The 3,000 Liter holding tank sits above and between the inflow of cells 1A and 2A and is kept at a constant head via pumping from the W36 sump (Figure 14). Overflow water is returned by gravity flow in a pipe to the W36 area. Meanwhile, water within the holding tank is gravity fed through control valves and flow meters prior to entering the parallel treatment cells (Figure 14). The tank was initially rinsed twice with the W36 water before releasing water into the demonstration CWTS because it had originally contained road dust suppressant (Envirobind). Water is constantly pumped from W36 to the tank that has been modified to maintain a constant head (and therefore pressure) to keep flow rate consistent when set using the manual valves. Flow rates are measured using ultra low flow and high accuracy/totalizer meters from GPI (Figure 14).

A flexible 1-inch braided rubber hose with perforations was attached to each of the flow meters and run to the inflow of cells 1A and 2A (Figure 12 and 14). The placement of these perforated hoses was adjusted to promote even flow across the width of the A cells. The system then operates by gravity flow, with Cell 1A and 2A flowing into 1B and 2B, respectively, before flowing into the catchment basin and returning by pipe to W36 (Figure 15).

Sandbags were used at the outflow of each cell to correct for unevenness in grade and prevent channeling to the lowest point. The average height of water in the cells above the soil was approximately 20 cm (Figure 16).

The flow rates for the systems were set to have a 10 day nominal hydraulic retention time (HRT), meaning water entering the wetland takes 10 days to exit. This is referred to as a nominal HRT because it is a calculation based on the size of the wetland and the amount of water entering, and not confirmed empirically using tracing dyes. The HRT was calculated based on the size of the CWTS at the soil, with a 20 cm overlay of water, but not adjusting for pore water because without dense vegetation, the pore spaces in the soil will only have minimal hydraulic relationship to the overlaying water. This HRT is much longer than what is necessary to achieve treatment based on the pilot-scale systems (~3 days), however, this was chosen to facilitate plant establishment and maturation. Because the sizes of the CWTS systems were slightly different, Series 1 (closer to the road) and Series 2 (further from road) were set with inflow rates of 13,928 L/day and 11,635L/day, respectively, both corresponding to an approximate 10 day HRT. As the flow meters record in US gal/min, this corresponds to 2.6 and 2.13 US gal/min.



**Figure 13**. Water source for demonstration-scale CWTS. Left, Grundfos CR1S-6 stage pump; Right, water source at W36.



**Figure 14**. Clockwise from left: holding tank, splitting control valve, and flow meters.



**Figure 15**. Demonstration-scale CWTS immediately after planting and filling with water (August 29, 2014). Top, photograph taken from camp behind kitchen looking down at inflow of CWTS; bottom, photograph taken from outflow holding pond looking towards camp in background.

### 2.5.Data Collection

Explanatory parameters are quantifiable aspects of a CWTS that can be used to assess the feasibility of treatment for a range of constituents, and therefore 'explain' the performance of a CWTS. These parameters, which often include acidity, alkalinity, conductivity, dissolved oxygen (DO), pH, oxidation reduction potential (ORP), ion balance, available electrons donors (e.g., organic carbon, reduced elements), and temperature, can be used to predict, promote, and/or optimize the ability of the system to treat different constituents.

The relative oxidation-reduction (redox) potential of the soil will be measured using inert electrodes (copper wire probes with platinum tips) permanently installed in the soil of the cells for the duration of the project (Faulkner et al., 1989; Figure 16). To take a reading of the relative redox potential between the soil and water, a reference electrode (Accumet Calomel) is suspended in the water column above the inert electrode and measured in millivolts by a voltmeter. There were 6 platinum tip probes distributed throughout each of the 4 demonstration-scale cells to try and achieve even distribution based on the varying cell sizes. The probes were inserted to cover the epoxy on the end of the probe and secured with flagging tape to the bamboo poles for visibility. The locations of each probe are provided in Figure 4 and Table 3.



**Figure 16.** Series 2 (cell 2B in foreground, cell 2A in background), showing sandbags used at inflows and outflows between cells.

**Table 3.** List of location and probe number for inert electrodes permanently installed in the soil of cells. General location also provided in Figure 4.

| Stake - Row | Cell 1A | Cell 1B | Stake - Row | Cell 2A | Cell 2B |
|---|---|---|---|---|---|
| 2nd - Inside | #181 | #187 | 2nd - Inside | #193 | #199 |
| 5th - Inside | #182 | #188 | 5th - Inside | #194 | #200 |
| 8th - Inside | #183 | #189 | 7th - Inside | #195 | #201 |
| 2nd - Outside | #184 | #190 | 2nd - Outside | #196 | #202 |
| 5th - Outside | #185 | #191 | 5th - Outside | #197 | #203 |
| 8th - Outside | #186 | #192 | 7th - Outside | #198 | #204 |

Probe numbers 205 to 209 were left as spares, in case of probe failure.

## 3. Sampling Schedule for 2015

The sampling schedule for 2015 was conceptually developed prior to beginning construction of the demonstration-scale CWTS (Table 4) and the analytical testing refined and summarized in Table 5. Actual dates of sampling will depend on timing of spring thaw and ability to bring the pumps online at the W36 pond to supply water to the demonstration-scale CWTS.

**Table 4.** Conceptual sampling parameters, locations, and frequencies.

| Frequency | Parameter | Location | Sample Type |
|---|---|---|---|
| Weekly | Temperature (by data logger) | All Cells + Inflow to CWTS | Water |
| | pH | | |
| | Dissolved Oxygen | | |
| | Conductivity | | |
| | ORP | | |
| | Inflow rates/outflow rates (by meter) | | |
| | Regulated Metals (ICP) (Total and dissolved) | | |
| | Relative redox potential | All Cells | Soil |
| Monthly | Alkalinity | Outflow All cells + Inflow to CWTS | Water |
| | Hardness | | |
| | Sulfate | | |
| | Chemical Oxygen Demand | | |
| | Total Organic Carbon | | |
| | Ammonia | | |
| | Nitrate/Nitrite | | |
| | Total Kjeldahl Nitrogen | | |
| | Biological Oxygen Demand | Outflow + Inflow of CWTS | |
| | Total Suspended Solids | | |

| | | | |
|---|---|---|---|
| | Stem counts (and height) | All cells | Plant |
| Seasonally | Available NPKS | All cells | Soil |
| | Regulated Metals (ICP) | | |
| | Total Organic Carbon | | |
| | Cation Exchange Capacity (CEC) | | |
| | Sodium Adsorption Ratio | | |
| | Conductivity | | |
| | Sequential Leaching | | |
| | MPN for SeIV, $NO_3$, and sulphate reducing microbes, and total heterotrophs | | |
| | Genetic microbial community profiles | | |
| Twice per year | Detritus depth/accretion measurement | All Cells | Soil |
| | Regulated Metals (ICP) | | Plant |
| | Available NPK and Sulphur | | |

**Table 5.** Summary of analytical sampling types, frequencies and locations

| | |
|---|---|
| **Water samples** | |
| routine package: Ca, Mg, Na, K, Cl, $SO_4$, $NO_3$, $NO_2$, hardness, alkalinity, pH, EC, TDS | Monthly, outflow of each cell and inflow water |
| Chemical oxygen demand (COD) | Monthly, outflow of each cell and inflow water |
| Total organic carbon | Monthly, outflow of each cell and inflow water |
| Ammonia | Monthly, outflow of each cell and inflow water |
| Total Kjeldahl Nitrogen (TKN) | Monthly, outflow of each cell and inflow water |
| Total suspended solids | Monthly, outflow of series, and inflow water |
| Biological Oxygen Demand (BOD) | Monthly, outflow of series, and inflow water |
| Regulated metals water package (dissolved and total) | Weekly, outflow of each cell and inflow water |
| In-situ water testing (pH, DO, ORP, Conductivity) | Weekly, all cells and inflow water |
| **Hydrosoil samples** | |
| Relative soil redox | Weekly, all probes (6 per cell) |
| Cation exchange capacity (CEC) | Seasonally (3x per year), 3 places per cell |
| SAR, pH, EC, %sat, Ca, Mg, Na, K, Cl, SO4 | Seasonally (3x per year), 3 places per cell |
| Available NPK and sulphur | Seasonally (3x per year), 3 places per cell |
| Total organic carbon | Seasonally (3x per year), 3 places per cell |
| Sequential Leaching | Seasonally (3x per year), 3 places per cell |
| **Plant tissue samples** | |
| ICP | 2 plant types in triplicate (pre-planting in 2014) |
| Available NPK and sulphur | 2 plant types in triplicate (pre-planting in 2014) |
| TOC | 2 plant types in triplicate (pre-planting in 2014) |

## 4. Long-term conceptual testing plan

A conceptual long-term testing plan has been developed for the demonstration-scale CWTS

(Table 6), which will be refined and adapted based on performance and scientific findings as the trials are conducted. The demonstration-scale wetlands will run for a minimum of 2 more years, until the end of 2016, but ideally longer in order to assess performance under a wider range of conditions. The conditions that could eventually be tested include both natural/environmental and selected influenced pressures, and can be imposed on the systems to mimic peak flow rates or droughts. In 2015 the systems will be allowed to continue to mature, with plants becoming more established and abundant, and microbial communities accordingly acclimating to the targeted conditions. Once plants are well established and showing signs of colonizing through the wetland, the water depth may be increased to 30 cm and the flow rate may also be increased. First, a 5 day HRT (i.e., twice as fast as currently) may be tested, and then fluctuations will be tested based on anticipated seasonal variation.

**Table 6.** Schedule as per proposed scope of work:

| Item | | Proposed | Actual |
|---|---|---|---|
| Identify potential location for demonstration scale CWTS (CSL site visit – 1 scientist) | | June 1-14 2014 | Completed |
| Engineering and geotechnical (Minto) | | June - July 2014 | Completed |
| Construction (Minto) | | July 2014 | Completed |
| Planting and bringing system online (CSL site visit – 1 scientist, 1 technologist), coordinate for local students to assist. | | August 2014 | Completed (no students available, brought 2 technologists) |
| Monitoring | 2014 | Acclimation and maturation at constant flow rate of 10 d HRT | Completed |
| | | September - CSL site visit/checkup (1 technologist, 1 scientist) | Did not occur because constructed was last week of August. |
| | 2015 | Continued maturation/acclimation. Operation at constant flow rate of 5-10 d HRT | On Schedule |
| | | Spring – CSL site visit/checkup (1 technologist, 1 scientist), includes micro sampling | |
| | | Summer - Increase depth from 10 cm to 20 cm (1 technologist), includes micro sampling | |
| | | Fall – CSL site visit/checkup (1 technologist), includes micro | |

| | | | |
|---|---|---|---|
| | | sampling | |
| | 2016 | Operation with weekly flow variations based on seasonal variations | |
| | | Spring – CSL site visit/checkup (1 technologist), includes micro sampling | |
| | | Summer - CSL site visit/checkup (1 technologist, 1 scientist), switch to hybrid bioreactor phase if appropriate, includes micro sampling | |
| | | Fall - CSL site visit/checkup (1 technologist), includes micro sampling | |
| | 2017 | Hybrid Bioreactor/CWTS phase, late in operation 2016 or 2017, exact timing to be determined based on results from initial operations of the demo scale and results of hybrid CWTS/bioreactor pilot testing. This will involve adding solid organic matter (such as alfalfa hay, straw) to the CWTS cell(s). | |
| Reporting | 2014-2016 | Reporting will be performed twice annually, in the form of an interim update and comprehensive (all data to date) report. | On Schedule |

## 5. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Respectfully submitted,
Contango Strategies Ltd

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## 6. References

Contango Strategies. Minto Mine Constructed Wetland Treatment Research Program – Pilot Scale Report, November 3, 2014.

Faulkner, S.P., Patrick, W.H. Jr. and Gambrell, R.P. (1989) Field techniques for measuring wetland soil parameters. Soil Science Society of America Journal, Vol. 53, pp. 883-890.

**Table A1**. Analytical results from initial soil sampled August 28, 2014

| Parameter | Units | Rep1 | Rep2 | Rep3 | Rep4 | Wood Shavings | Straw | RDL |
|---|---|---|---|---|---|---|---|---|
| **Calculated Parameters** | | | | | | | | |
| Anion Sum | meq/L | 5.0 | 3.1 | 0.89 | 0.81 | 1.0 | 14 | N/A |
| Cation Sum | meq/L | 8.1 | 6.5 | 13 | 5.4 | 2.2 | 24 | N/A |
| Cation/EC Ratio | N/A | 11 | 11 | 10 | 11 | 10 | 9.4 | 0.10 |
| Ion Balance | N/A | 1.6 | 2.1 | 15 | 6.7 | 2.2 | 1.7 | 0.010 |
| Cation exchange capacity | cmol+/Kg | 22 | 20 | 18 | 20 | <10 | 50 | 10 |
| **Soluble Parameters** | | | | | | | | |
| Soluble Chloride (Cl) | mg/L | 41 | 16 | 240 | 26 | 12 | 310 | 5.0 |
| Soluble Conductivity | dS/m | 0.72 | 0.61 | 1.3 | 0.51 | 0.21 | 2.5 | 0.020 |
| Soluble (CaCl2) pH | pH | 6.46 | 6.44 | 6.56 | 6.47 | 3.95 | | N/A |
| Sodium Adsorption Ratio | N/A | 0.55 | 0.53 | 2.0 | 0.65 | 0.30 | 0.63 | 0.10 |
| Soluble Calcium (Ca) | mg/L | 110 | 92 | 150 | 71 | 11 | 20 | 1.5 |
| Soluble Magnesium (Mg) | mg/L | 14 | 11 | 16 | 8.8 | 4.0 | 47 | 1.0 |
| Soluble Sodium (Na) | mg/L | 23 | 20 | 97 | 22 | 4.6 | 22 | 2.5 |
| Soluble Potassium (K) | mg/L | 7.6 | 7.4 | 8.5 | 7.1 | 39 | 710 | 1.3 |
| Saturation % | % | 47 | 48 | 47 | 44 | 620 | 1400 | N/A |
| Soluble Sulphate (SO4) | mg/L | 210 | 180 | 190 | 140 | <5.0 | 210 | 5.0 |
| **Nutrients** | | | | | | | | |
| Available (NH4F) Nitrogen (N) | mg/kg | 8.0 | 8.1 | 6.0 | 5.3 | <10 | <10 | 10 |
| Available (NH4F) Phosphorus (P) | mg/kg | 5.1 | 5.7 | 5.6 | 3.9 | 16 | 200 | 5.0 |
| Available (NH4OAc) Potassium (K) | mg/kg | 55 | 53 | 48 | 61 | 260 | 7700 | 10 |
| Available (CaCl2) Sulphur (S) | mg/kg | 29 | 24 | 27 | 24 | <20 | 850 | 20 |
| Nitrite (N) | mg/L | 0.0165 | 0.0216 | 0.0156 | 0.0623 | 0.0127 | <0.50 | 0.50 |
| Nitrate (N) | mg/L | 0.315 | 0.445 | 0.332 | 0.150 | 0.252 | <2.0 | 2.0 |
| Total Ammonia (N) | mg/L | <0.0050 | 0.0076 | 0.0086 | 0.0090 | 0.0428 | 0.067 | 0.050 |
| **Misc. Inorganics** | | | | | | | | |
| Fluoride (F) | mg/L | 0.220 | 0.350 | 0.250 | 0.210 | 0.041 | 0.089 | 0.010 |

| Parameter | Units | Rep1 | Rep2 | Rep3 | Rep4 | Wood Shavings | Straw | RDL |
|---|---|---|---|---|---|---|---|---|
| Dissolved Organic Carbon (C) | mg/L | 6.55 | 5.91 | 4.96 | 6.85 | 355 | 815 | 50 |
| Total Organic Carbon (C) | % | 1.9 | 1.8 | 3.1 | 1.8 | 48 | 45 | 0.10 |
| Alkalinity (Total as CaCO3) | mg/L | 33.5 | 126 | 36.7 | 34.8 | 30.7 | 304 | 0.50 |
| Alkalinity (PP as CaCO3) | mg/L | <0.50 | 13.2 | 2.49 | 8.01 | <0.50 | <0.50 | 0.50 |
| Bicarbonate (HCO3) | mg/L | 40.9 | 121 | 38.7 | 22.9 | 37.5 | 371 | 0.50 |
| Carbonate (CO3) | mg/L | <0.50 | 15.9 | 2.99 | 9.61 | <0.50 | <0.50 | 0.50 |
| Hydroxide (OH) | mg/L | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | 0.50 |
| **Physical Properties** | | | | | | | | |
| % sand by hydrometer | % | 59 | 60 | 55 | 57 | | | |
| % silt by hydrometer | % | 26 | 25 | 28 | 27 | | | |
| Clay Content | % | 15 | 16 | 17 | 16 | | | |
| Texture | N/A | SANDY LOAM | SANDY LOAM | SANDY LOAM | SANDY LOAM | | | |
| Total Dissolved Solids | mg/L | 80 | 200 | 104 | 222 | 692 | 2360 | 10 |
| **Dissolved Metals by ICPMS** | | | | | | | | |
| SPLP Aluminum (Al) | ug/L | 6540 | 3640 | 4840 | 34400 | 145 | 151 | 2.5 |
| SPLP Antimony (Sb) | ug/L | 0.242 | 0.208 | 0.243 | 0.48 | 0.042 | <0.10 | 0.10 |
| SPLP Arsenic (As) | ug/L | 3.24 | 2.19 | 2.67 | 15.0 | 0.446 | 1.57 | 0.10 |
| SPLP Barium (Ba) | ug/L | 141 | 79.9 | 102 | 476 | 46.8 | 396 | 0.10 |
| SPLP Beryllium (Be) | ug/L | 0.133 | 0.091 | 0.142 | 0.629 | 0.015 | <0.050 | 0.050 |
| SPLP Bismuth (Bi) | ug/L | 0.0440 | 0.0240 | 0.0270 | 0.193 | <0.0050 | 0.039 | 0.025 |
| SPLP Boron (B) | ug/L | 519 | 233 | 90 | <250 | 127 | <250 | 250 |
| SPLP Cadmium (Cd) | ug/L | 0.0470 | 0.0410 | 0.0740 | 0.158 | 0.137 | 0.484 | 0.025 |
| SPLP Cesium (Cs) | ug/L | 0.347 | 0.206 | 0.290 | 1.42 | <0.050 | 0.29 | 0.25 |
| SPLP Chromium (Cr) | ug/L | 10.7 | 7.80 | 6.12 | 43.1 | 0.62 | 0.94 | 0.50 |
| SPLP Cobalt (Co) | ug/L | 2.53 | 1.44 | 2.13 | 10.5 | 0.106 | 0.291 | 0.025 |
| SPLP Copper (Cu) | ug/L | 248 | 148 | 186 | 608 | 11.0 | 116 | 0.25 |
| SPLP Iron (Fe) | ug/L | 8900 | 4950 | 7040 | 47400 | 49.4 | 308 | 5.0 |
| SPLP Lanthanum (La) | ug/L | 5.72 | 4.16 | 4.81 | 17.9 | <0.050 | 0.27 | 0.25 |

| Parameter | Units | Rep1 | Rep2 | Rep3 | Rep4 | Wood Shavings | Straw | RDL |
|---|---|---|---|---|---|---|---|---|
| SPLP Lead (Pb) | ug/L | 3.00 | 1.79 | 2.21 | 12.4 | 1.10 | 14.7 | 0.025 |
| SPLP Lithium (Li) | ug/L | 2.90 | 1.66 | 2.00 | 12.6 | 1.05 | 3.5 | 2.5 |
| SPLP Manganese (Mn) | ug/L | 125 | 76.0 | 103 | 372 | 272 | 597 | 0.25 |
| SPLP Molybdenum (Mo) | ug/L | 1.75 | 1.46 | 1.94 | 1.86 | 0.230 | 2.52 | 0.25 |
| SPLP Nickel (Ni) | ug/L | 5.93 | 3.76 | 5.39 | 26.5 | 0.693 | 2.22 | 0.10 |
| SPLP Phosphorus (P) | ug/L | 132 | 84.6 | 107 | 503 | 416 | 1460 | 10 |
| SPLP Rubidium (Rb) | ug/L | 7.05 | 4.56 | 5.97 | 27.7 | 13.7 | 241 | 0.25 |
| SPLP Selenium (Se) | ug/L | 0.487 | 0.355 | 0.360 | 0.69 | <0.040 | 1.09 | 0.20 |
| SPLP Silicon (Si) | ug/L | 14900 | 8970 | 11200 | 67100 | 425 | 24000 | 500 |
| SPLP Silver (Ag) | ug/L | 0.123 | 0.0950 | 0.123 | 0.325 | 0.0560 | 0.446 | 0.025 |
| SPLP Strontium (Sr) | ug/L | 14.2 | 12.7 | 12.2 | 35.6 | 11.3 | 156 | 0.25 |
| SPLP Tellurium (Te) | ug/L | <0.020 | 0.024 | 0.021 | <0.10 | <0.020 | <0.10 | 0.10 |
| SPLP Thallium (Tl) | ug/L | 0.0500 | 0.0310 | 0.0410 | 0.184 | 0.0110 | 0.103 | 0.010 |
| SPLP Thorium (Th) | ug/L | 1.44 | 1.06 | 1.25 | 4.56 | 0.0140 | 0.151 | 0.025 |
| SPLP Tin (Sn) | ug/L | 0.32 | <0.20 | 0.22 | 1.1 | <0.20 | <1.0 | 1.0 |
| SPLP Titanium (Ti) | ug/L | 237 | 129 | 176 | 1280 | 1.28 | 4.7 | 2.5 |
| SPLP Tungsten (W) | ug/L | 0.093 | 0.080 | 0.086 | 0.203 | 0.054 | <0.050 | 0.050 |
| SPLP Uranium (U) | ug/L | 0.176 | 0.134 | 0.151 | 0.865 | 0.0110 | 0.057 | 0.010 |
| SPLP Vanadium (V) | ug/L | 22.0 | 11.9 | 16.2 | 92.1 | 1.24 | 2.3 | 1.0 |
| SPLP Zinc (Zn) | ug/L | 19.9 | 13.2 | 15.4 | 74.4 | 16.0 | 84.5 | 0.50 |
| SPLP Zirconium (Zr) | ug/L | 1.72 | 1.42 | 1.49 | 5.77 | 0.12 | <0.50 | 0.50 |
| SPLP Calcium (Ca) | ug/L | 3040 | 3290 | 3090 | 7240 | 3960 | 18000 | 250 |
| SPLP Magnesium (Mg) | ug/L | 1420 | 954 | 1110 | 6150 | 1670 | 38300 | 250 |
| SPLP Potassium (K) | ug/L | 1250 | 1010 | 1440 | 5780 | 14100 | 499000 | 250 |
| SPLP Sodium (Na) | ug/L | 43900 | 33900 | 22100 | 26900 | 8550 | 20500 | 250 |
| SPLP Mercury (Hg) | ug/L | <0.050 | <0.050 | <0.050 | <0.25 | 0.096 | <0.25 | 0.25 |
| SPLP Sulphur (S) | ug/L | <10000 | <10000 | <10000 | <50000 | <10000 | <50000 | 50000 |

**Table A2**. Sequentially extracted ICP-MS analytical results from initial soil sampled August 28, 2014

| mg/kg | Extraction 1 | | | | Extraction 2 | | | | Extraction 3 | | | | Extraction 4 | | | | Extraction 5 | | | | RDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R1 | R2 | R3 | R4 | R1 | R2 | R3 | R4 | R1 | R2 | R3 | R4 | R1 | R2 | R3 | R4 | |
| Al | - | - | - | - | 34 | 28 | 30 | 34 | 800 | 640 | 890 | 720 | 920 | 1500 | 1300 | 1300 | 17000 | 17000 | 16000 | 15000 | 10 |
| Sb | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.0 |
| As | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 6.5 | 6.7 | 6.7 | 6.3 | 2.0 |
| Ba | 45 | 24 | 39 | 46 | 91 | 51 | 80 | 76 | 120 | 100 | 120 | 110 | 46 | 150 | 63 | 65 | 540 | 620 | 510 | 530 | 5.0 |
| Be | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.0 |
| B | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5.0 |
| Cd | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.30 |
| Cr | - | - | - | - | - | - | - | - | - | - | - | - | 2.5 | 6.2 | 3.4 | 3.5 | 21 | 31 | 19 | 19 | 2.0 |
| Co | - | - | - | - | - | - | - | - | 2.6 | 2.4 | 2.4 | 2.2 | - | - | - | - | 12 | 11 | 11 | 11 | 1.0 |
| Cu | 2.9 | 4.9 | 2.8 | 3.7 | 93 | 35 | 67 | 120 | 270 | 180 | 240 | 290 | 480 | 380 | 630 | 650 | 1500 | 960 | 1400 | 1300 | 2.0 |
| Fe | - | - | - | - | - | 85 | - | - | 5000 | 4400 | 5300 | 4700 | 340 | 610 | 440 | 550 | 35000 | 31000 | 34000 | 33000 | 50 |
| Pb | - | - | - | - | - | - | - | - | 1.4 | 1.3 | 1.5 | 1.4 | - | 1.1 | 0.60 | 0.74 | 6.0 | 8.4 | 5.3 | 5.3 | 0.50 |
| Mn | - | - | - | 2.3 | 140 | 76 | 120 | 130 | 160 | 110 | 150 | 150 | 19 | 21 | 23 | 28 | 750 | 490 | 670 | 700 | 2.0 |
| Mo | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.9 | 2.0 |
| Ni | - | - | - | - | - | - | - | - | 3.7 | 5.9 | 3.7 | 3.4 | - | 3.3 | - | - | 18 | 28 | 17 | 17 | 2.0 |
| Se | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.0 |
| Ag | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.50 |
| Ar | 14 | 13 | 12 | 14 | 7.7 | 7.3 | 6.9 | 6.2 | - | 5.8 | - | - | - | - | - | - | 48 | 58 | 45 | 47 | 5.0 |
| Tl | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.22 | 0.16 | 0.20 | 0.20 | 0.10 |
| U | - | - | - | - | 0.19 | 0.46 | 0.17 | 0.15 | 0.17 | 0.38 | 0.17 | 0.15 | - | 0.45 | 0.10 | 0.11 | 0.87 | 2.1 | 0.78 | 0.77 | 0.10 |
| V | - | - | - | - | - | - | - | - | 10 | 12 | 11 | 9.3 | - | 3.8 | - | - | 80 | 79 | 75 | 74 | 2.0 |
| Zn | - | - | - | - | - | - | - | - | 11 | 9.1 | 12 | 10 | - | 6.1 | 5.2 | 5.5 | 89 | 70 | 83 | 82 | 5.0 |

**Table A3**. Sequentially extracted ICP-MS analytical results from initial wood shavings and straw amendments sampled August 28, 2014

| mg/kg | Wood Shavings | | | | | Straw | | | | | RDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E 2 | E3 | E4 | E5 | E1 | E2 | E3 | E4 | E5 | |
| **Al** | - | - | - | - | - | - | - | - | - | 35 | 10 |
| **Sb** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **As** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **Ba** | - | - | - | - | 10 | - | 11 | 10 | - | 55 | 5.0 |
| **Be** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **B** | - | - | - | - | - | - | - | - | - | - | 5.0 |
| **Cd** | - | - | - | - | - | - | - | - | - | - | 0.30 |
| **Cr** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **Co** | - | - | - | - | - | - | - | - | - | - | 1.0 |
| **Cu** | - | - | - | - | - | - | - | - | - | 3.5 | 2.0 |
| **Fe** | - | - | - | - | - | - | - | - | - | 140 | 50 |
| **Pb** | - | - | - | - | - | - | - | - | - | 2.6 | 0.50 |
| **Mn** | 21 | 13 | 5.4 | - | 86 | 3.5 | 14 | 7.5 | - | 70 | 2.0 |
| **Mo** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **Ni** | - | - | - | - | - | - | - | - | - | 7.1 | 2.0 |
| **Se** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **Ag** | - | - | - | - | - | - | - | - | - | - | 0.50 |
| **Ar** | - | - | - | - | - | - | - | - | - | 13 | 5.0 |
| **Tl** | - | - | - | - | - | - | - | - | - | - | 0.10 |
| **U** | - | - | - | - | - | - | - | - | - | - | 0.10 |
| **V** | - | - | - | - | - | - | - | - | - | - | 2.0 |
| **Zn** | - | - | - | - | 9.0 | - | - | - | - | 15 | 5.0 |

**Table A4**. Analytical results from plants sampled August 27, 2014

| Parameter | Units | Carex | | | | | | Moss | | | RDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Roots | | | Leaves | | | | | | |
| | | Rep 1 | Rep 2 | Rep 3 | Rep 1 | Rep 2 | Rep 3 | Rep 1 | Rep 2 | Rep 3 | |
| **Nutrients** | | | | | | | | | | | |
| Available Nitrogen (N) | mg/kg | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | 10 |
| Available Phosphorus (P) | mg/kg | 240 | 48 | 91 | 640 | 520 | 810 | 470 | 340 | 150 | 5.0 |
| Available Potassium (K) | mg/kg | 8100 | 1400 | 3200 | 9100 | 8100 | 11000 | 4000 | 5400 | 2700 | 10 |
| Available Sulphur (S) | mg/kg | 210 | 670 | 700 | 170 | 340 | 530 | 290 | 400 | 220 | 20 |
| **Misc. Inorganics** | | | | | | | | | | | |
| Total Organic Carbon (C) | % | 39 | 36 | 37 | 38 | 38 | 43 | 43 | 45 | 40 | 0.10 |
| Total Carbon | % | 41 | 37 | 38 | 45 | 40 | 44 | 41 | 45 | 44 | 0.20 |
| **Inorganics** | | | | | | | | | | | |
| Moisture | % | 87 | 88 | 86 | 74 | 77 | 75 | 90 | 94 | 92 | 1.0 |
| **Metals** | | | | | | | | | | | |
| Antimony (Sb) | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| Arsenic (As) | mg/kg | 1.7 | 1.0 | 0.4 | 0.3 | 0.1 | <0.1 | 0.2 | 0.1 | <0.1 | 0.1 |
| Barium (Ba) | mg/kg | 53.9 | 34.3 | 28.2 | 31.0 | 23.3 | 17.9 | 29.9 | 22.3 | 10.5 | 0.3 |
| Beryllium (Be) | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| Bismuth (Bi) | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| Boron (B) | mg/kg | <0.5 | 0.6 | 0.8 | 1.0 | 0.8 | 1.1 | 0.5 | <0.5 | <0.5 | 0.5 |
| Cadmium (Cd) | mg/kg | 0.02 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.01 | 0.01 |
| Calcium (Ca) | mg/kg | 973 | 648 | 752 | 1160 | 944 | 743 | 1460 | 1210 | 1160 | 50 |
| Chromium (Cr) | mg/kg | 1.4 | 1.2 | 0.6 | 1.3 | 0.5 | 0.4 | <0.3 | <0.3 | <0.3 | 0.3 |
| Cobalt (Co) | mg/kg | 1.45 | 0.864 | 0.965 | 0.594 | 0.333 | 0.164 | 0.645 | 0.464 | 0.166 | 0.005 |
| Copper (Cu) | mg/kg | 93.7 | 47.0 | 15.1 | 20.5 | 21.9 | 6.8 | 13.8 | 18.3 | 11.2 | 0.5 |
| Iron (Fe) | mg/kg | 7870 | 4540 | 2560 | 2080 | 1140 | 540 | 1190 | 1020 | 404 | 3 |
| Lead (Pb) | mg/kg | 0.27 | 0.11 | 0.11 | 0.08 | 0.06 | <0.03 | 0.04 | 0.04 | 0.03 | 0.03 |
| Magnesium (Mg) | mg/kg | 910 | 477 | 327 | 653 | 321 | 325 | 293 | 229 | 190 | 100 |
| Manganese (Mn) | mg/kg | 98.3 | 128 | 151 | 116 | 282 | 141 | 272 | 179 | 27.1 | 0.3 |
| Molybdenum (Mo) | mg/kg | 0.18 | 0.21 | 0.15 | 0.31 | 0.41 | 0.17 | 0.29 | 0.09 | 0.25 | 0.05 |
| Nickel (Ni) | mg/kg | 0.87 | 0.41 | 0.37 | 0.32 | 0.20 | 0.11 | 0.36 | 0.49 | 0.13 | 0.05 |
| Phosphorus (P) | mg/kg | <500 | <500 | <500 | <1000 | <1000 | <1000 | <500 | <500 | <500 | 500 |
| Potassium (K) | mg/kg | 1180 | 1070 | 1440 | 2860 | 3620 | 3430 | 674 | 363 | 315 | 100 |
| Selenium (Se) | mg/kg | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 0.2 |
| Silver (Ag) | mg/kg | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| Sodium (Na) | mg/kg | 509 | 512 | 508 | 222 | 149 | 180 | 94 | 54 | <50 | 50 |
| Strontium (Sr) | mg/kg | 5.8 | 4.4 | 5.7 | 5.7 | 5.4 | 4.7 | 10.1 | 8.2 | 7.1 | 0.5 |
| Thallium (Tl) | mg/kg | 0.007 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | 0.003 |
| Tin (Sn) | mg/kg | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | 0.3 |
| Titanium (Ti) | mg/kg | 109 | 49 | 24.3 | 42 | 22.8 | 8.0 | 6.0 | 5.9 | 4.6 | 0.5 |
| Uranium (U) | mg/kg | 0.049 | 0.025 | 0.035 | 0.016 | 0.016 | 0.012 | 0.014 | 0.015 | 0.007 | 0.005 |
| Vanadium (V) | mg/kg | 11.8 | 4.9 | 3.2 | 3.5 | 1.8 | 0.7 | 0.7 | 0.8 | 0.4 | 0.3 |
| Zinc (Zn) | mg/kg | 12 | 6 | 4 | 7 | 7 | 4 | 5 | 4 | 2 | 2 |

**Table A5**. Analytical results from water sampled September 18, 2014

| Parameter | Units | CWTS LINE 1 | CWTS 1A | CWTS 1B | CWTS LINE 2 | CWTS 2A | CWTS 2B | CWTS FINAL | RDL |
|---|---|---|---|---|---|---|---|---|---|
| **Elements** | | | | | | | | | |
| Total Aluminum (Al) | mg/L | 0.13 | 0.031 | 0.044 | 0.011 | 0.021 | 0.016 | 0.026 | 0.0030 |
| Dissolved Aluminum (Al) | mg/L | 0.0062 | 0.0093 | 0.015 | 0.0091 | 0.0097 | 0.013 | 0.017 | 0.0030 |
| Total Antimony (Sb) | mg/L | <0.00060 | <0.00060 | <0.00060 | <0.00060 | <0.00060 | <0.00060 | <0.00060 | 0.00060 |
| Dissolved Antimony (Sb) | mg/L | <0.00060 | <0.00060 | <0.00060 | <0.00060 | <0.00060 | <0.00060 | <0.00060 | 0.00060 |
| Total Arsenic (As) | mg/L | 0.00041 | 0.00041 | 0.00044 | 0.00034 | 0.00039 | 0.00038 | 0.00039 | 0.00020 |
| Dissolved Arsenic (As) | mg/L | 0.00038 | 0.00038 | 0.00040 | 0.00034 | 0.00034 | 0.00039 | 0.00042 | 0.00020 |
| Total Barium (Ba) | mg/L | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.010 |
| Dissolved Barium (Ba) | mg/L | 0.12 | 0.12 | 0.13 | 0.12 | 0.12 | 0.13 | 0.13 | 0.010 |
| Total Beryllium (Be) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Dissolved Beryllium (Be) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Total Boron (B) | mg/L | <0.020 | <0.020 | <0.020 | <0.020 | 0.024 | 0.020 | <0.020 | 0.020 |
| Dissolved Boron (B) | mg/L | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | 0.020 |
| Total Cadmium (Cd) | ug/L | 0.048 | 0.045 | 0.039 | 0.046 | 0.040 | 0.029 | 0.021 | 0.020 |
| Dissolved Cadmium (Cd) | ug/L | 0.046 | 0.036 | 0.030 | 0.041 | 0.038 | 0.022 | <0.020 | 0.020 |
| Total Calcium (Ca) | mg/L | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 0.30 |
| Dissolved Calcium (Ca) | mg/L | 130 | 120 | 120 | 130 | 120 | 120 | 120 | 0.30 |
| Total Chromium (Cr) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Dissolved Chromium (Cr) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Total Cobalt (Co) | mg/L | <0.00030 | <0.00030 | <0.00030 | <0.00030 | <0.00030 | <0.00030 | <0.00030 | 0.00030 |
| Dissolved Cobalt (Co) | mg/L | <0.00030 | <0.00030 | <0.00030 | <0.00030 | <0.00030 | <0.00030 | <0.00030 | 0.00030 |
| Total Copper (Cu) | mg/L | 0.088 | 0.047 | 0.046 | 0.053 | 0.047 | 0.041 | 0.041 | 0.00020 |
| Dissolved Copper (Cu) | mg/L | 0.046 | 0.041 | 0.039 | 0.047 | 0.042 | 0.036 | 0.034 | 0.00020 |
| Total Iron (Fe) | mg/L | 0.50 | 0.20 | 0.20 | 0.19 | 0.18 | 0.15 | 0.15 | 0.060 |
| Dissolved Iron (Fe) | mg/L | 0.13 | 0.11 | 0.12 | 0.15 | 0.12 | 0.10 | 0.10 | 0.060 |
| Total Lead (Pb) | mg/L | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | 0.00020 |
| Dissolved Lead (Pb) | mg/L | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | 0.00020 |

| Parameter | Units | CWTS LINE 1 | CWTS 1A | CWTS 1B | CWTS LINE 2 | CWTS 2A | CWTS 2B | CWTS FINAL | RDL |
|---|---|---|---|---|---|---|---|---|---|
| Total Lithium (Li) | mg/L | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | 0.020 |
| Dissolved Lithium (Li) | mg/L | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | 0.020 |
| Total Magnesium (Mg) | mg/L | 37 | 38 | 37 | 38 | 37 | 37 | 38 | 0.20 |
| Dissolved Magnesium (Mg) | mg/L | 37 | 36 | 37 | 37 | 36 | 36 | 36 | 0.20 |
| Total Manganese (Mn) | mg/L | 0.26 | 0.19 | 0.16 | 0.26 | 0.19 | 0.14 | 0.094 | 0.0040 |
| Dissolved Manganese (Mn) | mg/L | 0.25 | 0.18 | 0.15 | 0.25 | 0.20 | 0.14 | 0.090 | 0.0040 |
| Total Molybdenum (Mo) | mg/L | 0.0083 | 0.0082 | 0.0083 | 0.0084 | 0.0083 | 0.0081 | 0.0082 | 0.00020 |
| Dissolved Molybdenum (Mo) | mg/L | 0.0079 | 0.0076 | 0.0078 | 0.0077 | 0.0078 | 0.0079 | 0.0076 | 0.00020 |
| Total Nickel (Ni) | mg/L | 0.0013 | 0.0012 | 0.0015 | 0.0012 | 0.0012 | 0.0011 | 0.0012 | 0.00050 |
| Dissolved Nickel (Ni) | mg/L | 0.00075 | 0.00079 | 0.00079 | 0.00072 | 0.00074 | 0.00081 | 0.00068 | 0.00050 |
| Total Phosphorus (P) | mg/L | 0.12 | <0.10 | <0.10 | <0.10 | 0.14 | 0.11 | <0.10 | 0.10 |
| Dissolved Phosphorus (P) | mg/L | <0.10 | 0.13 | 0.12 | <0.10 | <0.10 | <0.10 | <0.10 | 0.10 |
| Total Potassium (K) | mg/L | 4.5 | 4.5 | 4.4 | 4.5 | 4.5 | 4.4 | 4.6 | 0.30 |
| Dissolved Potassium (K) | mg/L | 4.3 | 4.3 | 4.4 | 4.3 | 4.3 | 4.3 | 4.4 | 0.30 |
| Total Selenium (Se) | mg/L | 0.0064 | 0.0065 | 0.0064 | 0.0066 | 0.0063 | 0.0063 | 0.0062 | 0.00020 |
| Dissolved Selenium (Se) | mg/L | 0.0063 | 0.0061 | 0.0061 | 0.0063 | 0.0061 | 0.0063 | 0.0059 | 0.00020 |
| Total Silicon (Si) | mg/L | 7.8 | 7.2 | 7.0 | 7.6 | 7.2 | 7.1 | 7.2 | 0.10 |
| Dissolved Silicon (Si) | mg/L | 7.3 | 6.9 | 6.8 | 7.3 | 6.9 | 6.9 | 6.8 | 0.10 |
| Total Silver (Ag) | mg/L | <0.00010 | <0.00010 | <0.00010 | <0.00010 | <0.00010 | <0.00010 | <0.00010 | 0.00010 |
| Dissolved Silver (Ag) | mg/L | <0.00010 | <0.00010 | <0.00010 | <0.00010 | <0.00010 | <0.00010 | <0.00010 | 0.00010 |
| Total Sodium (Na) | mg/L | 22 | 22 | 22 | 22 | 22 | 22 | 23 | 0.50 |
| Dissolved Sodium (Na) | mg/L | 22 | 21 | 22 | 22 | 21 | 22 | 22 | 0.50 |
| Total Strontium (Sr) | mg/L | 1.3 | 1.3 | 1.3 | 1.4 | 1.3 | 1.3 | 1.3 | 0.020 |
| Dissolved Strontium (Sr) | mg/L | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 0.020 |
| Total Sulphur (S) | mg/L | 44 | 45 | 43 | 44 | 43 | 44 | 44 | 0.20 |
| Dissolved Sulphur (S) | mg/L | 42 | 41 | 42 | 42 | 41 | 42 | 42 | 0.20 |
| Total Thallium (Tl) | mg/L | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | 0.00020 |
| Dissolved Thallium (Tl) | mg/L | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | <0.00020 | 0.00020 |

| Parameter | Units | CWTS LINE 1 | CWTS 1A | CWTS 1B | CWTS LINE 2 | CWTS 2A | CWTS 2B | CWTS FINAL | RDL |
|---|---|---|---|---|---|---|---|---|---|
| Total Tin (Sn) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Dissolved Tin (Sn) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Total Titanium (Ti) | mg/L | 0.014 | 0.0023 | 0.0038 | <0.0010 | 0.0021 | <0.0010 | 0.0015 | 0.0010 |
| Dissolved Titanium (Ti) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Total Uranium (U) | mg/L | 0.0031 | 0.0029 | 0.0031 | 0.0031 | 0.0031 | 0.0030 | 0.0031 | 0.00010 |
| Dissolved Uranium (U) | mg/L | 0.0032 | 0.0032 | 0.0032 | 0.0032 | 0.0032 | 0.0034 | 0.0032 | 0.00010 |
| Total Vanadium (V) | mg/L | 0.0011 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Dissolved Vanadium (V) | mg/L | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0010 |
| Total Zinc (Zn) | mg/L | 0.075 | 0.055 | 0.049 | 0.071 | 0.059 | 0.042 | 0.029 | 0.0030 |
| Dissolved Zinc (Zn) | mg/L | 0.068 | 0.049 | 0.037 | 0.068 | 0.052 | 0.038 | 0.022 | 0.0030 |
| **Misc.** | | | | | | | | | |
| Dissolved Nitrite (N) | mg/L | 0.016 | 0.020 | 0.020 | 0.016 | 0.020 | 0.022 | 0.026 | 0.010 |
| Dissolved Nitrate (N) | mg/L | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 0.020 |
| Total Ammonia (N) | mg/L | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | 0.050 |
| Total Nitrogen (N) | mg/L | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 0.050 |
| Biochemical Oxygen Demand | mg/L | <2.0 | <2.0 | <2.0 | <2.0 | <2.0 | <2.0 | <2.0 | 2.0 |
| Total Chemical Oxygen Demand | mg/L | 27 | 28 | 31 | 26 | 41 | 27 | 27 | 5.0 |
| Conductivity | uS/cm | 920 | 920 | 910 | 930 | 920 | 910 | 900 | 1.0 |
| pH | pH | 8.27 | 8.23 | 8.34 | 8.20 | 8.32 | 8.30 | 8.44 | N/A |
| Total Organic Carbon (C) | mg/L | 9.7 | 9.3 | 9.7 | 9.5 | 10 | 11 | 10 | 0.50 |
| Total Suspended Solids | mg/L | 0.67 | 1.1 | 1.3 | <0.40 | 0.53 | 0.67 | 0.40 | 0.40 |
| Alkalinity (PP as CaCO3) | mg/L | <0.50 | <0.50 | 0.90 | <0.50 | <0.50 | <0.50 | 5.0 | 0.50 |
| Alkalinity (Total as CaCO3) | mg/L | 300 | 300 | 300 | 300 | 300 | 300 | 290 | 0.50 |
| Bicarbonate (HCO3) | mg/L | 360 | 360 | 360 | 370 | 360 | 360 | 350 | 0.50 |
| Carbonate (CO3) | mg/L | <0.50 | <0.50 | 1.1 | <0.50 | <0.50 | <0.50 | 6.0 | 0.50 |
| Hydroxide (OH) | mg/L | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | 0.50 |
| Dissolved Sulphate (SO4) | mg/L | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 1.0 |
| Dissolved Chloride (Cl) | mg/L | 22 | 21 | 22 | 21 | 22 | 21 | 21 | 1.0 |

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# Minto Mine Constructed Wetland Treatment Research Program – Demonstration Scale 2015 Update

Document – 011_0316_03B

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Appendix A – Tables of analytical results for water, soils, and plants
Appendix B – Copper Sequential Leach and Aluminum Graphs
Appendix C – Schedule of work

## 1. Introduction and Background

The Minto Mine, operated by Capstone Mining Corp., is located 240 km northwest of Whitehorse on the west side of the Yukon River. The Minto property lies within the eastern part of the Dawson Range, with elevations from 700 to 1,000 m; the landscape has rounded mountains intersected by broad valleys and drainages that are part of the Yukon River watershed.

The Minto Mine has been in commercial operation since October 2007 and the deposits being mined are copper sulphide mineralized zones. Surface and groundwater water quality is a key consideration in the evaluation of potential effects of mining and mineral development projects and changes to water quality parameters have the potential to affect aquatic and human use of water resources. A Reclamation and Closure Plan (RCP) is required under both the Water Licence and the Quartz Mining Licence. The RCP is intended to address the long-term physical and chemical stability of the site and closure of the proposed features and disturbances associated with the mine. As a part of the RCP, a Constructed Wetland Treatment System (CWTS) is being designed, evaluated, and optimized for water treatment at closure through a phased program (Minto Phase V/VI Expansion Project, YOR Project Number 2013-0100).

In order for CWTSs to be effective, they must be designed, piloted, optimized, implemented, and maintained in a site-specific manner. A scaled approach for CWTS implementation allows for improvement, optimization, and flexibility for modifications along each step. Phases include: 1) site assessment and information gathering, 2) technology selection and conceptual design, 3) pilot-scale testing and optimization (controlled environment), 4) on-site demonstration-scale confirmation and optimization, and 5) full-scale implementation. Phases 1-3 have been completed (reports 2013-0100-256 and 2013-0100-257 on YESAB registry, and Contango, March 2014; Contango, November 2014) and confirmed plant amenability to transplantation and the CWTS design for further on-site testing. During pilot-scale trials, the selected CWTS design achieved on average 92% removal of copper (mean influent 146 µg/L, outflow 11.3 µg/L) and 41% removal of selenium (mean influent 10.2 µg/L, outflow 6 µg/L) using synthetic influent designed to mimic the worst-case water chemistry of a long-term closure scenario, but tested under the controlled conditions (e.g., controlled flows, known temperature, etc) of an off-site treatability testing center (Contango, November 2014). It should be noted that lower influent concentrations will have a lower percent removal even when achieving the same final outflow concentrations.

Phase 4 of the project is underway, with the on-site demonstration scale CWTS constructed at the Minto Mine during fall 2014 (Contango, March 2015). This document reports on the on-site demonstration scale CWTS data from construction through 2015.

# 2. Construction

## 2.1. System layout and dimensions

The demonstration-scale CWTS includes 2 systems in parallel with 2 cells in each series and a final catchment basin that both systems flow into (Figure 1). Dimensions and construction details are available in the Minto Demonstration Scale Report Document 011_0315_01A (Contango, March 2015). The two parallel systems serve as a replicate for data analysis, and as testing has progressed, the two systems have also allowed for comparison of different management techniques. Dimensions of the systems are provided here in Table 1.

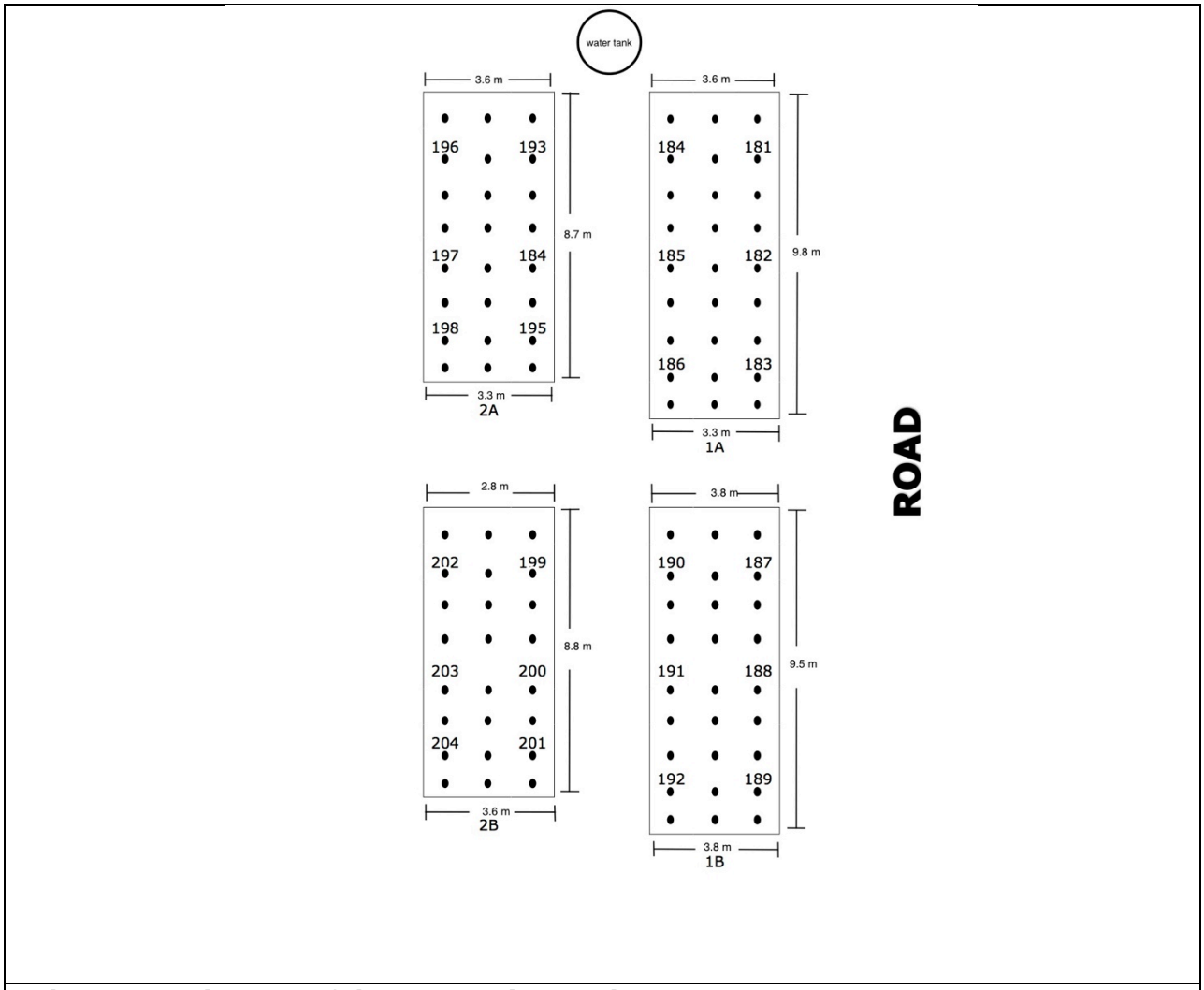


**Figure 1 – Diagram of demonstration-scale CWTS.**
Dimension measurements are indicated at soil surface. Black dots indicate initial construction grid marked by moss stakes, and locations of soil redox probes with identifying numbers.

**Table 1. Measurements of demonstration-scale CWTS cells at soil surface and resultant areas of treatment systems.**

| Measurement | | Series 1 | | Series 2 | |
|---|---|---|---|---|---|
| | | 1A | 1B | 2A | 2B |
| Width (m) | Inflow | 3.6 | 3.8 | 3.6 | 2.8 |
| | Outflow | 3.3 | 3.8 | 3.3 | 3.6 |
| Length (m) | | 9.8 | 9.5 | 8.7 | 8.8 |
| Approximate surface area at soil ($m^2$) | | 33.8 | 36.1 | 30.0 | 28.2 |
| Total area of system at soil ($m^2$) | | 69.9 | | 58.2 | |

### 2.2.Substrate Soils in Construction

Soils used to construct the CWTS are described in the initial report that outlines construction (Contango, March 2015). In brief, the recommended soil for the CWTS was sand, with 2-7% by volume as organic material (e.g., woodchips, peat). In the pilot-scale systems, this resulted in a total organic carbon (TOC) content by weight of 0.2-0.6% (the sand itself was at 0.1% TOC prior to adding amendment). Ideally, this number could be higher, approximately 2-10% by weight to stimulate the desired reducing conditions. For the demonstration-scale system, the soil added to each of the 4 cells during construction was from a local borrow site. As is expected in a mining area, the soils are likely mineralized. Although a potential borrow source was tested prior to construction ("Tested Soil"; Table 2), a different borrow source was available upon construction of the demonstration-scale wetland ("Soil Used"; Table 2). The material used in the construction of the demonstration-scale wetland was an organic peat, and analyses received after construction indicated an elevated concentration of leachable copper (Table 2). It should be noted that in a full-scale system, the variability in soil substrate would be normalized by the larger volume of soil used. The substrate in the wetland (composed of the organic peat soil, wood chips, and straw) had a TOC content of 1.8-3.1%. The implications of this are discussed in Section 4 if this report.

**Table 2. Comparison of Copper Concentrations in Soils of Pilot- and Demonstration-Scale CWTS**

| Test Method | Pilot-scale | Demonstration-scale | |
|---|---|---|---|
| | Initial Soil | Tested Soil (June, 2014) | Soil Used (August, 2014) |
| SPLP Copper (mg/L)[1] | - | 0.00546-0.0296[2] | 0.148-0.608 |
| Total Copper (mg/kg) | 5.3-5.5 | 210-1400[2] | 960-1400[3] |

[1] SPLP - Synthetic Precipitation Leaching Procedure
[2] For the June 2014 samples, the soil with the highest total copper concentration also had the lowest leachable copper concentration, and was therefore deemed acceptable for use.
[3] Total copper value for soils used was taken in June 2015 (no data for August 2014).

### 2.3. Vegetation Used in Planting

The demonstration-scale CWTS was planted with *Carex aquatilis* (aquatic sedge) and aquatic mosses from the W10 area of the Minto Site. The plant selection and borrow source was previously determined through the site assessment (reports 2013-0100-256 and 2013-0100-257 on the YESAB registry) and pilot-scale testing (Contango, November 2014). Five *C. aquatilis* were planted per square meter, with moss tied to stakes that outlined the 1 m x 1 m grid for planting (details provided in Contango, March 2015).

### 2.4. Water source

Water from the W36 area receiving seepage from the toe of the Mill Valley Fill Extension (MVFE) was selected for the demonstration-scale CWTS testing as the leachate is similar to that expected upon closure in the MVFE area. The chemistry of this water at the time of bringing the demonstration-scale CWTS online (September 18, 2014) is provided in Contango, March 2015.

After construction, the flow rates for the systems were planned to be set to have a 10 day nominal hydraulic retention time (HRT), meaning water entering the wetland takes 10 days to exit. This is referred to as a nominal HRT because it is a calculation based on the size of the wetland and the amount of water entering, and not confirmed empirically using tracing dyes. This HRT is much longer than what is necessary to achieve treatment based on the pilot-scale systems (~3 days), and was chosen to facilitate plant establishment and maturation. However, due to the leachable copper concentrations in the soils used for construction, it was instead decided to run the systems at a faster flow to wash as much leachable copper from the soils as possible. As such, a shorter nominal HRT of ~20 hrs was used as a starting point (HRT calculated using measured water depths of approximately 15 cm and negligible pore water involvement [30cm of soil at 10% pore volume] due to peat soils). The actual HRT will be confirmed by a tracer study in 2016 (Section 8). Despite the shorter HRT resulting from the faster flow of water, the systems have acclimated and matured as was expected for the longer HRT. Because the sizes of the CWTS systems are slightly different, Series 1 (closer to the road) and Series 2 (further from road) are set with flow rates to result in similar HRTs in each system. Flow rates were monitored and adjusted throughout 2015 based on CWTS establishment and maturation (Sections 3 and 4).

## 3. Commissioning

The time period between the construction of the CWTS and achieving the expected treatment performance is referred to as the commissioning period. This period is needed for operational adjustments to be made (e.g., raising water depth, modifying outflow patterns), and for plant and microbial populations to establish and mature. Based on pilot-scale testing (Contango, November 2014), the estimated commissioning period for the Minto demonstration-scale CWTS is 4 months of operation (i.e., period when water is flowing). In 2014, the demonstration-scale CWTS operated for less than one month prior to freezing, and was restarted along with spring thaw (freshet) in mid-May 2015. Based on these timelines, September 2015 was month 4 of commissioning, and the demonstration-scale system is trending towards performance as expected during the commissioning period.

Functionality similar to that of the matured pilot-scale systems is expected to occur by summer 2016.

Operational adjustments made in 2015 include:

- Increasing water depth
- Adding more aquatic moss
- Modifying inflow and outflow distribution
- Removing *Carex utriculata* (a small quantity was erroneously planted)
- Wrapping inflow tank to prevent algae growth

While full treatment functionality of the demonstration-scale system is not expected during the commissioning period, there is important data that should be collected during this period as it applies to the full-scale system in the following ways:

- evaluation of construction effectiveness and optimizations that could be made.
- assessment of timelines to reach targeted operational parameters to allow for effective phasing of implementation (e.g., soil redox, percentage and abundance of sulphate reducing bacteria).
- Effectiveness of *Carex aquatilis* and aquatic moss transplantation to assess planting density, time period to full density, and if plant propagation and/or a replanting schedule is necessary.

## 4. Timeline and Sampling Schedule

Major events and operational adjustments are listed in Table 3. The actual dates as well as relative days of operation are provided, which adjusts for time that the CWTS was not receiving water as it was frozen. The relative days of operation allows for comparison to expected timelines from the pilot-scale testing, and for planning and scheduling to be done for full-scale construction and commissioning in the context of mine closure planning.

The sampling schedule for 2015 was conceptually developed prior to beginning construction of the demonstration-scale CWTS (Appendix A). Actual dates of sampling were dependent on timing of spring thaw and winter freeze-up, and the associated ability to have the pumps operating at the W36 pond to supply water to the demonstration-scale CWTS.

**Table 3. Events and sampling activities since construction**

| Event | Key Activity | Flow Rate Setting $m^3$/day (gal/min) | | Calendar Date | Day of Operation |
|---|---|---|---|---|---|
| | | CWTS Series 1 | CWTS Series 2 | | |
| CWTS constructed and planted | First sampling, water started. | - | - | August 27 – 31, 2014 | 0-4 |
| Freeze up for winter | Feed water pumps turned off. | - | - | September 19, 2014 | 23 |
| Start up for 2015 | Feed water pumps turned on. | 14.17 (2.60) | 11.61 (2.13) | May 16, 2015 | 24 |
| Contango Site Visit #1 | Microbiology, soils, water tested. *Carex* stem counts. Added more aquatic moss. Put black wrap on water tank to prevent algal growth. Water depth adjusted with sandbags. | | | June 18, 2015 | 57 |
| Flow rate increased | Flow rates increased. | 17.44 (3.20) | 15.81 (2.90) | July 13, 2015 | 82 |
| Contango Site Visit #2 | Microbiology, soils, water tested. Added more aquatic moss. | | | August 16, 2015 | 116 |
| Contango Site Visit #3 | Water tested. Started Fe-EDTA test on System 2. | | | September 17, 2015 | 148 |
| | Microbiology, soils, plants, water tested. | | | September 18, 2015 | 149 |
| Fe-EDTA Testing | Daily total and dissolved copper analysis conducted at Minto. | | | September 19 – 26, 2015 | 150-157 |
| Freeze up for Winter | Feed water pumps turned off. | - | - | September 29, 2015 | 160 |

## 5. Monitoring Explanatory Parameters

Explanatory parameters are quantifiable aspects of a CWTS environment that can be used to assess feasibility of treatment for a range of constituents, and therefore 'explain' the performance of a CWTS. These parameters, which often include acidity, alkalinity, conductivity, dissolved oxygen (DO), pH, oxidation reduction potential (ORP), ion balance, available electrons donors (e.g., organic carbon, reduced elements), and temperature, can be used to predict, promote, and/or optimize the ability of the system to treat different constituents (Haakensen et al., 2015). A YSI ProPlus meter was used in the field to test for water temperature, DO, conductivity (and specific conductivity; SPC), pH, and ORP.

Average water temperature of the demonstration-scale CWTS was 12.9°C, ranging from 0.5°C to 25°C through 2015. As would be expected, both the month of testing and time of day were found to affect temperature variation. DO concentrations of the CWTS feed and cells were on average 10 mg/L, which is higher than the pilot-scale systems (average 4.8 mg/L), which make it more difficult to carry out nitrate and selenium treatment, and sulphide production for copper and cadmium treatment. The conductivity, pH and ORP of the demonstration-scale CWTS cells are all very similar to the pilot-scale systems.

An additional explanatory parameter that can be used to monitor maturation of the wetland during the commissioning period is the soil redox potential, which is measured using platinum tip probes (in soil) and Calomel electrodes (in water). This measurement offers insight into the direction of electron flux between the sediment/soil/pore water and overlying water column (Faulkner et al., 1989; Huddleston & Rodgers, 2008), and can be used to confirm reducing conditions in the soil. Based on the information gathered in pilot-scale testing, the targeted soil redox for the demonstration-scale CWTS is between -100 and -250 mV. In these redox ranges, bacterial sulphide-production through reduction of sulphur compounds (e.g., sulphate) is expected. Sulphide production directly results in metals and metalloid treatment for elements such as cadmium, copper, molybdenum, nickel, lead, and zinc by precipitation as metal sulphides (Figure 2).

This maturation period is necessary for sufficient quantities of microbes to populate the wetland and become active in decomposing organic material. It is the electrons produced by the decomposition of organic material that is reported by the soil redox measurements. The decomposition of organic material then feeds the sulphate-reducing bacteria the type of energy they need to produce the sulphides that remove the copper from the water. The microbial activity of the system is discussed further in Section 6.5.

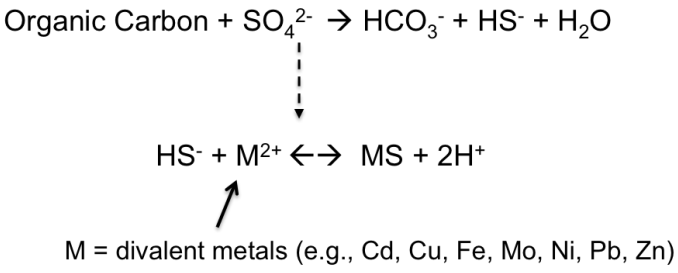


**Figure 2 – Example equation of sulphate reduction**
Equation is not balanced; demonstrates sulphate reduction with creation of alkalinity and sulphides, which can then form metal sulphide complexes.

As expected from the pilot-scale testing, the soil redox in all of the demonstration-scale CWTS cells decreased over time, indicating maturation of the system (Figure 2). At the end of 2015, only Series 1 had begun to achieve targeted soil redox values that are conducive to sulphide production (ahead of anticipated schedule). It is possible that Series 1 had more organic material in the soils than Series 2, because of how construction occurred and this wasn't reflected in the small sample size sent for analytical testing.

Some soil redox probes were reporting negative values in the targeted range by July 18, 2015 (87 days); however, in general the CWTS took approximately 4 months of operation to establish generally reducing conditions. By September 17, 2015 (day 148), most of the soil redox probes within Series 1 were reporting redox values within the targeted performance range, with Series 2 still trending downwards but not yet within the targeted range. In comparison, the pilot-scale systems were stable and reducing within approximately 4 months of construction (Figure 2).

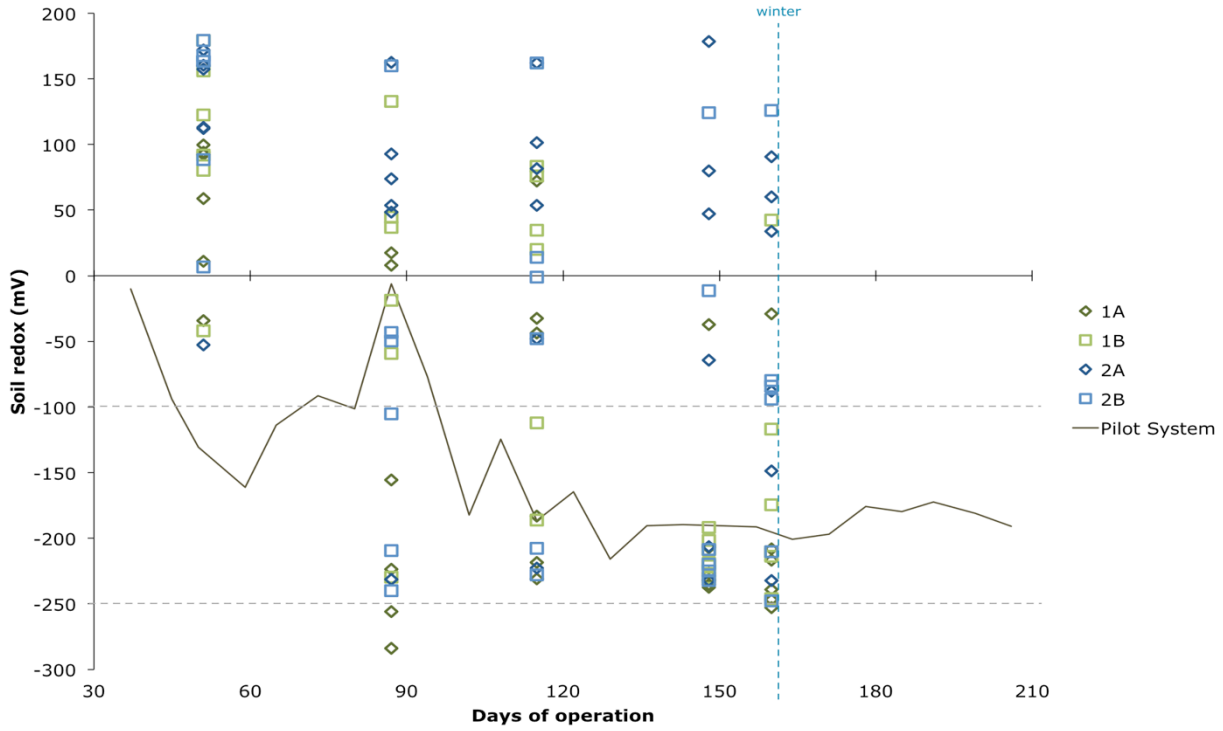


**Figure 3 – Soil redox potential of each CWTS cell over time**

All demonstration-scale CWTS soil redox measurements are plotted, along with the average soil redox of the pilot-scale systems. Targeted soil redox values based on pilot-scale testing are indicated with dotted lines. The blue dotted line indicates winter 2015.

# 6. Performance progress during commissioning period

## 6.1. Soils

To assess the effect of copper in the soils on CWTS functionality, three soil analytical test methods were used:

- total concentration of elements in the soils by ICP
- leachable concentrations of elements in the soils by Synthetic Precipitation Leaching Procedure (SPLP), which is a method to assess the mobility of elements in soils at the pH of rain water (i.e., if the wetland were to entirely dry out, then be subjected to leaching by rain water)
- concentration of elements in chemical extractions by sequential ICP-MS to assess the stability and form of elements in soils (Table 4)

**Table 4. Summary of extractable fractions from sequential ICP-MS analysis [1]**

| Fraction | Description | Elements Unstable when |
|---|---|---|
| **1** | Exchangeable fraction for adsorbed minerals | Readily released (i.e., soluble and exchangeable) |
| **2** | Mineral fraction bound to carbonates | Decreased pH |
| **3** | Mineral fraction bound to Fe-Mn oxides | Reducing conditions |
| **4** | Mineral fraction bound to organic matter and sulphides | Oxidizing conditions |
| **5** | Residual mineral fraction (primary and secondary minerals) | Not expected to be released in solution over time under conditions normally encountered in nature |

[1] Method based on Tessier *et al.,* 1979

Although unintentional, the use of soils in the CWTS with high initial leachable copper concentrations (Table 2) allowed for additional types of testing to be carried out on these systems. Because the soil substrates used for construction of the CWTS were from overburden sources, the copper was not in a mineral form that would typically be found in a reducing CWTS (i.e., negative relative soil redox). Therefore, there has been some initial leaching of copper (and other elements, such as aluminum) from the soils into the water (Figure 5 and Figure 7).

While the total copper concentrations have not changed significantly, the leachable copper (measured by SPLP) has decreased over time. By day 58 of operation, the top 5 cm of soil was decreased to only 10-20% of the initial leachable copper concentration, and the lower 10-20 cm layers reached similar concentrations by day 149 (Table 5). Analysis of the soils by ICP-MS with sequentially extracted acid analysis shows that despite elevated initial leachable copper concentrations, the soils have become more stable (less leachable) over time in the wetland setting as the soils have aged (Figure 4). This beneficial aging of soils to less soluble (sulphide) mineralized form is expected for this type of treatment wetland

design. It should be noted that due to the starting soil substrate containing leachable copper and other metals such as aluminum (Appendices A and B) that these elements are leaching from the substrate into the water, putting additional treatment demands on the systems. It is recommended that for construction of the full-scale systems, soils with low total and leachable copper concentrations should be used.

**Table 5. Total and Leachable Soil Copper Concentrations in First Year of Operations.**

| Cell | Sampling Date | Days in Operation | Sample Depth (cm) | Total Cu (mg/kg) | SPLP Cu (mg/L) |
|---|---|---|---|---|---|
| **CWTS 1A** | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) |
| | 19-Jun-15 | 58 | 0-5 | 960 | 0.055[1] |
| | 16-Aug-15 | 116 | 10-20 | 950 | 0.187 |
| | 18-Sep-15 | 149 | 10-20 | 1300 | 0.049 |
| | 29-Sep-15 | 160 | 10-20 | 910 | 0.069 |
| **CWTS 1B** | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) |
| | 19-Jun-15 | 58 | 0-5 | 1400 | 0.033[1] |
| | 16-Aug-15 | 116 | 10-20 | 1400 | 0.209 |
| | 18-Sep-15 | 149 | 10-20 | 830 | 0.065 |
| | 29-Sep-15 | 160 | 10-20 | 880 | 0.059 |
| **CWTS 2A** | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) |
| | 19-Jun-15 | 58 | 0-5 | 1175 | 0.037[1] |
| | 16-Aug-15 | 116 | 10-20 | 660 | 0.139 |
| | 18-Sep-15 | 149 | 10-20 | 880 | 0.081 |
| | 29-Sep-15 | 160 | 10-20 | 1000 | 0.073 |
| **CWTS 2B** | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) |
| | 19-Jun-15 | 58 | 0-5 | 1100 | 0.039[1] |
| | 16-Aug-15 | 116 | 10-20 | 1000 | 0.201 |
| | 18-Sep-15 | 149 | 10-20 | 830 | 0.078 |
| | 29-Sep-15 | 160 | 10-20 | 540 | 0.059 |

[1] Samples collected in June 2015 were at a shallow depth (0-5 cm) and copper content had therefore likely already been removed by washing from the faster flows of the CWTS system. The aging of the deeper (10-20 cm) soil copper concentrations over time to a less soluble form is shown in Figure 4.

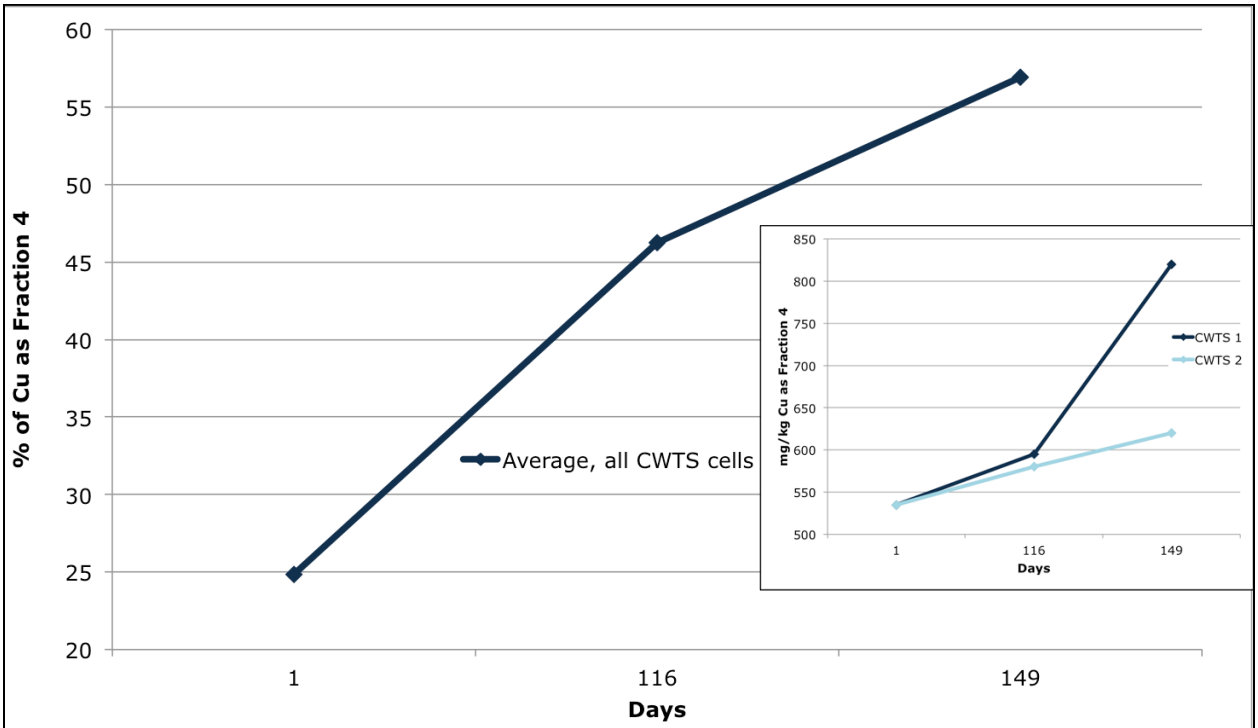


**Figure 4 – Copper as sequential leach fraction 4 over time.**
Copper in the form of the targeted Fraction 4 (sulphide mineral form and bound to organics), increased in the CWTS over time as the soils matured. Additional information in Appendix B.

### 6.2.Water

Pilot-scale testing was performed with water that mimicked the worst-case long-term post-closure water chemistry (mean influent concentrations of 146 µg/L copper and 10.2 µg/L selenium). In contrast, the on-site demonstration-scale system uses water from the W36 pond and therefore has inflow concentrations that are currently occurring during operations (mean influent concentrations of 58 µg/L copper and 6 µg/L selenium). Because of this, a lower percent removal will achieve the same extent of removal and associated outflow concentrations than was required in the pilot-scale systems. For example, the pilot-scale system achieved on average 92% removal of copper (mean outflow of 11.3 µg/L) and 41% removal of selenium (mean outflow of 6 µg/L). To achieve these same outflow concentrations with the demonstration-scale system, 80% removal of copper and minimal (or no) removal of selenium would be needed.

The treatment of copper has been improving through commissioning as the system has matured (Figure 7). However, as shown in Figure 5 and Appendix B, several elements are being released through the wetland by the soils, such as aluminum, cadmium, and copper (discussed further in Section 6.1). Because of this, negative percent removals of copper have been observed, especially in early operations (Figure 7). It was initially theorized that this was occurring when the May and June 2015 data reported outflow concentrations higher than the influent. This paired with the soils data (Section 6.1 and Appendix A) led to the design of a new sampling scheme to determine whether detectable levels of metals were being released from the soils within the wetland. For two timepoints (August 15, 2015 and

September 17, 2015), water was sampled not only at the feed and the outflow of each cell, but also through the cell. Beginning at the outflow of cell B and working upwards towards the feed, samples were taken at the B cell outflow, 1 m upstream of the B cell outflow, B cell mid point, 1 m downstream of the B cell inflow, and then the same 4 points for the A cell (Figure 6). In each case, the sample was taken from within a reaching distance of the side shore to ensure that sediments were not suspended in sampling.

It was found that significant metals concentrations were leaching from the wetlands soils of all cells (Figure 5). Moreover, metal types and concentrations (e.g., Aluminum, Appendix B) that could not be accounted for by the influent water chemistry were elevated at random points within the wetland. This suggested that because of metals leaching from the soils, the treatment occurring within the wetlands was far greater than what was being observed by simply measuring the inflow and outflow points (Figure 7). For example, in August of 2015, influent copper concentrations were measured as 50 µg/L, but within the first meter of cell 1A increased to 100 µg/L, and by the outflow of cell A, down to 42 µg/L (58 µg/L decrease), they then increased to 70 µg/L at the beginning of cell B, and again were treated to a final outflow concentration was 40 µg/L (30 µg/L) for a total of at least 88 µg/L removed by Series 1 of the treatment wetland. This suggests the wetland is actually achieving much greater copper treatment (88 µg/L removed), than would be suggested by only measuring the inflow and outflow of the system (suggests 10 µg/L removed). Similar leaching was observed through the wetland during testing in September 2015.

Copper, cadmium, zinc, and other metals and metalloids are being noticeably decreased in concentration from the water entering the wetlands (Figure 7 and Appendix B), while other metals/metalloids of potential concern are below background water quality for the area or below the detection limit in the influent of the wetland. Dissolved zinc had on average 65% removal in the wetland systems and by September 2015, the outflow concentrations were on average 20% and 50% lower than influent concentrations for dissolved copper and cadmium, respectively. This suggests that not only is the wetland maturing as expected, creating reducing sulphide-producing conditions, but that it is already performing far beyond what was anticipated from the design, sequestering orders of magnitude more copper than would be apparent by looking at the influent water alone (i.e., is also removing copper that has leached from the soils over time).

Removal rate coefficients ($k$) based on the HRT of each system would normally be calculated to compare treatment efficiency. However, because of the leaching of various elements from the soil, calculation of $k$ for constituents of concern is not representative of what is ongoing in the system, as there is concurrent leaching and treatment occurring throughout a given cell (Figure 5). Furthermore, because the soil used for construction of the demonstration-scale system is different than what was used for pilot-scale systems, the hydrology and pore volume of the system is not known; a parameter that is needed for accurate calculation of the HRT and therefore $k$. As the same wetland substrate was used to construct both demonstration-scale systems, the removal rate coefficients can be estimated and compared between these two systems; however, comparison with removal rates achieved during pilot-scale testing is not possible until the HRT is defined. It is therefore recommended that a tracer study be performed in 2016 to assess the hydrology and pore volume of the CWTS (see Section 8).

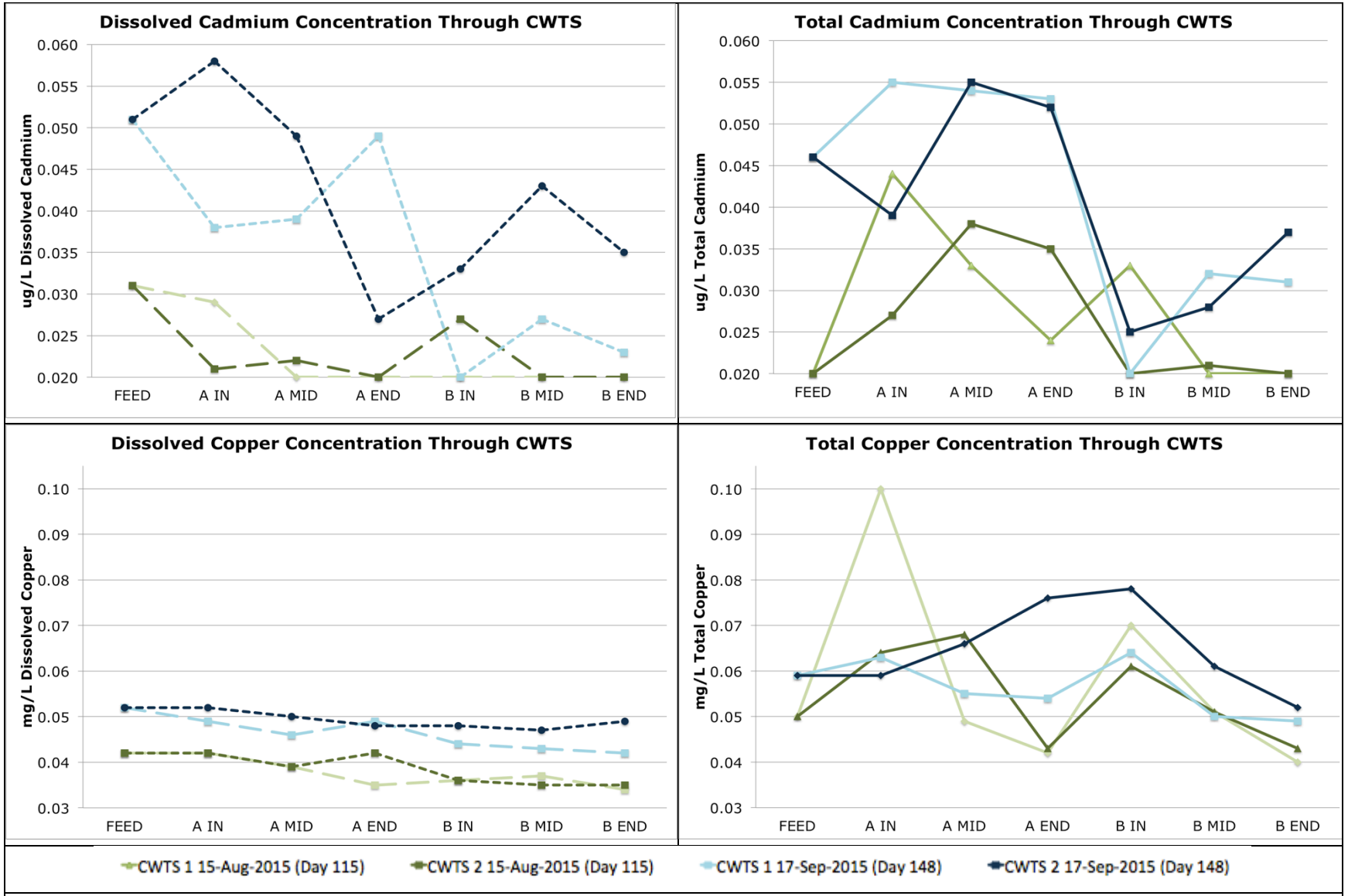


**Figure 5 – Concentrations of key elements through the CWTS.**
The y-axis values start at the detection limits.
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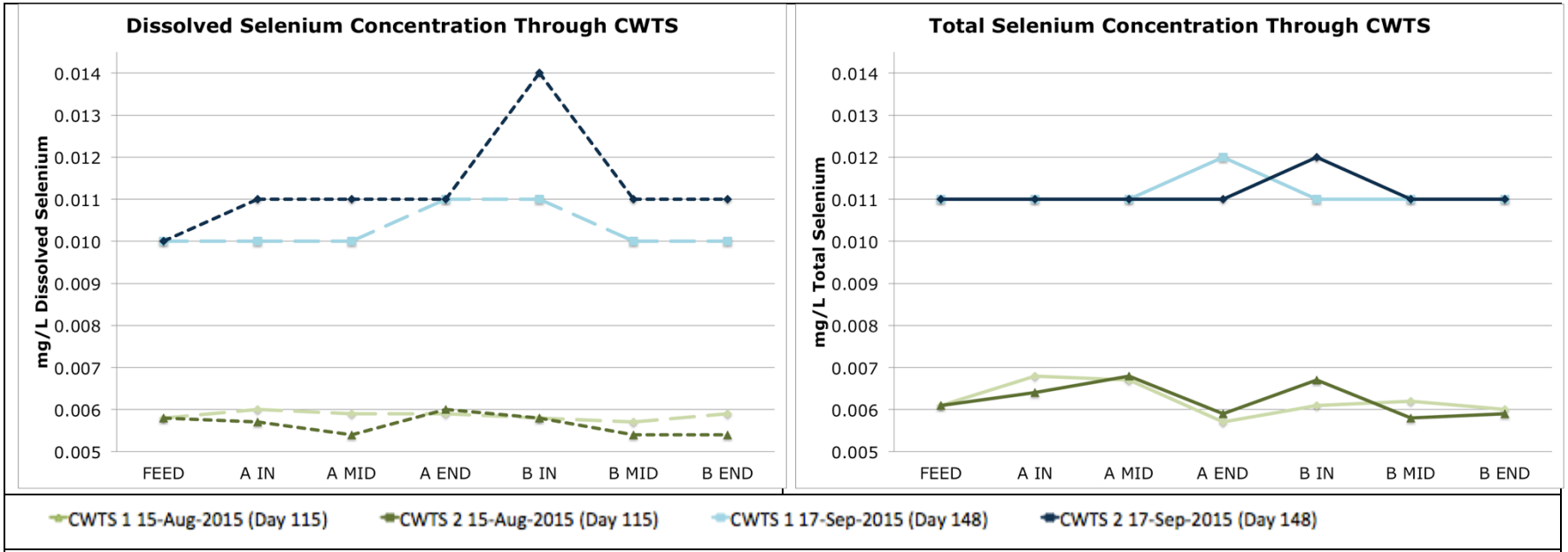


**Figure 5 – Continued**

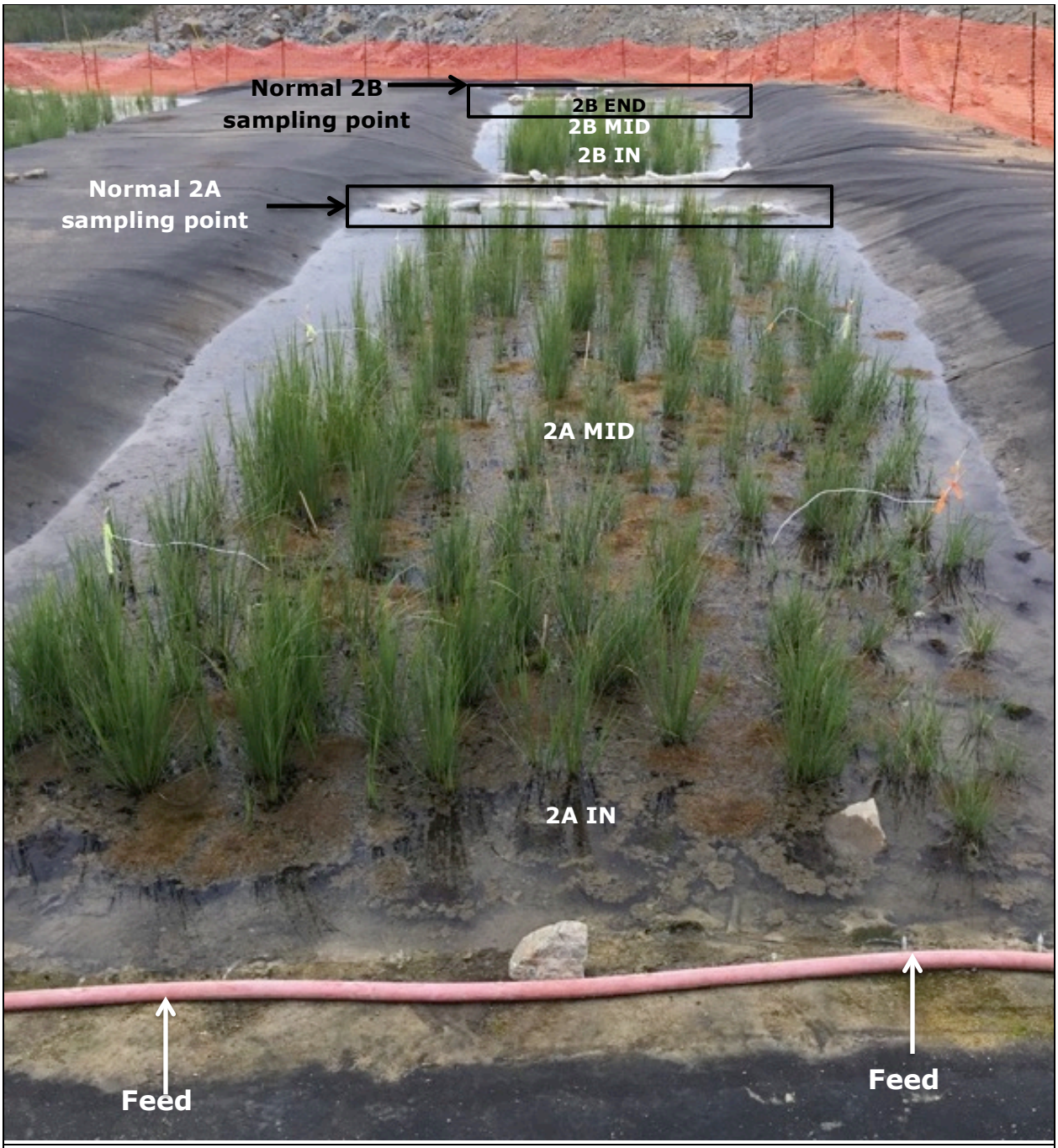


**Figure 6 – Sampling points through the CWTS.**

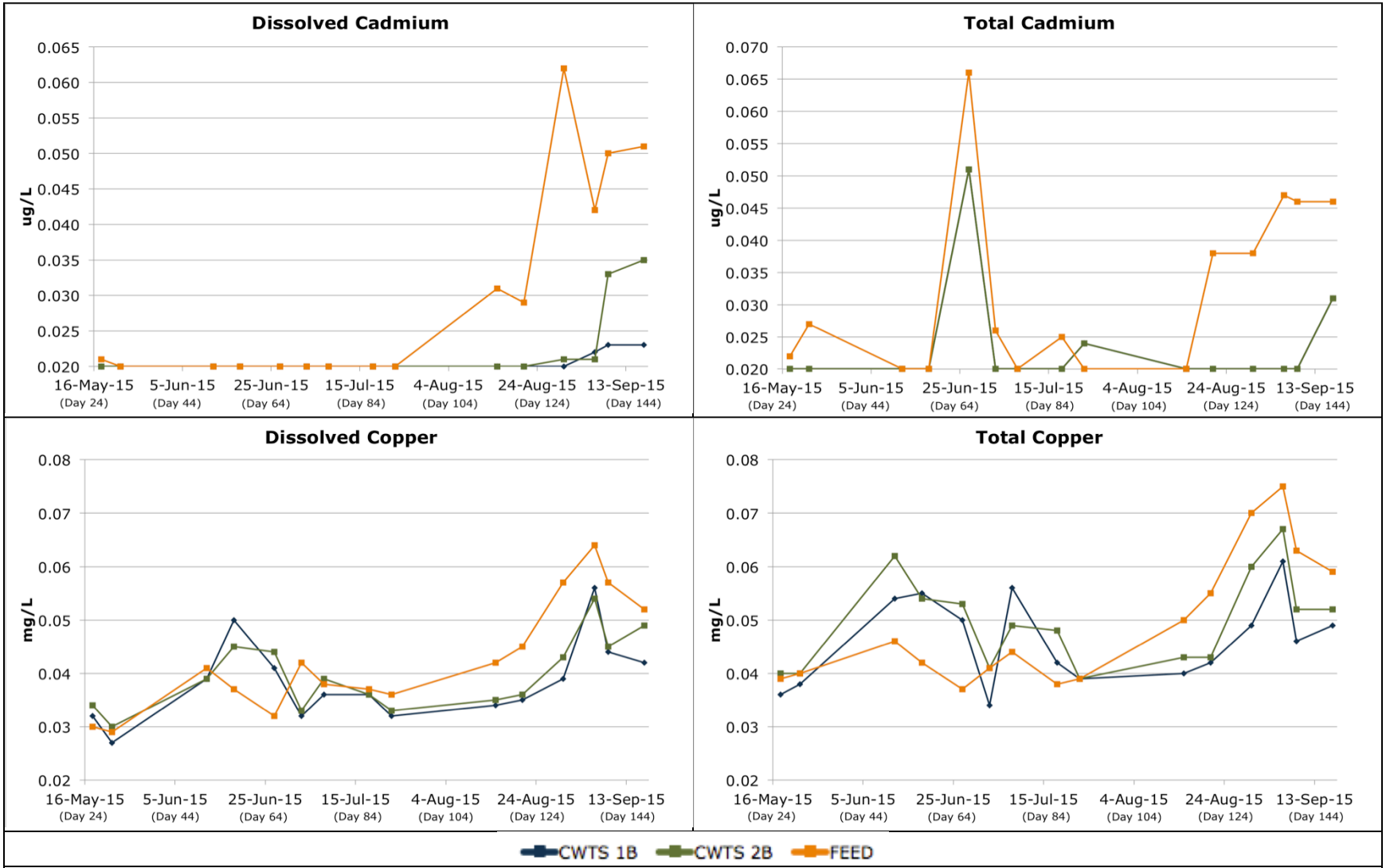


**Figure 7 – Element concentrations in the demonstration scale wetland from May 17, 2015 to Sept 17, 2015.**
The Measurement Uncertainty (MU) for cadmium is +/- 0.020 µg/L. The MU for copper and selenium is +/- 0.0002 mg/L. Timepoints where the dissolved cadmium concentration is higher than the total concentration are within the limit of uncertainty (Maxxam Analytics). Detection limits for cadmium, copper, and selenium are at or below y-axis values.
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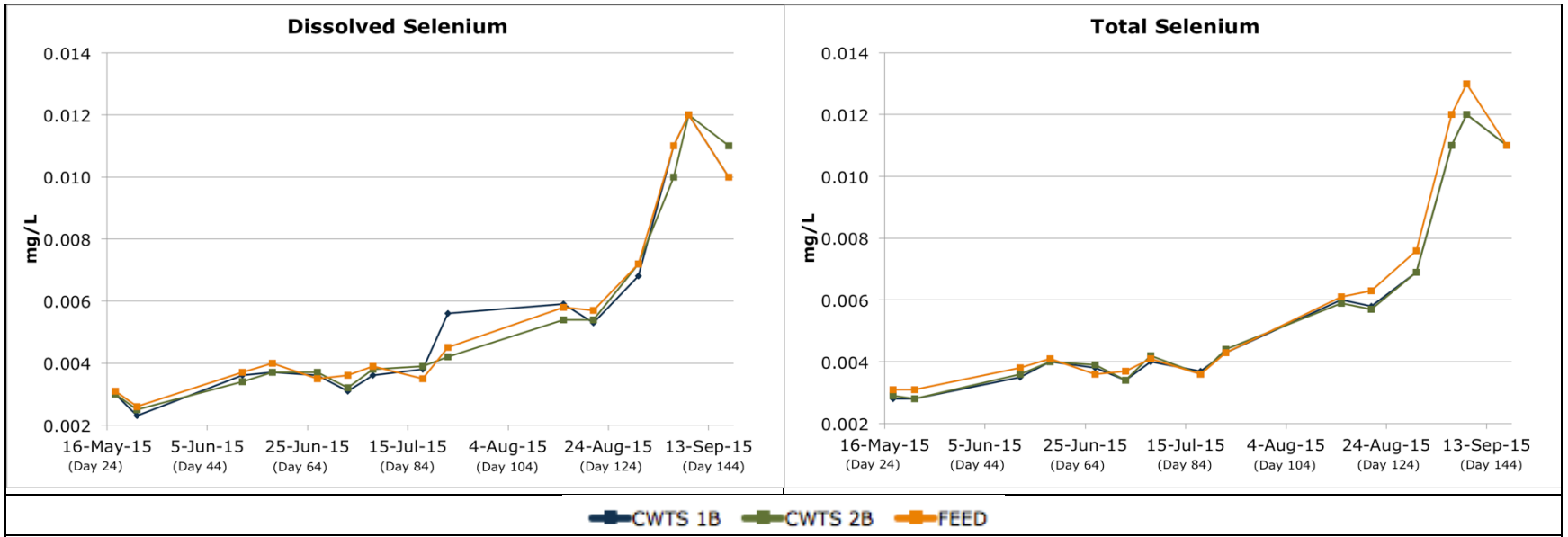


**Figure 7 -** Continued

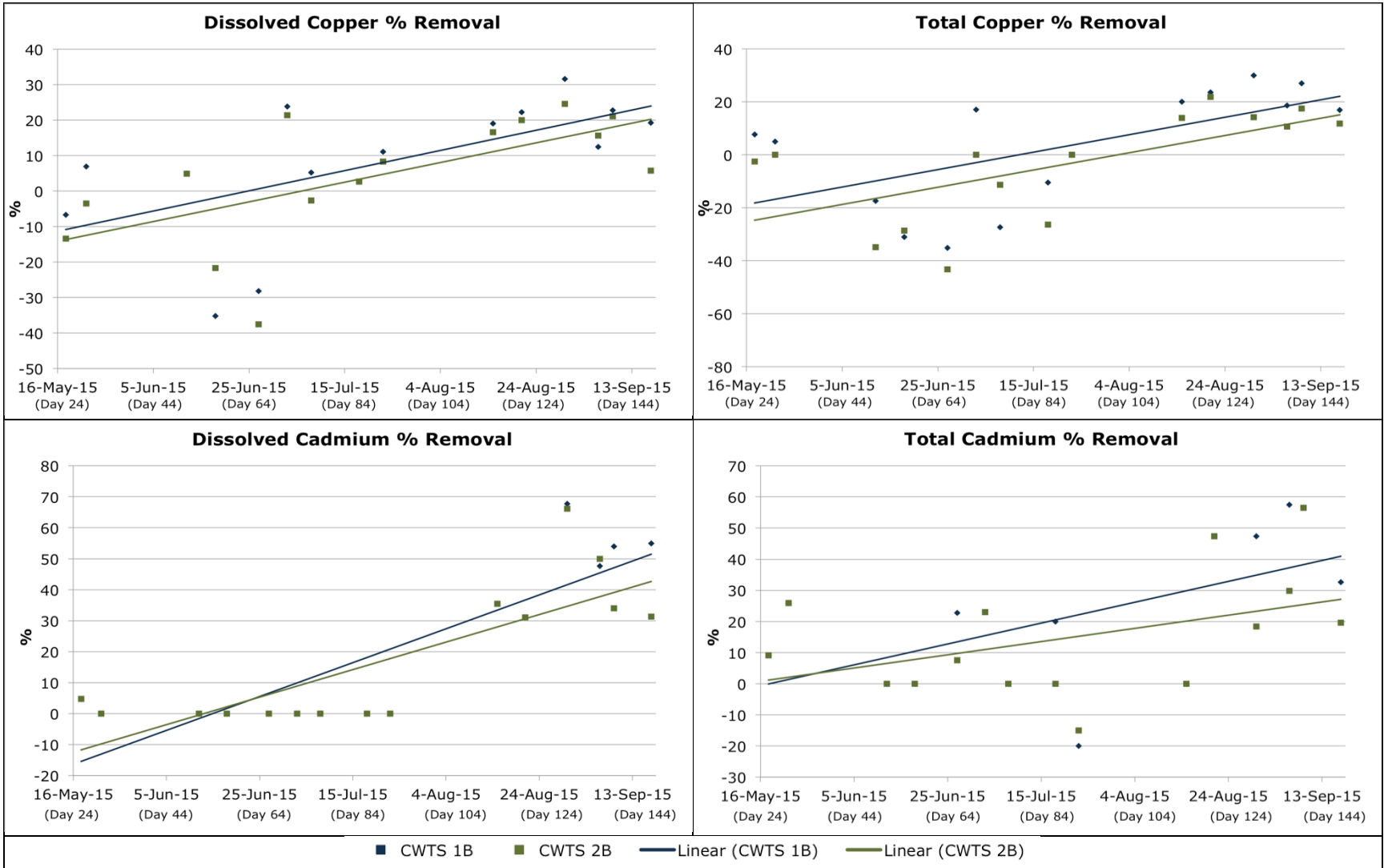


**Figure 8 – Percent removal of elements in the demonstration scale wetland from May 17, 2015 to Sept 17, 2015.**
If the concentration was below the detection limit of the assay, the detection limit was used to calculate the percent removal. Note the Measurement Uncertainty (MU) for cadmium was +/- 0.020 µg/L. The MU for copper and selenium is +/- 0.0002 mg/L (Maxxam Analytics) (Appendix A). The percent removal calculations for cadmium are therefore estimations within this range of error.
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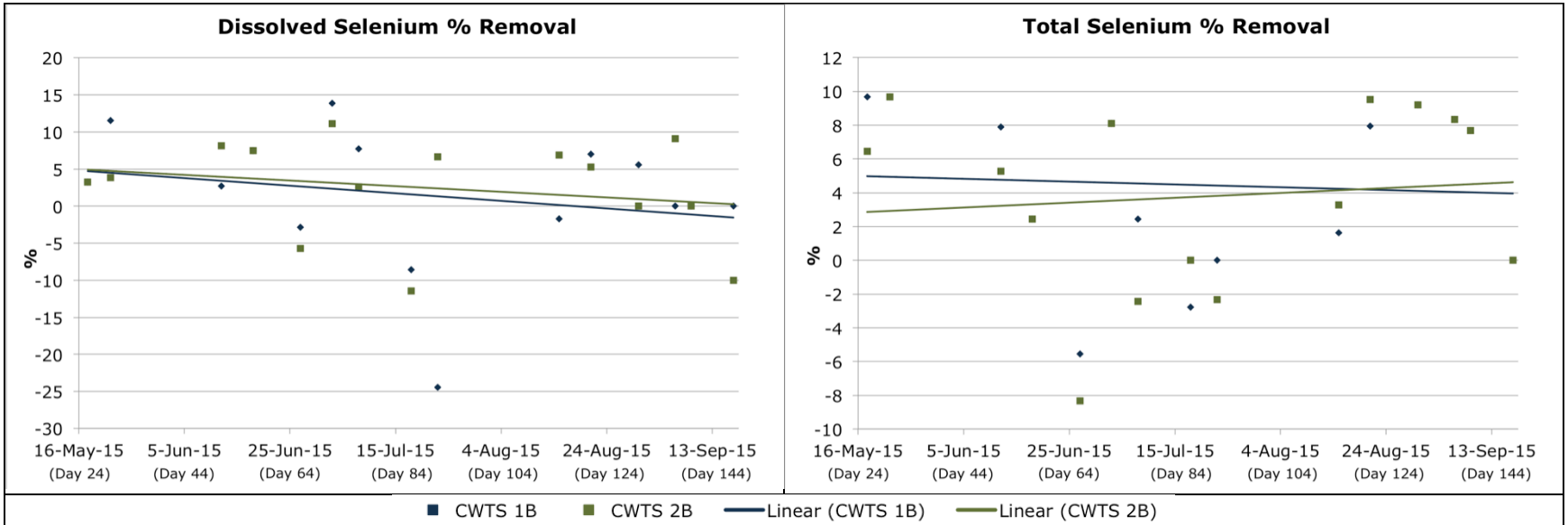


**Figure 8 – Continued**

### 6.3.Chelated iron (fertilizer micronutrient) treatment

Because elevated metals were present in the soils used for construction, there was an opportunity to assess whether non-invasive treatments could be used to further leach the metals and improve soil quality. A chelated iron (Fe-EDTA) product was added to the Series 2 wetland on September 17, 2015. The product selected is Fe-EDTA called Plant-Prod 13.2% Iron Chelate (containing 68% of the chelating agent Ethylenediaminetetraacetic acid (EDTA)), and is routinely used in the agricultural industry as a micronutrient supplement for iron-deficient soils. Fe-EDTA is also commonly used in remediation of metals contaminated soils (e.g., Thayalakumaran *et al.,* 2003).

The Fe-EDTA dissociates based on the pH of the water, and the free EDTA will be available to bind other elements such as copper and remove them from the soils, leaving the Fe in the wetland. Fe-EDTA was chosen instead of fertilizer with EDTA (which is also a commonly used agricultural product), as the fertilizer would provide additional nitrogen sources, which can interfere with selenium treatment, and phosphate which could cause an algal bloom that would be detrimental to the active water treatment facility at Minto that receives the CWTS outflow water. The Fe-EDTA treatment was performed on Series 2, with Series 1 remaining untreated for comparison purposes.

After addition of Fe-EDTA, copper concentrations in the wetland water for both CWTS Series 1 and 2 were monitored daily by Minto's internal laboratory. Increases in copper concentrations were observed in the outflow from both cells in CWTS Series 2 after the addition of Fe-EDTA (Figure 9). Unfortunately, the CWTS feed copper concentration also increased, as the outflow from the demonstration-scale wetlands reports to the same area as the feed water draws from at the W36 area. As such, the leached copper (and presumably, also EDTA) is recirculating through the wetland (including Series 1).

In the 10 days following the addition of Fe-EDTA, approximately 75 g of copper was removed from the wetland Series 2. This is approximately 1.25 g of copper per $m^2$ of wetland. Testing of the soils at different depths in Spring 2016 will determine how much copper has been removed from the wetland as a result of this treatment.

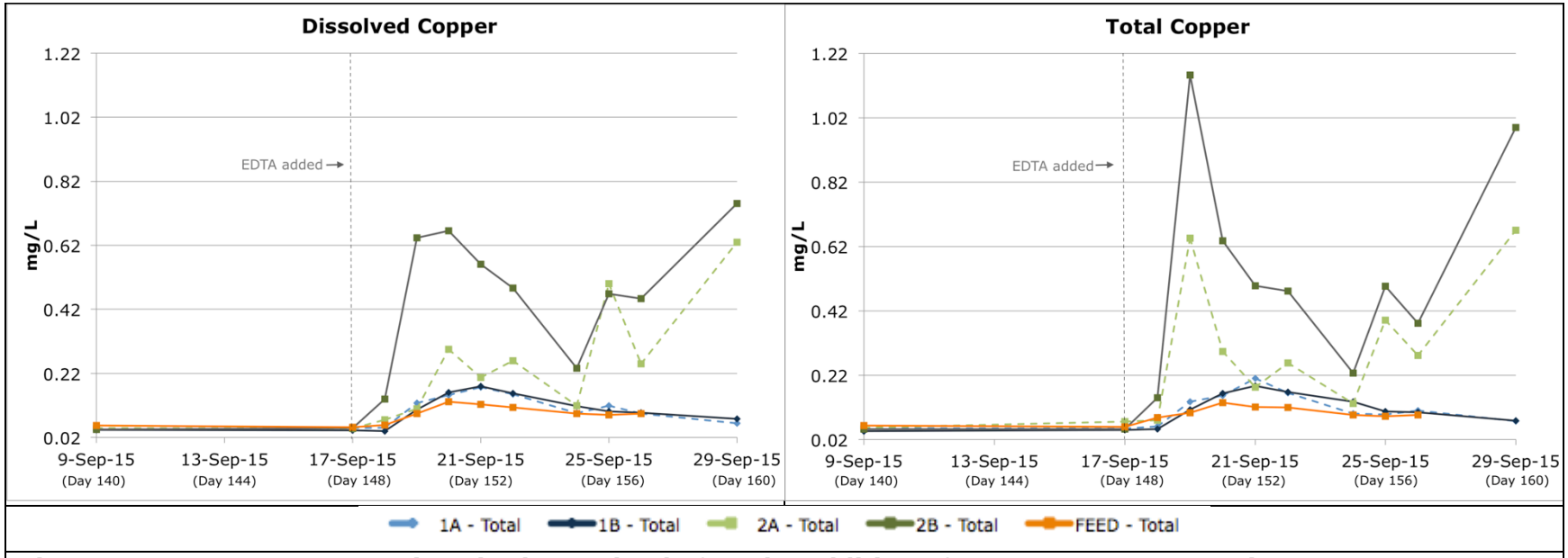


**Figure 9 – Copper concentrations in the wetland after the addition of Fe-EDTA to CWTS Series 2**
Detection limits are below y-axis values. No influent (feed) was tested September 29th as the system had frozen and was turned off for the winter.

### 6.4. Plants

During the commissioning period, plants establish and mature, with density expected to increase over time. When counted at the first site visit in June 2015, >95% of the plants were found to have survived their first winter. This survival rate is impressive considering the late fall planting of August 28, 2014 and suggests the *C. aquatilis* are very robust and reaffirms they are a good candidate for use in the full-scale CWTS at Minto. Additionally, there was a greater than 20% increase in total stems in the short growing season up to June 2015 (as counted by new shoots/runners). By the second site visit in August 2015, the plants were too dense to count stems, and therefore the survival and establishment was considered a success and no longer monitored by counting (Figure 6). Despite several mosses drying out during the winter after planting, there was 100% survival and establishment. However, their growth was much slower than the sedge and therefore they were supplemented with additional aquatic moss (harvested from the same W10 area as the original plants for the CWTS) in June and August 2015 to augment their general abundance and bring the CWTS through commissioning more quickly (Figure 10).

Pilot-scale testing suggested that *C. aquatilis* would increase more quickly the number of stems once the maximum plant height was achieved, and also that maximum plant height is dependent upon water depth (with deeper water resulting in taller plants). This was also seen in the demonstration-scale wetland on site, with the density of plants filling in greatly through July and August (Figure 11). It is anticipated that the *C. aquatilis* will have grown uniformly across the wetland by end of the 2016 or 2017 growing season.

Of note, it was observed that during the last site visit of the year by Contango (September 17-18$^{th}$, 2015), the *C. aquatilis* in the demonstration-scale CWTS were still predominantly green, while other plants in the area had turned brown. This suggests that the CWTSs may have a longer range of activity than natural systems in the area, possibly due to liners and separation from colder ground water.

Concentrations of various elements in *C. aquatilis* and moss from the demonstration-scale systems were compared to those from pilot-scale testing. It is expected that the concentrations would be higher in the demonstration-scale system as the CWTS is not yet fully functional (i.e., elements are in greater bioavailability when in dissolved form) and also due to the composition of the soils used for construction. Accordingly, *C. aquatilis* and moss in the demonstration-scale system had higher copper concentrations than the pilot systems. However, concentration of copper in the *C. aquatilis* at the end of 2015 was not significantly different than that of the plants borrowed from the W10 area for planting of the systems in 2014 (Figure 12). The moss had higher copper and cadmium concentrations which is expected as it removes these elements in the wetland through sorption (and will eventually mineralize in subsequent years). As mosses are not a significant food source for any fauna, this is a safe mechanism to transfer elements from water eventually into stable mineral forms.

Cadmium concentrations were either below or close to the detection limit in *Carex* (Figure 12). Similarly, cadmium concentrations in moss and selenium concentrations in both plant types tested were lower in the demonstration-scale compared to pilot-scale. This result was presumably due to lower concentrations of both cadmium and selenium in the water of the demonstration-scale system than pilot scale. As mosses continue to grow and fill in the wetland, selenium treatment performance is expected to increase as mosses are a source of sorption, and also harbor the highest abundance of selenate-reducing microorganisms of all samples tested (see Section 6.5.2).




**Figure 10 – Moss maturation in CWTS.**

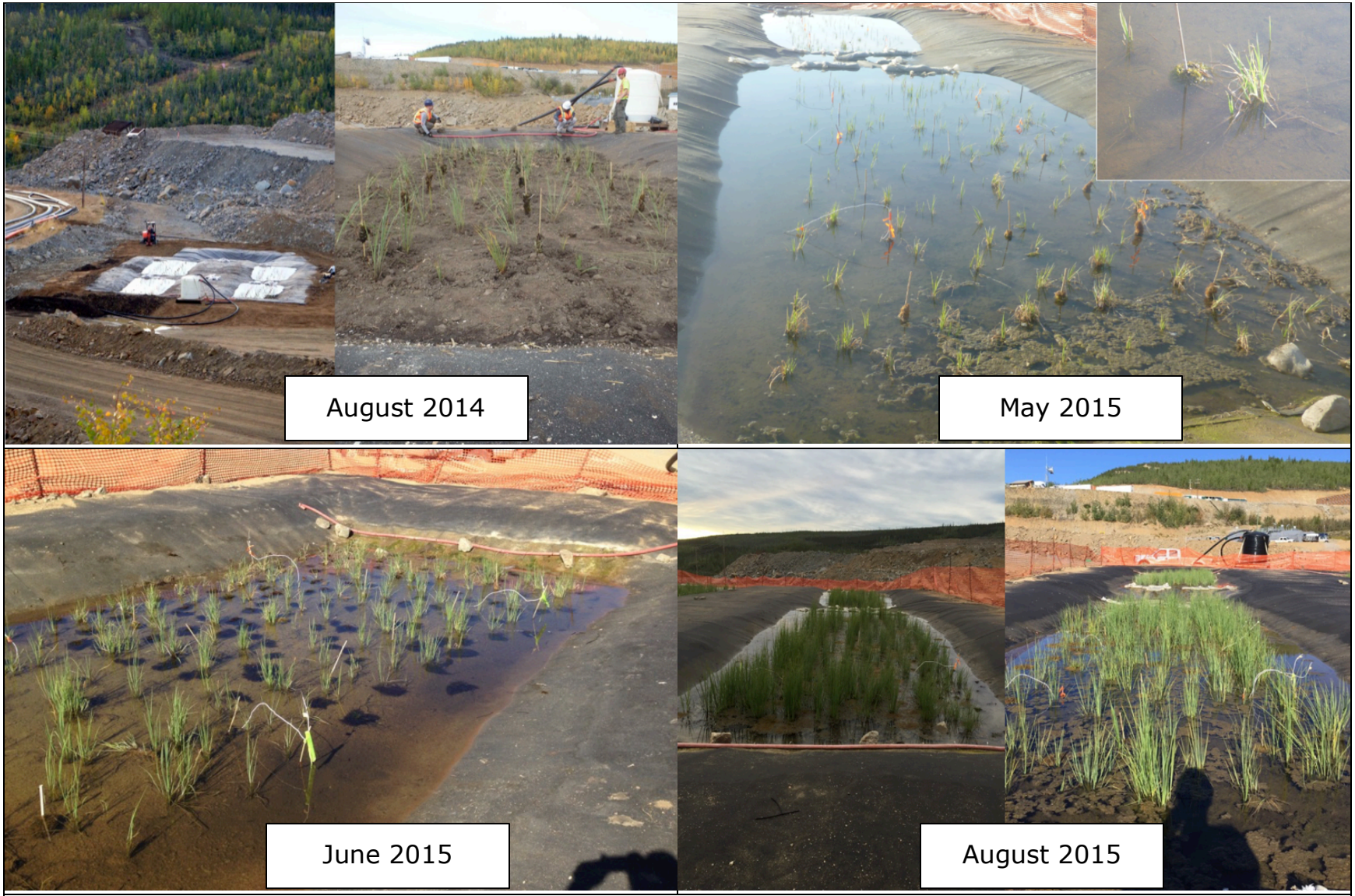


**Figure 11 – Maturation of the CWTS from construction to year-end 2015.**
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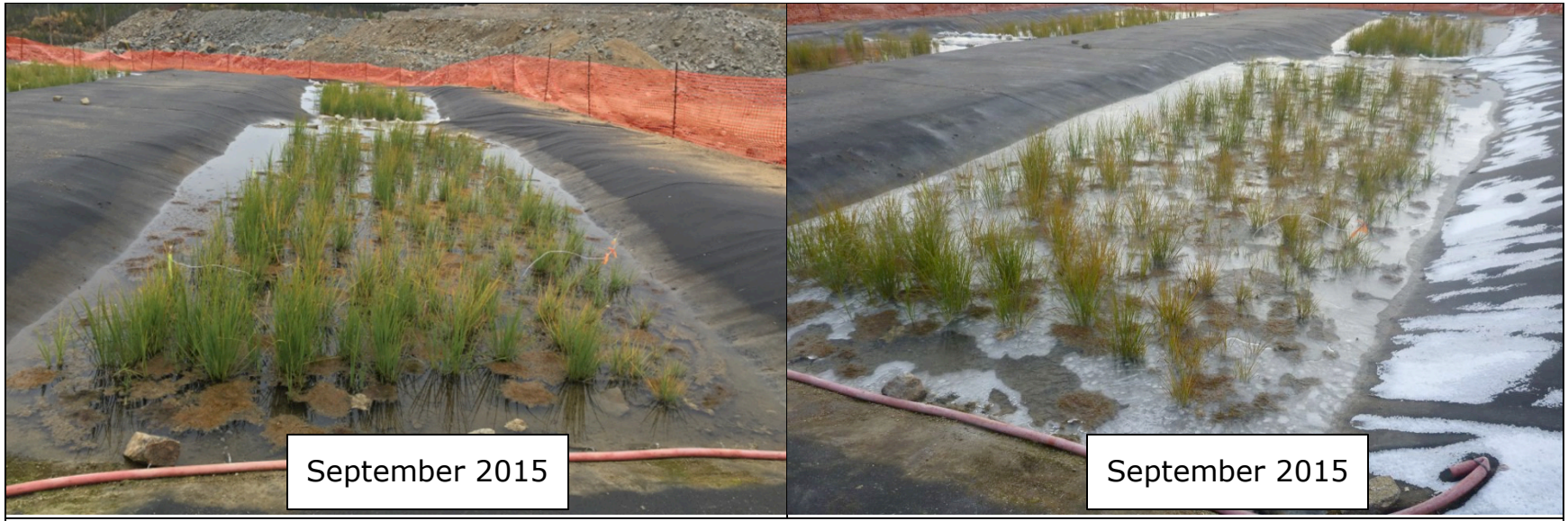


**Figure 11 - Continued**

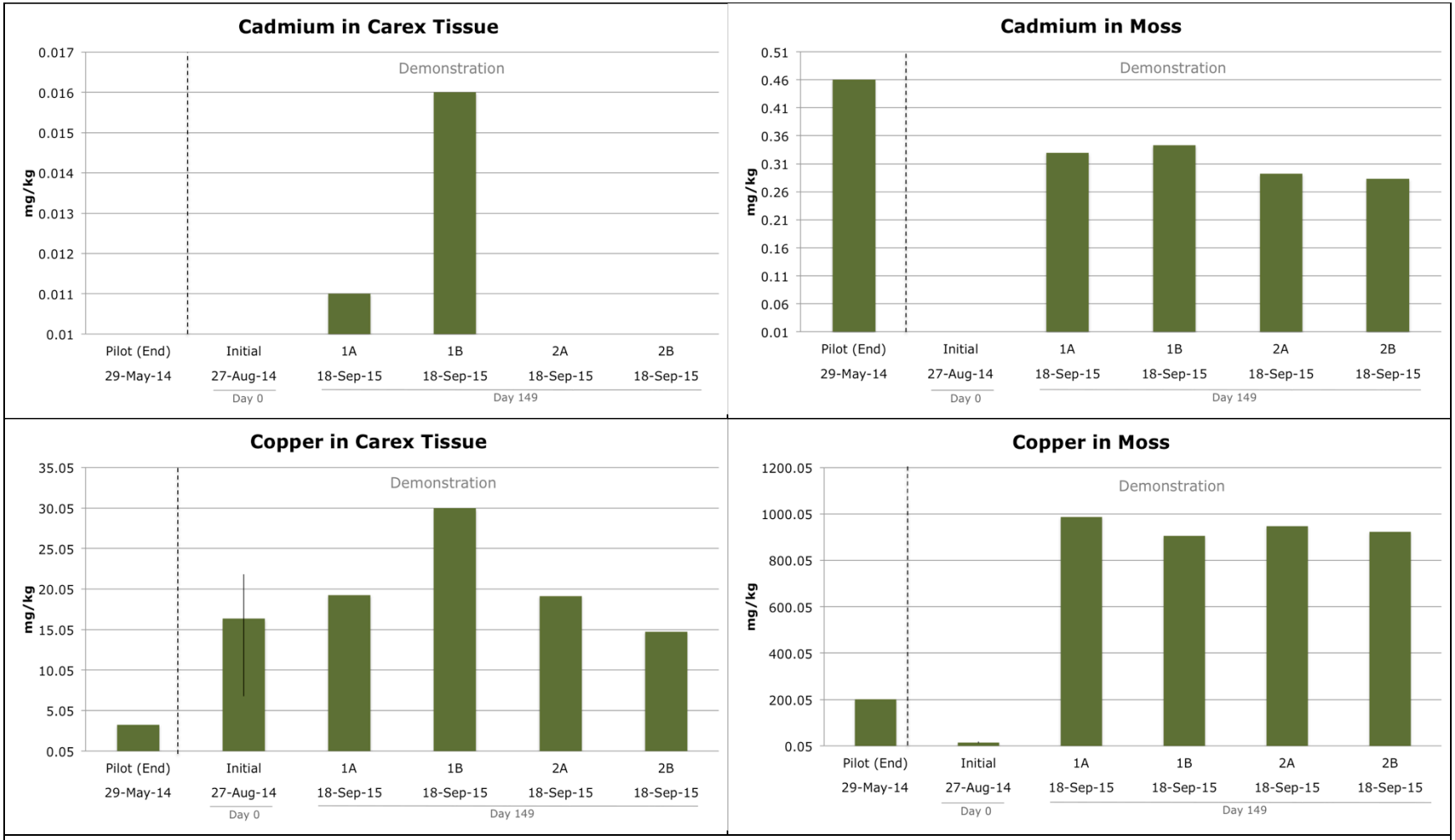


**Figure 12 – Element concentrations in plant tissue.**
Y-axis starts at the 2015 detection limit (DL). The 2014 DL for Cadmium is the same as 2015. The 2014 DL for Copper is 0.5 mg/kg, and Selenium is 0.2 mg/kg. The initial data set is the average value of CWTS 1A-2B. The error bars indicate the minimum and maximum values in that data set.
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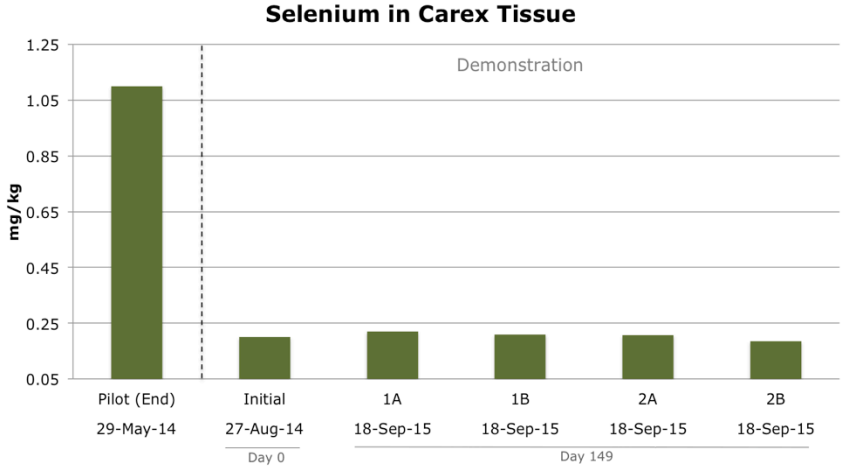


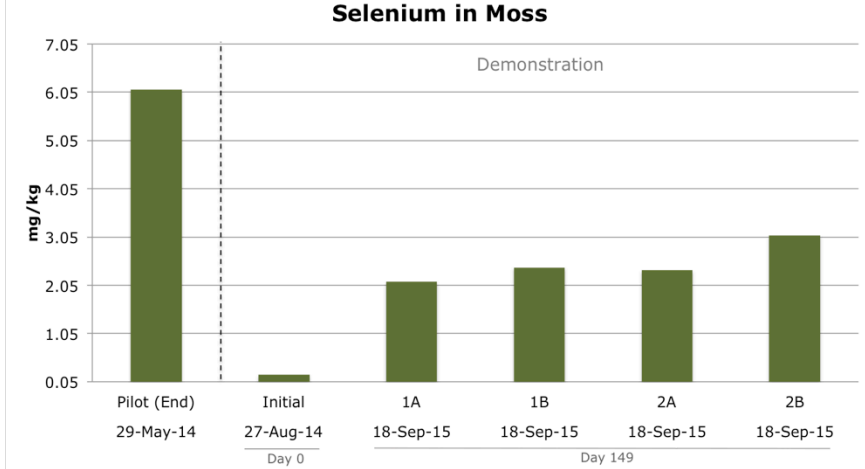




**Figure 12 - Continued**

## 6.5.Beneficial Microbes

Microbes are the driving force of many treatment pathways that are targeted in CWTSs. The beneficial microbes in these systems catalyze biogeochemical cycles for remediation of specific constituents of concern. Careful design of CWTSs can mimic the environmental conditions needed to enhance the abundance and metabolic activity of these beneficial microbes. Accordingly, complimentary methods of genetic and growth-based testing were used to characterize the microbial populations associated with a range of microbial habitats in the demonstration-scale CWTS (e.g., soils, sediment, biofilms, aquatic mosses, and plant roots).

In the context of the Minto Mine CWTSs, beneficial microbes include those that are involved in the reduction of selenium (selenate and selenite), nitrate, and sulphur compounds (which in turn treats copper and cadmium). Information on each of these mechanisms and the associated microbial populations in the demonstration-scale system is outlined in the following sections.

### *6.5.1. Sulphide-producing bacteria*

Treatment is achieved by targeting the lithic biogeochemical sequestration of divalent metals through sulfide (i.e., $S^{2-}$, $HS^{-}$) precipitation as mineralized species (e.g., chalcocite [CuS], covellite [$Cu_2S$]). These sulfide bound species are relatively insoluble (CuS; ksp=$10^{-16}$; Stumm and Morgan 1996), and are transferred from the water column into the CWTS soil as non-bioavailable fractions (Murray-Gulde et al., 2003; Huddleston et al., 2008). Moreover, similar reactions occur with cadmium rending it non-bioavailable. As such, sulphide production is a key biogeochemical treatment mechanism for water treatment at Minto Mine. Sulphides can be created by beneficial microorganisms through the reduction of sulphur-containing compounds, such as sulphate, sulphite, thiosulphate, and elemental sulphur.

Based on the information gathered in pilot-scale testing, the targeted soil redox for the demonstration-scale CWTS is between -100 and -250 mV. This is in agreement with literature that indicates anaerobic conditions with relatively low ORP (-250 to -100 mV) are necessary for promoting anaerobic metabolisms in bacteria which oxidize organic matter, producing electrons which reduce sulfate to hydrogen sulfide ($H_2S$) and other reduced sulfide species (i.e. bisulfide ion ($HS^{-}$), sulfide ion [$S^{2-}$]; Mitsch and Gosselink 2007). In these redox ranges, bacterial sulphide-production through reduction of sulphur compounds is expected, alongside increases in the proportion (percentage) and abundance of these microbes.

The percentage of sulphate-reducing bacteria in the community increased over time in the demonstration-scale CWTS (Figure 13), as would be expected during the commissioning period. The percentage of sulphate-reducing bacteria is similar to what was present in pilot-scale systems at a comparable time point in operation (i.e., day 114 vs. day 80 in Figure 13), however, the types of microbes differ. Conversely, when considering all sulphide-

producing bacteria (i.e., including those capable of sulphur, sulphate, sulphite, and thiosulphate reduction), the demonstration-scale systems have a higher percentage than the pilot-scale systems at a comparable time point (Figure 14), indicating the commissioning period is proceeding well. Sulphide-producing organisms identified during the site assessment at W10 and in low proportions at W15 (Contango, March 2014) were also present in both the pilot- and demonstration-scale systems, indicating that harvested plants were also a source of beneficial microbes.

As expected, the proportion of sulphide-producing bacteria increased as the soil redox decreased (Figure 14). Furthermore, the overall abundance of sulphide-producing bacteria has increased in the soil of the CWTSs over time as reducing conditions are achieved during the commissioning period (Figure 15). This is particularly notable in Series 1, which achieved targeted soil redox conditions quicker than Series 2, which is still establishing reducing conditions (see Section 5). The soils and *C. aquatilis* roots had the highest abundance of sulphide-producing organisms of all sample types tested, with the deeper soil (10-20 cm) having higher abundances than the shallow soils (0-5 cm) at day 149. As expected, algae and biofilm samples had very low abundances of sulphide-producing bacteria. Interestingly, the aquatic mosses had a large variability in the abundance of sulphide-producing bacteria (sometimes having as many or more than the soils). This variability may be related to general growth habits of the moss, with live, photosynthetic (oxygenating) parts of the moss having fewer sulphide-producing bacteria, while the older, decomposing regions have more. This fits with the targeted processes in the CWTS, where metals are first sorbed to moss, then eventually mineralized through sulphide-production.

The microbial analysis of various sample types in the CWTS has therefore confirmed that the commissioning period is proceeding as expected, with beneficial sulphide-producing bacterial populations establishing in the soils alongside reducing conditions.

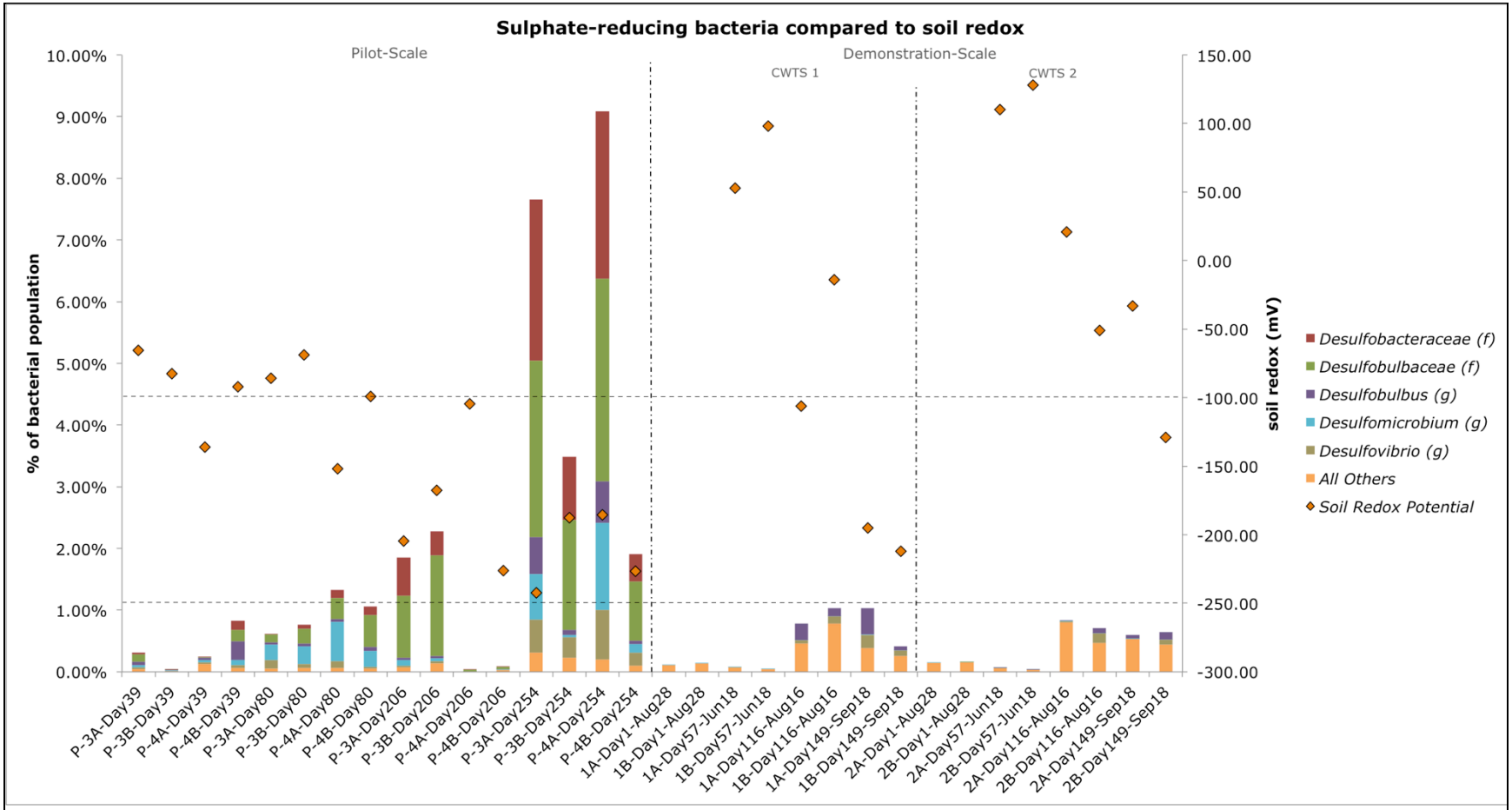



**Figure 13 – Percentage and identity of sulphate-reducing bacteria in soil of the pilot-scale and demonstration-scale CWTSs**

The vertical dashed lines separate the pilot-scale system data from the demonstration-scale system 1 and system 2 data. The horizontal dashed lines indicate the targeted soil redox range.

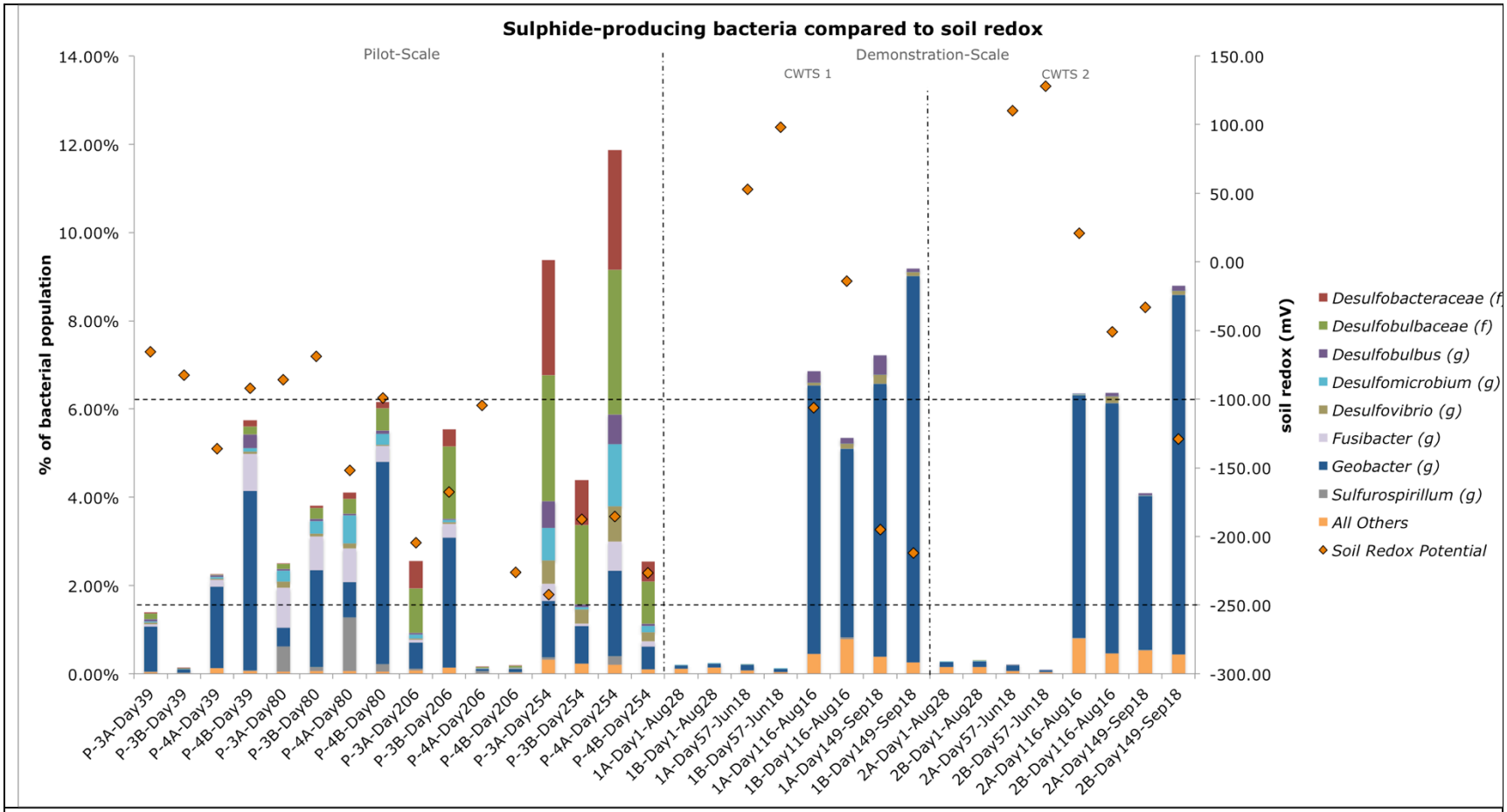



**Figure 14 – Percentage and identity of sulphide-producing bacteria in soil of the pilot-scale and demonstration-scale CWTSs**

The vertical dashed lines separate the pilot-scale system data from the demonstration-scale system 1 and system 2 data. The horizontal dashed lines indicate the targeted soil redox range.

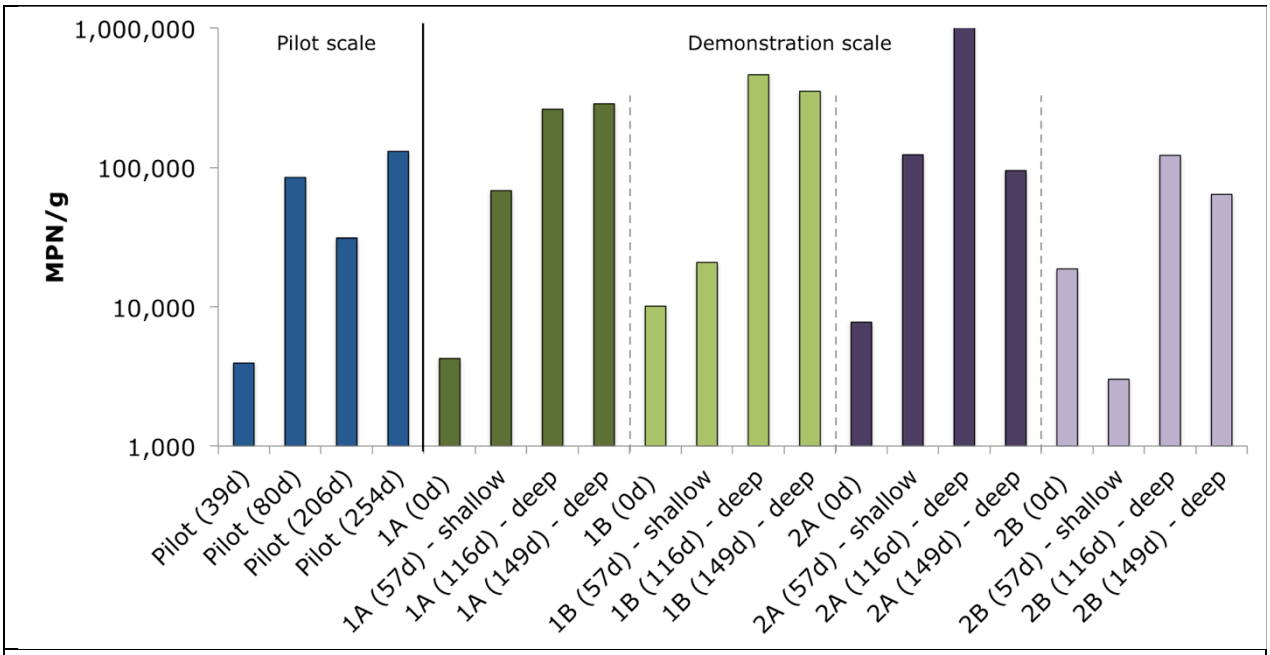



**Figure 15 – Inferred abundance of sulphide-producing bacteria in soil of the pilot- and demonstration-scale CWTSs**
Inferred abundance is calculated based on a combination of genetic and growth-based data.
- shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of wetland

### *6.5.2. Selenium-reducing bacteria*

The targeted selenium treatment pathways in the Minto CWTS include sorption to moss and soils, and subsequent microbial reduction of soluble (sorbed) selenate (Se(VI)) and selenite (Se(IV)) to insoluble elemental selenium (Se(0)). This reductive process can also be achieved directly in the water column, but is more effective associated with mosses and biofilms due to their sorptive properties that bring the selenium in contact with beneficial selenium-reducing bacteria. This is achieved within the range of soil redox conditions targeted for sulphate-reduction as suggested by pilot-scale testing and literature (see Section 5).

Selenite-reducing organisms are ubiquitous in nature and as expected, were detected in all sample types, including algae, biofilm, moss, soil, sediment, and roots. Although selenate-reducing organisms are generally less abundant in the environment, they were found associated with all sample types, indicating that the conditions conducive to their proliferation have been created within the CWTS. Moreover, the abundance of selenite- and selenate-reducing organisms increased over time in the demonstration-scale system during the commissioning period (Figure 16). Aquatic mosses were found to host the highest abundances of both selenate- and selenite- reducing organisms, affirming the importance of the inclusion of moss in the CWTS. Additionally, shallow soils (i.e., top few centimeters, including associated biofilms) were found to host an abundance of selenite-reducing organisms, particularly in Series 1. The abundance of selenite-reducing organisms associated with the demonstration-scale moss and shallow soils is similar if not higher than

that observed in the soil of the pilot-scale testing, indicating the commissioning period is proceeding as anticipated (selenate-reducing organisms were not tested for at pilot-scale).

### *6.5.3. Nitrate-reducing bacteria*

Nitrate is sometimes a constituent of concern during operations and early closure owing to residuals from blasting activities. Even if not in exceedance of water quality guidelines in terms of receiving environment objectives, nitrate often requires attention in order to achieve treatment of other constituents. The presence of nitrate can interfere with the treatment of certain elements in water (such as selenium). Nitrate can be removed from water by different types of microbes, including nitrate reducing bacteria which are capable of reducing nitrate ($NO_3$) to nitrite ($NO_2$), and also denitrifying organisms that are capable of fully reducing nitrate to nitric oxide (NO), nitrous oxide ($N_2O$), and dinitrogen gas ($N_2$ - which is the most abundant gas in air). MPN analysis was therefore used to quantify these organisms.

Nitrate-reducing and denitrifying organisms were found associated with all sample types in the demonstration-scale CWTS (Figure 17). Soil samples had an increase in nitrate reducers over time, with the highest abundance of all samples found in the deeper soil sample from day 149. In contrast, denitrifying organisms were found to be associated primarily with the shallower soil depths and also a high abundance associated with moss, which increased in abundance over the commissioning period.

Although the pilot-scale systems had higher nitrate concentrations (30 mg/L as N during High Nitrogen testing phase) than the demonstration-scale systems (average 10 mg/L as N), the abundance of nitrate-reducing and denitrifying organisms are both similar. As such, these results also confirm that the demonstration-scale system is establishing as expected during the commissioning period.

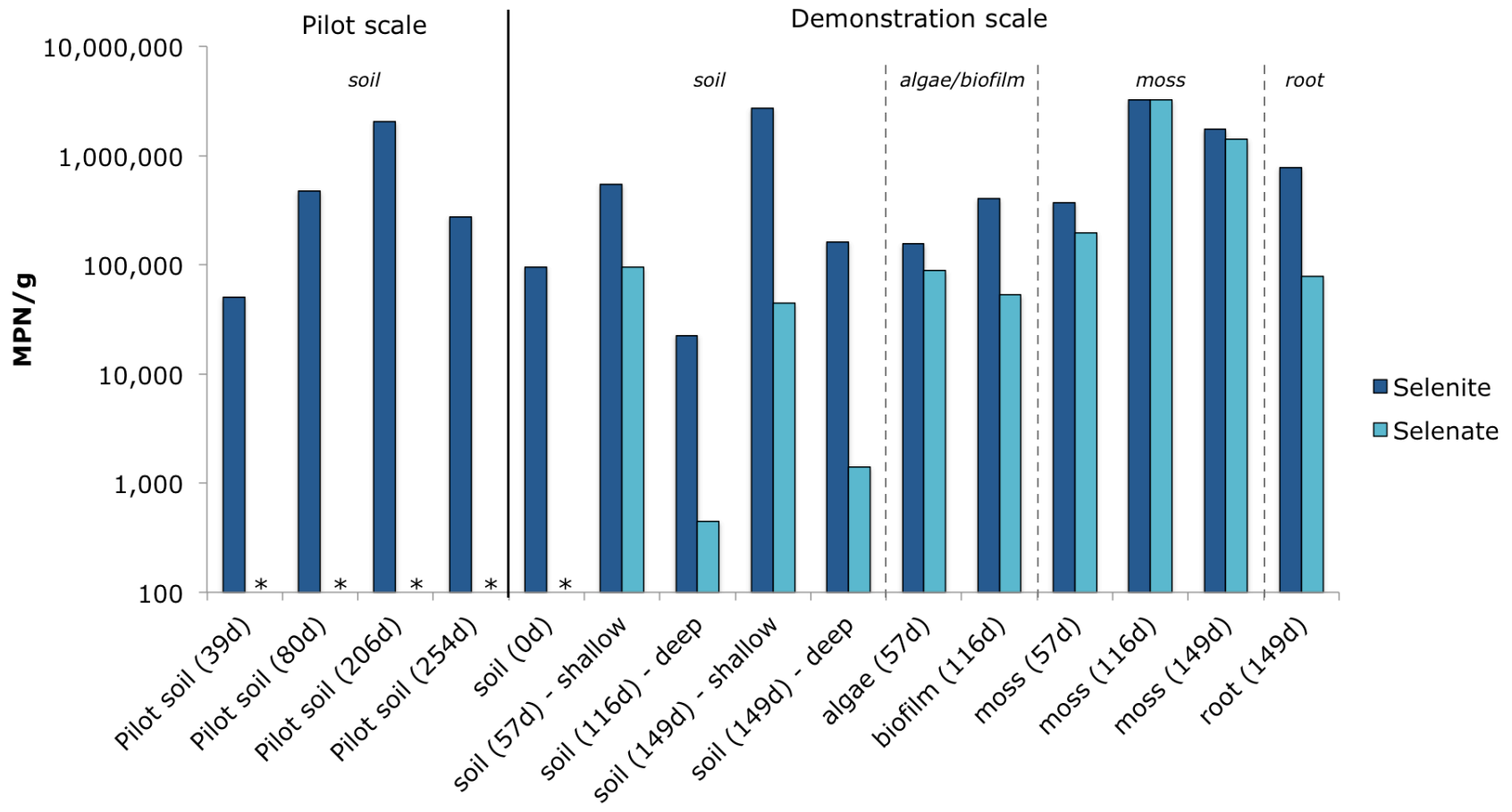



**Figure 16 – Abundance of selenite- and selenate-reducing organisms in various CWTS sample types over time**
* - pilot-scale system and initial timepoint for demonstration-scale system not tested for selenate-reduction
- shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of wetland

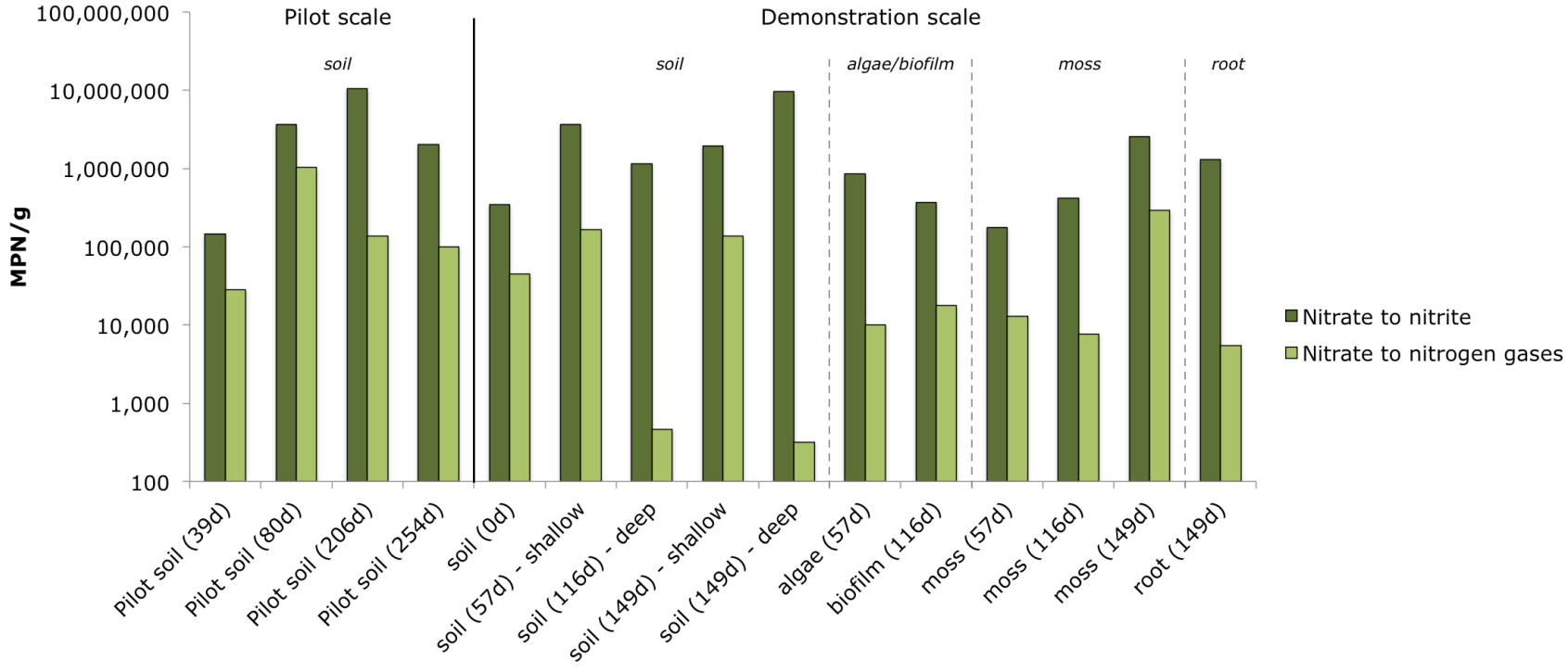



**Figure 17 – Abundance of nitrate-reducing and denitrifying organisms in various CWTS sample types over time**
Nitrate-reducing = reduction of nitrate to nitrite; denitrifying = reduction of nitrate to nitrogen gases. Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of wetland.

## 7. Summary of Results

Table 6 summarizes results and findings from 2015 commissioning of the demonstration-scale system at Minto.

**Table 6. Summary of Minto Demonstration-scale 2015 Testing**

| Objective | Purpose | Key Findings |
|---|---|---|
| Evaluate construction | Optimize construction and effectiveness of operation of full-scale systems | **Layout**<br>-Outflow collection pond should have outflow at base (not top), with shutoff valve<br>-Increased slope on sides, and riprap or sandbags added at shores would prevent water short circuiting and deter wildlife access |
| | | **Soils**<br>-Use substrate with less total and leachable metals and metalloids (especially copper)<br>-Higher sand content would improve hydrology, constructability (ability to level soils, ease of planting) and accessibility for sampling<br>-Organics should be mixed in bulk to soils prior to adding to cells |
| Assess commissioning timelines | Allow for proper phasing of implementing full-scale systems for closure | **Water**<br>-Copper treatment improving through commissioning period; wetland achieving better treatment than suggested by inflow and outflow concentrations of system, as soils are leaching copper<br>-Cadmium and selenium are also being removed from water<br>-Wetland is maturing as expected and is performing beyond anticipated from the design<br>-Tracer study recommended for 2016 to assess hydrology and pore volume of CWTS and determine HRT and removal rate coefficients for full-scale sizing |
| | | |

| Objective | Purpose | Key Findings |
|---|---|---|
| | | **Soils**<br>-Soil redox has decreased as expected, reaching targeted ranges in Series 1 by the end of 2015, while Series 2 continues to establish<br>-Significant amounts of metals are leaching from soil substrate into water, putting additional treatment demands on system |
| | | **Microbes**<br>-Sulphide-producing bacteria needed for copper and other metals removal have increased over time as soil redox achieved target ranges. Proportions are comparable to those in pilot system at similar point in commissioning<br>-Abundance of selenium- and nitrate-reducing organisms are similar to those in pilot testing, indicating maturation as expected<br>-Selenium treatment performance expected to increase as mosses continue to grow, as they can sorb dissolved selenium and harbour highest abundance of selenate-reducing microorganisms to render the selenium insoluble |
| *Carex aquatilis* transplantation effectiveness | Determine if plant propagation and/or replanting schedule will be needed for full-scale systems | ->95% survival from transplanting<br>-Within first 2 months a further increase of >20%<br>-Full-scale system could be planted more densely to bring online faster, or less densely if time is less of an issue than sourcing plants (the plants are vigorous and will fill in the wetland in due time) |
| Moss colonization/distribution | | -100% survival from transplanting<br>-Slower to spread, needs to be started more densely<br>-Staking helps maintain moss in 'upstream' parts of wetland, or could be transplanted multiple times through commissioning period |

## 8. Tentative Schedule and Action Items for 2016

Based on progress of commissioning and early performance results in 2015, an action plan for CWTS optimization and testing for 2016 has been developed (Table 7). An updated multi-year schedule as per the proposed scope of work in the Minto Demonstration Scale Report Document 011_0315_01A (Contango, March 2015) is provided in Appendix C.

**Table 7. Minto 2016 CWTS Demonstration-scale Action Items**

| Who/When | Task | Contango Action Required | Additional Information |
|---|---|---|---|
| Minto Staff, prior to first site visit | Add sandbags to perimeter of CWTS to minimize short circuiting | Provide diagram of sandbag location | Use sand that was confirmed to be good borrow source in 2016 (i.e., low copper) |
| | W15 creek monitoring | Develop research plan and schedule of testing | This is the creek(s) feeding the W15 area pond |
| Site visit 1 (May 2016) | Tracer study (salt) | Experimental design | Ensure salt tracer study will not affect other planned activities at the site (e.g., hydrogeology studies) |
| | Change AgCl probes | Replace old probes with new ones | These are the reference probes for soil-redox testing |
| | Develop flow rates for 2016 | Based on tracer study | Flow rates will be set (and varied) according to expected flows at water storage pond in closure, and theoretical hydraulic retention times needed to develop outflow water quality predictions |
| | Check on W15 creek monitoring | Confirm monitoring locations | Because at least 3 entry points exist from the creek to the W15 pond, check which creek is being monitored and how this compares to the W15 sampling point water quality |
| Site visit 2 (July 2016) | Add organic material to System 2 | Determine amount and type to add | This will only be performed if soil redox conditions have not consistently met targeted ranges by July 2016 |
| Site visit 3 (September 2016) | General follow up | Final sampling for year | |

## 9. Monitoring plan

A conceptual long-term testing plan was developed for the demonstration-scale CWTS and has been refined and adapted based on performance and scientific findings (Appendix A). The demonstration-scale wetlands are expected run until at least the end of 2016, and ideally longer in order to assess performance under a wider range of conditions. The conditions that could eventually be tested include both natural/environmental and selected influenced pressures, and can be imposed on the systems to mimic peak flow rates or droughts. In 2016 the systems are expected to continue to mature (i.e., complete commissioning), with plants becoming more established and abundant, and microbial communities accordingly acclimating to the targeted conditions. We expect to achieve targeted ranges of soil redox in 2016, which will indicate that the commissioning period has completed and allow for the monitoring program to shift focus to testing of operations and performance. A multi-year plan is provided in Appendix C, and includes work performed to date as well as a schedule for 2016 and potential activities for 2017.

## 10. Closure

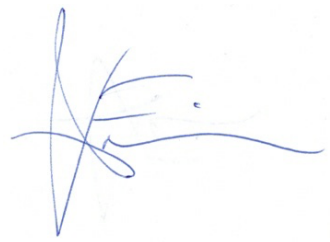
We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Respectfully submitted,

Contango Strategies Ltd



Monique Haakensen
PhD, RPBio, PBiol, EP



Vanessa Friesen (Pittet)
PhD, EPt







with contributions from: Rachel Martz, BSc and Jenny Liang, BSc

## 11. References

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# Appendix A

**Table 1. Summary of analytical sampling types, frequencies and locations**

| | |
|---|---|
| **Water** | |
| Dissolved and total metals | Weekly, outflow of each cell and feed |
| Flow rate | Weekly, feed |
| pH, DO, ORP, Conductivity (in situ) | Weekly, all cells and feed |
| Anion Sum | Monthly, outflow of each cell and feed |
| Cation Sum | |
| Hardness ($CaCO_3$) | |
| Ion Balance | |
| Total Dissolved Solids (TDS) | |
| Chloride (Cl) | |
| Sulphate ($SO_4$) | |
| Nitrate | |
| Nitrite | |
| Nitrogen (Total) | |
| Alkalinity | |
| pH | |
| Conductivity | |
| Chemical Oxygen Demand (COD) | |
| Total Organic Carbon (TOC) | |
| Ammonia | |
| Total Kjeldahl Nitrogen (TKN) | |
| Total Suspended Solids | |
| Biological Oxygen Demand (BOD) | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Hydroxide (OH) | |
| **Soil** | |
| Relative soil redox (in situ) | Monthly, all probes (6 per cell) |
| Cation exchange capacity (CEC) | Seasonally (3x per year) |
| SAR, pH, EC, %sat, Ca, F, Mg, Na, K, Cl, SO4 | |
| Available NPK and sulphur | |
| Alkalinity | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Hydroxide (OH) | |
| Total Organic Carbon (TOC) | |
| Dissolved Organic Carbon | |
| Metals Analysis (Total) | |
| Metals Leachable (SPLP) | |

| | |
|---|---|
| Ammonia | |
| Nitrate | |
| Nitrite | |
| Total Dissolved Solids | |
| Anion Sum | |
| Cation Sum | |
| Cation/EC ratio | |
| Ion Balance | |
| Sequential Leaching (5 Acid Test) | |
| Cation exchange capacity (CEC) | |
| **Plant tissue samples** | |
| Metals Analysis | *Carex aquatilis* and aquatic moss, each cell, year end |
| **Microbial samples** | |
| Growth-based most-probable number analysis (nitrate reduction, selenite and selenate reduction, total heterotrophs) | Seasonally (3x per year) |
| Genetic sequencing analysis for bacterial community composition and distribution | Seasonally (3x per year) |

# Appendix B – Copper Sequential Leach and Aluminum Graphs

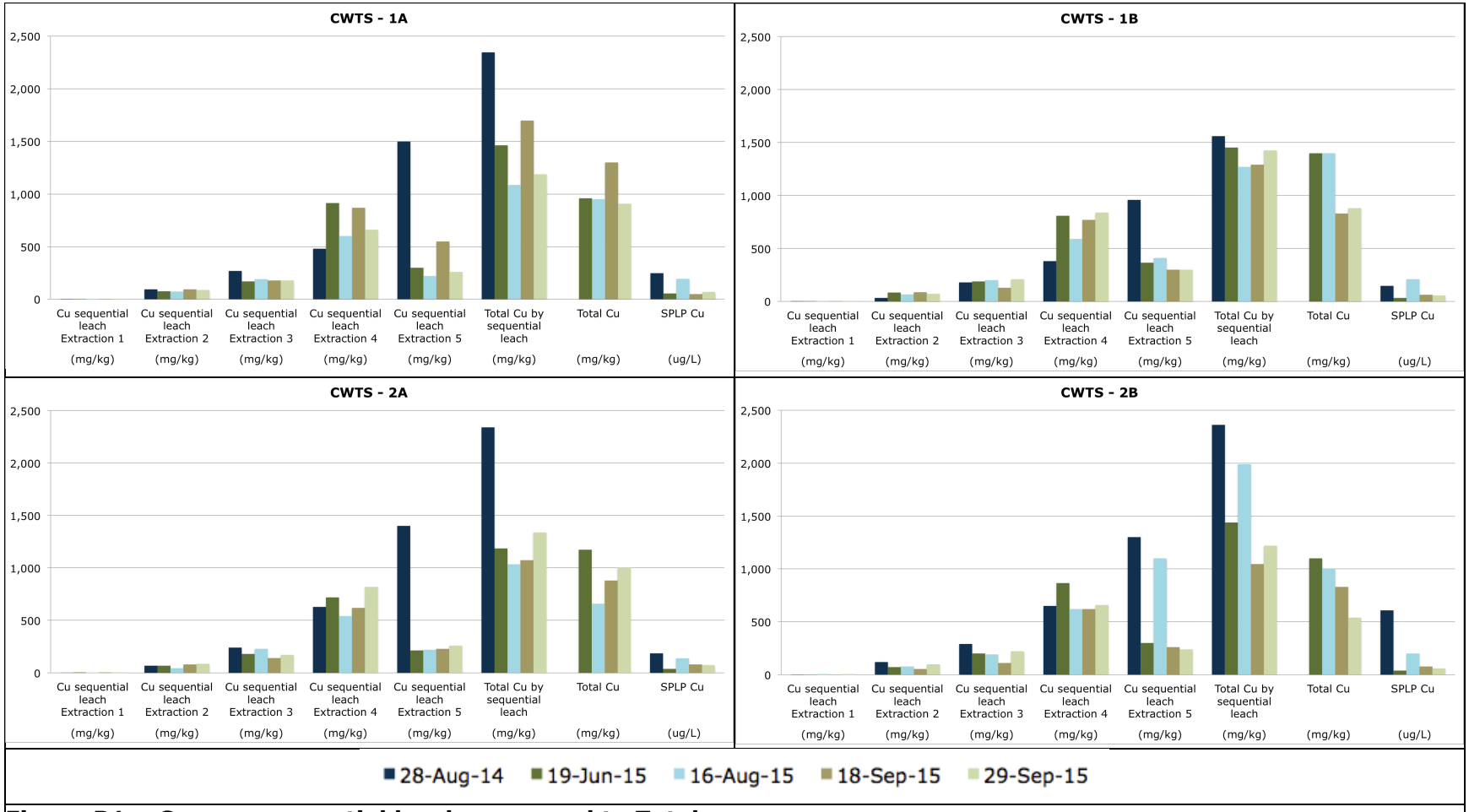


**Figure B1 – Copper sequential leach compared to Total copper**

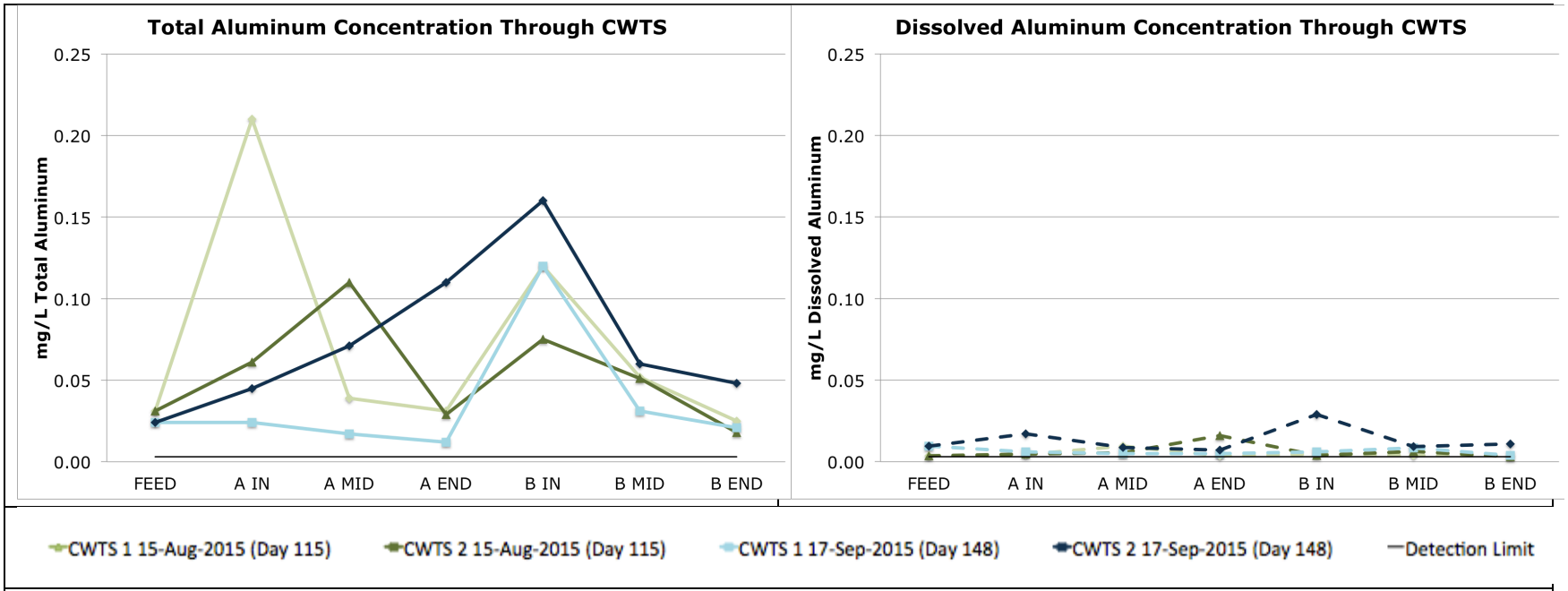


**Figure B2 – Concentrations of Aluminum in water through the CWTS.**
Water samples were collected from the CWTS feed, and from the beginning, middle, and end of each wetland cell on 2 occasions.

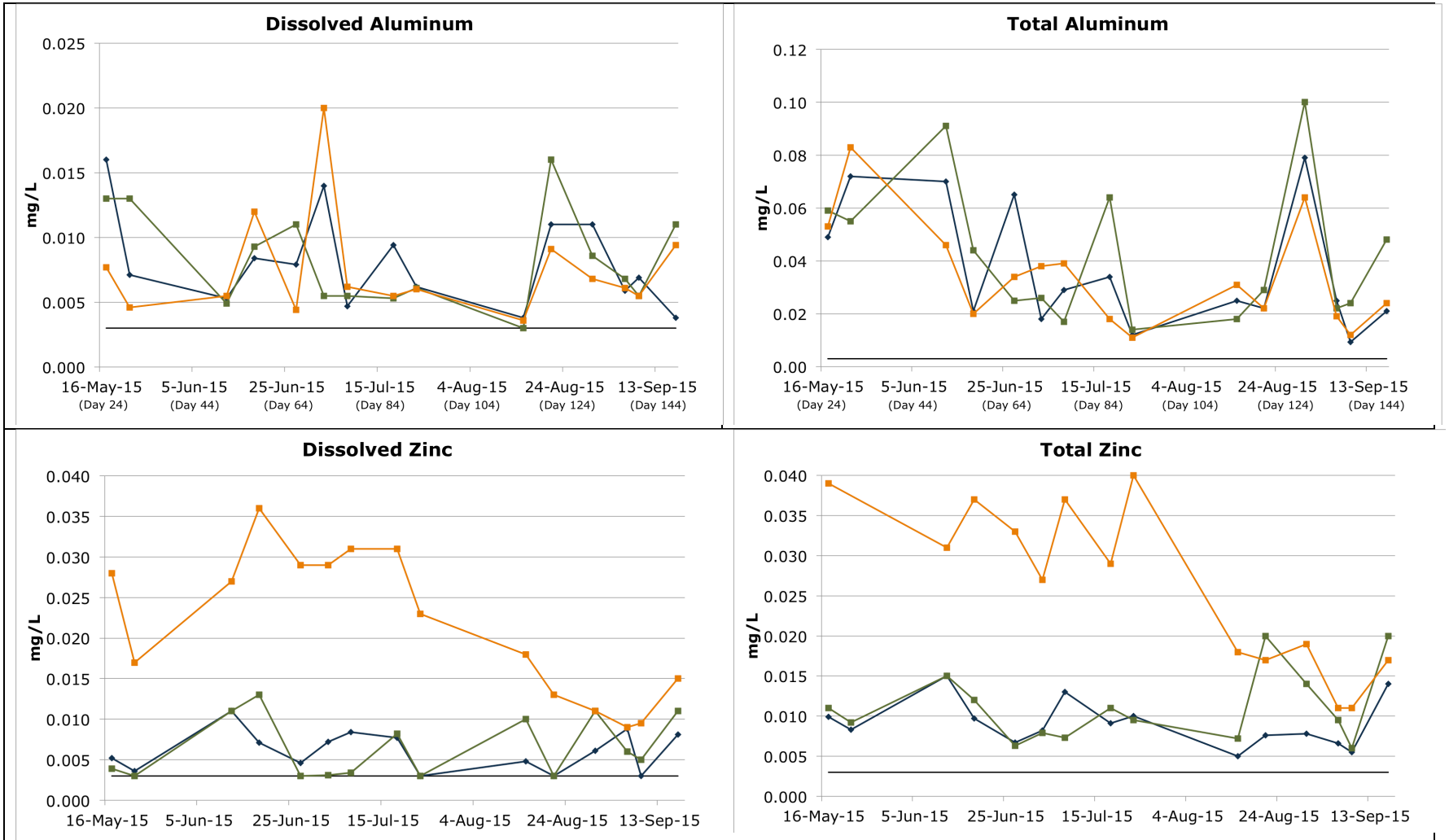


**Figure B3 – Aluminum and Zinc concentrations in the demonstration scale wetland from May 17, 2015 to Sept 17, 2015.**

The Measurement Uncertainty (MU) for aluminum and zinc is +/- 0.003 mg/L.

# Appendix C

**Table C1.** Schedule of work

| Item | Date | Activities | Actual |
|---|---|---|---|
| Construction | June 1-14 2014 | Identify potential location for demonstration scale CWTS (CSL site visit – 1 scientist) | Completed |
| | June - July 2014 | Engineering and geotechnical (Minto) | Completed |
| | July 2014 | Construction (Minto) | Completed |
| | August 2014 | Planting and bringing system online (CSL site visit – 1 scientist, 1 technologist), coordinate for local students to assist. | Completed (no students available, brought 2 technologists) |
| Commissioning | 2014 | Acclimation and maturation at constant flow rate, ~20 hr HRT | Completed |
| | | September - CSL site visit/checkup (1 technologist, 1 scientist) | Did not occur because construction was last week of August. |
| | 2015 | Continued commissioning. Operation at constant flow rate, ~20 hr HRT | Completed (at shorter HRT) |
| | | Spring – CSL site visit/checkup (1 technologist, 1 scientist), includes micro sampling | Completed |
| | | Summer - Increase depth from 10 cm to 20 cm (1 technologist), includes micro sampling | Completed (scientist) |
| | | Fall – CSL site visit/checkup (1 technologist), includes micro sampling | Completed (scientist) |
| Performance Monitoring | 2016 | Minto to add sandbags prior to first site visit and begin W15 creek monitoring | Expected May/June 2016 |
| | | Spring – CSL site visit (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Table 7 of report | Expected May/June 2016 |
| | | Summer - CSL site visit/checkup (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Table 7 of report | Expected July/August 2016 |
| | | Fall - CSL site visit/checkup (1 technologist), includes microbial sampling and tasks outlined in Table 7 of report | Expected September 2016 |
| | 2017* | Continued performance monitoring | *Putative activities, may not be necessary depending on performance and outflow water quality in other years.* |
| | | Possible testing of semi-passive hybrid Bioreactor/CWTS phase. This will involve adding solid organic matter (such as alfalfa hay, straw) to the CWTS cell(s). | |
| Reporting | 2014-2016 | Reporting will be performed annually, with verbal and/or emailed interim updates | On Schedule |

# Appendix C

**Table C1.** Schedule of work

| Item | Date | Activities | Actual |
|---|---|---|---|
| Construction | June 1-14 2014 | Identify potential location for demonstration scale CWTS (Contango site visit – 1 scientist) | Completed |
| | June - July 2014 | Engineering and geotechnical (Minto) | Completed |
| | July 2014 | Construction (Minto) | Completed |
| | August 2014 | Planting and bringing system online (Contango site visit – 1 scientist, 1 technologist), coordinate for local students to assist | Completed (no students available, brought 2 technologists) |
| Commissioning A | 2014 | Acclimation and maturation at constant flow rate, ~20 hr HRT | Completed |
| | | September - Contango site visit/checkup (1 technologist, 1 scientist) | Did not occur because construction was last week of August |
| | 2015 | Continued commissioning. Operation at constant flow rate, ~20 hr HRT | Completed (at shorter HRT) |
| | | Spring – Contango site visit/checkup (1 technologist, 1 scientist), includes micro sampling | Completed |
| | | Summer - Increase depth from 10 cm to 20 cm (1 technologist), includes micro sampling | Completed (scientist) |
| | | Fall – Contango site visit/checkup (1 technologist), includes micro sampling | Completed (scientist) |
| | 2016 | Minto to add sandbags prior to first site visit and begin W15 creek monitoring | Completed May/June 2016 |
| | | Spring – Contango site visit (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Table 5 of report. HRT tracer study completed, outlined in section 7 of report. | Completed June 2016 |
| | | Summer - Contango site visit/checkup (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Table 5 of report. Evapotranspiration study completed as outlined in section 9 of report. Organics were added to the CWTS as outlined in section 5.1 of report. | Completed July 2016 |
| Commissioning B[1] | | Fall - Contango site visit/checkup (1 technologist), includes microbial sampling and tasks outlined in Table 5 of report | Completed September 2016 |
| | 2017 | Continue commissioning B. Operation at constant flow rate developed based on 2016 HRT tracer study. | Expected May 2017 |
| | | Spring – Contango site visit (1 scientist, 1 technologist), includes microbial | Expected May/June 2017 |

| | | | |
|---|---|---|---|
| | | sampling and tasks outlined in Appendix A of report. Proposed HRT tracer study. Sample for AVS to assess if the added organics are having the desired effect. | |
| | | Summer - Contango site visit/checkup (1 scientist), includes microbial sampling and tasks outlined in Appendix A of report. Proposed evapotranspiration study. | Expected July/August 2017 |
| | | Fall – Contango site visit/checkup (1 scientist), includes microbial sampling and tasks outlined in Table 5 of report. | Expected September 2017 |
| | | Monitor soil redox. Determine when it consistently reaches targeted range. | Throughout 2017 |
| Performance monitoring | *2018* | Fluctuate flow rates weekly, based on expected amount of water for full-scale wetland (scaled to size). Evaluate performance of wetland at different key periods. | *Putative activities, may not be necessary depending on performance and outflow water quality in other years.* |
| | 2014-2018 | Reporting will be performed annually, with verbal and/or emailed interim updates | On Schedule |

[1] The commissioning-B period will continue in 2017 until the demonstration-scale CWTS performance is consistently achieving performance expectations.

Contango STRATEGIES LTD.

*Forward looking*. Lateral thinking.

# Minto Mine Constructed Wetland Treatment Research Program – Demonstration Scale 2016 Update

Document – 011_0217_05B

capstone MINTO MINE

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**Executive summary**

The Minto Mine, operated by Capstone Mining Corp., is located 240 km northwest of Whitehorse on the west side of the Yukon River. In 2013 Contango Strategies Ltd. (Contango) was retained by Capstone Mining Corp. to conduct a phased assessment to determine the feasibility of using passive means to treat water at closure at the Minto Mine. Pilot-scale testing, completed by Contango in July 2014, determined that plants and beneficial microbes found at the Minto site could be used to remediate contaminated mine drainage in a constructed wetland treatment system (CWTS; November, 2014). In August 2014, a demonstration-scale CWTS was implemented at the Minto Mine site. The performance results from the on-site demonstration-scale CWTS confirm that a passive water treatment system can be used to successfully improve mine-impacted waters.

To date, the demonstration-scale CWTS has had 312 operational days (i.e., water flowing), consisting of 24 days in 2014, 137 days in 2015, and 152 days in 2016. Day 248 (July 28, 2016) is when organics were added to the CWTS to aid in treating the additional copper load originating from the soils used as substrate, and marked the end of what we will now be referring to as the period "commissioning-A", and the beginning of period "commissioning-B". The commissioning-B period will continue in 2017 until the demonstration-scale CWTS performance is consistently achieving performance expectations. These commissioning periods are necessary for operational adjustments to be made (e.g., raising water depth, modifying outflow patterns), and for plant and microbial populations to establish and mature to achieve full operational performance of the CWTS. Owing to the types of soils used as substrate in construction (i.e., high concentrations of oxidized copper), commissioning has taken longer than would normally be the case (or would be the case for the full-scale system).

The commissioning period is also being used to collect additional information about the on-site demonstration-scale CWTS that will aid in the final full-scale CWTS design, sizing, and construction. For example, a tracer study was carried out in June 2016 to assess the hydrology and hydraulic retention time (HRT) of the CWTS. Using the data from the tracer study, the pore space involvement of the CWTS substrate was calculated.

Performance continues to be monitored and while full treatment functionality of the demonstration-scale system is not expected during the commissioning period, the information would aid in the development of the full-scale system in the following ways:

- Evaluation of construction effectiveness and potential optimizations.
- Assessment of timelines to reach targeted operational parameters to allow for effective phasing of implementation (e.g., soil redox, percentage and abundance of sulphate reducing bacteria).
- Assessment of the effectiveness of *Carex aquatilis* and aquatic moss transplantation to assess planting density, time period to full density, and if plant propagation and/or a replanting schedule is necessary.

In July 2016 the demonstration-scale system was not achieving stable soil redox values within the targeted range (nor associated performance expectations); therefore, woodchips and straw were added to the demonstration-scale CWTS as sources or organic carbon. Because

the demonstration-scale system takes time for plants to mature (and generate organic carbon for the microbes to feed on), the addition of organics early in the operation of the system can supplement the carbon sources needed for beneficial microbes that drive treatment of selenium and other constituents. This will be included in the full-scale system design specifications. The addition of organics marked the end of the commissioning-A period.

Once the commissioning–A period was complete, the commissioning-B period began on July 29 and continued to the end of 2016 operations on September 30, 2016. During the commissioning-B period, the demonstration-scale CWTS achieved on average 64% removal of dissolved cadmium (mean influent 0.0185 µg/L, mean outflow 0.0066 µg/L), 37% removal of dissolved copper (mean influent 46.1 µg/L, mean outflow 28.8 µg/L), a 21% removal of molybdenum (mean influent 7.3 µg/L, mean outflow 5.7 µg/L), a 41% removal of dissolved selenium (mean influent 5.7 µg/L, mean outflow 3.3 µg/L) and a 69% removal of dissolved zinc (mean influent 37.6 µg/L, mean outflow 11.6 µg/L). The percent removal of molybdenum and selenium is notable, as it has increased from 0% removal during commissioning-A, to achieving 21% and 41% removal, respectively during commissioning-B. Monitoring through 2015 and 2016 has indicated that percent removal of elements of concern have been increasing over time. The results of the 2016 on-site demonstration-scale CWTS performance indicate that the CWTS is continuing to mature. Plans for 2017 will focus on testing operations and performance. Flow rates will be set at a constant flow to evaluate the stability of the CWTS performance over one year. A second HRT tracer study will be performed using an updated method based on the findings from the 2016 HRT tracer study. A second evapotranspiration study will also be performed to determine the amount of water that is being lost to evapotranspiration from the CWTS. Weekly monitoring will continue throughout 2017 to evaluate performance of the CWTS.

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**Abbreviations and definitions**

**Acidity** – A measure of the capacity of water to neutralize base. Influences pH along with alkalinity.

**Alkalinity (Alk)** – A measure of the capacity of water to neutralize acids. Influences pH along with acidity.

**Amendment** – A chemical or organic material added to encourage specific conditions (e.g., aerobic/anaerobic, pH, ORP) or as a source of something that is needed for passive treatment (e.g., nutrients, alkalinity, binding sites, etc).

**ANAMMOX –** Anaerobic ammonium oxidation; a microbiological process where ammonium and nitrite are converted directly to dinitrogen gas ($NH_4^+ + NO_2^- \rightarrow N_2 + 2H_20$).

**Biofilm(s)** – A visible and often slimy-looking film (community) of bacteria (may contain other microbes).

**Carbon source** – A source of carbon (energy/electrons) for microbes (see **electron donors**). Examples include ethanol, methanol, acetate, sugar (glucose), molasses, wood chips, detritus (dead plant matter).

***Carex aquatilis*** – A plant (emergent macrophyte) commonly known as water sedge.

**Carex utriculata** – A plant (emergent macrophyte) commonly known as Northwest Territory sedge or beaked sedge.

**Contango** – Contango Strategies Ltd.

**Constructed wetland treatment system (CWTS)** – Wetlands that are designed and constructed to remove compounds from water, using natural processes to sequester them into the soils rendering them less bioavailable. They are different from wetlands that provide habitat for wildlife.

**Denitrification** – Where nitrate ($NO_3^-$) is reduced by microorganisms to form nitrite ($NO_2^-$), nitric oxide (NO), or nitrous oxide ($N_2O$), or nitrogen gas ($N_2$) (see **nitrate reduction**).

**Dissolved oxygen (DO)** – Diatomic oxygen ($O_2$) dissolved in water; oxygen can dissolve in water by diffusion from surrounding air, as a product of photosynthesis, or through forced aeration.

**Electron donor(s)** – A chemical compound that donates electrons to another compound (see **carbon source**). An electron donor is a reducing agent, which that by virtue of it donating electrons, is itself oxidized (see **oxidation** and **reduction**).

**Explanatory parameters** – Quantifiable parameters that describe how water treatment reactions take place.

**Evapotranspiration** – The combined effects of open water evaporation and plant transpiration (Beebe *et al*, 2014).

**Genetic analysis** – Analysis to assess the presence, identity, and diversity of different microbes in a sample.

**ICP-MS** – Inductively coupled plasma mass spectrometry.

**Macrophytes** – An aquatic plant, large enough to be seen by eye. Can be emergent, submergent, or floating.

**Microbes** – Microscopic organisms that can be uni- or multi-cellular. This includes algae, bacteria, fungi, viruses, and yeast.

**Most probable number (MPN)** – A statistical value representing the viable population of microbes in a sample through use of dilution and multiple inoculations.

**Oxidation** – The loss of electrons, or increase in valence state, by a molecule, atom, or ion. Can be driven by microbes. Process is complementary to chemical reduction.

**Oxidation-reduction potential (ORP)** – A measure of the tendency of a chemical species to acquire or donate electrons, thus becoming reduced or oxidized, respectively, measured in millivolts.

**Passive or semi-passive treatment system(s) (PTS)** – General term used to refer to both passive and semi-passive treatment systems that use processes coupling transformations (e.g., chemical and biogeochemical reactions) with physical transfers (e.g., sorption, filtration) to remove constituents from water, often operationally passive with little long-term management required.

**Redox** – Oxidation-reduction potential (in sediment), a measure of the tendency of a chemical species acquire or donate electrons, thus becoming reduced or oxidized, measured in millivolts. This measurement is relative to the water ORP.

**Reduction** – The gain of electrons, or a decrease in valence state, by a molecule, atom, or ion. Can be catalyzed by microbes. Process is complementary to chemical oxidation.

**Simultaneously extracted metals (SEM)** – Amounts of heavy metals such as Ni, Zn, Cd, Pb, Cu, Hg in sediment, assessed in the context of AVS for excess sulphide. (also see **acid volatile sulphide**)

**Sorption** – The physical and/or chemical process by which one substance becomes attached to another substance.

**Specific conductivity (SPC)** – A measurement of electrical conductivity in water that is typically expressed in µs/cm, which has been adjusted for temperature (25°C).

**Species (sp.)** – One of the basic units of biological classification and a taxonomic rank. Rank in the classification of organisms below genus and above strain. Also can be used to refer to the oxidation state of a mineral (e.g., selenate and selenite are species of selenium).

**SPLP** – Synthetic precipitation leachate procedure.

**Sulphide** – An inorganic anion of sulphur that can form stable complexes with metals and make them insoluble in water (remove them from the water).

**Sulphide producing bacteria (SPB)** – Microbial reduction of sulphur compounds, such as sulphate, sulphite, thiosulphate, and sulphur, which produces sulphides and alkalinity. (see also **SRB**).

**Sulphate reducing bacteria (SRB)** – A form of sulphide producing bacteria that specifically uses sulphate for reduction (see **sulphide producing bacteria**).

**Sulphide production** – Microbial reduction of sulphur compounds, such as sulphate, sulphite, thiosulphate, and sulphur, which produces sulphides and alkalinity.

**Total dissolved solids (TDS) –** A measure of the combined organic and inorganic salts dissolved in water.

**Total organic carbon (TOC)** – A measurement of the total organic carbons present in water.

**Total suspended solids (TSS)** – A measurement of all particles in water that are larger than 2 µm (anything smaller than 2 µm considered a dissolved solid).

**Transfer –** Processes that treat water by transferring a constituent to another location without changing its form. For example: absorption, adsorption, dilution, dispersion, filtration, precipitation (aqueous to solid), and volatilization.

**Transform –** Processes that change the chemical form or state of a constituent. For example: biodegradation, biotransformation, hydrolysis, ionization, oxidation, photolysis, and reduction.

## 1. Introduction and background

The Minto Mine, operated by Capstone Mining Corp., is located 240 km northwest of Whitehorse on the west side of the Yukon River. The Minto property lies within the eastern part of the Dawson Range, with elevations from 700 to 1,000 m; the landscape has rounded mountains intersected by broad valleys and drainages that are part of the Yukon River watershed.

The Minto Mine has been in commercial operation since October 2007 and the deposits being mined are copper sulphide mineralized zones. Surface and groundwater water quality is a key consideration in the evaluation of potential effects of mining and mineral development projects and changes to water quality parameters have the potential to affect aquatic and human use of water resources. A Reclamation and Closure Plan (RCP) is required under both the Water License and the Quartz Mining License. The RCP is intended to address the long-term physical and chemical stability of the site and closure of the proposed features and disturbances associated with the mine. As a part of the RCP, a Constructed Wetland Treatment System (CWTS) is being designed, evaluated, and optimized for water treatment at closure through a phased program (Minto Phase V/VI Expansion Project, YOR Project Number 2013-0100).

For CWTSs to be effective, they must be designed, piloted, optimized, implemented, and maintained in a site-specific manner. A scaled approach for CWTS implementation allows for improvement, optimization, and flexibility for modifications along each step. Phases include:

1) site assessment and information gathering,
2) technology selection and conceptual design,
3) pilot-scale testing and optimization (controlled environment),
4) on-site demonstration-scale confirmation and optimization, and
5) full-scale implementation.

Phases 1-3 have been completed (reports 2013-0100-256 and 2013-0100-257 on YESAB registry, and Contango, March 2014; Contango, November 2014) and confirmed plant amenability to transplantation and the CWTS design for further on-site testing. During pilot-scale trials, the selected CWTS design achieved on average 92% removal of cadmium (mean influent 0.336 µg/L, outflow 0.027 µg/L), 92% removal of copper (mean influent 146 µg/L, outflow 11.3 µg/L), 41% removal of selenium (mean influent 10.2 µg/L, outflow 6 µg/L), and 92% removal of zinc (mean influent 40 µg/L, outflow 3.2 µg/L), using synthetic influent designed to mimic the worst-case water chemistry of a long-term closure scenario, but tested under the controlled conditions (e.g., controlled flows, known temperature, etc) of an off-site treatability testing center (Contango, November 2014). It should be noted that lower influent concentrations will have a lower percent removal even when achieving the same final outflow concentrations.

Phase 4 of the project is underway, with the on-site demonstration scale CWTS constructed at the Minto Mine during fall 2014 (Contango, March 2015). The on-site demonstration-scale CWTS operated for 137 days in 2015 and 152 days in 2016 (Table 1). The results of the 2015 and 2016 on-site demonstration-scale CWTS performance indicate that the CWTS is maturing as expected and maturation continued to be monitored in 2016. This document reports on

the on-site demonstration scale CWTS data from construction, and through two years of commissioning-A (2015/2016) and into the commissioning-B period (late 2016).

**Table 1 – Days of operation of CWTS.**

| Scale | Year | Days Operated | Date | |
|---|---|---|---|---|
| | | | Start | End |
| **Pilot (off-site)[1]** | **2013 -2014** | 205 | Nov 4 | May 28 |
| **Demonstration (on-site) Commissioning-A** | **2014[2]** | 23 | Aug 27 | Sep 19 |
| | **2015** | 137 | May 16 | Sep 29 |
| | **2016** | 101 | May 2 | Jul 28 |
| **Demonstration (on-site) Commissioning-B** | **2016** | 51 | Jul 29 | Sep 30 |

[1] Pilot-scale system operated from Nov 4, 2013 to July 16, 2014.
[2]The system was constructed in 2014, but no water testing occurred during this first month of commissioning-A.

## 2. Construction and operation

### 2.1. System layout and dimensions

The demonstration-scale CWTS includes 2 systems in parallel with 2 cells in each series and a final catchment basin that both systems flow into (Figure 1). Dimensions and construction details are available in the Minto Demonstration Scale Report Document 011_0315_01A (Contango, March 2015). The two parallel systems serve as a replicate for data analysis, and as testing has progressed, the two systems have also allowed for comparison of different management techniques. Dimensions of the systems are provided here in Table 2.

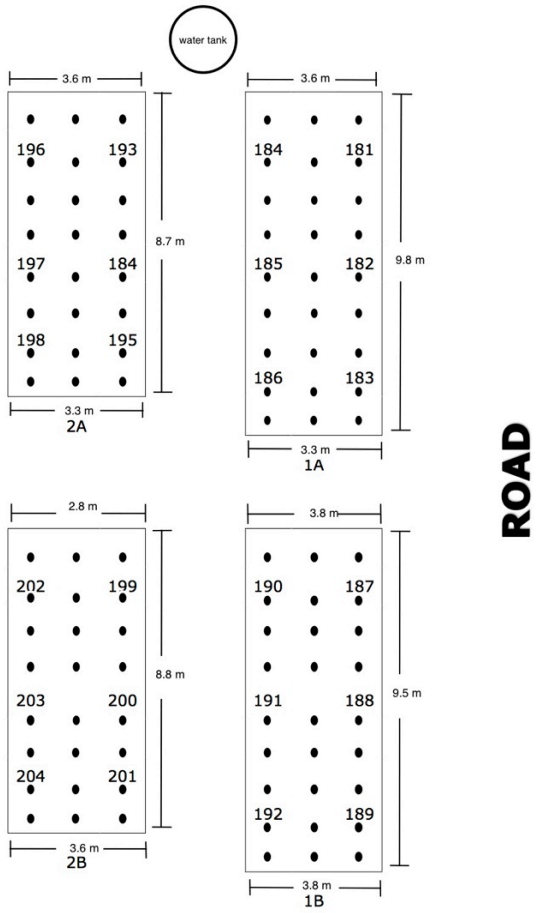



**Figure 1 – Diagram of demonstration-scale CWTS.**
Dimension measurements are indicated at soil surface. Black dots indicate initial construction grid marked by moss stakes, and locations of soil redox probes with identifying numbers.

**Table 2 – Dimensions of demonstration-scale CWTS cells at soil surface and resultant areas of treatment systems.**

| Measurement | | Series 1 | | Series 2 | |
|---|---|---|---|---|---|
| | | 1A | 1B | 2A | 2B |
| Width (m) | Inflow | 3.6 | 3.8 | 3.6 | 2.8 |
| | Outflow | 3.3 | 3.8 | 3.3 | 3.6 |
| Length (m) | | 9.8 | 9.5 | 8.7 | 8.8 |
| Approximate surface area at soil ($m^2$) | | 33.8 | 36.1 | 30.0 | 28.2 |
| Total area of system at soil ($m^2$) | | 69.9 | | 58.2 | |

### 2.2.Substrate soils used in construction

Soils used to construct the CWTS are described in the initial report that outlines construction (Contango, March 2015). In brief, the recommended soil for the CWTS was sand, with 2-7% by volume as organic material (e.g., woodchips, peat). In the pilot-scale systems, this resulted in a total organic carbon (TOC) content by weight of 0.2-0.6% (the sand itself was at 0.1% TOC prior to adding amendment). Ideally, this percentage could be higher, approximately 2-10% by weight to stimulate the desired reducing conditions. For the demonstration-scale system, the soil added to each of the 4 cells during construction was from a local borrow site. As is expected in a mining area, the soils are likely mineralized. Although a potential borrow source was tested prior to construction ("Tested Soil"; Table 3), a different borrow source was available upon construction of the demonstration-scale wetland ("Soil used"; Table 3). The material used in the construction of the demonstration-scale wetland was an organic peat, and analyses received after construction indicated an elevated concentration of leachable copper (Table 3). It should be noted that in a full-scale system, the variability in soil substrate would be normalized by the larger volume of soil used. The substrate in the wetland (composed of the organic peat soil, wood chips, and straw) had a TOC content of 1.8-3.1%. The implications of this are discussed in section 6.1 of this report.

**Table 3 – Comparison of copper concentrations in soils of pilot- and demonstration-scale CWTS.**

| Test method | Pilot-scale | Demonstration-scale | |
|---|---|---|---|
| | Initial soil | Tested soil (June, 2014) | Soil used (August, 2014) |
| SPLP Copper (mg/L)[1] | - | 0.00546-0.0296[2] | 0.148-0.608 |
| Total Copper (mg/kg) | 5.3-5.5 | 210-1400[2] | 960-1400[3] |

[1] SPLP - Synthetic Precipitation Leaching Procedure
[2] For the June 2014 samples, the soil with the highest total copper concentration also had the lowest leachable copper concentration, and was therefore deemed acceptable for use.
[3] Total copper value for soils used was taken in June 2015 (no data for August 2014).

### 2.3.Vegetation used in planting

The demonstration-scale CWTS was planted with *Carex aquatilis* (aquatic sedge) and aquatic mosses from the W10 area of the Minto Site. The plant selection and borrow source was previously determined through the site assessment (reports 2013-0100-256 and 2013-0100-257 on the YESAB registry) and pilot-scale testing (Contango, November 2014). Five *C. aquatilis* plants were planted per square meter, with moss tied to stakes that outlined the 1 m x 1 m grid for planting (details provided in Contango, March 2015).

### 2.4.Water source and flow

Water from the W36 area receiving seepage from the toe of the Mill Valley Fill Extension (MVFE) was selected for the demonstration-scale CWTS testing as the leachate is similar to that expected upon closure in the MVFE area. The chemistry of this water at the time of bringing the demonstration-scale CWTS online (September 18, 2014) is provided in Contango,

March 2015. In 2015 the water for the CWTS was pumped out of the sump at the toe of the MVFE. The Mill Valley Fill Extension Stage 2 (MVFE2) collection sump (W62 sump) was constructed from November 9, 2015 to February 7, 2016. The sump was constructed as a replacement for the sump used in 2015. The W36 sump was decommissioned in February, 2016 as part of the MVFE2 construction. The new sump approximately 30m downslope was the supply water for the CWTS for the summer of 2016 (Figure 2).




**Figure 2 – Water source for the demonstration-scale CWTS in 2016.**

After construction in 2014 and in early 2015, the flow rates for the systems were planned to be set to have a 10 day nominal hydraulic retention time (HRT), meaning water entering the wetland takes 10 days to exit. This is referred to as a nominal HRT because it is a calculation based on the size of the wetland and the amount of water entering, and not confirmed empirically using tracing dyes. This HRT is much longer than what is necessary to achieve treatment based on the pilot-scale systems (~3 days), and was chosen to facilitate plant establishment and maturation. However, due to the leachable copper concentrations in the soils used for construction, it was instead decided to run the systems at a faster flow to wash as much leachable copper from the soils as possible. As such, a shorter nominal HRT of ~20 hrs (Figure 3) was used as a starting point (HRT calculated using measured water depths of approximately 15 cm and negligible pore water involvement [30cm of soil at 10% pore volume] due to peat soils). Despite the shorter HRT resulting from the faster flow of water, the systems have acclimated and matured as was expected for the longer HRT. Because the sizes of the CWTS systems are slightly different, Series 1 (closer to the road) and Series 2

(further from road) are set with flow rates to result in similar HRTs in each system. Flow rates were monitored and adjusted throughout 2015 based on CWTS establishment and maturation (further information in sections 3 and 4).

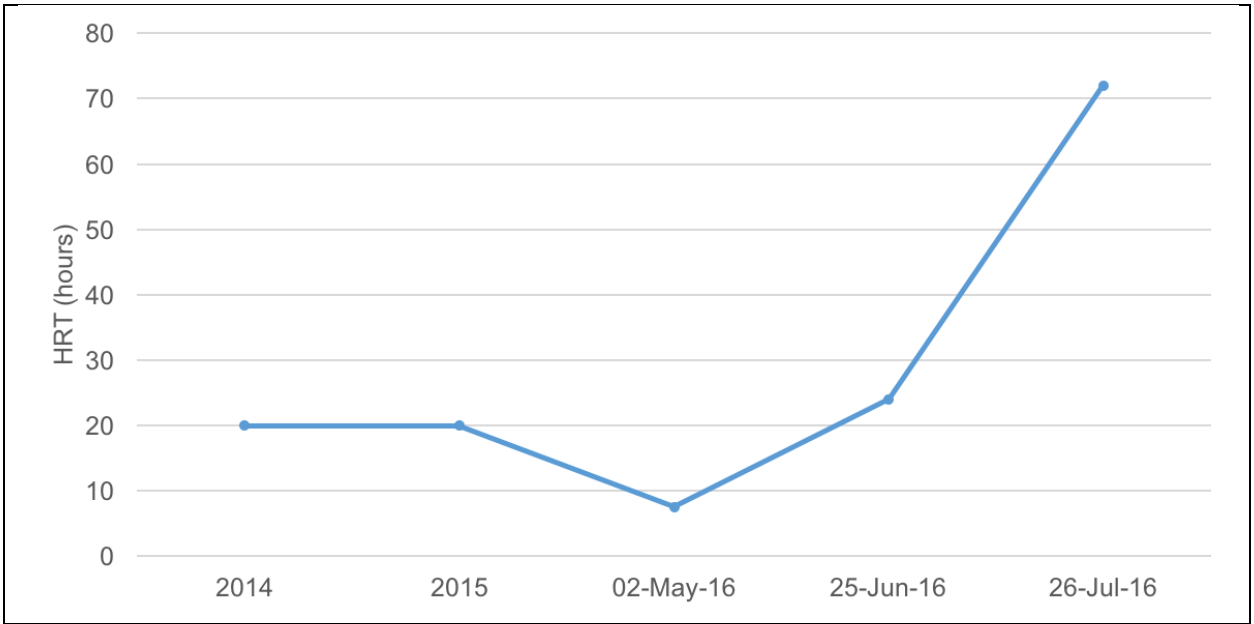



**Figure 3 – Demonstration-scale CWTS targeted hydraulic retention time from construction to present.**

Three flow rates were used during operation of the CWTS in 2016. At start up in May 2016 the nominal HRT was set to ~7.5 hours to further attempt to flush copper out of the soil (further enhancing the 2015 EDTA trials conducted in System 2 (section 6.3)). In early June, HRT was increased to ~24 hours to allow for a tracer study to be conducted during a 2-day site visit in attempt to determine the actual HRT (vs nominal, calculated HRT) of the CWTS (section 7). At the end of June, the HRT was lengthened to a calculated ~72 hours (3 days) for performance testing and remained at this HRT until the end of operations in September 2016. Due to pump and flow meter issues the actual flow rates varied from the target flow rates throughout 2016 operations. Table 5 outlines known pump and flow meter issues that occurred in 2016, and Figure 4 shows the fluctuation in actual vs targeted flow rates throughout the 2016 operations.

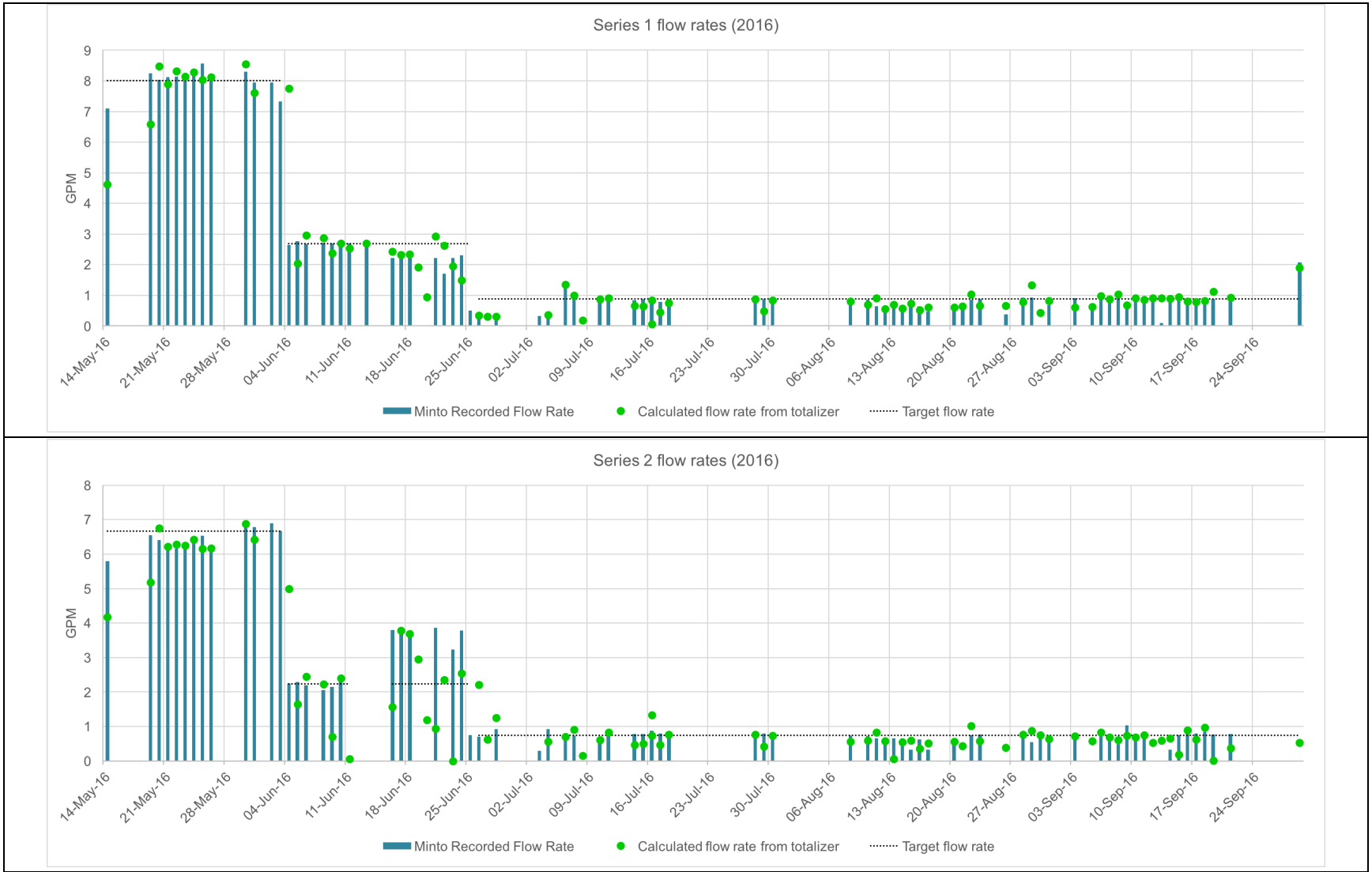



**Figure 4 – Flow rates during CWTS operations in 2016.**
Blue bars indicate flow rates displayed on meter, while green dots are flow rates calculated from the totalizer values (values from meter were recorded by Minto personnel. The totalizer value is the cumulative volume of water passing through the flow meter between two measurement dates. Areas with no blue bars or green dots are time periods where flow rates and totalizer values were not recorded.

## 3. Commissioning

The period between the construction of the CWTS and achieving the expected treatment performance is referred to as the commissioning period. During this period, the plant and microbial populations establish and mature, and construction effectiveness and optimization opportunities are evaluated to make operational adjustments (e.g., raising water depth, modifying outflow patterns) and inform on the full-scale system (Table 4). For the demonstration-scale CWTS the commissioning period was divided into two periods, commissioning-A, and commissioning-B. The end of the commissioning-A period and the beginning of the commissioning-B period was marked by the addition of organics on July 28, 2016.

Performance continues to be monitored and while full treatment functionality of the demonstration-scale system is not expected during the commissioning period, the information will aid in the development of the full-scale system in the following ways:

- Evaluation of construction effectiveness and potential optimizations.
- Assessment of timelines to reach targeted operational parameters to allow for effective phasing of implementation (e.g., soil redox, percentage and abundance of sulphate reducing bacteria).
- Assessment of the effectiveness of *Carex aquatilis* and aquatic moss transplantation to assess planting density, time period to full density, and if plant propagation and/or a replanting schedule is necessary.

However, there are aspects of the demonstration-scale CWTS that are not directly transferrable to the planned construction of the full-scale CWTS. Notably, the demonstration-scale CWTS was built with a different soil type and chemistry than recommended for the full-scale system. Therefore; it is taking a longer time to commission the demonstration-scale system as the copper in the soils needs to be treated in addition to the copper and other constituents in the water.

Based on pilot-scale testing (Contango, November 2014), the estimated commissioning period for the Minto demonstration-scale CWTS was 4 months of operation (i.e., period when water is flowing). In 2014, the demonstration-scale CWTS operated for less than one month prior to freezing, and was restarted along with spring thaw (freshet) in mid-May 2015. Based on these timelines, September 2015 was month 4 of commissioning, and the demonstration-scale system was trending towards performance as expected during the commissioning period (Contango, March 2016). However, as discussed further in sections 2.2 and 6.1, the soil used in the CWTS had high concentrations of leachable copper, and therefore optimization opportunities were evaluated throughout 2015, and adjustments were implemented in 2015 and 2016. The last operational adjustment during the commissioning period was the addition of organic material in 2016, which marked the end of the commissioning-A period and the beginning of the commissioning-B period. Organic material will also be added during construction of the full-scale design to enhance desired reducing conditions to establish in the CWTS until vegetation is sufficient to provide for this required component.

**Table 4 – Operational adjustments made to the demonstration-scale wetland.**

| Year | Activity | Purpose |
|---|---|---|
| 2014 | Construction | Construction |
| 2015 | Increasing water depth | Plant acclimation and establishment |
| | Adding more aquatic moss | Increase moss density |
| | Modifying inflow and outflow distribution areas | Promote uniform flow field |
| | Removing *Carex utriculata* | Was erroneously planted |
| | Wrapping inflow tank | Prevent algal growth |
| | Fe-EDTA test on CWTS series 2 | To test if non-invasive treatments could be used to further leach the metals and improve soil quality |
| 2016 | Adding sandbags to the perimeter of the CWTS | Promote uniform flow field and prevent short circuiting of water around perimeter |
| | Perform tracer study | Determine the actual hydraulic retention time (HRT) of the CWTS |
| | Increase water depth of Series 1 | Bring to desired specification depth |
| | Evapotranspiration study | Determine the amount of water loss occurring (and therefore concentration of elements) |
| | Setting flow rates at a 3 day calculated HRT (compared to 20 hrs previously used) | Continue commissioning period and develop rate kinetics |
| | Adding organics (woodchips and straw)[1] | Enhance desired reducing conditions (will be added to full-scale design specifications) |

[1] This marked the end of the commissioning-A period and the beginning of the commissioning-B period.

## 4. Timeline and sampling schedule

Major events and operational adjustments are listed in Table 5. The actual dates as well as relative days of operation are provided, which adjusts for time that the CWTS was not receiving water when it was frozen. The relative days of operation allows for comparison to expected timelines from the pilot-scale testing, and for planning and scheduling to be done for full-scale construction and commissioning in the context of mine closure planning.

The sampling schedules for 2015 and 2016 were conceptually developed prior to beginning construction of the demonstration-scale CWTS (Appendix A). Actual dates of sampling were dependent on timing of spring thaw and winter freeze-up, and the associated ability to have the pumps operating at the W62 sump to supply water to the demonstration-scale CWTS.

**Table 5 – Events and sampling activities since construction.**

| Event | Key Activity | Flow Rate Setting $m^3$/day (gal/min) | | Calendar Date | Day(s) of Operation |
|---|---|---|---|---|---|
| | | CWTS Series 1 | CWTS Series 2 | | |
| CWTS constructed and planted | First sampling, water started. | - | - | August 27 – 31, 2014 | 0-4 |
| Freeze up for winter | Feed water pumps turned off. | - | - | September 19, 2014 | 23 |
| Winter 2014/2015 | | | | | |
| Start up for 2015 | Feed water pumps turned on. | 14.17 (2.60) | 11.61 (2.13) | May 16, 2015 | 24 |
| Contango Site Visit #1 | Microbiology, soils, water tested. *Carex* stem counts. Added more aquatic moss. Put black wrap on water tank to prevent algal growth. Water depth adjusted with sandbags. | | | June 18, 2015 | 57 |
| Flow rate increased | Flow rates increased. | 17.44 (3.20) | 15.81 (2.90) | July 13, 2015 | 82 |
| Contango Site Visit #2 | Microbiology, soils, water tested. Added more aquatic moss. | | | August 16, 2015 | 116 |
| Contango Site Visit #3 | Water tested. Started Fe-EDTA test on System 2. | | | September 17, 2015 | 148 |
| | Microbiology, soils, plants, water tested. | | | September 18, 2015 | 149 |
| Fe-EDTA Testing | Daily total and dissolved copper analysis conducted at Minto. | | | September 19 – 26, 2015 | 150-157 |
| Freeze up for Winter | Feed water pumps turned off. | - | - | September 29, 2015 | 160 |
| Winter 2015/2016 | | | | | |
| Flow meters installed and pumps turned on | Flush copper leaching from soil (associated with 2015 EDTA test). | 44.10 (8.09) | 38.10 (6.99) | May 2, 2016 | 161 |
| Start up for 2016 | Feed water pumps turned on. | | | May 13, 2016 | 172 |
| Pump problems | Getting proper pumps installed at new sump location. | | | May 13-17, 2016 | 172-176 |
| Flow rate decreased | HRT increased to 24 hours. | 14.39 (2.68) | 12.26 (2.24) | June 4, 2016 | 194 |
| Added sandbags | Added sandbags to perimeter of CWTS. | | | June 7, 2016 | 197 |
| Contango Site Visit #4 | Microbiology, soils, water tested. | | | June 13 – 15, 2016 | 203-205 |
| | Tracer test for HRT. | | | June 13 – 17, 2016 | 203 - 207 |

**Table 5 – Continued.**

| Event | Key Activity | Flow Rate Setting $m^3$/day (gal/min) | | Calendar Date | Day(s) of Operation |
|---|---|---|---|---|---|
| | | CWTS Series 1 | CWTS Series 1 | | |
| Inconsistent flow | Flow rates in series 2 inconsistent and above targeted flow rate. | 14.39 (2.68) | 20.71 (3.80) | June 16 - 24, 2016 | 206-214 |
| Flow rate decreased | HRT increased to 72 hours. | 2.73 (0.89) | 4.09 (0.75) | June 25, 2016 | 215 |
| Flow meter switched on series 1 | Max flow on new flow meter is lower than targeted flow rate due to flow meter being installed backwards. | Unknown | | June 25 – July 4, 2016 | 215-224 |
| Flow meter for series 1 was on backwards resulting in unknown flow rates | Installed the flow meter correctly and reset flow rate to meet targeted HRT range of 72 hrs. | (0.89) | | July 4, 2016 | 224 |
| Evaporation Study | Flow stopped. | - | - | July 18 – 26, 2016 | 238-246 |
| End of evaporation study | Flow turned back on. | 2.73 (0.89) | 4.09 (0.75) | July 26, 2016 | 246 |
| Contango Site Visit #5 | Microbiology and water tested. | | | July 27 - 28, 2016 | 247-248 |
| | Added organic material (straw and woodchips) | | | July 28, 2016 | 248 |
| Flow interruptions | Flow meters plugged. | | | August 15 –18 2016 | 266-268 |
| Contango Site Visit #6 | Microbiology, soils, water, and plants tested. | | | September 7 – 8, 2016 | 289-290 |
| Freeze up for Winter | Feed water pumps turned off. | - | - | September 30, 2016 | 312 |

## 5. Monitoring explanatory parameters

Explanatory parameters are quantifiable aspects of a CWTS environment that can be used to assess feasibility of treatment for a range of constituents, and therefore 'explain' the performance of a CWTS. These parameters, which often include acidity, alkalinity, conductivity, dissolved oxygen (DO), pH, oxidation reduction potential (ORP), ion balance, available electrons donors (e.g., organic carbon, reduced elements), and temperature, can be used to predict, promote, and/or optimize the ability of the system to treat different constituents (Haakensen et al., 2015). A YSI ProPlus meter was used in the field to test for water temperature, DO, conductivity (and specific conductivity; SPC), pH, and ORP.

Average water temperature of the demonstration-scale CWTS in 2015 was 12.9°C, ranging from 0.5°C to 25°C, and in 2016 was 10.2°C, ranging from 0.8°C to 23.2°C. As would be expected, both the month of testing and time of day were found to affect temperature variation (section 7). DO concentrations in the CWTS cells were on average 10 mg/L in 2015, 15.9 mg/L in 2016 prior to commissioning being complete, and 8.4 mg/L in 2016 after commissioning was complete, which is higher than the pilot-scale systems (average 4.8 mg/L). This higher DO concentration makes the system more oxidizing and therefore more difficult to carry out nitrate and selenium treatment, and produce sulphides for copper and cadmium treatment. However, the conductivity, pH and ORP of the demonstration-scale CWTS cells are all very similar to the pilot-scale systems (Table 6).

**Table 6 – Average in situ measurements from the pilot scale and demonstration-scale system.**

| Testing Period | | DO (mg/L) | SPC (µS/cm) | pH | ORP (mV) | Soil redox (mV) |
|---|---|---|---|---|---|---|
| Pilot 2014[1] | | 5.73 | 990.0 | 7.71 | 159 | -185 |
| Demonstration-scale 2015 | | 10 | 817.9 | 8.11 | 147.9 | -52 |
| Demonstration-scale 2016 | commissioning-A[2] | 15.9 | 890.9 | 7.79 | 143.7 | -85 |
| | commissioning-B[3] | 8.4 | 1020 | 7.59 | 157.6 | -89 |

[1] Pilot system data is from the low N system with moss and *Carex*. This was the system that was used as the foundational design.
[2] Data for commissioning-A period is from May 2-July 28, 2016.
[3] Data for commissioning-B period is from July 29-September 30, 2016.

An additional explanatory parameter that can be used to monitor maturation of the wetland during the commissioning period is the soil redox potential, which is measured using platinum tip probes (in soil) and Calomel electrodes (in water). This measurement offers insight into the direction of electron flux between the sediment/soil/pore water and overlying water column (Faulkner et al., 1989; Huddleston & Rodgers, 2008), and can be used to confirm reducing conditions in the soil. Based on the information gathered in pilot-scale testing, the targeted soil redox for the demonstration-scale CWTS is between -100 and -250 mV. In these redox ranges, bacterial sulphide-production through reduction of sulphur compounds (e.g., sulphate) is expected. Sulphide production directly results in metals and metalloid treatment

for elements such as cadmium, copper, molybdenum, nickel, lead, and zinc by precipitation as metal sulphides (Figure 5).

This maturation period is necessary for sufficient quantities of microbes to populate the wetland and become active in decomposing organic material. It is the electrons produced by the decomposition of organic material that is reported by the soil redox measurements. The decomposition of organic material then feeds the sulphate-reducing bacteria the type of energy they need to produce the sulphides that remove the copper, cadmium, molybdenum, and zinc from the water. The microbial activity of the system is discussed further in Section 10.3.

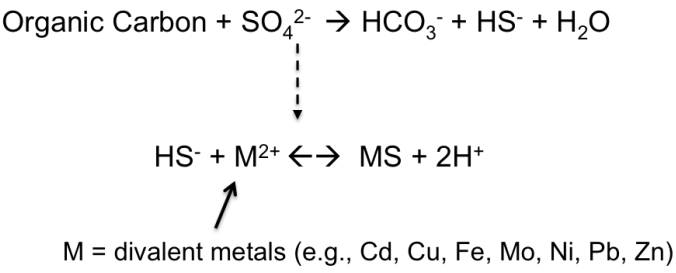



**Figure 5 – Example equation of sulphate reduction and resultant metals mineralization and treatment.**
Equation is not balanced; demonstrates sulphate reduction with creation of alkalinity and sulphides, which can then form metal sulphide complexes.

As expected from the pilot-scale testing, the soil redox in all the demonstration-scale CWTS cells has decreased over time, indicating maturation of the system (Figure 6). At the end of 2015, only Series 1 had begun to achieve targeted soil redox values that are conducive to sulphide production (ahead of anticipated schedule). It is possible that Series 1 had more organic material in the soils than Series 2, because of how construction occurred and this wasn't reflected in the small sample size sent for analytical testing.

Some soil redox probes were reporting negative values in the targeted range by July 18, 2015 (87 days); however, in general the CWTS took approximately 4 months of operation to establish generally reducing conditions. By September 17, 2015 (day 148), most of the soil redox probes within Series 1 were reporting redox values within the targeted range, with Series 2 still trending downwards but not yet within the targeted range. In comparison, the pilot-scale systems were stable and reducing within approximately 4 months of construction (Figure 6). In early 2016, the soil redox in both series was not being maintained within the targeted range, which indicated that additional organics may be needed in the CWTS to enhance maturation.

### 5.1. Addition of organics

Since the demonstration-scale system was not achieving stable redox values (nor associated performance expectations) within the targeted range, woodchips and straw were added to the

demonstration-scale CWTS on July 28, 2016. Because the demonstration-scale system takes time for plants to mature (and generate organic carbon for the microbes to feed on), the addition of organics early in the operation of the system can supplement the carbon sources needed for sulphate-reducing bacteria, and produce the desired sulphur- and selenium-reducing conditions (section 10.3). This will be included in the full-scale system design specifications.

One compressed 20-liter pail of woodchips was spread across the surface of each of the four CWTS cells (Figure 7). The A cells also each received one 0.16 $m^3$ bale of straw while the B cells received half of a straw bale of the same size. In the A cells, the straw was added along the inflow, outflow and along the sides of the cell in between the sand bags. In the B cells, straw was added at the inflow before and after the sand bags, and along the sides in between the sand bags (Figure 7).

By September 8, 2016 (final redox readings of 2016) redox values for cell 2B were consistently within the targeted range, and the redox values for series 1 were achieving targeted ranges 50% of the time (3 of the 6 in situ probes were reading within the targeted range). It is anticipated that the addition of organics will continue to provide the necessary carbon source to stimulate desired reducing conditions in 2017.

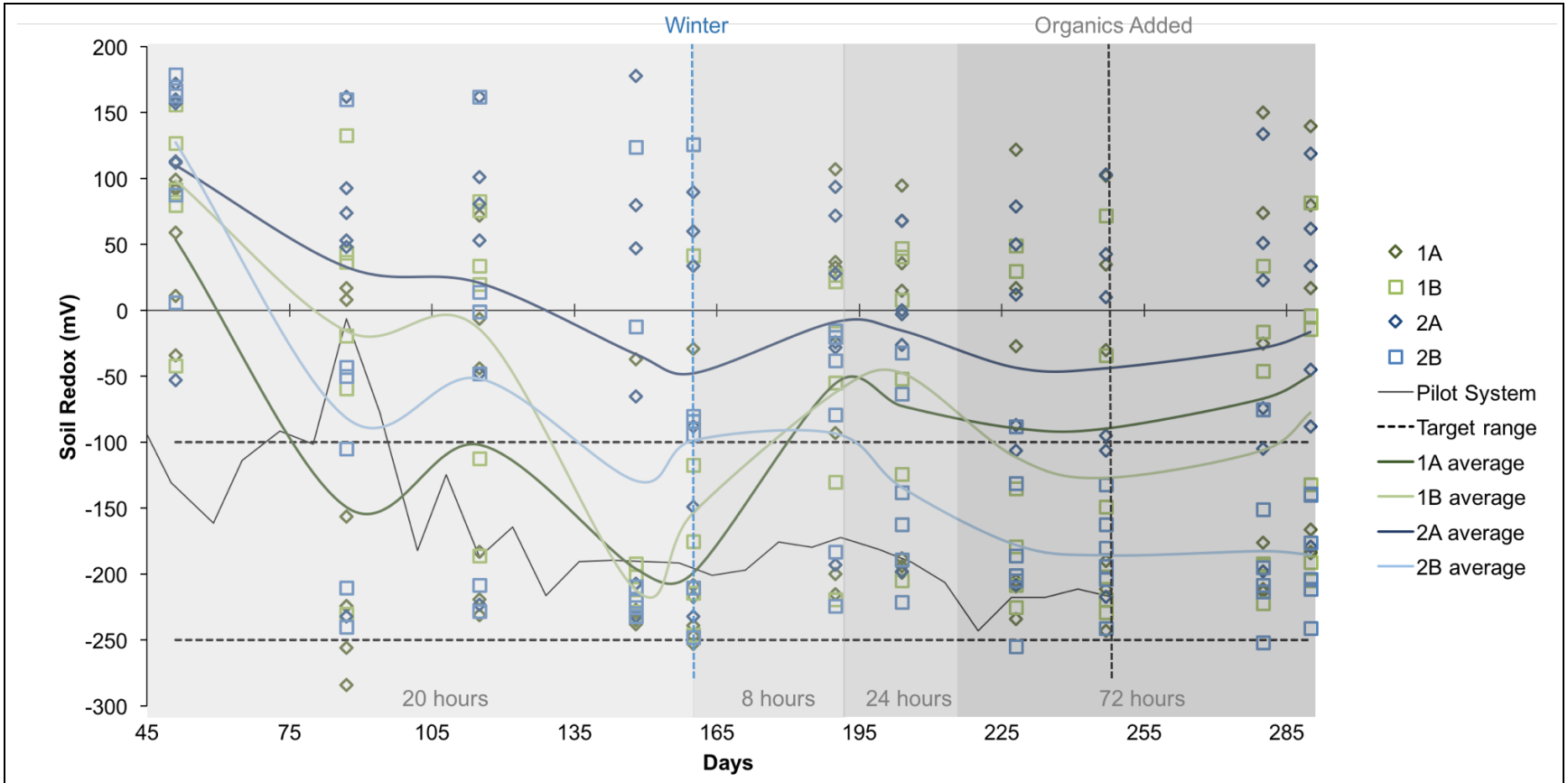



**Figure 6 – Soil redox potential of each CWTS cell over time.**
All demonstration-scale CWTS soil redox measurements are plotted, along with the average soil redox of the pilot-scale systems. Targeted soil redox values based on pilot-scale testing are indicated with dotted lines. The blue dotted line indicates break in measurements for winter 2015. Hours and associated grey shading indicate the HRT.



**Figure 7 – Addition of organics on July 28, 2016.**
Top picture shows cell 1A with woodchips that were added (floating on water surface). Bottom picture shows cell 2A with straw that was added after woodchips.

# 6. Performance progress during commissioning period and early operation

## 6.1. Soils

### *6.1.1. Methods*

Although unintentional, the use of soils in the CWTS with high initial leachable copper concentrations (Table 3) allowed for additional types of testing to be carried out on these systems. Because the soil substrates used for construction of the CWTS were from overburden sources, the copper was not in a mineral form that would typically be found in a reducing CWTS (i.e., negative relative soil redox). Therefore, there has been some initial leaching of copper (and other elements, such as aluminum) from the soils into the water (Table 8, Figure 10, and Figure 12).

To assess the effect of the elevated metals (aluminum and copper) in the soils used in construction on CWTS functionality, four soil analytical test methods were used:

- Total concentration of elements in the soils by ICP,
- In 2015, leachable concentrations of elements in the soils by Synthetic Precipitation Leaching Procedure (SPLP), which is a method to assess the mobility of elements in soils at the pH of rain water (i.e., if the wetland were to entirely dry out, then be subjected to leaching by rain water) (EPA Method 1312/6010B)
- In 2016 a leach method was used. This analysis was carried out using a leaching procedure which involved the gentle tumbling of a sample in a specified leaching solution (water from the CWTS) for 2 hours. The resulting extract is then analyzed by inductively coupled plasma – optical emission spectrophotometry (EPA method 6010A). This method was selected in 2016 to determine the concentration of metals that are being released from the soil into the overlying water column.
- Sequential extraction procedure for the speciation of particulate trace metals (Tessier *et al*, 1979, EPA 6020A) to assess the stability and form of elements in soils (Table 7).

**Table 7 – Summary of extractable fractions from sequential extraction procedure for the speciation of particulate trace metals[1].**

| Fraction | Description | Elements unstable when |
|---|---|---|
| **1** | Exchangeable fraction for adsorbed minerals | Readily released (i.e., soluble and exchangeable) |
| **2** | Mineral fraction bound to carbonates | Decreased pH |
| **3** | Mineral fraction bound to Fe-Mn oxides | Reducing conditions |
| **4** | Mineral fraction bound to organic matter and sulphides | Oxidizing conditions |
| **5** | Residual mineral fraction (primary and secondary minerals) | Not expected to be released in solution over time under conditions normally encountered in nature |

[1] Method based on Tessier *et al.,* 1979.

### *6.1.2. Soil Aging*

While the total copper concentrations have increased over time (with the addition of mineralized copper from the water), the leachable copper (measured by SPLP) in 2015 decreased over time. By day 58 of operation, the top 5 cm of soil was decreased to only 10-20% of the initial leachable copper concentration, and the lower 10-20 cm layers reached similar concentrations by day 149 (Table 8). In 2016 a new leach method was used to determine the concentration of metals that are being released from the soil into the overlying water column, rather than using the SPLP method which assumes leaching at rain water pH. The main difference between these methods is that the SPLP method uses laboratory water at the pH of rain water, while the new leach method uses a sample of the overlaying water in the CWTS. Therefore, the leach method is more representative of actual potential leachability of the soils into the wetland than is the SPLP method. In 2016 there was an overall decrease in leachable aluminum and copper from a depth of 0-10 cm (Table 8 and Appendix D). The B cells experienced a significant decrease of leachable copper of approximately 80% between June 15 and September 7, 2016. Cell 1A decreased 53%, and cell 2A had very little change in leachable copper. Cells 1A, 2A, and 2B experienced a similar decrease of leachable aluminum between 70% and 77%. Cell 1B experienced a decrease of leachable aluminum of 54%.

In 2016 there was an overall increase in leachable copper from a depth of 10-20 cm: cell 1A increased by 25%, cell 1B increased by 32%, cell 2A increased by 46%, and cell 2B increased by 7% (Table 8). In 2016 there was a decrease in leachable aluminum from 28% to 58% at a depth of 10-20 cm in cell 1A, 1B, and 2A. Cell 2B increased in leachable aluminum by 49% (appendix D).

Analysis of the soils by ICP-MS with sequentially extracted acid analysis shows that despite elevated initial leachable copper concentrations, the soils have become more stable (less leachable) over time in the wetland setting as the soils have aged (Figure 8). This beneficial aging of soils to a less soluble mineralized form of sulphide is expected for this type of treatment wetland design. It should be noted that due to the starting soil substrate containing leachable copper and other metals such as aluminum (Appendix B) that these elements are leaching from the substrate into the water, putting additional treatment demands on the systems.

The evapotranspiration study also confirmed that due to copper, metals, and metalloids in the initial substrates placed in the soils, constituents continue to leach from the substrate as these constituents shift from oxidized fractions 2 and 3 to reduced fraction 4 (Appendix B). Copper concentrations in the CWTS increased on average from 58 µg/L in in 2016 prior to evaporation study, to an average 80 µg/L during the evapotranspiration study. Additionally, aluminum concentrations in the CWTS in 2016 increased on average from 10.9 µg/L prior to evaporation study, to an average 32 µg/L during the evapotranspiration study. Molybdenum, selenium, and zinc all decreased in concentrations during the evapotranspiration study compared to the average concentration prior to the study in 2016. Molybdenum decreased from ~7.5 µg/L to ~6.0 µg/L, selenium decreased from ~3.3 µg/L to ~1.3 µg/L, and zinc decreased from ~52 µg/L to ~28 µg/L. Cadmium concentrations were so low that there was not a notable change in concentration during the evaporation study.

It is noted that the increase in copper concentration during the evapotranspiration trial is not representative of what would occur during periods with no flow in a full-scale system, where soils with minimal leachable copper are used and copper is deposited in sulphide form (fraction 4) by the biogeochemical activity of the CWTS. Rather, enhanced removal of constituents such as copper and selenium is expected during these periods as the system becomes more reducing with no flow. In the case of the demonstration-scale wetland, due to the elements switching from oxidized to reduced forms in the soils, the increased concentration of some constituents is seen despite a substantial decrease of sulphate. That is, there are more metals switching from oxidized to reduced forms, than sulphides being produced during this time based on available organic carbon to produce the sulphides (sulphate decreased from ~134 mg/L to ~104 mg/L). This was one of the pieces of data that prompted the addition of carbon sources to the wetland to initiate commissioning-B and address these remaining oxidized metals in the CWTS. If metals continue to leach in 2017, flows could be stopped temporarily to promote this shift from oxidized to reduced forms, with the additional carbon sources of straw and wood chips now available for the bacteria to use to produce more sulphides for metals treatment.

For the CWTS to treat the copper from the soils, additional organic carbon is needed beyond that necessary for the waters alone. Organic carbon is contributed to the CWTS through decomposition of plant material as the wetland matures. However, in 2015 the CWTS did not host enough plants that would decompose and contribute organic carbon in 2016 to the wetland, as plants were still establishing. Therefore, in 2016 additional carbon was added to the wetland in the form of woodchips and straw (Section 5.1). Organic carbon is used as food by the microbes, which in turn produce sulphides which drive metals treatment through mineralization by coupled biogeochemical processes. Presently, as there are excess copper forms transitioning from oxidized to reduced in the soils, these will bind to the sulphides, transforming them to the sulphide bound fraction 4 (Table 7). This in turn impacts the ability to treat water, as it uses the available electrons and results in insufficient sulphides to treat metals in the water. When the mineral fractions of the soils have completed transforming the oxidized copper in the soils to a sulphide bound fraction 4 mineral, the soils will no longer be sulphide hungry, allowing for the soil-produced sulphides to be utilized for metals treatment in the water. This progress can be followed by the Tessier extractions, and also by the appearance of acid volatile sulphides (AVS) in the soils. AVS was tested for in 2016 prior to adding the straw and wood chips and was non-detectable (hence, the decision to add the straw and wood chips). The appearance of measurable AVS over time will indicate that the microbes in the soil have worked through the additional copper and the wetland should start performing the way it should have had soils with high leachable copper not been used. In 2017 an AVS soil test should be conducted to determine if the soils have completed the transition to fraction 4.

It is recommended that for construction of the full-scale systems, soils with low total and leachable copper concentrations should be used. Additionally, to supplement carbon until the vegetation has fully established, solid phase organic carbon (e.g., straw, woodchips) should be mixed into the soils. After plants have begun to grow, but are not yet fully mature and able to provide enough annual carbon to the wetland through their growth, solid phase organic carbon can also be added into the wetland in the same way as was done in the demonstration-scale CWTS in 2017.

**Table 8 – Total and leachable soil copper concentrations in first year of operations.**

| CWTS Cell | Sampling Date | Days in Operation | Sample Depth (cm) | Total Cu (mg/kg) | SPLP Cu (mg/L) | Leachable Cu (mg/kg) |
|---|---|---|---|---|---|---|
| 1A | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 960 | 0.055[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 950 | 0.187 | - |
| | 18-Sep-15 | 149 | 10-20 | 1300 | 0.049 | - |
| | 29-Sep-15 | 160 | 10-20 | 910 | 0.069 | - |
| | 15-Jun-16 | 194 | 0-10 | 1440 | - | 0.953 |
| | 15-Jun-16 | 194 | 10-20 | 1210 | - | 0.66 |
| | 8-Jul-16 | 217 | 0-10 | 1430 | - | 0.603 |
| | 8-Jul-16 | 217 | 10-20 | 1730 | - | 0.832 |
| | 7-Sep-16 | 247 | 0-10 | 1290 | - | 0.449 |
| 1B | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 1400 | 0.033[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 1400 | 0.209 | - |
| | 18-Sep-15 | 149 | 10-20 | 830 | 0.065 | - |
| | 29-Sep-15 | 160 | 10-20 | 880 | 0.059 | - |
| | 15-Jun-16 | 194 | 0-10 | 1130 | - | 1.01 |
| | 15-Jun-16 | 194 | 10-20 | 1240 | - | 0.822 |
| | 8-Jul-16 | 217 | 0-10 | 1250 | - | 1.11 |
| | 8-Jul-16 | 217 | 10-20 | 1620 | - | 1.21 |
| | 7-Sep-16 | 247 | 0-10 | 1190 | - | 0.197 |
| 2A | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 1175 | 0.037[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 660 | 0.139 | - |
| | 18-Sep-15 | 149 | 10-20 | 880 | 0.081 | - |
| | 29-Sep-15 | 160 | 10-20 | 1000 | 0.073 | - |
| | 15-Jun-16 | 194 | 0-10 | 1100 | - | 0.823 |
| | 15-Jun-16 | 194 | 10-20 | 1280 | - | 0.900 |
| | 8-Jul-16 | 217 | 0-10 | 1450 | - | 0.963 |
| | 8-Jul-16 | 217 | 10-20 | 1150 | - | 1.68 |
| | 7-Sep-16 | 247 | 0-10 | 1290 | | 0.838 |

**Table 8 – Continued.**

| CWTS Cell | Sampling Date | Days in Operation | Sample Depth (cm) | Total Cu (mg/kg) | SPLP Cu (mg/L) | Leachable Cu (mg/kg) |
|---|---|---|---|---|---|---|
| 2B | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 1100 | 0.039[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 1000 | 0.201 | - |
| | 18-Sep-15 | 149 | 10-20 | 830 | 0.078 | - |
| | 29-Sep-15 | 160 | 10-20 | 540 | 0.059 | - |
| | 15-Jun-16 | 194 | 0-10 | 1040 | - | 0.771 |
| | 15-Jun-16 | 194 | 10-20 | 1310 | - | 1.16 |
| | 8-Jul-16 | 217 | 0-10 | 1070 | - | 1.38 |
| | 8-Jul-16 | 217 | 10-20 | 1180 | - | 1.25 |
| | 7-Sep-16 | 247 | 0-10 | 1520 | - | 0.123 |

[1] Samples collected in June 2015 were at a shallow depth (0-5 cm) and copper content had therefore likely already been removed by washing from the faster flows of the CWTS system. The aging of the deeper (10-20 cm) soil copper concentrations over time to a less soluble form is shown in Figure 8.
The blue shading indicated samples that were taken from a shallower depth.

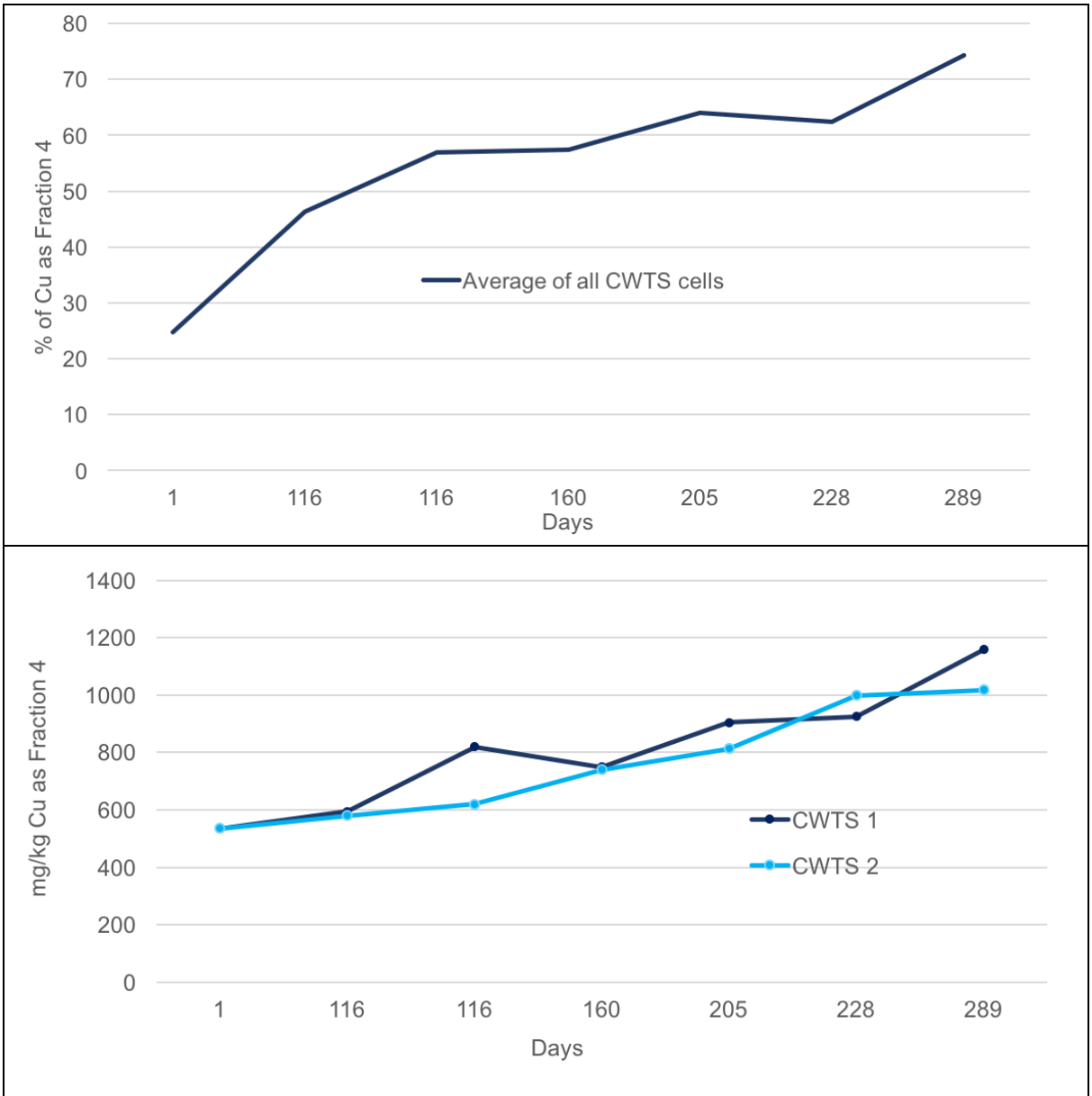



**Figure 8 – Copper as sequential leach fraction 4 over time.**
Copper in the form of the targeted Fraction 4 (sulphide mineral form and bound to organics), increased in the CWTS over time as the soils matured. Additional information in Appendix B.

### 6.2.Water

#### *6.2.1. Pilot-scale testing performance*

Pilot-scale testing was performed with water that mimicked the worst-case long-term post-closure water chemistry (mean influent concentrations of 146 µg/L copper and 10.2 µg/L selenium). In contrast, the on-site demonstration-scale system uses water from the sump downslope of the dry stack tailings facility and the MVFE (W36 or W62) and therefore

has inflow concentrations that are currently occurring during operations (mean influent concentrations of 58 µg/L copper and 6 µg/L selenium). Because of this, a lower percent removal will achieve the same extent of removal and associated outflow concentrations than was required in the pilot-scale systems. For example, the pilot-scale system achieved on average 92% removal of copper (mean outflow of 11.3 µg/L) and 41% removal of selenium (mean outflow of 6 µg/L). To achieve these same outflow concentrations with the demonstration-scale system, 80% removal of copper and minimal (or no) removal of selenium would be needed.

### *6.2.2. Demonstration-scale metal leaching from soils*

The treatment of copper has been improving through commissioning as the system has matured (Figure 16). However, as shown in Figure 10 and Figure 12 several elements are being released through the wetland by the soils, such as aluminum, and copper (as discussed in Section 6.1). Because of this, negative percent removals of copper have been observed, especially in early operations (Appendix B). It was initially theorized that this was occurring when the May and June 2015 data reported outflow concentrations higher than the influent. This paired with the soils data (Section 6.1 and Appendix A) led to the design of a new sampling scheme to determine whether detectable levels of metals were being released from the soils within the wetland (2015) and to monitor this (2016). For two timepoints in 2015 (August 15, 2015 and September 17, 2015) and 2 timepoints in 2016 (June 14, 2016 and September 7, 2016), water was sampled not only at the feed and the outflow of each cell, but also through the cell. Beginning at the outflow of cell B and working upwards towards the feed, samples were taken at the B cell outflow, B cell mid-point, and B cell inflow, and then the same 3 points for the A cell (Figure 9). In each case, the sample was taken from within a reaching distance of the side shore to ensure that sediments were not suspended in sampling.

Since the beginning of operations of the demonstration-scale CWTS, significant concentrations of copper have been leaching from the wetlands soils of all cells (Figure 12). Moreover, metal types and concentrations (e.g., Aluminum, Appendix B) that could not be accounted for by the influent water chemistry were elevated at random points within the wetland. This suggested that because of metals leaching from the soils, the treatment occurring within the wetlands was far greater than what was being observed by simply measuring the inflow and outflow points (Figure 16). For example, in August of 2015, influent copper concentrations were measured as 50 µg/L, but within the first meter of cell 1A increased to 100 µg/L, and by the outflow of cell 1A, down to 42 µg/L (58 µg/L decrease), they then increased to 70 µg/L at the beginning of cell B, and again were treated to a final outflow concentration of 40 µg/L (30 µg/L decrease) for a total of at least 88 µg/L removed by Series 1 of the treatment wetland. This suggested the wetland is achieving much greater copper treatment (88 µg/L removed), than would be suggested by only measuring the inflow and outflow of the system (suggests 10 µg/L removed). Similar leaching was observed through the wetland during testing in September 2015.

When the flow through the wetland was tested for metals leaching from soils in September 2016, influent copper concentrations were measured as 51 µg/L, but within the first meter of cell 1A increased to 74 µg/L, and by the midpoint of cell 1A they decreased to 36 µg/L and at

the outflow of cell 1A, increased to 40 µg/L (i.e., a net 39 µg/L decrease, although only appearing as 14 µg/L compared to inflow). Copper concentrations were 34 µg/L at the beginning of cell B, and again were treated to a final outflow concentration of 28 µg/L (6 µg/L decrease) for a total of at least 45 µg/L removed by cells A and B of Series 1 of the treatment wetland. This suggests the wetland is achieving much greater copper treatment (45 µg/L removed), than would be suggested by only measuring the inflow and outflow of the system (suggests 23 µg/L removed). Copper continues to leach from the wetland soils, however the amount of leaching has decreased in 2016, with an 80% decrease in leachable copper from the soil in B cells, and 50% decrease in leachable copper in cell 1A, and cell 2A has become more stable with little change in leachable copper through 2016 (Figure 12).

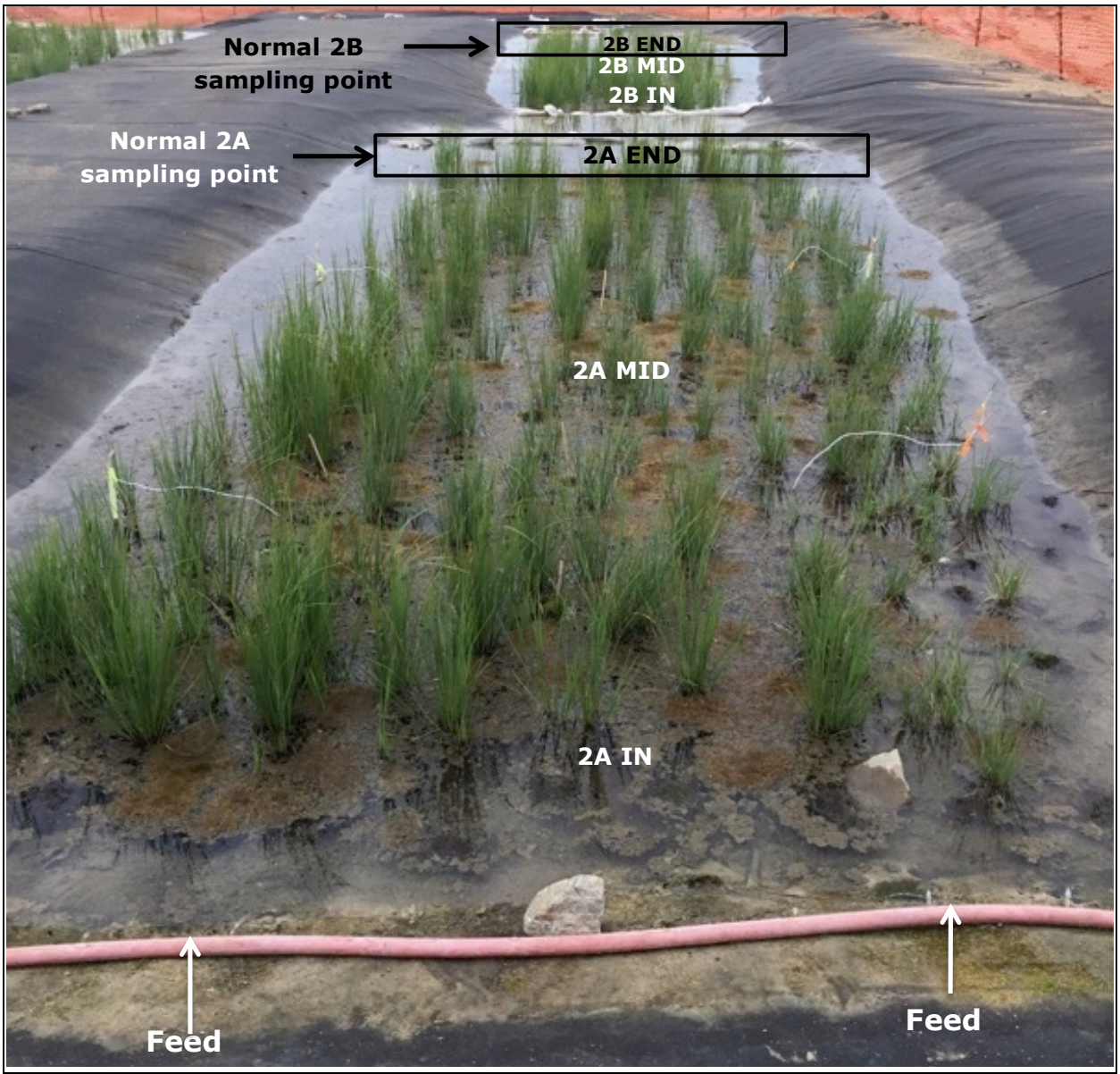



**Figure 9 – Sampling points through the CWTS (Photo taken August 16, 2015).**

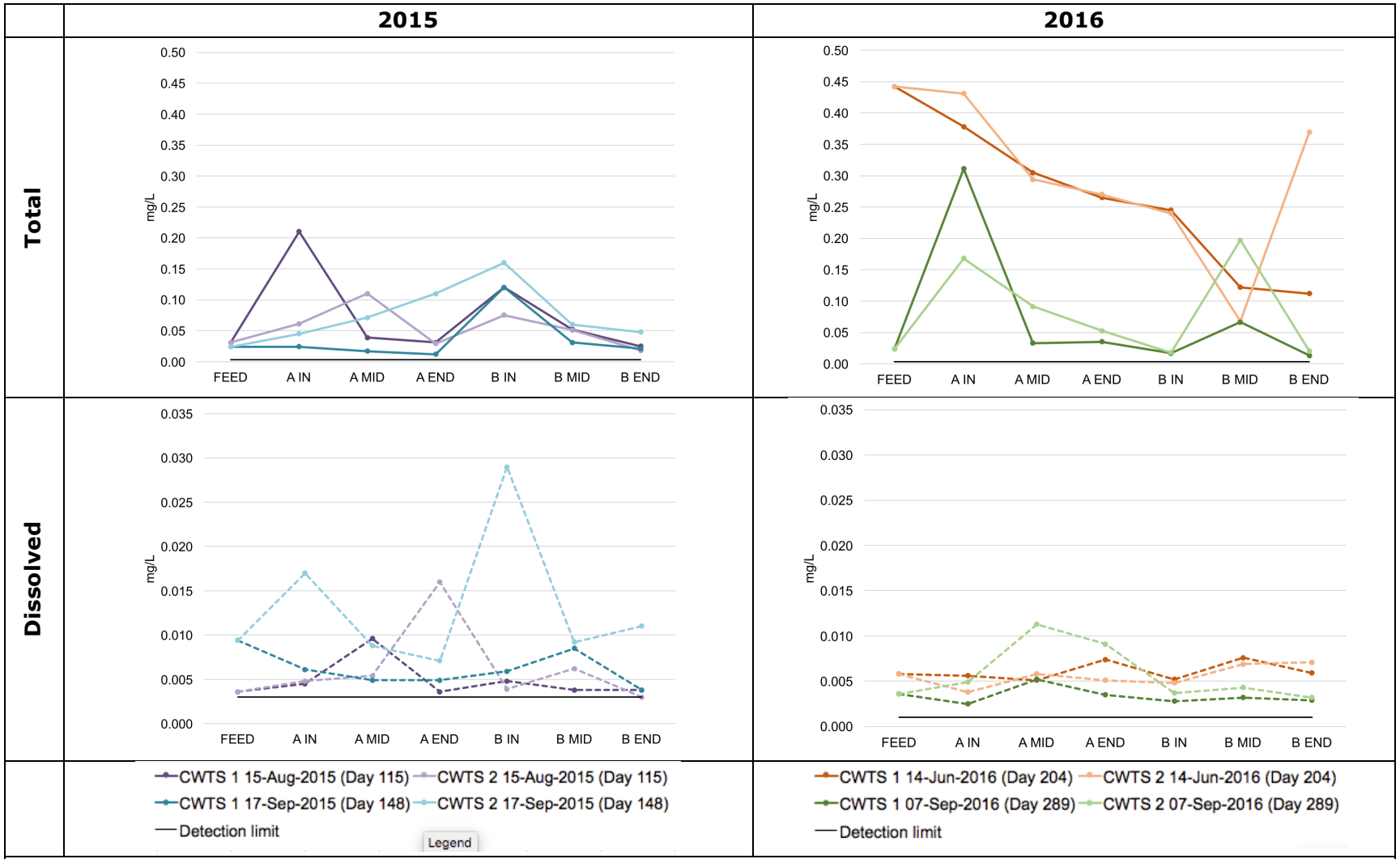



**Figure 10 – Aluminum concentrations through the CWTS.**
Left is 2015, right is 2016, top graphs are total concentrations and bottom graphs are dissolved concentrations. Data shown for four timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. Y-axes are set to be the same for total and the same for dissolved. The Maxxam (2015 results) detection limits for aluminum are 0.0030 mg/L. The ALS (2016 results) dissolved aluminum detection limit is 0.0010 mg/L, and the total aluminum detection limit is 0.0030 mg/L.




**Figure 11 – Cadmium concentrations through the CWTS.**
Left is 2015, right is 2016, top graphs are total concentrations and bottom graphs are dissolved concentrations. Data shown for four timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. Y-axes are set to be the same for total and the same for dissolved. The Maxxam (2015 results) detection limits for cadmium are 0.020 µg/L. The ALS (2016 results) detection limits are 0.005 µg/L.

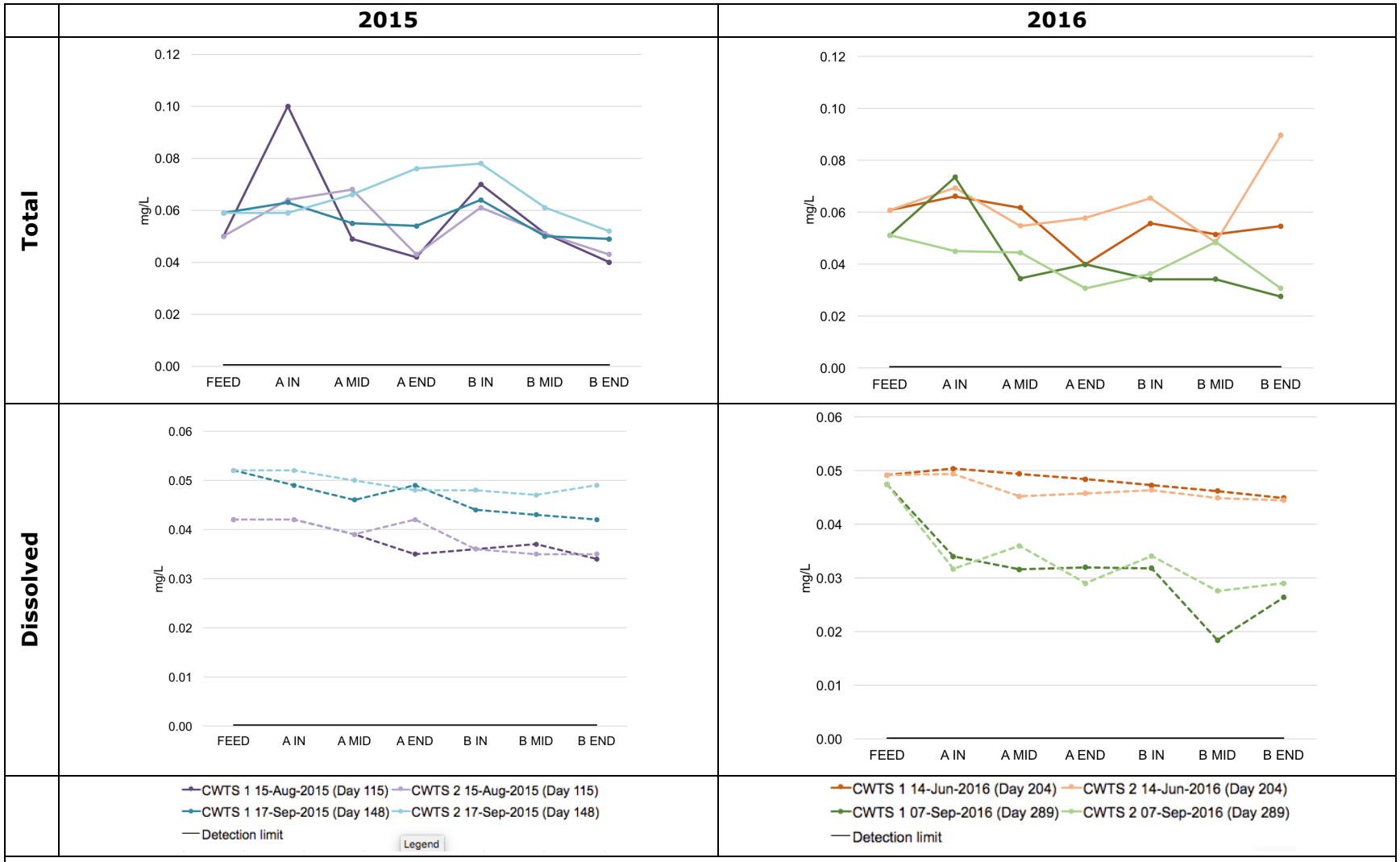



**Figure 12 – Copper concentrations through the CWTS.**
Left is 2015, right is 2016, top graphs are total concentrations and bottom graphs are dissolved concentrations. Data shown for four timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. The Maxxam (2015 results) detection limits for copper are 0.0002 mg/L. The ALS (2016 results) detection limits for copper are 0.0005 mg/L.




**Figure 13 – Molybdenum concentrations through the CWTS.**
Left is 2015, right is 2016, top graphs are total concentrations and bottom graphs are dissolved concentrations. Data shown for four timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. Y-axes are set to be the same for total and dissolved. The Maxxam (2015 results) detection limits for molybdenum are 0.0002 mg/L. The ALS (2016 results) detection limits are 0.000050 mg/L.

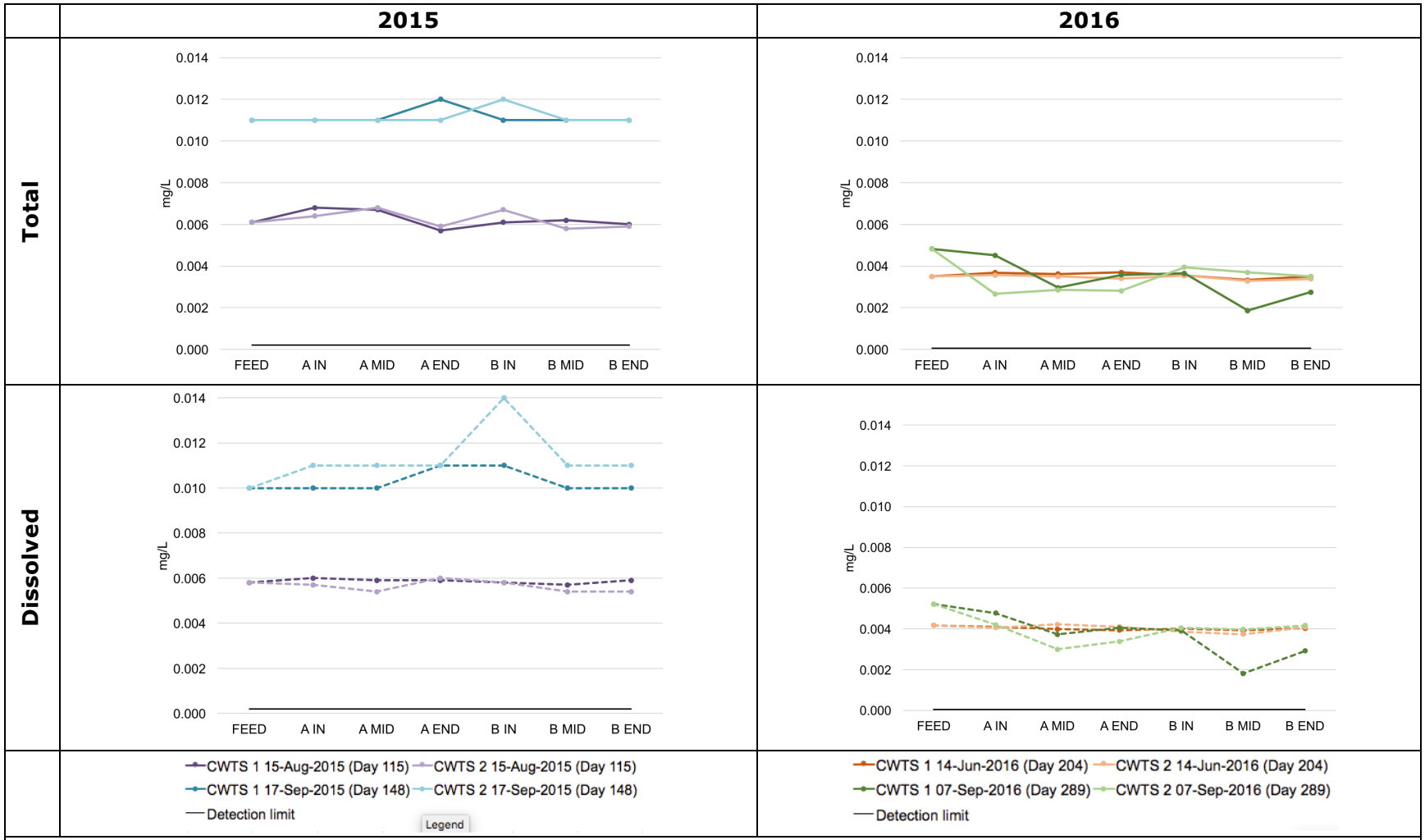



**Figure 14 – Selenium concentrations through the CWTS.**
Left is 2015, right is 2016, top graphs are total concentrations and bottom graphs are dissolved concentrations. Data shown for four timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. Y-axes are set to be the same for total and dissolved. The Maxxam (2015 results) detection limit for selenium is 0.0002 mg/L. The ALS (2016 results) detection limit is 0.000050 mg/L.

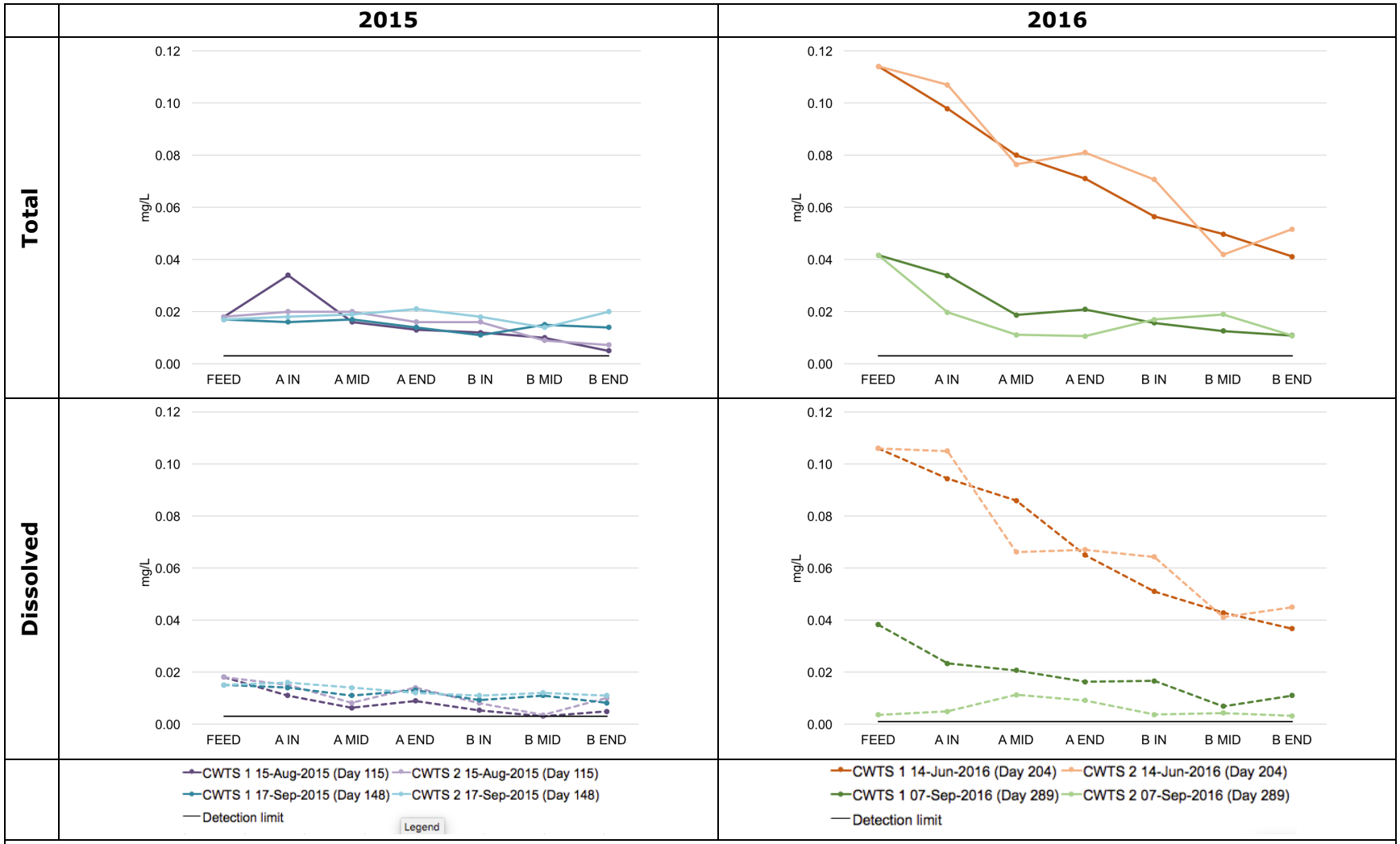



**Figure 15 – Zinc concentrations through the CWTS.**
Left is 2015, right is 2016, top graphs are total concentrations and bottom graphs are dissolved concentrations. Data shown for four timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. Y-axis is set to be the same for total and dissolved. The Maxxam (2015 results) detection limit for zinc is 0.0030 mg/L. The ALS (2016 results) detection limit is 0.0010 mg/L.

### *6.2.3. Demonstration-scale performance during commissioning-A*

By the end of 2015 the outflow concentration for dissolved cadmium, was on average 49% lower than influent concentrations, with average influent concentrations of 0.0505 µg/L decreasing to an average outflow concentration of 0.0248 µg/L. During commissioning-A in 2016 treatment decreased to an average removal of 40%, with average influent concentrations of 0.0240 µg/L decreasing to an average outflow concentration of 0.0142 µg/L. Dissolved copper also experienced the same trend with an average outflow concentration 17% lower than influent concentrations at the end of 2015, with average influent concentrations of 54.5 µg/L decreasing to an average outflow concentration of 45.0 µg/L. During commissioning-A in 2016, treatment decreased to an average removal of 8%, with average influent concentrations of 61.6 µg/L decreasing to an average outflow concentration of 56.7 µg/L. Molybdenum experienced no treatment through commissioning-A in 2015 and 2016, with average outflow concentrations being very similar to average influent concentrations. Dissolved selenium also experienced no treatment through commissioning-A in 2015, however by the end of commissioning-A in 2016 dissolved selenium was on average 8% lower than influent concentrations, with average influent concentrations of 3.7 µg/L decreasing to an average outflow concentration of 3.4 µg/L. By the end of 2015 the outflow concentration for dissolved zinc, was on average 42% lower than influent concentrations, with average influent concentrations of 12.3 µg/L decreasing to an average outflow concentration of 6.8 µg/L. During commissioning-A in 2016 treatment increased to an average removal of 47%, with average influent concentrations of 92.8 µg/L decreasing to an average outflow concentration of 49.0 µg/L lower than influent concentrations.

### *6.2.4. Elevated zinc in influent in 2016*

The concertation of zinc in the influent to the CWTS increased significantly in 2016 compared to 2015 concentrations (Table 9, Figure 15, and Figure 20). It is uncertain whether the increase in zinc is a result of the change in sump source water location at the toe of the MVFE, where a metal culvert was installed at the beginning of operations in 2016 (Section 2.4), or if this is a result of seasonal variation.

### *6.2.5. Demonstration-scale performance during commissioning-B*

After commissioning-A was complete at the end of July 2016, cadmium, copper, molybdenum, selenium, and zinc were being treated by the CWTS (Figure 16 to Figure 21 and Appendix B), while other metals/metalloids of potential concern as outlined in the Adaptive Management Plan (AMP) (Minto, 2016) were below the non- degradation central tendency water quality objectives (NDCT-WQO) for the Lower Minto Creek (W2) area.

Dissolved cadmium treatment improved through the commissioning-A period in 2016 to achieve on average 64% removal during the commissioning-B period from July 29 to September 30, 2016, with average influent concentrations of 0.0185 µg/L decreasing to an average outflow concentration of 0.0066 µg/L (Table 9, Figure 16 and Appendix B) Copper, and zinc experienced the same trends with treatment improving through the commissioning-A period in 2016 to achieve on average 37% and 69% removal during the commissioning-B

period from July 29 to September 30, 2016 (Table 9, Figure 17, Figure 20, and Appendix B). During the commissioning-B period, the average influent concentrations for copper (46.1 µg/L) decreased to an average outflow concentration of 28.8 µg/L. During the same time period the average influent concentrations for zinc (37.6 µg/L) decreased to an average outflow concentration of 11.6 µg/L. The treatment of molybdenum and selenium in 2016 is notable as there was minimal treatment in 2015, improving through 2016 to achieve on average 21% and 41% removal during the commissioning-B period from July 29 to September 30, 2016 (Table 9, Figure 18, Figure 19, and Appendix B). This suggests that not only is the wetland maturing as expected, creating reducing sulphide-producing conditions, but that it is already performing far beyond what was anticipated from the design, sequestering orders of magnitude more copper than would be apparent by looking at the influent water alone (i.e., is also removing copper that has leached from the soils over time). All constituents of concern have percent removal rates that continue to trend upward and are becoming more stable as the wetland matures.

**Table 9 – Percent removal of constituents in the demonstration-scale CWTS.**

| Element (µg/L) | | Pilot-scale[1] | Demonstration-scale | | | |
|---|---|---|---|---|---|---|
| | | 2013 | 2014 | 2015[2] | 2016 [3] | 2016[4] |
| **Cd** | In | 0.336 | NA | 0.0505 | 0.0240 | 0.0185 |
| | Out | 0.027 | NA | 0.0248 | 0.0142 | 0.0066 |
| | **%** | **92** | NA | **49** | **40** | **64** |
| **Cu** | In | 146 | NA | 54.5 | 61.6 | 46.1 |
| | Out | 11.3 | NA | 45.0 | 56.7 | 28.8 |
| | **%** | **92** | NA | **17** | **8** | **37** |
| **Mo** | In | 13.0 | NA | 11.0 | 7.6 | 7.3 |
| | Out | 10.4 | NA | 11.3 | 7.6 | 5.7 |
| | **%** | **20** | NA | **0** | **0** | **21** |
| **Se** | In | 10.2 | NA | 11.0 | 3.7 | 5.7 |
| | Out | 6 | NA | 11.3 | 3.4 | 3.3 |
| | **%** | **41** | NA | **0** | **8** | **41** |
| **Zn** | In | 40 | NA | 12.3 | 92.8 | 37.6 |
| | Out | 3.2 | NA | 6.8 | 49.0 | 11.6 |
| | **%** | **92** | NA | **42** | **47** | **69** |

[1]The pilot-scale system operated from Nov 4, 2013 to July 16, 2014. The data used in this table is from the low N period in the *carex* and moss system which operated from April 13, 2014 to May 28, 2014.
[2] Values calculated from end last two sampling event in 2015 before the addition of EDTA (September 9 and 17, 2015).
[3] Commissioning-A (May 2, 2016 to July 28, 2016).
[4] Commissioning-B (July 29, 2016 to September 30, 2016).

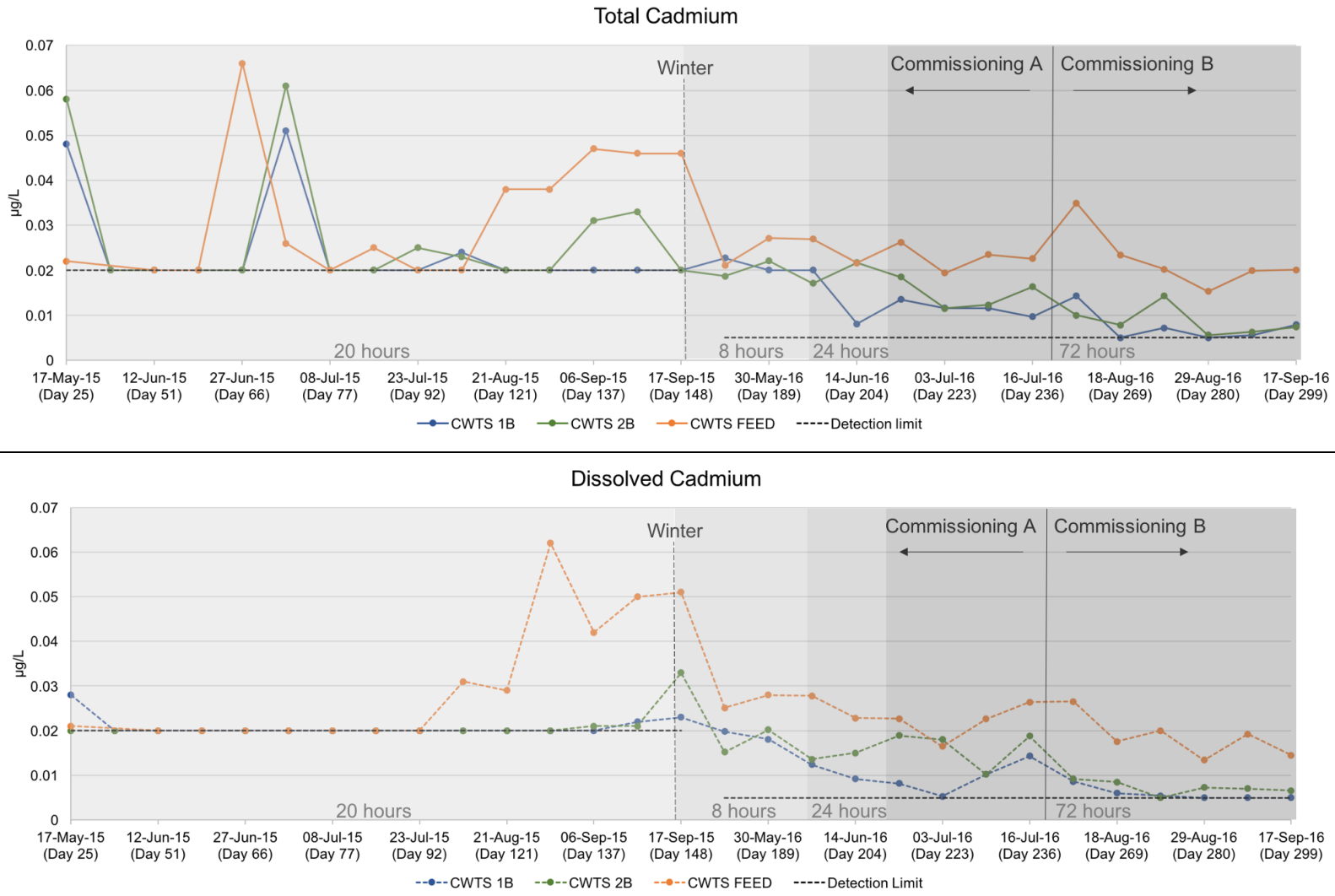
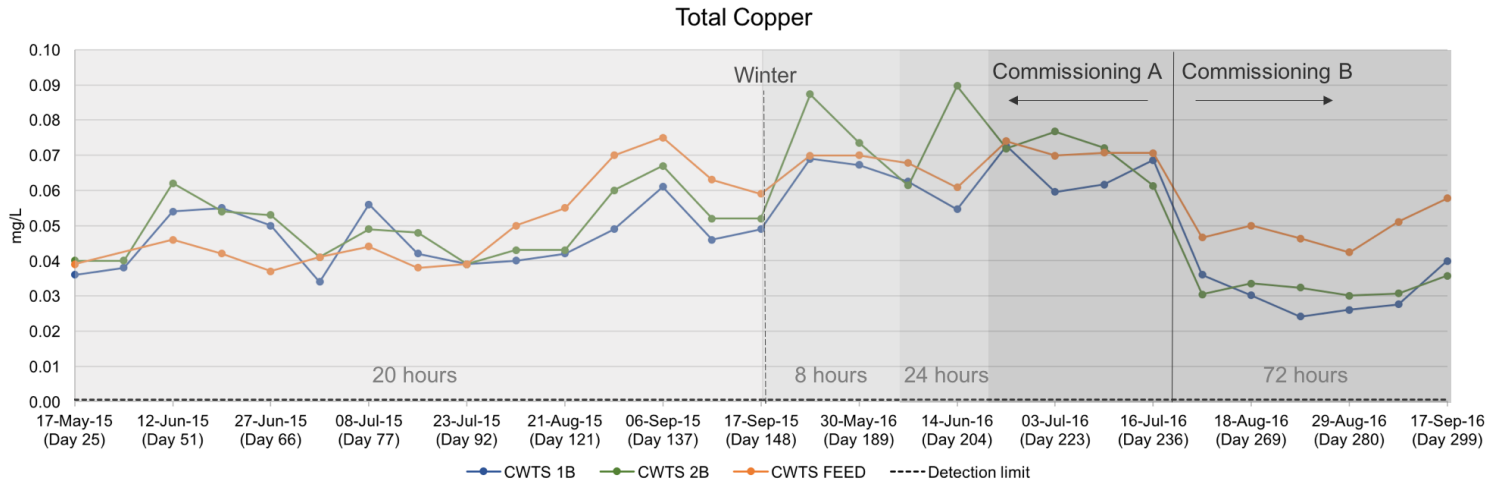



**Figure 16 – Cadmium concentrations in the demonstration scale wetland.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) measurement uncertainty (MU) for cadmium is +/- 0.020 µg/L. The ALS (2016 results) MU is +/- 0.005 µg/L. Timepoints where the dissolved concentration is higher than the total concentration are within the limit of uncertainty.



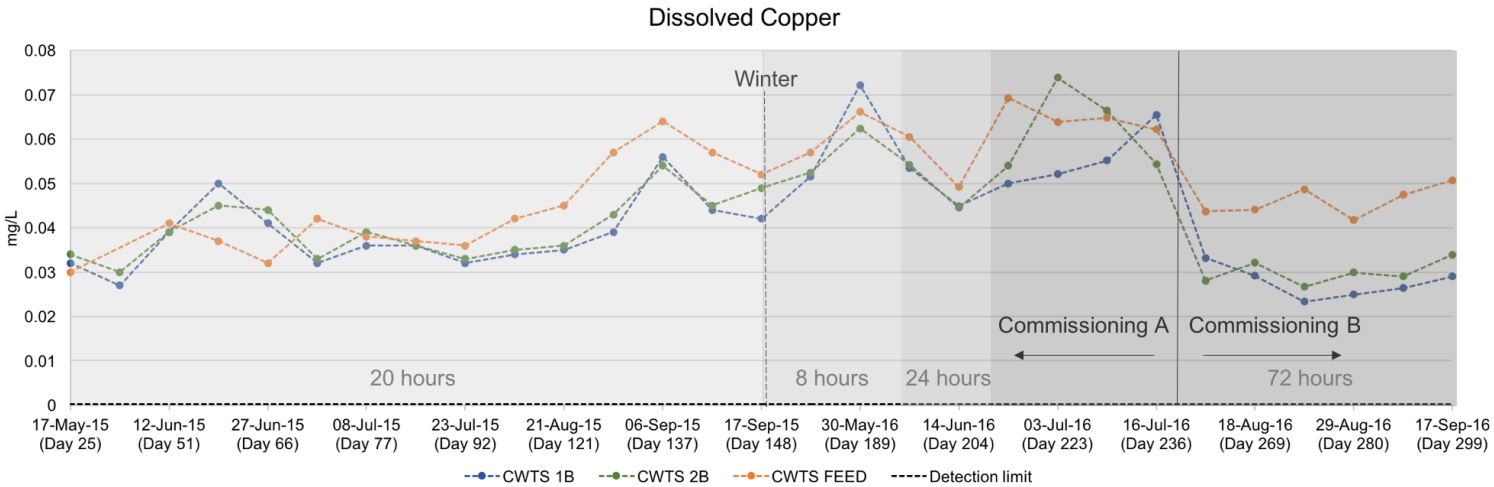




**Figure 17 – Copper concentrations in the demonstration scale wetland.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) and The ALS (2016 results) measurement uncertainty (MU) for copper is +/- 0.0002 mg/L. Timepoints where the dissolved concentration is higher than the total concentration are within the limit of uncertainty.

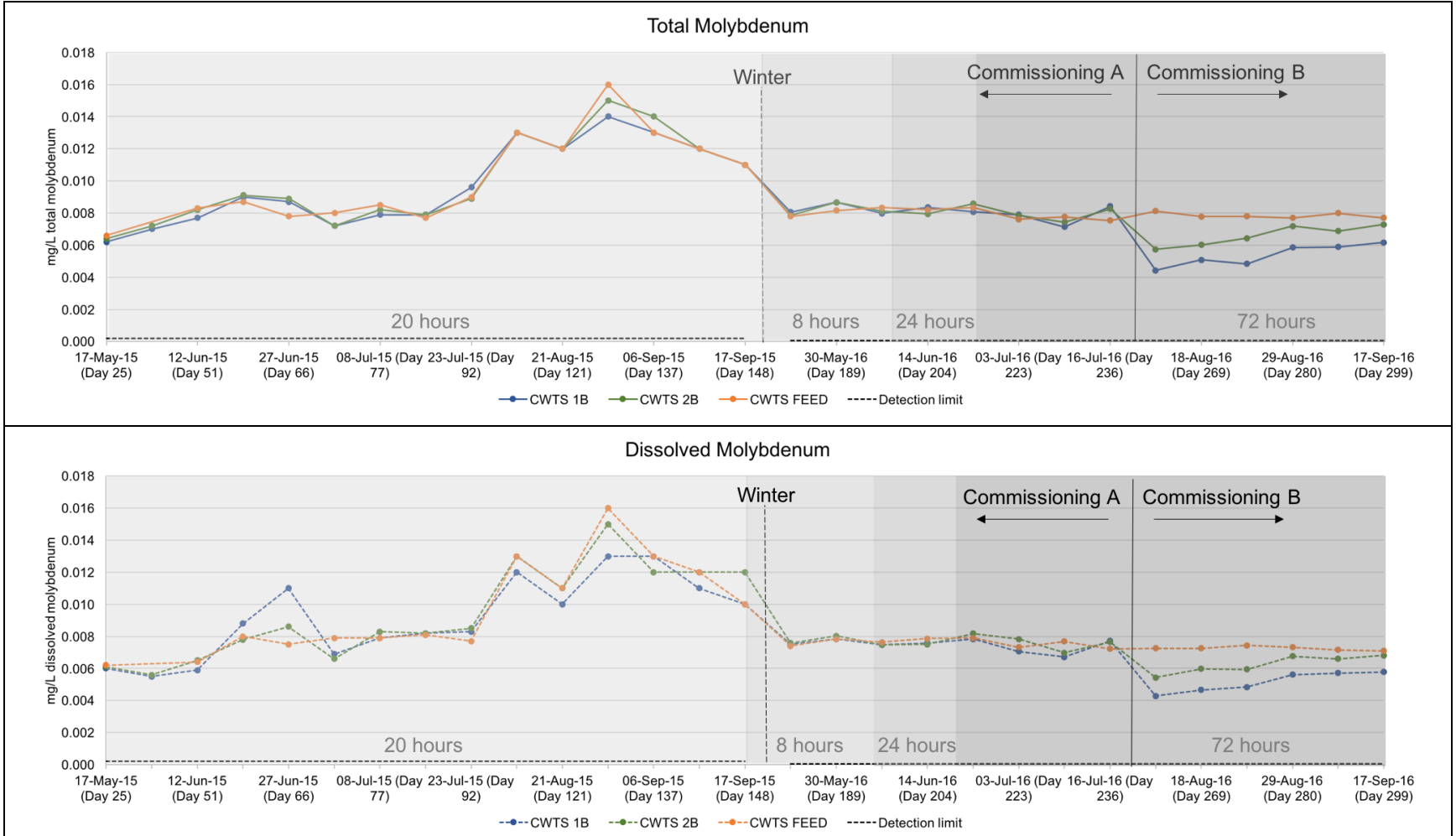
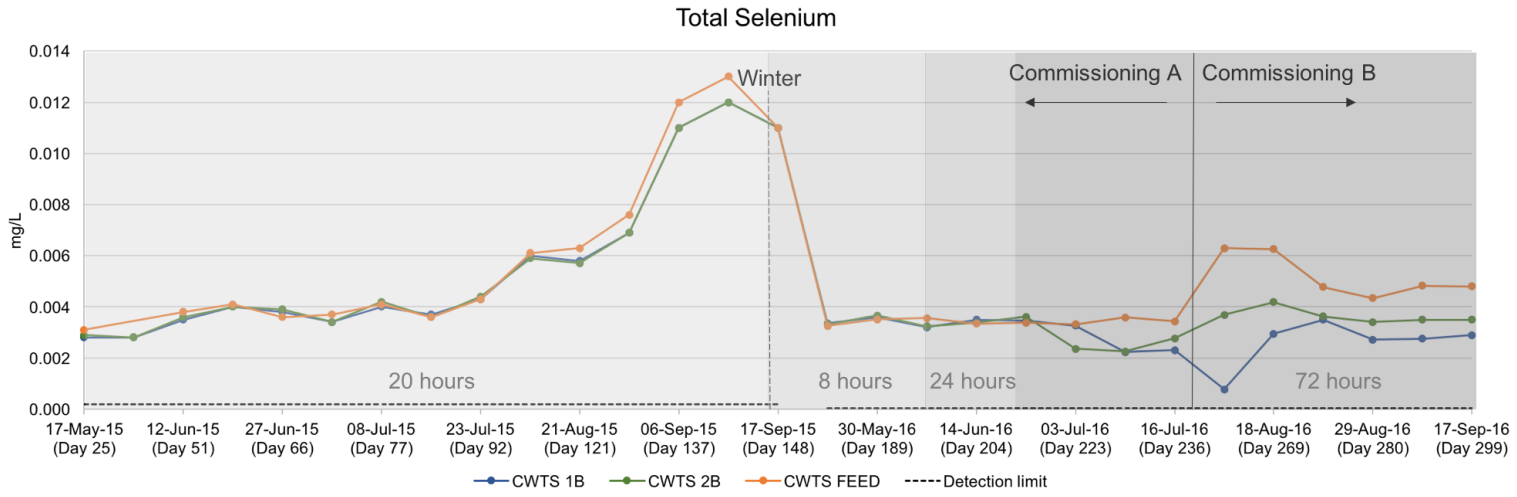



**Figure 18 – Molybdenum concentrations in the demonstration scale wetland.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) measurement uncertainty (MU) for molybdenum is +/- 0.0002 mg/L. The ALS (2016 results) MU is +/- 0.000050 mg/L. Timepoints where the dissolved concentration is higher than the total concentration are within the limit of uncertainty.



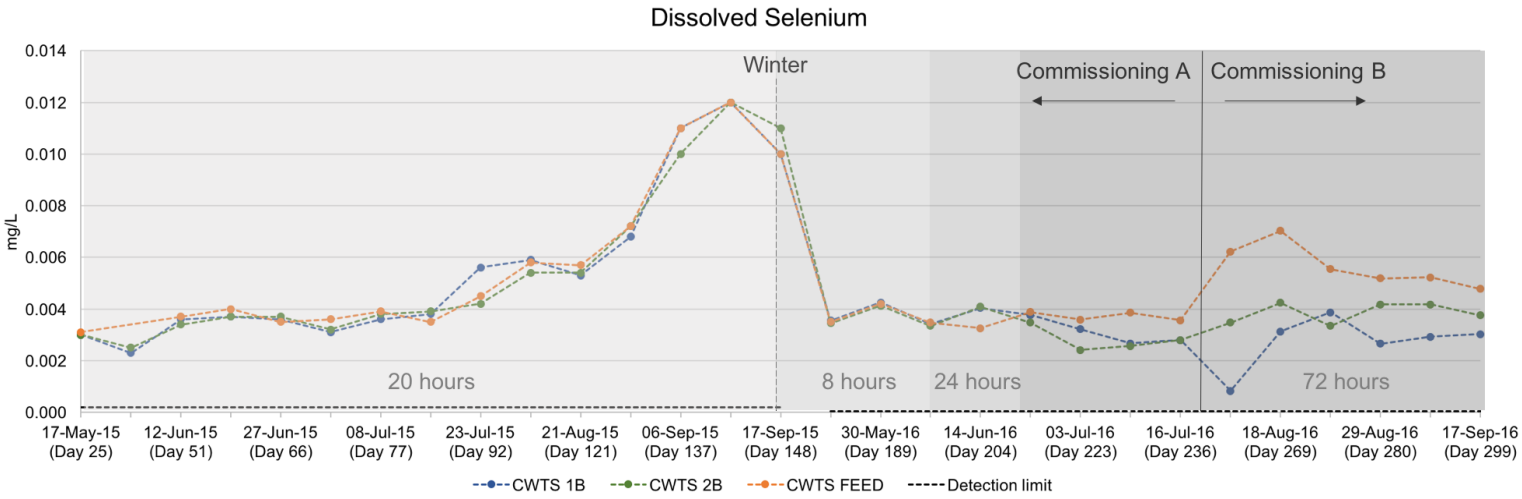




**Figure 19 – Selenium concentrations in the demonstration scale wetland.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) measurement uncertainty (MU) for selenium is +/- 0.0002 mg/L. The ALS (2016 results) MU is +/- 0.000050 mg/L. Timepoints where the dissolved concentration is higher than the total concentration are within the limit of uncertainty.

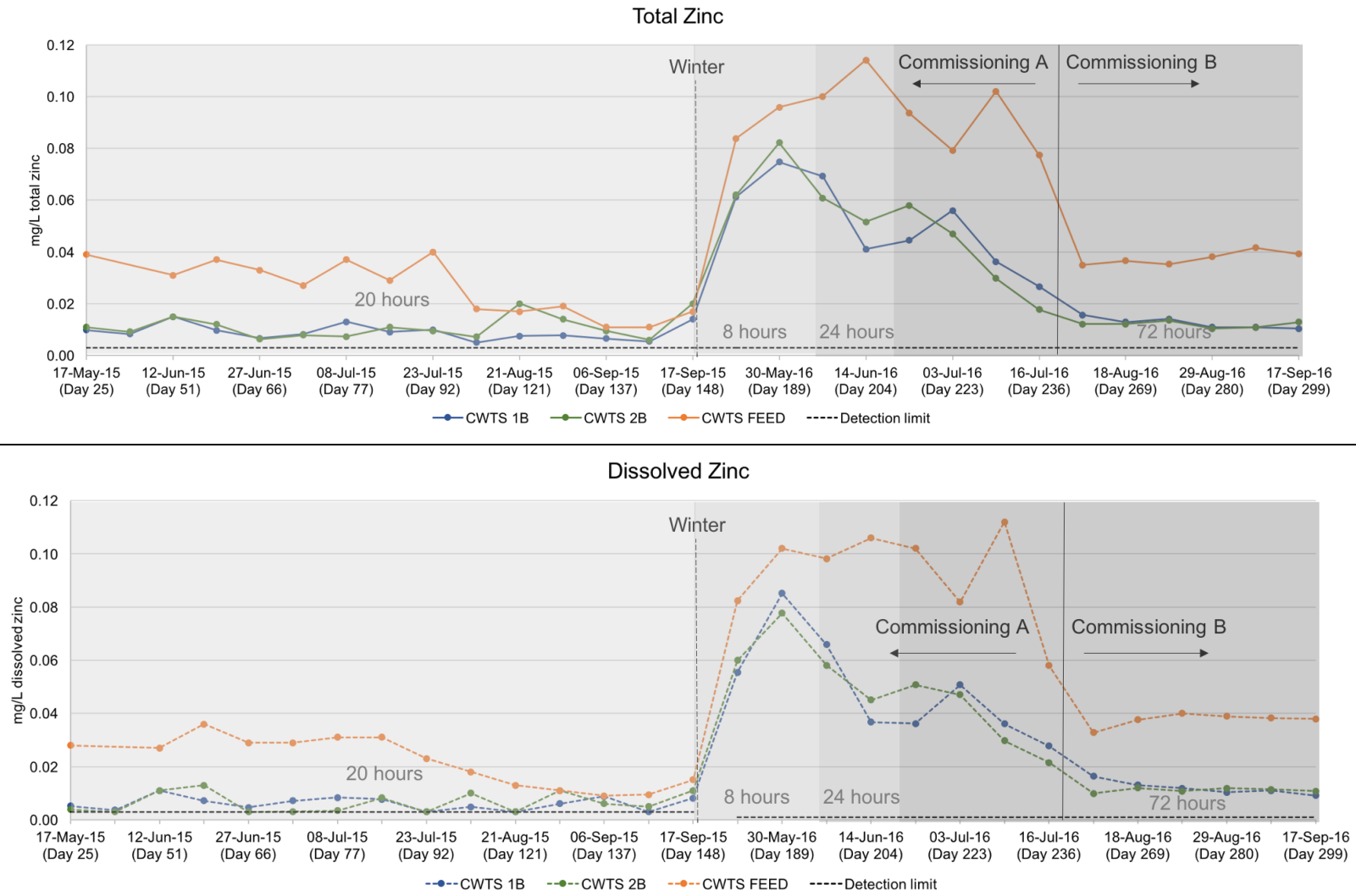



**Figure 20 – Zinc concentrations in the demonstration scale wetland.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) measurement uncertainty (MU) for zinc is +/- 0.0030 mg/L. The ALS (2016 results) MU is +/- 0.0010 mg/L. Timepoints where the dissolved concentration is higher than the total concentration are within the limit of uncertainty.

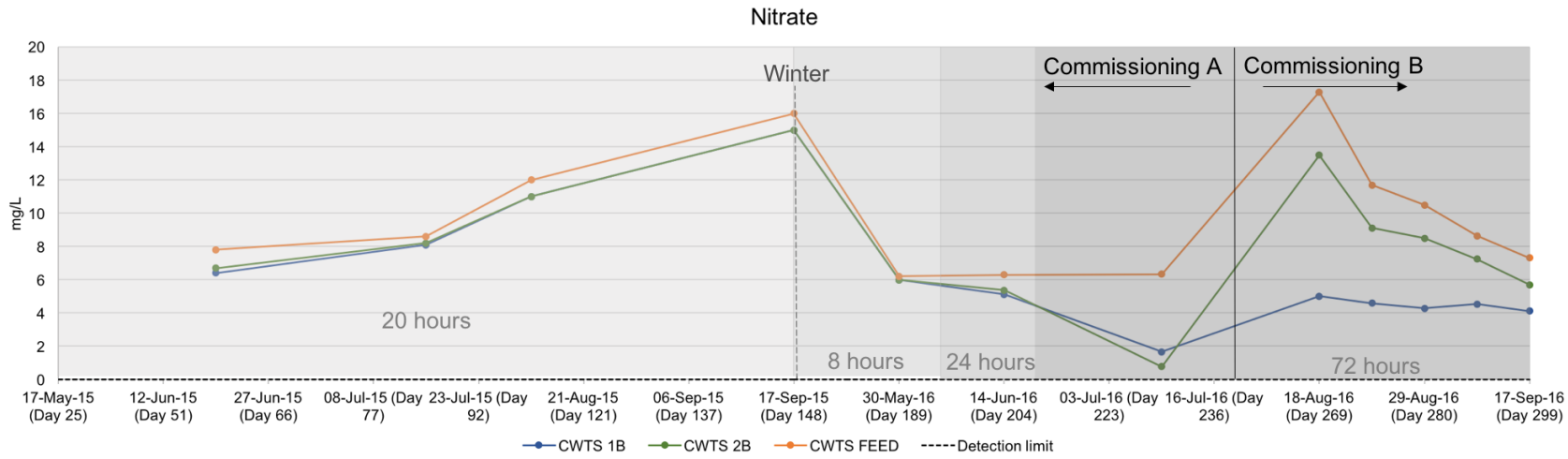



**Figure 21 – Nitrite as N ($NO_2$) and Nitrate as N ($NO_3$) concentrations in the demonstration scale wetland.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) measured uncertainty (MU) for nitrite is +/- 0.010 mg/L. The ALS (2016 results) MU is +/- 0.0010 mg/L. The Maxxam (2015 results) measured uncertainty for nitrate is +/- 0.010 mg/L. The ALS (2016 results) MU is +/- 0.0050 mg/L.

### 6.3.Chelated iron (fertilizer micronutrient) treatment

Because elevated metals were present in the soils used for construction, there was an opportunity to assess whether non-invasive treatments could be used to further leach the metals and improve soil quality. A chelated iron (Fe-EDTA) product was added to the Series 2 wetland on September 17, 2015. The Fe-EDTA treatment was performed on Series 2, with Series 1 remaining untreated for comparison purposes. Increases in copper concentrations were observed in the outflow from both cells in CWTS Series 2 after the addition of Fe-EDTA. In the 10 days following the addition of Fe-EDTA, approximately 75 g of copper was removed from the wetland Series 2. This is approximately 1.25 g of copper per $m^2$ of wetland. Elevated flow rates were selected for CWTS start up in 2016 to flush copper leaching from soil (associated with 2015 EDTA test).

## 7. Hydraulic retention time tracer study

A tracer study was conducted from June 13-15, 2016 on cell 1A of the CWTS with a flow rate of 2.43 GPM (13.25 $m^3$/day). The purpose of the tracer study was to determine the actual hydraulic retention time, and the flow path of water through the CWTS. Salt (NaCl) was used as the tracer in this study. By adding a salt solution at the inflow of the wetland, and placing a YSI meter at the outflow of the wetland, it can be determined how long it takes for the salt to pass through the wetland by monitoring the specific conductance (SPC) in situ (as salt raises the SPC). The HRT of the CWTS can be determined through a calculation using the volume and concentration of salt solution added at the inflow of the wetland and the time over which the specific conductance remains elevated above background levels at the outflow.

The HRT tracer study used 1.87 kg of salt dissolved into 480L of water. The 480 L of water was gradually removed from the end of the CWTS, 20 liters at a time, dosed with salt, and added at the front of the CWTS. This method took 50 minutes to dose in the 480 liters of salt solution into the CWTS and was selected as it did not affect the total volume of water in the CWTS during the HRT tracer study. The volume of water and weight of salt was calculated based on the amount required to increase the specific conductance (SPC) of cell 1A to at least twice its background level (i.e., from 850 µs/cm, to 1700 µs/cm) (Oakton Instruments, 1997). The volume of water used was then selected to ensure the concentration of the salt solution was sufficiently diluted and would mix with the water of the CWTS (i.e., wasn't so dense that it would stratify and sink to the bottom of the CWTS).

In situ monitoring of the HRT tracer study was carried out from June 13, 2016 at 14:52 until June 15 at 12:12. This time period was selected because Contango was on site for 2 days to conduct the HRT tracer study and to collect data. Also the battery life of the YSI unit was approximately 2 days, and at the time, it was not feasible to implement dosing pumps and in situ monitoring (data logging) for a longer period of time. The YSI unit was placed in the wetland for approximately 20 mins prior to starting the HRT tracer study to record background levels before dosing of the salt solution into the CWTS. The background SPC prior to commencing the HRT tracer study was approximately 900 µS/cm. During the tracer study, there were two tracer breakthroughs. The first breakthrough was at 1.03 days (24.72 hours),

with peak SPC at 2228 µS/cm. The second breakthrough was at 0.75 days (18 hours), with a peak SPC of 1928 µS/cm. Based on the results of the two breakthroughs in the HRT tracer study, it is possible that there are two flow paths through the wetland, however, this may also be due to how the salt solution was added to the CWTS.

In 2017 it is recommended that another 1 $m^3$ tank be added to the CWTS area, and another HRT tracer study be conducted. The second $1m^3$ tank could provide a way to mix a lower concentration salt solution, and dose it into the CWTS over a longer period at a constant flow using a metering pump. This would allow the flow rate to be calculated for the duration of time the salt solution is dosed into the CWTS. To conduct the HRT tracer study over a longer period, the YSI unit would need to be connected to a power source due to a limited battery life. By conducting the tracer study in 2017 as described above it is anticipated that only one breakthrough would occur, providing more accurate results.

The data from the 2016 HRT tracer study suggests that the HRT of cell 1A is 0.89 days (21.36 hours), the average of the two breakthroughs. It is possible that not all the tracer salt had yet flowed through the wetland, as SPC had not yet reached original background levels, and so the average HRT may be longer slightly than the 0.89 days observed here. By comparison, the calculated HRT was 0.53 days (12.82 hours), therefore the actual HRT was approximately 40% slower than the calculated HRT. Most of this difference in calculated vs tracer study HRT is owing to the exclusion of pore water involvement in the calculated HRT (because of the soil type used, it was an unknown factor that could not be inferred from the off-site pilot-scale trials). However, part of this difference can also be attributed to loss of water through evapotranspiration (Section 9) which results in a lower flow and therefore longer HRT.

Based on the results of the HRT tracer study, the depth of cell 1A including pore water involvement was able to be calculated following Equation 1. The actual HRT of 0.89 days (21.36 hours) was used to solve Equation 1, resulting in a total depth of 0.35 meters. The measured depth of water in cell 1A was then subtracted from total depth (0.35 meters – 0.16 meters), to obtain a pore water involvement of 0.19 meters. The measured depth of cell 1A was obtained from the depth sticks that were installed in the CWTS in June 2016 (Figure 23).

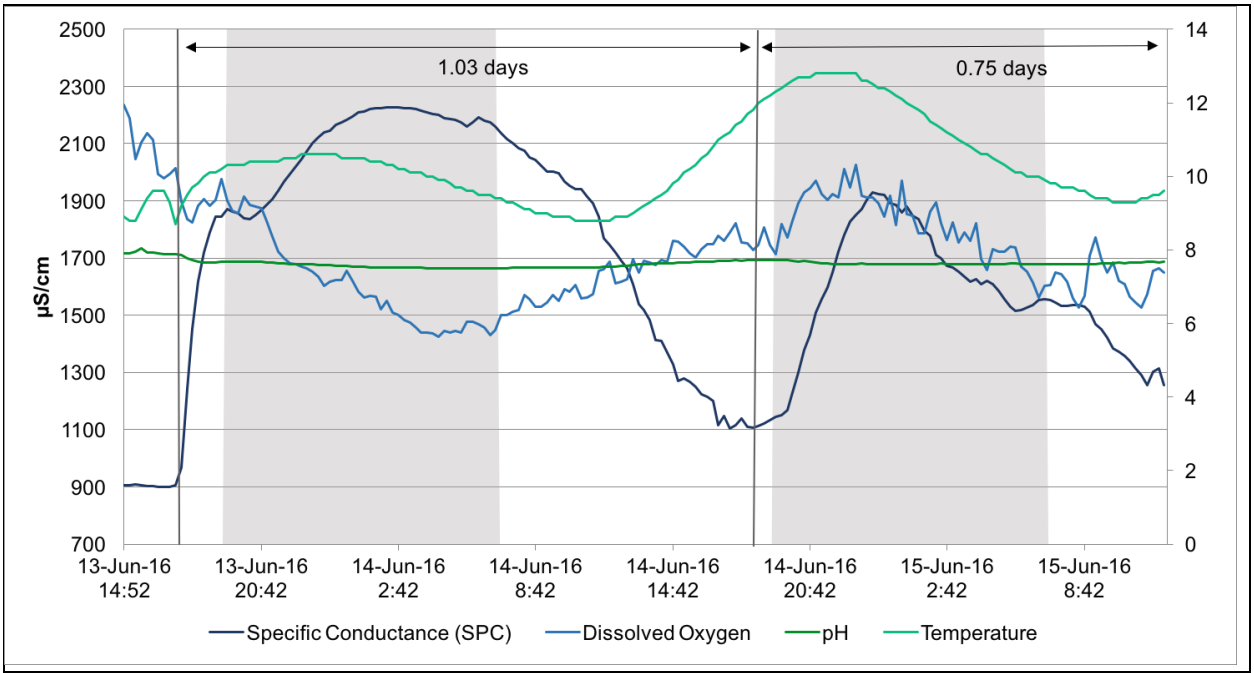



**Figure 22 – Tracer study results.**
SPC (µS/cm) on primary y-axis. Dissolved oxygen (mg/L), pH, and temperature (°C) on secondary y-axis. The grey shading indicated a 12-hour night period from 7am to 7 pm. The vertical black lines indicate the beginning and end of the tracer breakthrough.

$$\text{Depth} = \left({}^{Q}/_{length * width}\right) * \text{HRT}$$

**Equation 1 – Equation for calculation of the CWTS depth including pore water involvement.**
Q is the flow rate.

## 8. Calculations of rate coefficients (*k*)

### 8.1. Rate coefficients

An important factor for CWTS design is the rate of treatment, also known as the treatment (or removal) rate coefficient (*k*). The rate coefficient is based on the treatability of a specific compound and the hydraulic retention time of the system, both of which are site-specific based on water chemistry, wetland designs, and characteristics of the system. A treatment rate coefficient (*k*) was applied for cadmium, copper, molybdenum, selenium and zinc, to develop a conceptual size for the Minto CWTSs and determine which elements and load sources were key for treatment (Table 10). Based on pilot-scale testing for the Minto CWTS, in this site-specific situation, the treatment rate coefficient (*k*) for selenium follows a zero-order reaction kinetic, while the rate coefficients for cadmium, copper, molybdenum, and zinc follow first-order kinetics.

In Equations 2-3, *Cf* is final concentration, *Ci* is initial concentration, and *HRT* is *the* hydraulic retention (Equation 4) time calculated using the CWTS depth result of the tracer study (Equation 1). The HRT was calculated using the volume of each CWTS series including the pore water involvement calculated from the results of the tracer study (Equation 1), and the flow rate from during the time period that *k* was calculated for in 2016 (from August 10 – September 17, 2016) to obtain the HRT.

Using the removal rate coefficients (*k*) in Table 10 and Equations 2-4, parameters can be rearranged to solve for those of interest, such as the volume needed, that in turn determines the area of wetland required which is dependent upon the design. Analytical results from August 10 – September 17, 2016 were chosen to calculate *k* because this is the period after the final operational adjustment were completed in 2016 (addition of organics) and flow rates were stable and at targeted values. The treatment rate coefficients applied here are intended to be a conservative estimate for conceptual sizing purposes, and will need to be refined through further demonstration-scale (on site) testing.

$$k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{\mathrm{HRT}}$$

**Equation 2 – Equation for calculation of first-order removal rate coefficient.**
*k* is the removal rate coefficient, *Cf* is the final concentration, *Ci* is the initial concentration, and HRT is the hydraulic retention time.

$$k = \frac{(Ci - Cf)}{\mathrm{HRT}}$$

**Equation 3 – Equation for calculation of zero-order removal rate coefficient.**
*k* is the removal rate coefficient, *Cf* is the final concentration, *Ci* is the initial concentration, and HRT is the hydraulic retention time.

$$HRT = {}^{V}/_{Q}$$

**Equation 4 – Equation for calculation of hydraulic retention time.**
HRT is the hydraulic retention time, V is the volume of the wetland, and Q is the flow rate.

**Table 10 – Rate coefficients (*k*) for elements in exceedance of proposed WQO's[1].**

| Element[2] | Pilot *k**hour$^{-1}$ | Demonstration[6] *k**hour$^{-1}$ | | | | Demonstration[6] *k**day$^{1}$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Series 1 | | Series 2 | | Series 1 | | Series 2 | |
| | Total | Dissolved | Total | Dissolved | Total | Dissolved | Total | Dissolved | Total |
| **First order removal rate coefficients** | | | | | | | | | |
| **Cd** | 0.0476[4] | 0.00817 | 0.00803 | 0.00610 | 0.00640 | 0.196 | 0.193 | 0.147 | 0.154 |
| **Cu[3]** | 0.0497[5] | 0.00365[3] | 0.00341[3] | 0.00283[3] | 0.00276[3] | 0.0876[3] | 0.0819[3] | 0.0680[3] | 0.0661[3] |
| **Mo** | 0.0042[4] | 0.00248 | 0.00273 | 0.000989 | 0.00117 | 0.0594 | 0.0655 | 0.0237 | 0.0280 |
| **Zn** | 0.0477[4] | 0.00824 | 0.00790 | 0.00799 | 0.00752 | 0.198 | 0.190 | 0.192 | 0.181 |
| **Nitrate** | 0.0380[4] | N/A | 0.00610 | N/A | 0.00149 | N/A | 0.147 | N/A | 0.0358 |
| **Zero order removal rate coefficients** | | | | | | | | | |
| **Se** | 7 | 0.0000179 | 0.0000160 | 0.0000118 | 0.0000103 | 0.000430 | 0.000385 | 0.000284 | 0.000246 |

[1] Non- degradation central tendency water quality objectives (NDCT-WQO) for the Lower Minto Creek (W2) area from the Adaptive Management Plan (Minto, 2016).
[2]All treatment rate coefficients are for first-order reaction kinetics except for selenium which is a zero-order reaction rate kinetic.
[3] Rate coefficients for copper in demonstration scale system are artificially lower than actual due to leaching of copper into water from soils, which increases outflow copper concentrations and affects the *k* calculation (Section 6.2.2).
[4] Values calculated from data in Table 8 of the pilot-scale report (Contango, November 2014).
[5] Value retrieved from Table 10 of the pilot-scale report (Contango, November 2014).
[6]Analytical results from August 10 – September 17, 2016 were used to calculate *k.*

## 9. Evapotranspiration study

An evapotranspiration study was conducted in a controlled greenhouse at Contango in April 2016 using the same general summer temperatures and vegetation types as the Minto CWTS. Total evapotranspiration from the system is the combined effects of open water evaporation and plant transpiration (Beebe *et al*, 2014). The purpose of calculating the evapotranspiration of a system is to understand the amount of water lost, which in turn concentrates elements and should be considered in the context of the difference of decrease in outflow concentration (or not) and outflow load reduction. The findings of the controlled environment (off site) evapotranspiration study suggested that on average 15.53 L/m$^2$/day would be lost from a CWTS design such as that at Minto through evapotranspiration. This would result in an equivalent concentration of elements (the actual percentage concentration being dependent on the amount of water in the system).

An evapotranspiration study was then performed on site July 18-25, 2016. The flow to the CWTS was shut off on July 18, 2016 and depth measuring sticks were installed at each end of the wetland to record the amount the water level decreases due to evapotranspiration (Figure 23). However, this time period experienced rain, and also the Minto weather station was not functional at this time, and therefore the evapotranspiration rates of the on-site wetland could not be determined and it is recommended this study should be repeated in 2017.

Applying the findings of the off-site evapotranspiration study to the demonstration-scale CWTS, series 1 could lose 1,085 L/day and series 2 could lose 903 L/day in dry periods. Using the 3 different HRT under which the demonstration-scale CWTS was operated in 2016, evapotranspiration loss could result in a concentration of elements in the outflow water from 3 – 31 % (Table 11), meaning the actual load removed is this much greater than would be appreciated by looking at the concentrations alone. An on-site evaporation trial in 2017 can determine if these findings are accurate for the Minto CWTS. Evapotranspiration must be accounted for in sizing of a full-scale wetland.

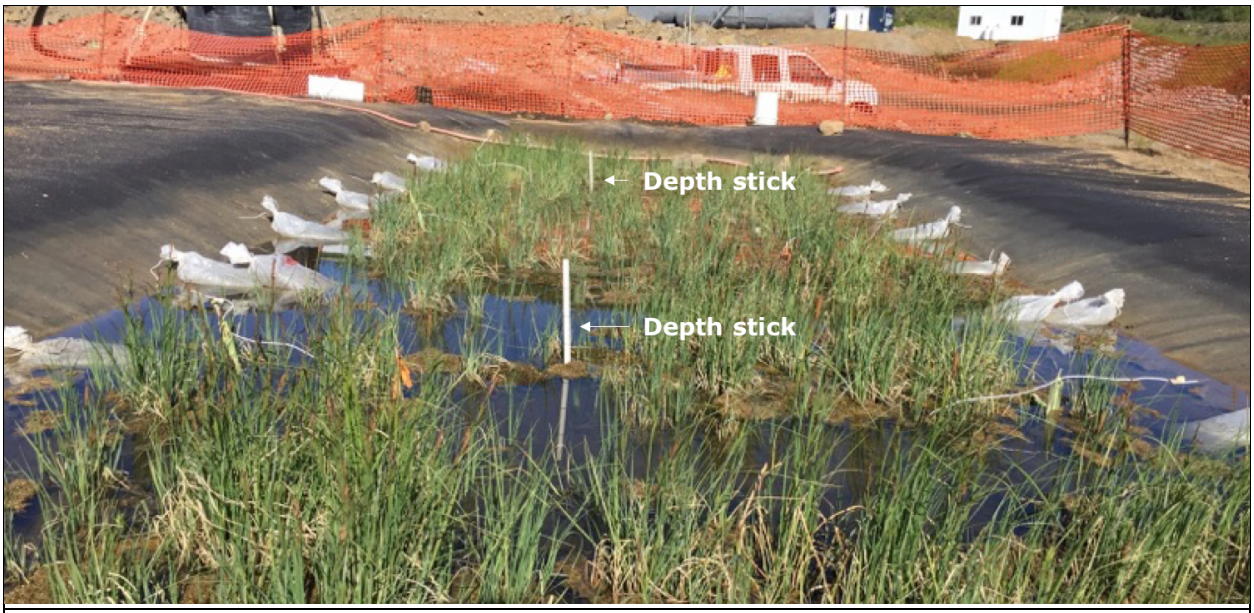



**Figure 23 – Depth sticks installed in CWTS to record evapotranspiration.**

**Table 11 – Potential loss of water through evapotranspiration in the CWTS .**

| HRT (days) | L/day through series | | L/day lost | | % Lost /day |
|---|---|---|---|---|---|
| | Series 1 | Series 2 | Series 1 | Series 2 | |
| 0.3 | 34,998 | 28,638 | 1,085 | 904 | 3 |
| 1 | 10,510 | 8,600 | | | 10 |
| 3 | 3,503 | 2,867 | | | 31 |

# 10.Vegetation

## *10.1.* Health and establishment

### *10.1.1. Carex aquatilis*

During the commissioning period, plants establish and mature, with density expected to increase over time. When counted at the first site visit in June 2015, >95% of the plants were found to have survived their first winter. This survival rate is impressive considering the late fall planting of August 28, 2014 and suggests the *C. aquatilis* are very robust and reaffirms they are a good candidate for use in the full-scale CWTS at Minto. Additionally, there was a greater than 20% increase in total stems in the short growing season up to June 2015 (as counted by new shoots/runners). By the second site visit in August 2015, the plants were too dense to count stems, and therefore the survival and establishment was considered a success and no longer monitored by counting (Figure 26). By the second site visit in 2016 (July) the CWTS cells hosted a dense monoculture of *C. aquatilis* that continued to thrive until the end of operations in 2016.

Pilot-scale testing suggested that *C. aquatilis* would increase more quickly the number of stems once the maximum plant height was achieved, and that maximum plant height is dependent upon water depth (with deeper water resulting in taller plants). This was also seen in the demonstration-scale wetland on site, with the density of plants filling in greatly through July and August 2015 and throughout 2016 (Figure 26).

Of note, it was observed that during the last site visit of the year by Contango (September 17-18$^{th}$, 2015), the *C. aquatilis* in the demonstration-scale CWTS were still predominantly green, while other plants in the area had turned brown. This suggests that the CWTSs may have a longer range of activity than natural systems in the area, possibly due to liners and separation from colder ground water.

#### *10.1.1.1. Aphids*

Aphids were observed in all CWTS cells in July 2016 (Figure 28), and had originally been noticed in cell 2A in August 2015. Aphids occur naturally in the area and have been observed during site visits and background sampling in the Yukon and Northwest Territories on *Carex* and *Typha*. The effects of aphids on a CWTS are not expected to be pronounced unless it has a large buffer zone between it and other insect habitat (e.g., forest, prairie, etc), which prevents predator insects from also colonizing and keeping the aphids at a lower population density. At Minto, there is a large buffer area (MVFE) around the demonstration-scale CWTS, and as such, the aphids may colonize more robustly than anticipated in the full-scale CWTS at site, which would not have the same buffer zone. The aphids will continue to be watched in 2017, and other background areas (e.g., W10 and W15) compared to see if increases in aphid populations are specific to the CWTS, or general in the area.

### *10.1.2. Moss*

Despite several mosses drying out during the winter of 2015 after planting, there was 100% survival and establishment. However, their growth was much slower than the sedge and therefore they were supplemented with additional aquatic moss (harvested from the same W10 area as the original plants for the CWTS) in June and August 2015 to augment their general abundance and bring the CWTS through commissioning more quickly (Figure 24). Mosses continued to mature and expand in size through 2016. The mature mosses are beginning to show characteristics of the desired coupled transfer (sorption, filtration) and transformation (mineralization, reduction) processes, with the top of the moss growing and producing new biomass (i.e., is green new growth; transfer sites), and the older bottom of the moss turning black (i.e., beginning to decompose producing sulphidic reducing zones; transformation reactions) (Figure 24).

## 10.2. Metals uptake

Concentrations of various elements in *C. aquatilis* and moss from the demonstration-scale systems were compared to those from pilot-scale testing. It is expected that the concentrations would be higher in the demonstration-scale system as the CWTS is not yet fully functional (i.e., elements are in greater bioavailability when in dissolved form) and also due to the composition of the soils used for construction.

*C. aquatilis* and moss in the demonstration-scale system had higher copper concentrations than the pilot systems. However, concentration of copper in the *C. aquatilis* at the end of 2015 was not significantly different than that of the plants borrowed from the W10 area for planting of the systems in 2014. Concentration of copper in the *C. aquatilis* in series 1 at the end of 2016 were comparable to the 2015 concentrations, however the concentration of copper in series 2 was higher (Figure 30). This is possibly due to the increased soluble (i.e., bioavailable) copper in series 2 after the addition of Fe-EDTA in September 2015. The moss had higher copper concentrations compared to the initial moss sample in all cells in 2015, and increased to nearly double the 2015 values by the end of 2016 (Figure 30). Mosses remove metals from water through sorption, which is different than the plant uptake that occurs in macrophytes such as *Carex* (and therefore, expected to release copper when exposed to EDTA, rather than have an increased uptake). Additionally, because the mosses were being added through 2015 (from the W10 source), it is expected that mosses would have lower metals concentrations (of any element) in 2015 compared to 2016 as they were not exposed to the CWTS water chemistry for the full year. It should be noted that over time, the mosses convert the sorbed elements to reduced minerals, rendering them lower bioavailability (Section 10.1.2.). As mosses are not a significant food source for any fauna, this is a safe mechanism to transfer elements from water eventually into stable mineral forms in the wetland soils and substrate.

Cadmium concentrations were either below or close to the detection limit in *Carex* in 2015 and 2016 (Figure 29). Additionally, cadmium concentrations in moss and selenium concentrations in both plant types tested were lower in the demonstration-scale (2015 and

2016) compared to pilot-scale. This result was presumably due to lower concentrations of both cadmium and selenium in the water of the demonstration-scale system than pilot scale. In 2016 molybdenum concentrations in *Carex* tissue were higher than the pilot-scale system, but lower than the 2015 CWTS concentrations. In 2016 zinc concentrations in *Carex* tissue has increased compared to the pilot-scale system and the 2015 demonstration-scale system concentrations. This could be attributed to the increase in zinc in the feed water in 2016 (Figure 20). Additionally, in 2016 molybdenum, selenium, and zinc concentrations in moss increased compared to the 2015 concentrations, which suggests that as mosses are continuing to grow and fill in the wetland. Selenium treatment performance is increasing as mosses are a source of sorption, and also harbor a high abundance of selenate-reducing microorganisms (see Section 10.3.2).




**Figure 24 – Moss maturation in CWTS.**




**Figure 25 – Moss top, bottom, and side view June 2016.**




**Figure 26 – Maturation of the CWTS from construction to year-end 2016.**
Top left picture is of cell 1A, top right picture is of cell 2B, bottom left picture is of cell 1B, and the bottom right picture is of cells 2A and 2B. Continued next page

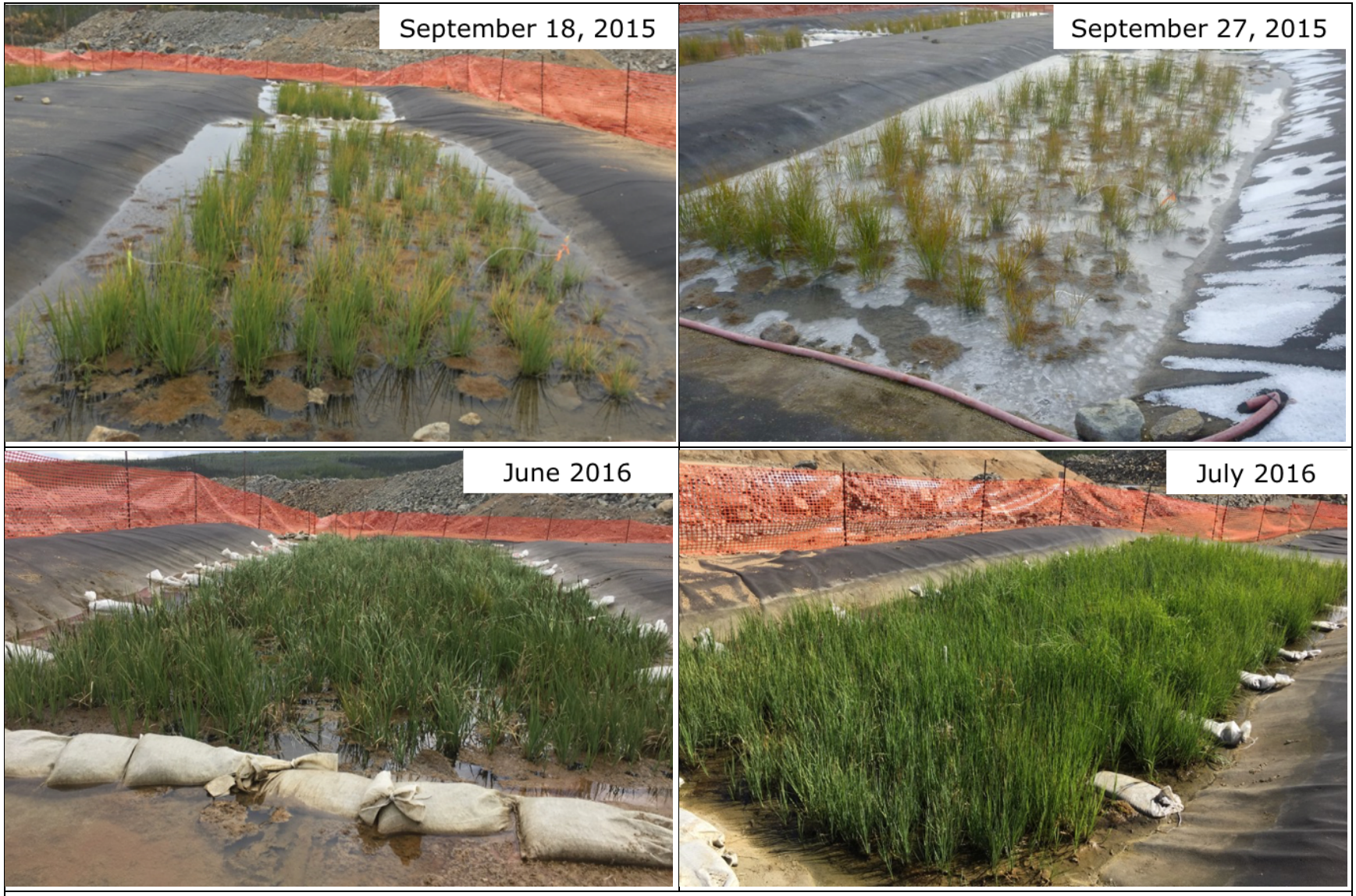



**Figure 26 – Continued.**
Top pictures are of cell 2A, and bottom picutes are of cell 1B.

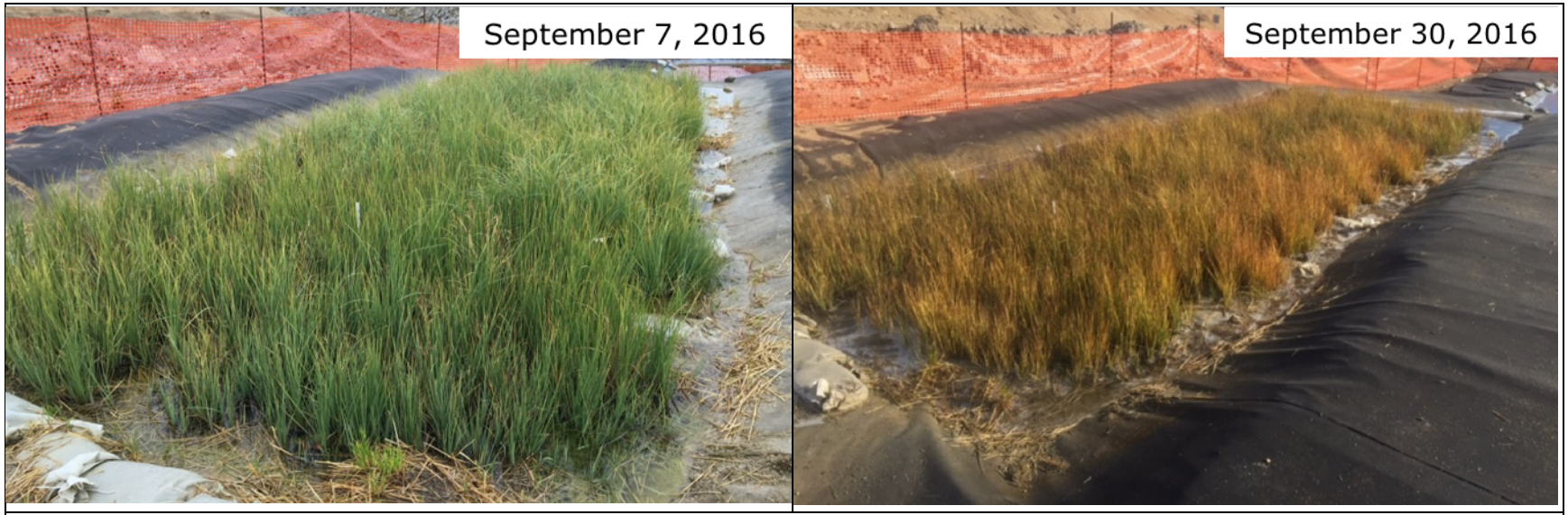


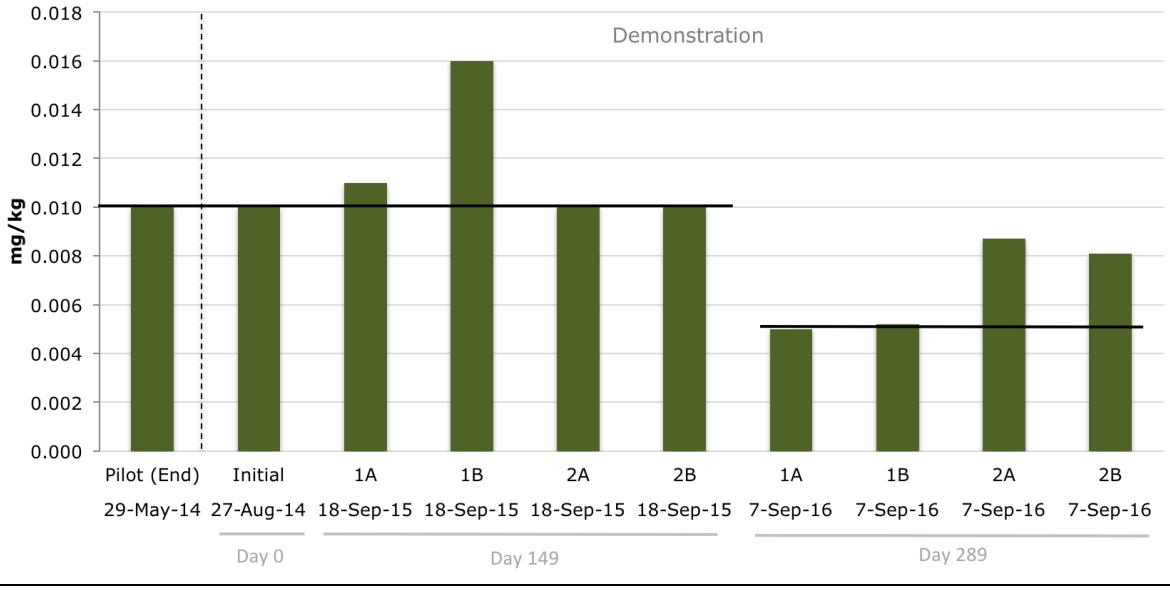

**Figure 26 – Continued.**
Pictures are of cell 1B.



**Figure 27 – Aphids observed in cell 1A and 2A.**
Left picture is of cell 1A. Right picture is of cell 2A. Note the increased yellowing in cell 2A due to a denser aphid population.



**Figure 28 – Aphids observed on Carex (September 8, 2016).**
The top picture is of cell 2A, the bottom picture is of cell 1B. Note cell 2A has more yellowing due to larger aphid population.



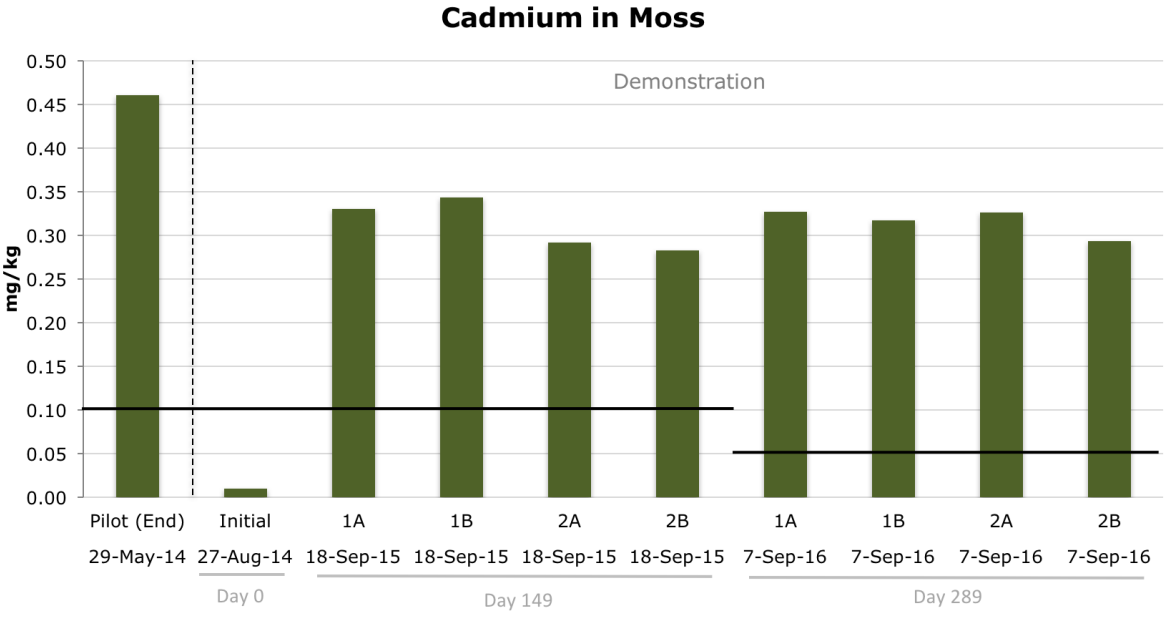
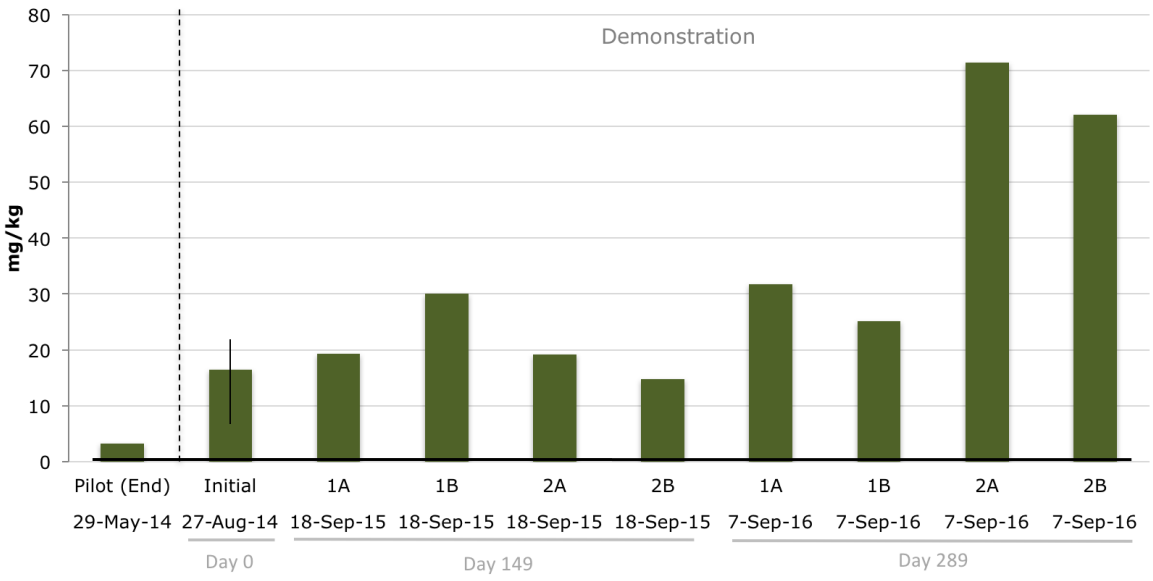




**Figure 29 – Cadmium concentrations in plant tissue.**
The 2014 and 2015 DL for Cadmium is 0.10 mg/kg. The initial data set is the average value of CWTS 1A-2B. The error bars indicate the minimum and maximum values in that data set.



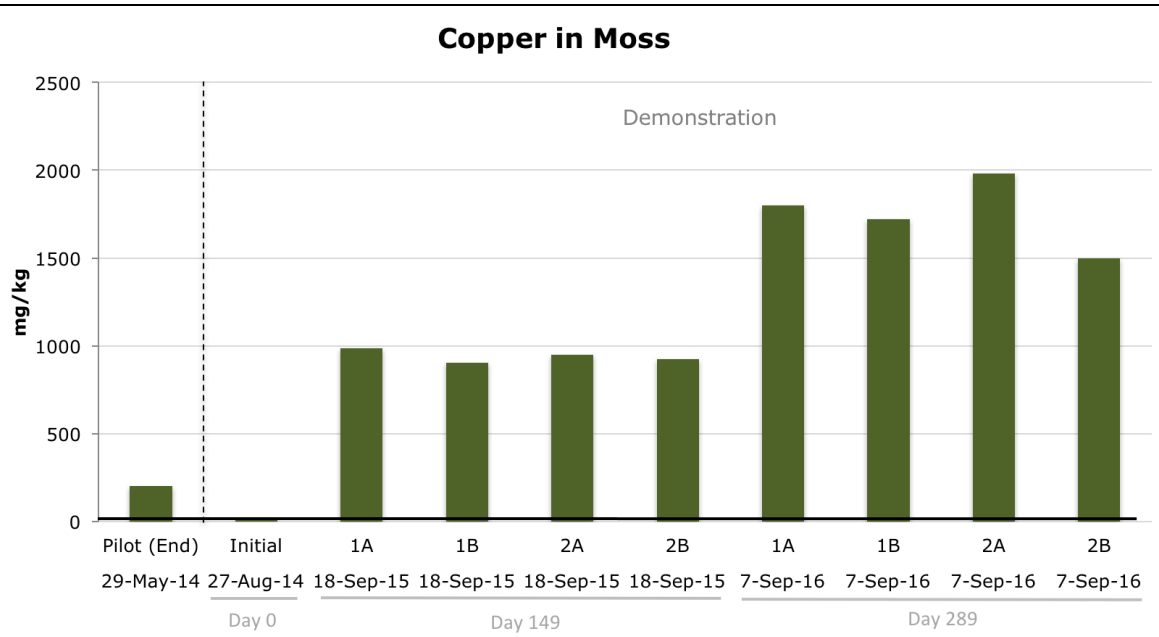
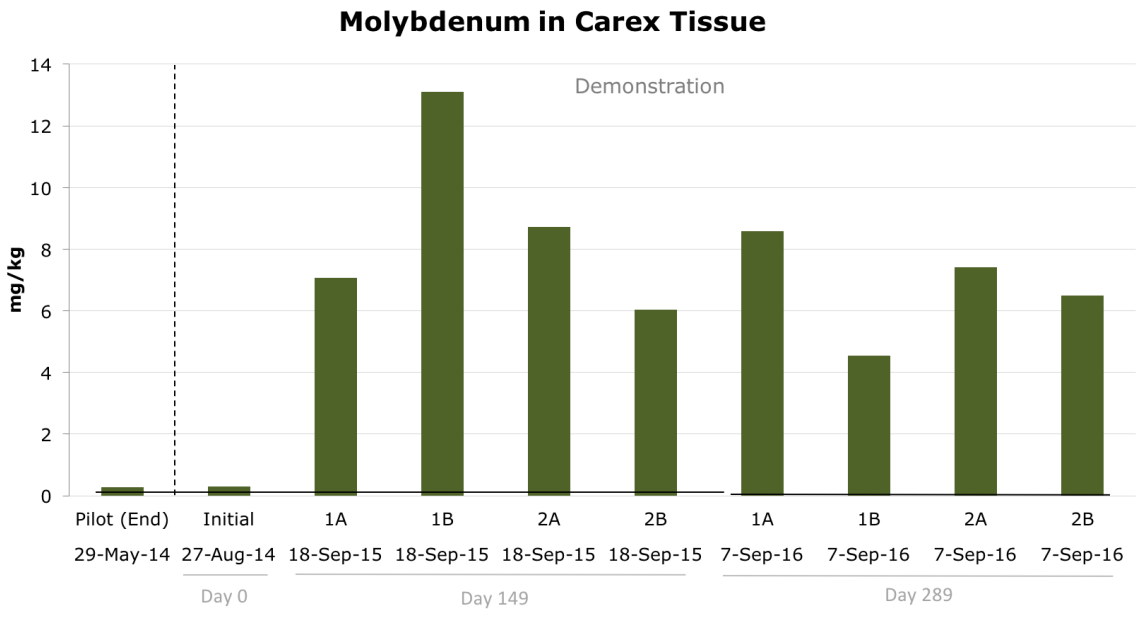




**Figure 30 – Copper concentrations in plant tissue.**
The 2014 DL for Copper is 0.5 mg/kg, the 2015 DL is 0.1 mg/kg, and the 2016 DL is 0.05 mg/kg. The initial data set is the average value of CWTS 1A-2B. The error bars indicate the minimum and maximum values in that data set.



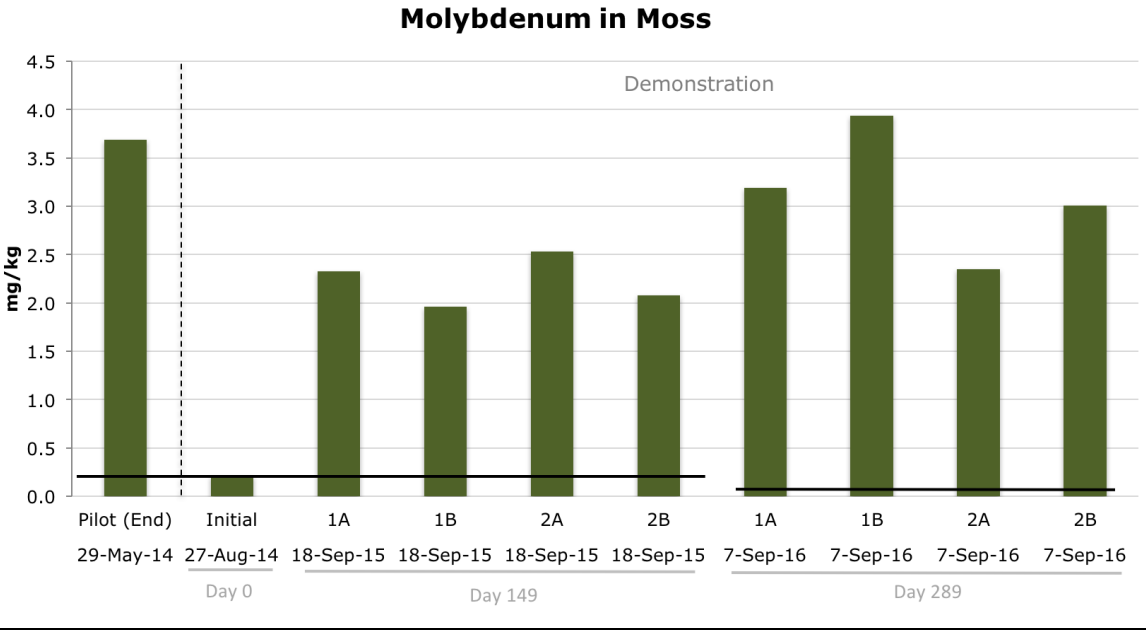
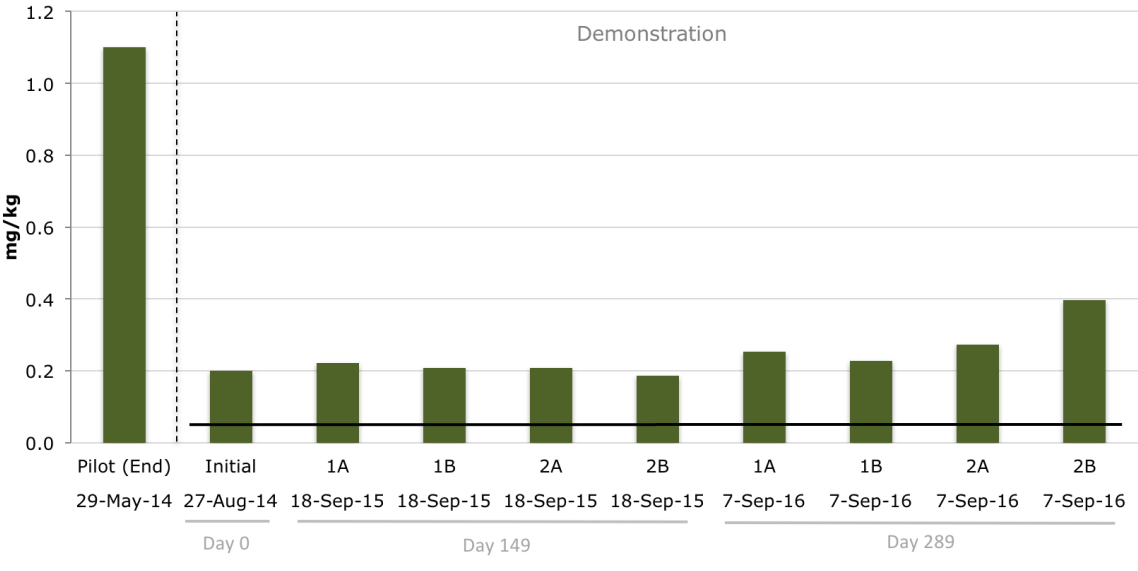




**Figure 31 – Molybdenum concentrations in plant tissue.**
The 2014 and 2015 DL for Molybdenum is 0.05 mg/kg, the 2016 DL is 0.020 mg/kg. The initial data set is the average value of CWTS 1A-2B. The error bars indicate the minimum and maximum values in that data set.



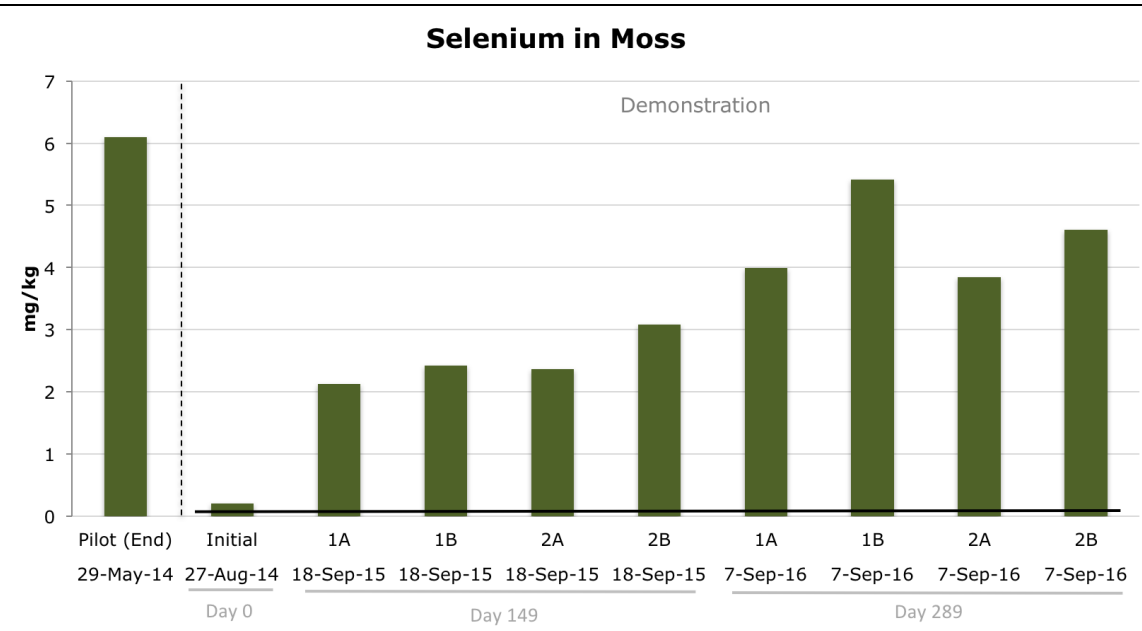
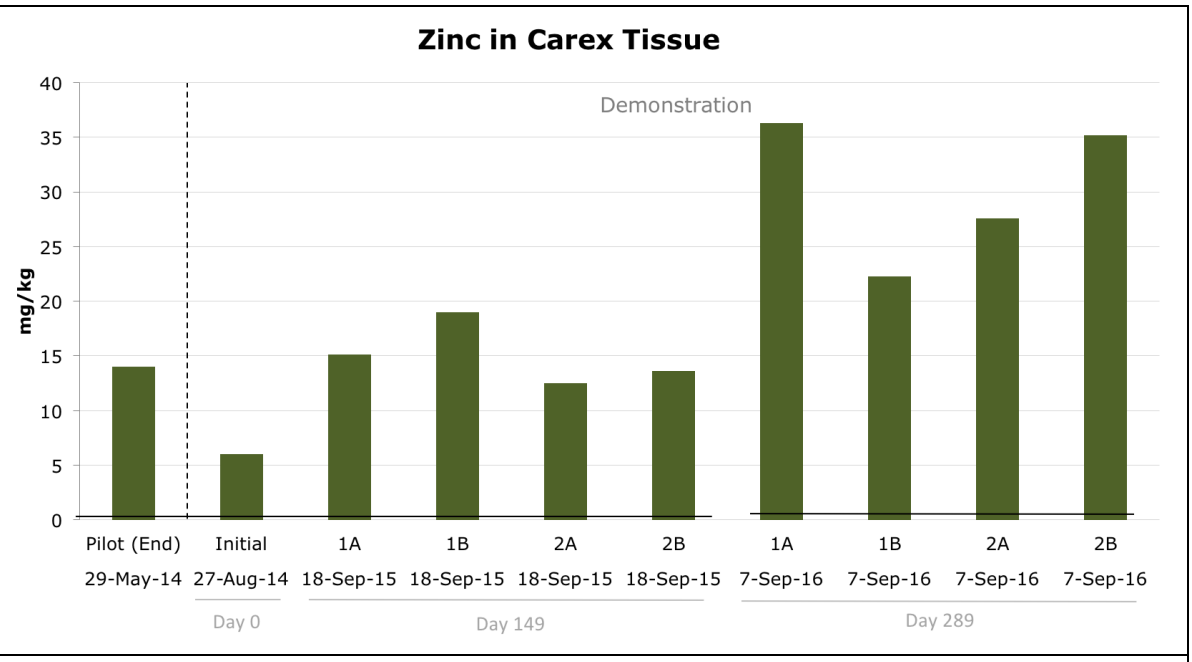




**Figure 32 – Selenium concentrations in plant tissue.**
The method detection limit for Selenium is 0.2 mg/kg. Initial data set is the average value of replacates used for planting of all CWTS cells. Error bars indicate the minimum and maximum values in that data set.



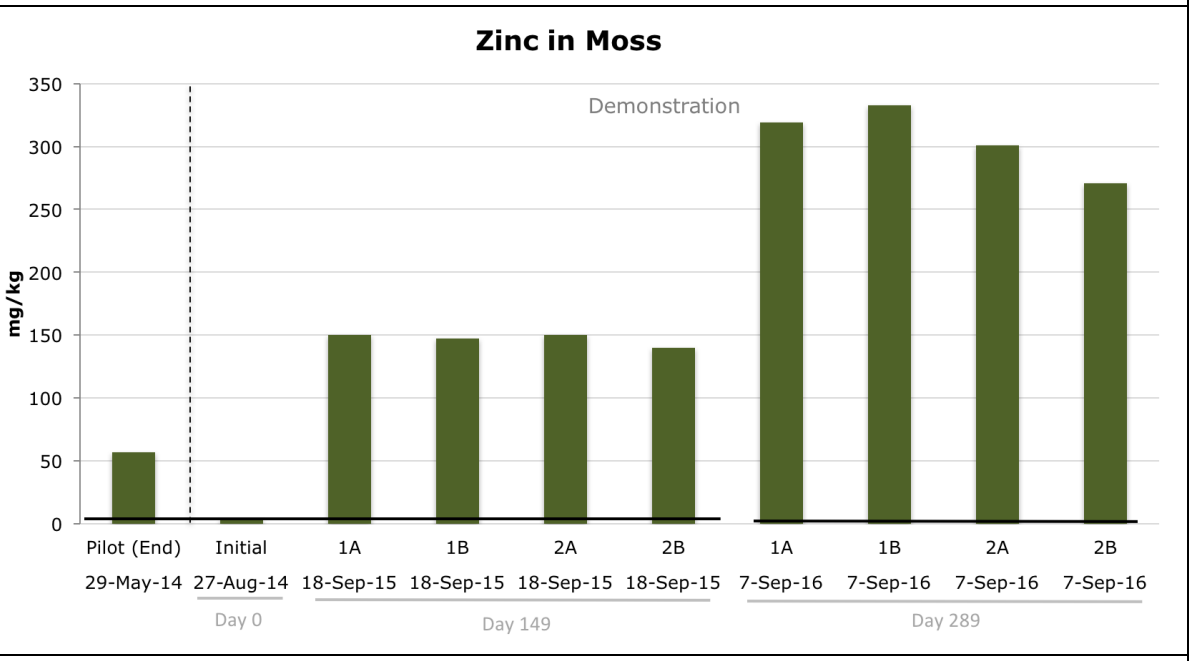




**Figure 33 – Zinc concentrations in plant tissue.**
The 2014 DL for Zinc is 2.0 mg/kg, the 2015 DL is 0.002 mg/kg, and the 2016 DL is 0.5 mg/kg. The initial data set is the average value of CWTS 1A-2B. The error bars indicate the minimum and maximum values in that data set.

### 10.3. Beneficial microbes

Microbes are the driving force of many treatment pathways that are targeted in CWTSs. The beneficial microbes in these systems catalyze biogeochemical cycles for remediation of specific constituents of concern. Careful design of CWTSs can create the environmental conditions needed to enhance the abundance and metabolic activity of these beneficial

microbes. Accordingly, complimentary methods of genetic and growth-based testing were used to characterize the microbial populations associated with a range of microbial habitats in the demonstration-scale CWTS (e.g., soils, sediment, biofilms, aquatic mosses, and plant roots).

In the context of the Minto Mine CWTS, beneficial microbes include those that are involved in the reduction of selenium (selenate and selenite), nitrate, and sulphur compounds (which in turn can treat copper, cadmium, molybdenum, and zinc). Information on each of these mechanisms and the associated microbial populations in the demonstration-scale system is outlined in the following sections.

### *10.3.1. Sulphide-producing bacteria*

Treatment is achieved by targeting the lithic biogeochemical sequestration of divalent metals through sulfide (i.e., $S^{2-}$, $HS^-$) precipitation as mineralized species (e.g., chalcocite [CuS], covellite [$Cu_2S$]). These sulfide bound species are relatively insoluble (CuS; $K_{sp}=10^{-16}$; Stumm and Morgan 1996), and are transferred from the water column into the CWTS soil as non-bioavailable fractions (Murray-Gulde et al., 2003; Huddleston et al., 2008). Moreover, similar reactions occur with cadmium and zinc, rending them non-bioavailable. As such, sulphide production is a key biogeochemical treatment mechanism for water treatment at Minto Mine. Sulphides can be created by beneficial microorganisms through the reduction of sulphur-containing compounds, such as sulphate, sulphite, thiosulphate, and elemental sulphur.

Based on the information gathered in pilot-scale testing, the targeted soil redox for the demonstration-scale CWTS is between -100 and -250 mV. This is in agreement with literature that indicates anaerobic conditions with relatively low ORP (-250 to -100 mV) are necessary for promoting anaerobic metabolisms in bacteria which oxidize organic matter, producing electrons which reduce sulfate to hydrogen sulfide ($H_2S$) and other reduced sulfide species (i.e. bisulfide ion ($HS^-$), sulfide ion [$S^{2-}$]; Mitsch and Gosselink 2007). In these redox ranges, bacterial sulphide-production through reduction of sulphur compounds is expected, alongside increases in the proportion (percentage) and abundance of these microbes.

As expected, the proportion of sulphide-producing bacteria increased as the soil redox decreased in the demonstration-scale system through commissioning (Figure 34). The *C. aquatilis* roots were found to harbor high proportions of beneficial sulphide-producing bacteria (SPB), as well as a diversity of SPB (Table 12) which were different types than those found in the soil (Figure 34). This is good as it increases the diversity of bacteria in the CWTS that can carry out the beneficial reaction under a wider range of conditions than a small diversity of organisms could. Mosses, algae, and biofilms were typically associated with low proportions of sulphide-producing bacteria (data not shown), as would be expected in these photosynthetic and oxidizing environments.

**Table 12 – Average number of different types of sulphide-producing bacteria in different sample types.**

| Sample Type | Before organics (all cells) | A cells post organic | B cells post organic |
|---|---|---|---|
| algae/biofilm | 2 | NT | NT |
| detritus | NT | 6 | 8 |
| moss | 5 | 4 | 5 |
| root | 9 | 8 | 15 |
| soil | 7 | 11 | 15 |

NT – not tested. Post organic addition are samples collected in September 2016. The number of different types is based on counting the number of operational taxonomic units (clustered at 97% identity) that are classified as known sulphide-producing bacteria.

In addition to assessing the proportion of the community that are SPB, the inferred abundance of SPB was analyzed for all sample types (Figure 35 ). Soil and root samples were found to have the highest inferred abundances of sulphide-producing bacteria per gram of sample, while mosses typically had lower abundances. The black bottom part of the moss had ~100x more sulphide-producing bacteria per gram than the top part of the moss collected from the same location (Figure 24). This is desired as the mature mosses begin to show characteristics of the desired coupled transfer and transformation processes (with new biomass, and decomposition of older bottom; Section 10.1.2).

The overall abundance of sulphide-producing bacteria in the B cells have also increased in the soil and *C. aquatilis* root samples of the CWTSs over time, particularly in series 1 after the addition of organics (Figure 35 ). There was also an increase in the average number of different types of sulphide-producing bacteria in samples after the addition of organics (Table 12, Figure 34). The addition of organics was done to provide carbon sources needed by sulphide-producing bacteria and to provide the desired sulphur- and selenium-reducing conditions. It is anticipated the addition of organics will continue to provide the necessary carbon source to stimulate desired reducing conditions and microbial populations in 2017, and until the vegetation has established sufficiently to provide this carbon source annually going forward.

The microbial analysis of various sample types in the CWTS has therefore confirmed that the commissioning period is proceeding as expected, with beneficial sulphide-producing bacterial populations establishing in the soils alongside reducing conditions, which will continue to be monitored for stability or further improvement in 2017.

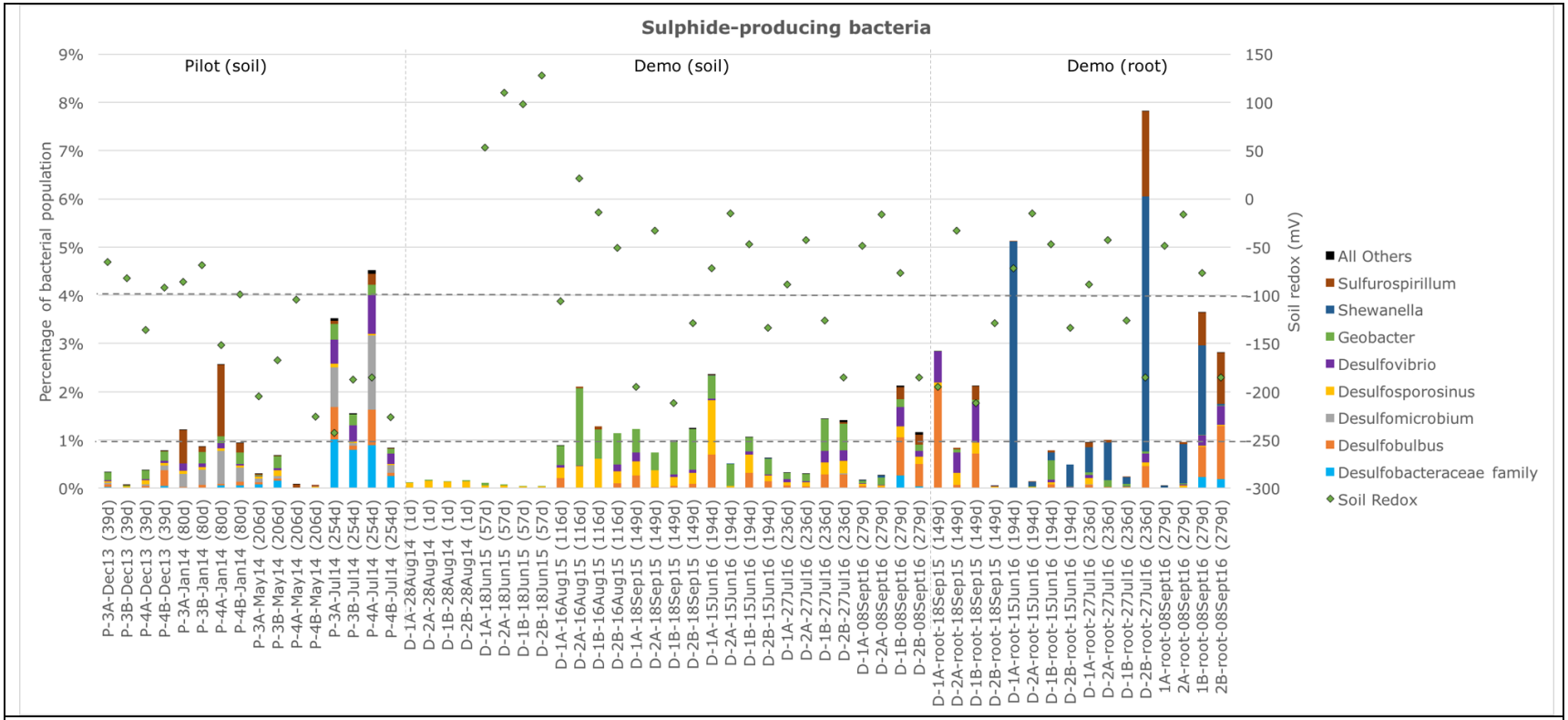



**Figure 34 – Percentage and identity of sulphide-producing bacteria in soil of the pilot-scale and demonstration-scale CWTSs.**

The vertical dashed lines separate the pilot-scale system data from the demonstration-scale system 1 and system 2 data. The horizontal dashed lines indicate the targeted soil redox range. Organism classifications and data analysis methods have been updated from Contango (March 2016).

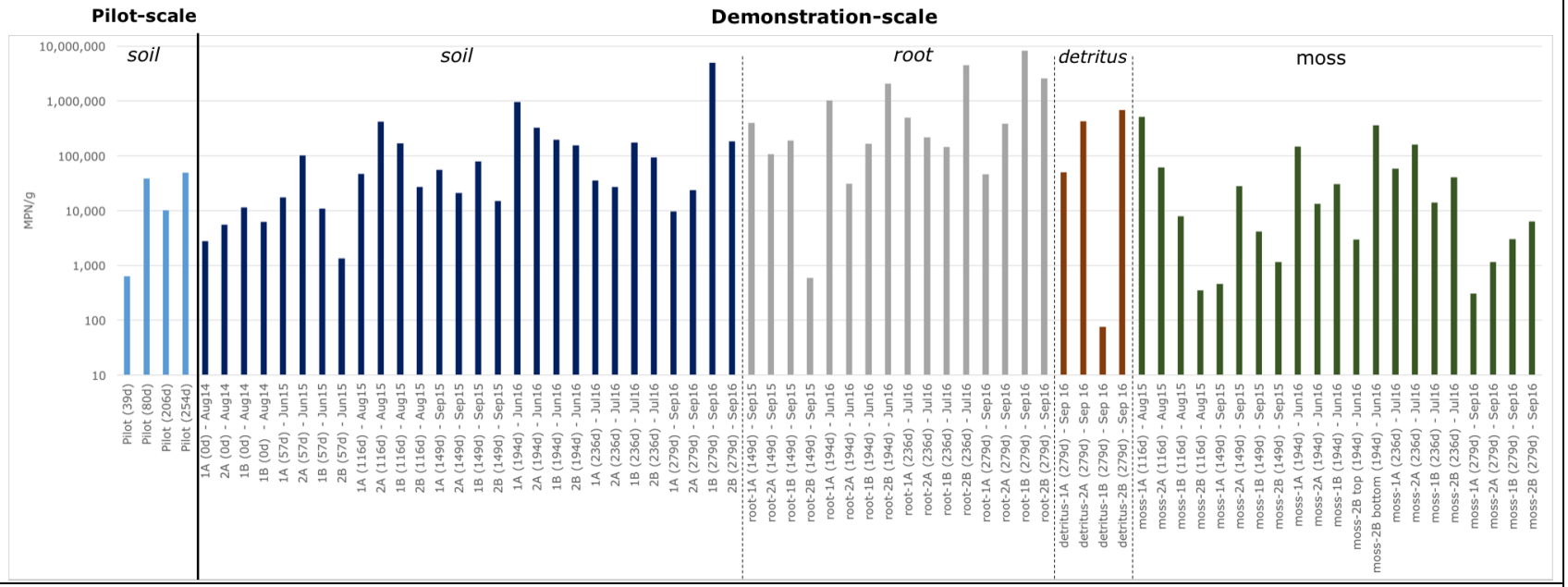



**Figure 35 – Inferred abundance of sulphide-producing bacteria in soil of the pilot- and demonstration-scale CWTSs.**

Inferred abundance is calculated based on a combination of genetic and growth-based data.
Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of wetland.

### *10.3.2. Selenium-reducing bacteria*

The targeted selenium treatment pathways in the Minto CWTS include sorption to moss and soils, and subsequent microbial reduction of soluble (sorbed) selenate (Se(VI)) and selenite (Se(IV)) to insoluble elemental selenium (Se(0)). This reductive process can also be achieved directly in the water column, but is more effective associated with mosses and biofilms due to their sorptive properties that bring the selenium in contact with beneficial selenium-reducing bacteria. This is achieved within the range of soil redox conditions targeted for sulphate-reduction as suggested by pilot-scale testing and literature (see Section 5).

Selenite-reducing organisms are ubiquitous in nature and as expected, were detected in all sample types, including algae, biofilm, moss, soil, sediment, roots, and detritus. Although organisms that reduce selenate to elemental selenium (rather than intermediary selenium compounds) are generally less abundant in the environment, they were found associated with all sample types, indicating that the conditions conducive to their proliferation have been created within the CWTS. Moreover, the abundance of selenite- and selenate-reducing organisms increased over time in the demonstration-scale system during the commissioning period (Figure 36). Aquatic mosses were found to initially host the highest abundances of both selenate- and selenite- reducing organisms, affirming the importance of the inclusion of moss in the CWTS. Over time, as the vegetation has established, selenium-reducing bacteria have increased in abundance on the roots of *C. aquatilis,* and were also found associated with the added organic material once it began decomposing (Figure 36

These findings indicate the demonstration-scale CWTS has established beneficial selenium-reducing microbes in several areas of the wetland, which would be involved in selenium removal in the CWTS (either by reducing selenium that has been sorbed to moss or detritus, or by interacting directly with selenium in water that has been drawn into the root zone by plants). Their abundance is similar to what was found during pilot-scale testing in the soil, indicating they have established as expected. Selenium-reducing microorganisms will continue to be monitored in 2017, alongside performance testing.

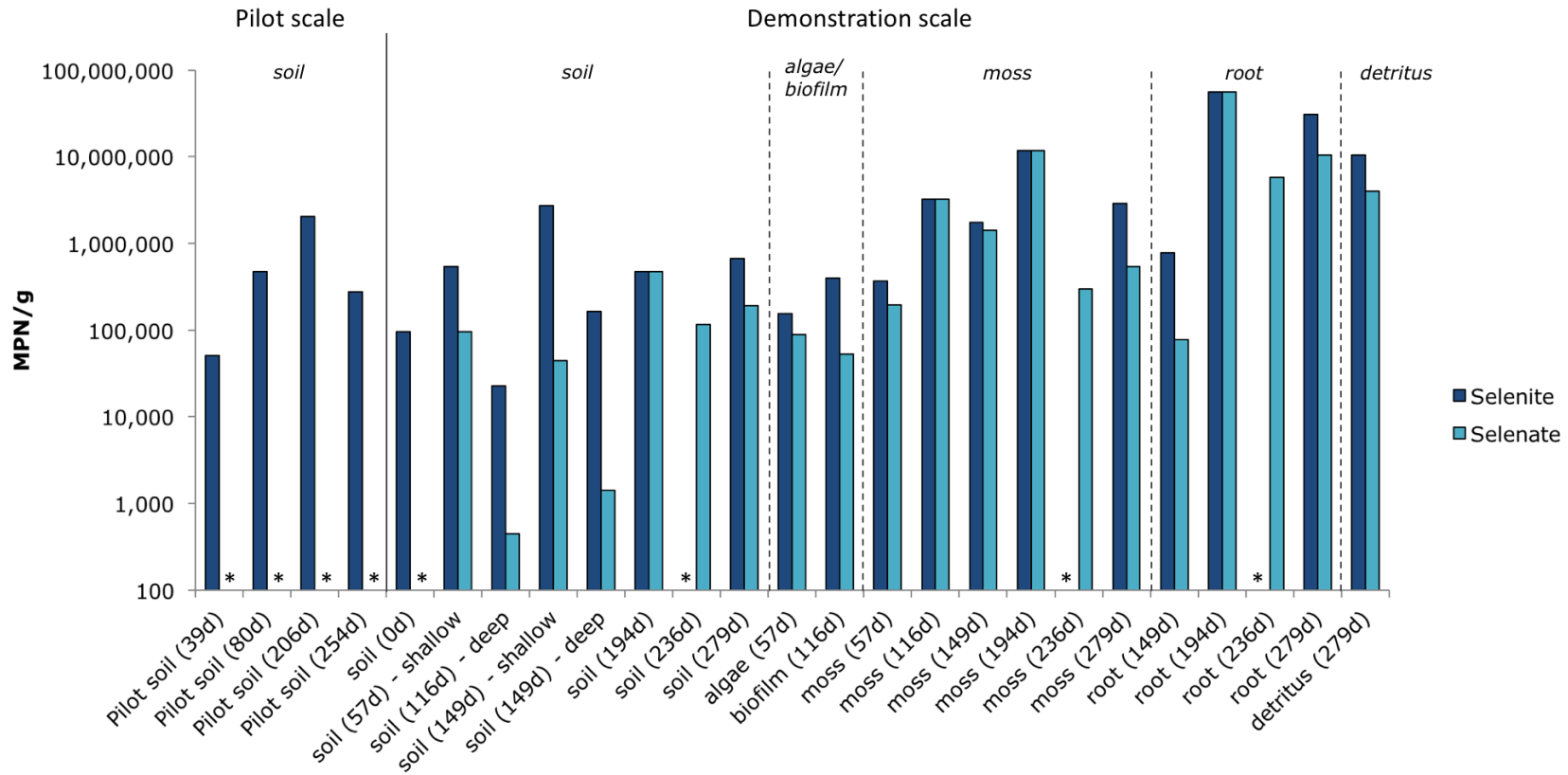



**Figure 36 – Abundance of selenite- and selenate-reducing organisms in various CWTS sample types over time.**
* Selenite or selenate not tested at this timepoint
Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of wetland. Organics material was added to the wetland after day 236.

### 10.1. Nitrate-reducing bacteria

Nitrate is sometimes a constituent of concern during operations and early closure owing to residuals from blasting activities. Even if not in exceedance of water quality guidelines in terms of receiving environment objectives, nitrate often requires attention to achieve treatment of other constituents. The presence of nitrate can interfere with the treatment of certain elements in water (such as selenium). Nitrate can be removed from water by different types of microbes, including nitrate reducing bacteria which can reduce nitrate ($NO_3$) to nitrite ($NO_2$), and also denitrifying organisms that are capable of fully reducing nitrate to nitric oxide (NO), nitrous oxide ($N_2O$), and dinitrogen gas ($N_2$ - which is the most abundant gas in air). MPN analysis was therefore used to quantify these organisms.

Nitrate-reducing and denitrifying organisms were found associated with all sample types in the demonstration-scale CWTS (Figure 37 ). Roots and detritus had a high abundance of both nitrate and denitrifying organisms, with soil being similar to what was found during pilot-scale testing. These results indicate nitrate reducers have established in the CWTS during the commissioning period as expected. Nitrate-reducing microorganisms will continue to be monitored in 2017, alongside performance testing.

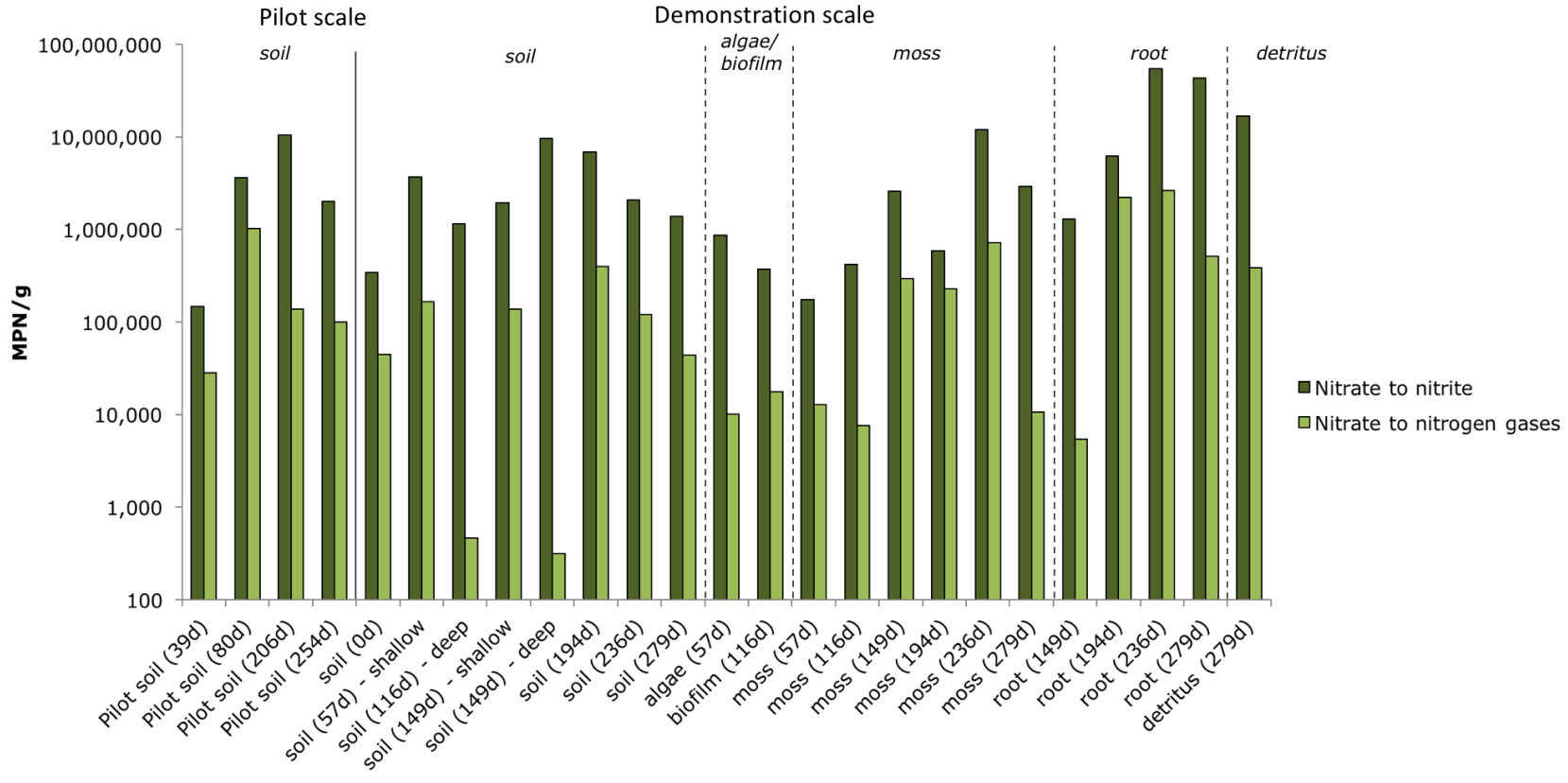



**Figure 37 – Abundance of nitrate-reducing and denitrifying organisms in various CWTS sample types over time.**
Nitrate-reducing = reduction of nitrate to nitrite; denitrifying = reduction of nitrate to nitrogen gases.
Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of wetland.

## 11.Summary of results

Table 13 summarizes results and findings from 2015 - 2016 commissioning of the demonstration-scale system at Minto.

**Table 13 – Summary of Minto demonstration-scale 2015 - 2016 testing.**

| Objective | Purpose | Key Findings or Changes for Full-scale |
|---|---|---|
| Evaluate construction | Optimize construction and effectiveness of operation of full-scale systems | **Layout**<br>-Outflow collection pond should have outflow at base (not top), with shutoff valve.<br>-In 2016 sandbags were added at shores to prevent water short circuiting. Sandbags were also added to the outflow of series 1 to increase water depth. |
| | | **Soils**<br>-Use substrate with less total and leachable metals and metalloids (especially copper).<br>-Higher sand content would improve hydrology, constructability (ability to level soils, ease of planting) and accessibility for sampling.<br>-Organics should be mixed in bulk to soils prior to adding to cells. |
| Assess commissioning timelines | Allow for proper phasing of implementing full-scale systems for closure | **Water**<br>-Commissioning-A period was complete at the end of July 2016 and the commissioning-B period (addition of organics to remediate the copper in substrates used) began July 29, 2016 and is ongoing.<br>-Copper is being treated by the CWTS, and during the commissioning-B period the average influent concentration decreased by 37% compared to the average outflow concentration.<br>-The wetland is achieving better treatment than suggested by inflow and outflow concentrations of the system, as soils are leaching aluminum and copper into the water.<br>-Cadmium and zinc are also being treated in the CWTS, and during the commissioning-B period, the average outflow |

| Objective | Purpose | Key Findings or Changes for Full-scale |
|---|---|---|
| | | concentrations were 64% and 69% lower than average influent concentrations respectively.<br>- Molybdenum and selenium experienced notably greater treatment after during the commissioning-B period. The average outflow concentrations were 21% and 41% lower than average influent concentrations respectively.<br>-The wetland is maturing as expected and is performing beyond anticipated based on the design.<br>- Cadmium, copper, molybdenum, and selenium % removal and *k* rates are increasing over time. Zinc % removal is increasing over time.<br>- HRT tracer study conducted in 2016 assessed hydrology and pore volume incorporation of the CWTS and determined HRT and removal rate coefficients for full-scale sizing. Rate coefficients should be re-evaluated after commissioning-B is completed.<br>-Evapotranspiration study conducted to determine amount of evapotranspiration occurring in the CWTS in warmer months and to incorporate into load removal models. Due to rain the results were inconclusive and should be redone in 2017. |
| | | **Soils**<br>-Soil redox not consistently reaching targeted ranges by July 2016 therefore organics were added to stimulate desired reducing conditions, which marked the end of commissioning-A and the beginning of commissioning-B.<br>-Cell 2B consistently reaching targeted ranges by the end of 2016.<br>-In 2015 significant amounts of metals were leaching from soil substrate into water, putting additional treatment demands on system. In 2016 the amount of metals leaching from soil substrate into the water has decreased. |
| | | **Microbes**<br>-Sulphide-producing bacteria needed for copper and other metals removal have increased through the commissioning period as soil redox approached targeted ranges. Proportions are comparable to |

| Objective | Purpose | Key Findings or Changes for Full-scale |
|---|---|---|
| | | those in pilot system at similar points in commissioning. After the addition of organics which marked the end of the commissioning-A period and the beginning of the commissioning-B period, sulphide-producing bacteria continued to increase, especially in the soil and roots in the B cells.<br>-Abundance of selenium- and nitrate-reducing organisms are similar to those in pilot testing, indicating maturation as expected.<br>-Selenium treatment performance increased through the commissioning period as mosses continued to grow, as they can sorb dissolved selenium and harbour highest abundance of selenate-reducing microorganisms to render the selenium insoluble. After the addition of organics which marked the end of the commissioning-A period, selenium-reducing bacteria were also associated with the added organic material once it started decomposing. Therefore the CWTS has established beneficial selenium reducing bacteria in several areas of the wetland (moss, detritus, roots, and soil). |
| *Carex aquatilis* transplantation effectiveness | Determine if plant propagation and/or replanting schedule will be needed for full-scale systems | ->95% survival from transplanting.<br>-Within first 2 months a further increase of >20%.<br>-Full-scale system could be planted more densely to bring online faster, or less densely if time is less of an issue than sourcing plants (the plants are vigorous and will fill in the wetland in due time).<br>- By the end of 2016 the plants had densely filled in the CWTS and transplanting was considered a success. |
| Moss colonization/distribution | | -100% survival from transplanting.<br>-Slower to spread, needs to be started more densely.<br>-Staking helps maintain moss in 'upstream' parts of wetland, or could be transplanted multiple times through commissioning period.<br>- Moss continued to mature in 2016 and does not appear to require additional transplanting. |

## 12.Schedule and action items for 2017

Based on the performance results through 2015 and 2016, an action plan for CWTS optimization and testing for 2017 has been developed (Table 14). An updated multi-year schedule as per the proposed scope of work in the Minto Demonstration Scale Report Document 011_0315_01A (Contango, March 2015) is provided in Appendix C.

**Table 14 – Minto 2017 CWTS demonstration-scale action items.**

| Who/When | Task | Contango Action Required | Additional Information |
|---|---|---|---|
| Minto Staff, prior to first site visit | Set flow rates at constant flow | Develop flow rate based on 2016 tracer study. | Do not change flow rate throughout year. Evaluate stability of wetland performance over one year, apply adjustments to models for full scale as necessary. |
| Contango site visit 7 (May/June 2017) | HRT Tracer study (salt) | Complete a second tracer study optimized from 2016 findings. | Coordinate an additional 1 $m^3$ tank at the CWTS site and a power source for the YSI. |
| | Aphid control (if needed) | Determine the appropriate method for aphid control. | |
| | General follow up | Complete seasonal sampling. | |
| Contango site visit 8 (July/August 2017) | Evapotranspiration study | Determine length of time and appropriate timeline to conduct the evapotranspiration study | Ensure the evapotranspiration study will not affect other planned activities at the site. |
| | General follow up | Complete seasonal sampling. | |
| Contango site visit 9 (September 2017) | General follow up | Complete seasonal sampling. | |
| Contango data monitoring throughout 2017 operations | Monitor metals leaching from soils | If metals continue to leach in 2017, flows could be stopped temporarily to promote this shift from oxidized to reduced forms. With the additional carbon sources of straw and wood chips now available for the bacteria to use to produce more sulphides for metals treatment | |
| | Monitor soil redox | Determine when it consistently reaches targeted range. | |
| December 2017 | Report | 2017 Update Report. | |

## 13. 2017 Monitoring plan

A conceptual testing plan was developed for the demonstration-scale CWTS and has been refined and adapted based on performance and scientific findings. The demonstration-scale wetlands are expected to run until at least the end of 2018 in order to assess performance under a wider range of conditions. The conditions that are planned to be tested include both natural/environmental and selected influenced pressures, and can be imposed on the systems to mimic peak flow rates or droughts. In 2016 the systems completed the commissioning-A period and began the commissioning-B period, with plants becoming more established and abundant, microbial communities acclimating to the targeted conditions, and soil redox beginning to achieve targeted ranges. In 2017 the monitoring program will shift focus to testing of operations and performance. A multi-year plan is provided in Appendix C, and includes work performed to date as well as a schedule for 2017 and potential activities for 2018.

## 14. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Respectfully submitted,

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# Appendix A

**Table 1 - Summary of analytical sampling types, frequencies and locations.**

| | |
|---|---|
| **Water** | |
| Dissolved and total metals | Weekly, outflow of each cell and feed |
| Ammonia | |
| Nitrate | |
| Nitrite | |
| Flow rate | Weekly, feed |
| pH, DO, ORP, Conductivity (in situ) | Weekly, all cells and feed |
| Anion Sum | Monthly, outflow of each cell and feed |
| Cation Sum | |
| Hardness ($CaCO_3$) | |
| Ion Balance | |
| Total Dissolved Solids (TDS) | |
| Chloride (Cl) | |
| Sulphate ($SO_4$) | |
| Nitrogen (Total) | |
| Alkalinity | |
| pH | |
| Conductivity | |
| Chemical Oxygen Demand (COD) | |
| Total Organic Carbon (TOC) | |
| Total Kjeldahl Nitrogen (TKN) | |
| Total Suspended Solids | |
| Dissolved Organic Carbon (DOC) | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Hydroxide (OH) | |
| **Soil** | |
| Relative soil redox (in situ) | Monthly, all probes (6 per cell) |
| **Analyses completed on soil sample** | |
| SAR, pH, EC, %sat, Ca, F, Mg, Na, K, Cl, SO4 | Seasonally (3x per year) from a depth of 0-10 cm. |
| Available NPK and sulphur | |
| Alkalinity | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Total Organic Carbon (TOC) | |
| Metals Analysis (Total) | |
| Sulfur by LECO | |
| Metals Leach | |
| AVS+SEM | |

| | |
|---|---|
| Sequential Leaching (5 Acid Test) | |
| Metals SPLP | Spring Sampling (1x per year). |
| **Analyses completed on special leach** | |
| Bromide (Br) | Seasonally (3x per year) |
| Chloride (Cl) | |
| Sulphate ($SO_4$) | |
| Fluoride (F) | |
| Alkalinity | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Hydroxide (OH) | |
| Dissolved Organic Carbon (DOC) | |
| Ammonia | |
| Nitrate | |
| Nitrite | |
| Total Dissolved Solids | |
| Anion Sum | |
| Cation Sum | |
| Cation/EC ratio | |
| Ion Balance | |
| **Plant tissue samples** | |
| Metals Analysis | *Carex aquatilis* and aquatic moss, each cell, year end |
| **Microbial samples** | |
| Growth-based most-probable number analysis (nitrate reduction, selenite and selenate reduction, total heterotrophs) | Seasonally (3x per year) |
| Genetic sequencing analysis for bacterial community composition and distribution | Seasonally (3x per year) |

# Appendix B – Additional graphs

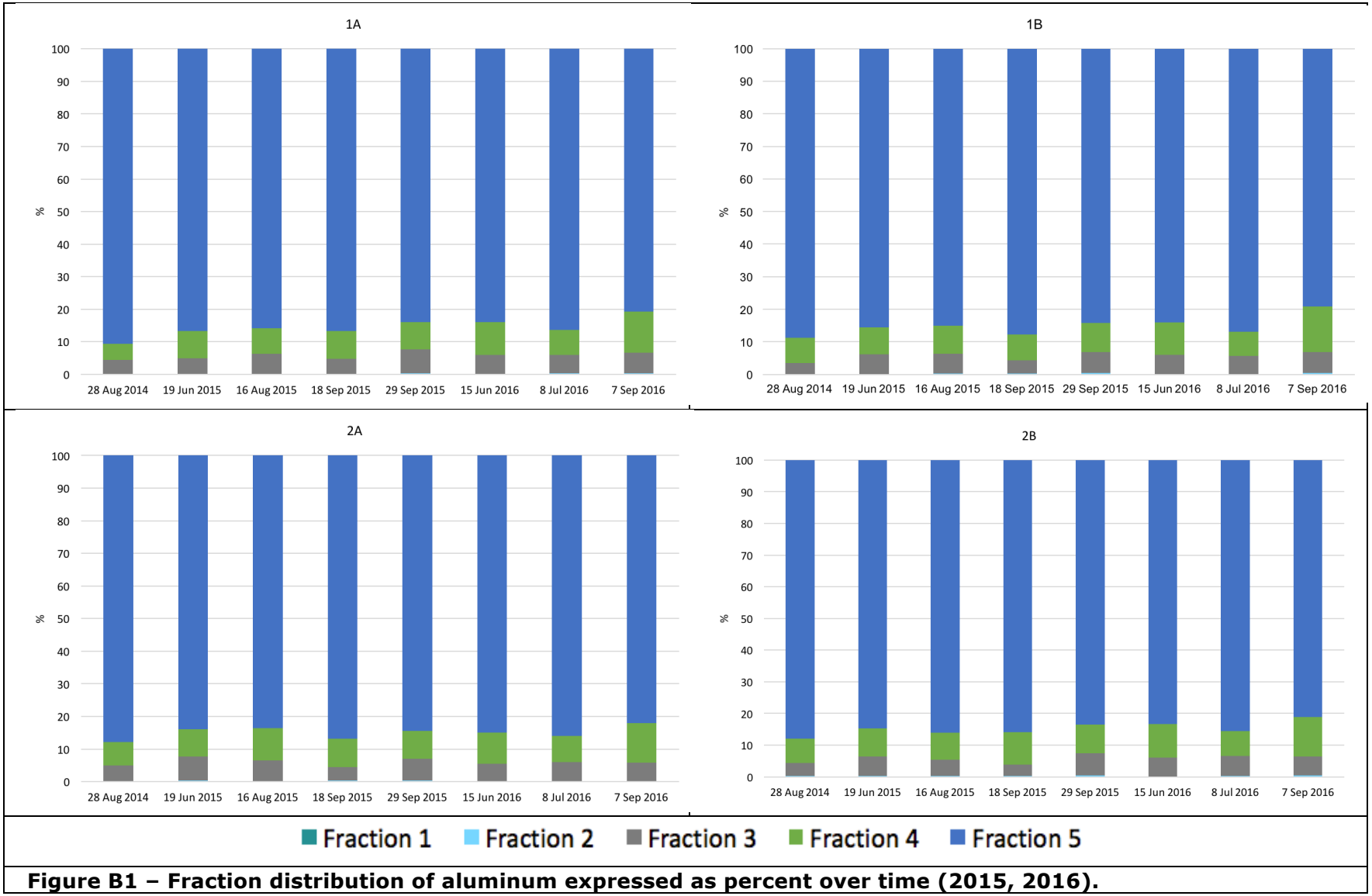



**Figure B1 – Fraction distribution of aluminum expressed as percent over time (2015, 2016).**

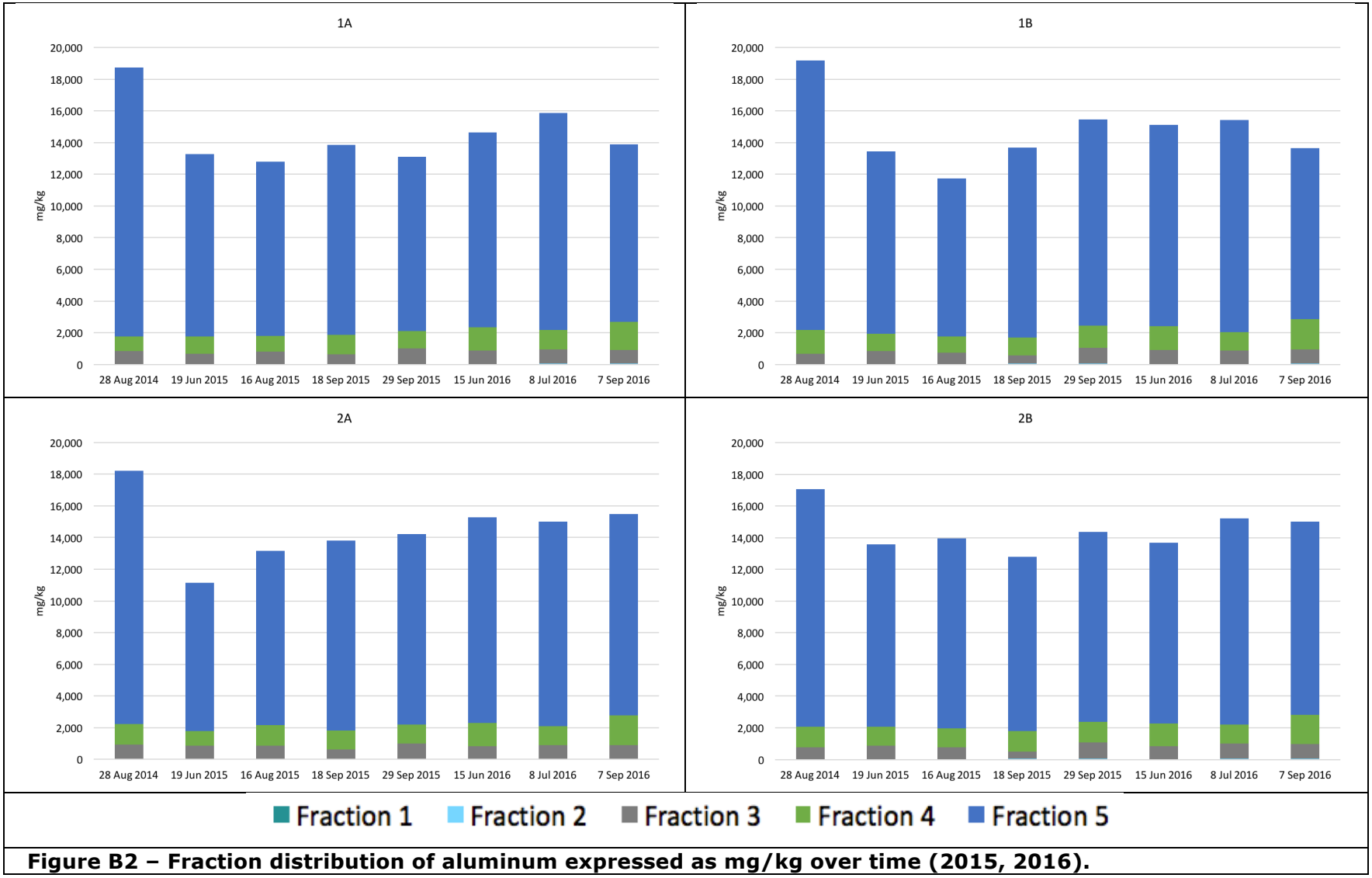



**Figure B2 – Fraction distribution of aluminum expressed as mg/kg over time (2015, 2016).**

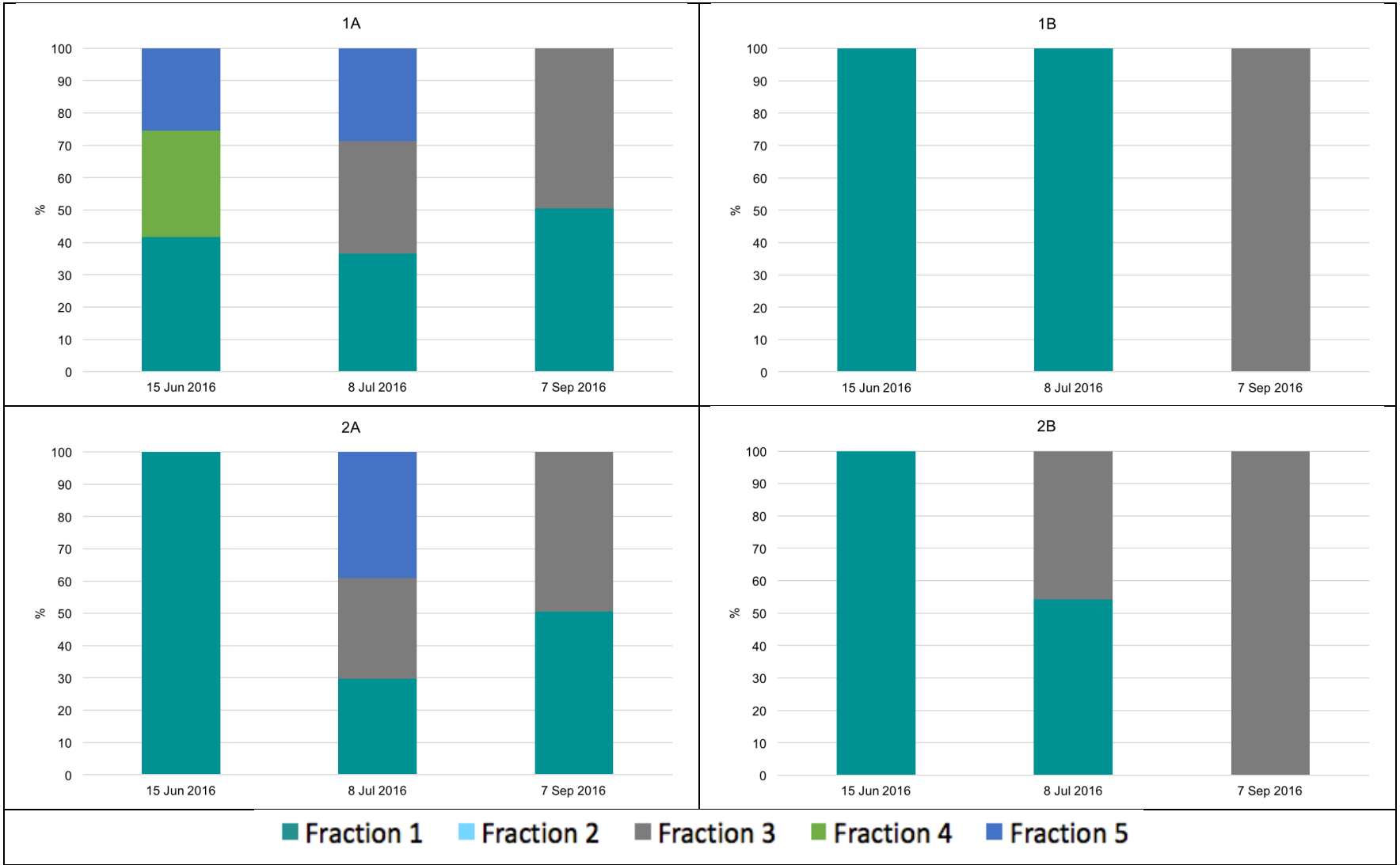



**Figure B3 – Fraction distribution of cadmium expressed as percent over time (2016).**
Data in 2014 and 2015 was below detection limits.

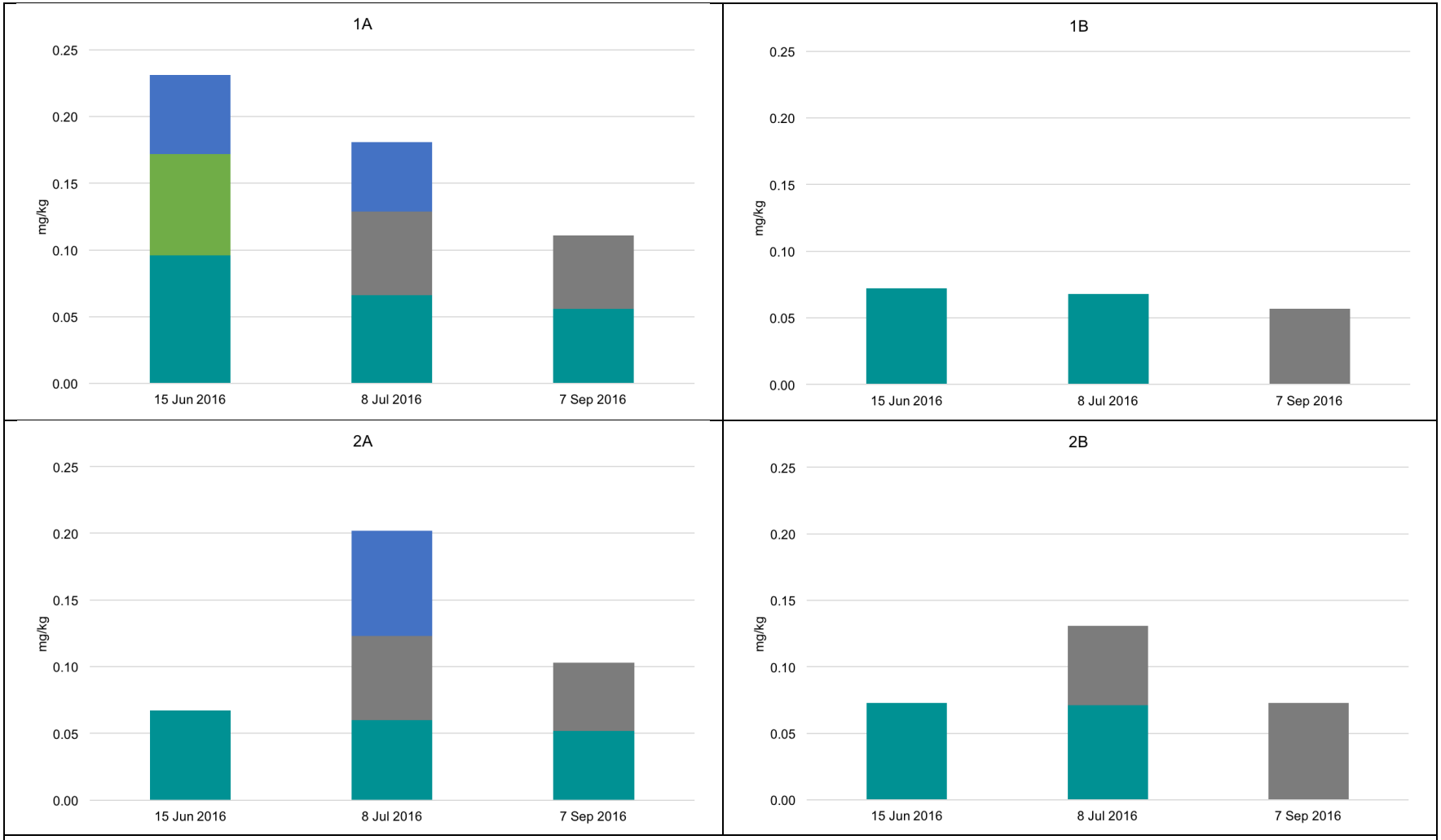



**Figure B4 – Fraction distribution of cadmium expressed as mg/kg over time (2015, 2016).**
Data in 2014 and 2015 was below detection limits.

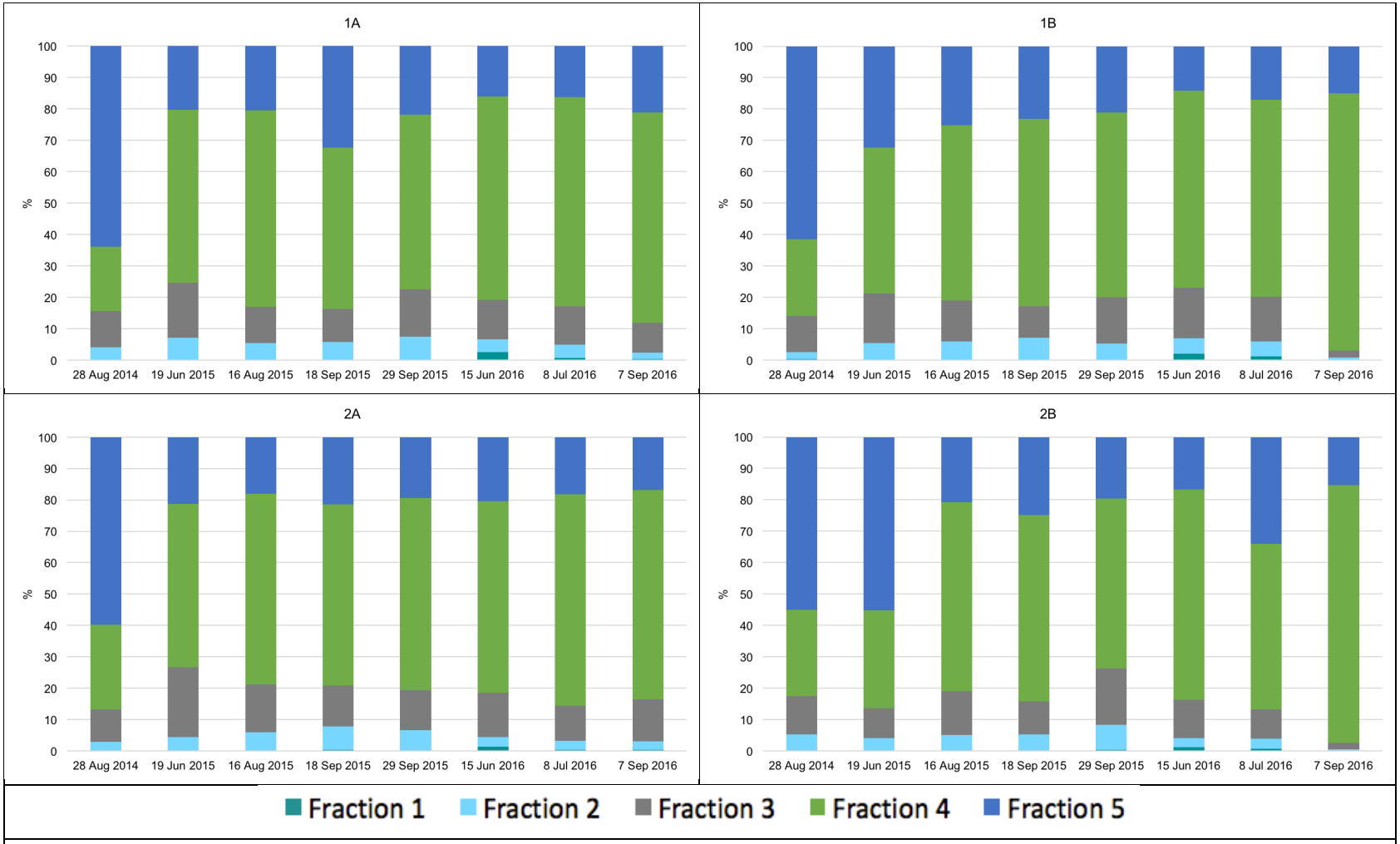



**Figure B5 – Fraction distribution of copper expressed as percent over time (2015, 2016).**

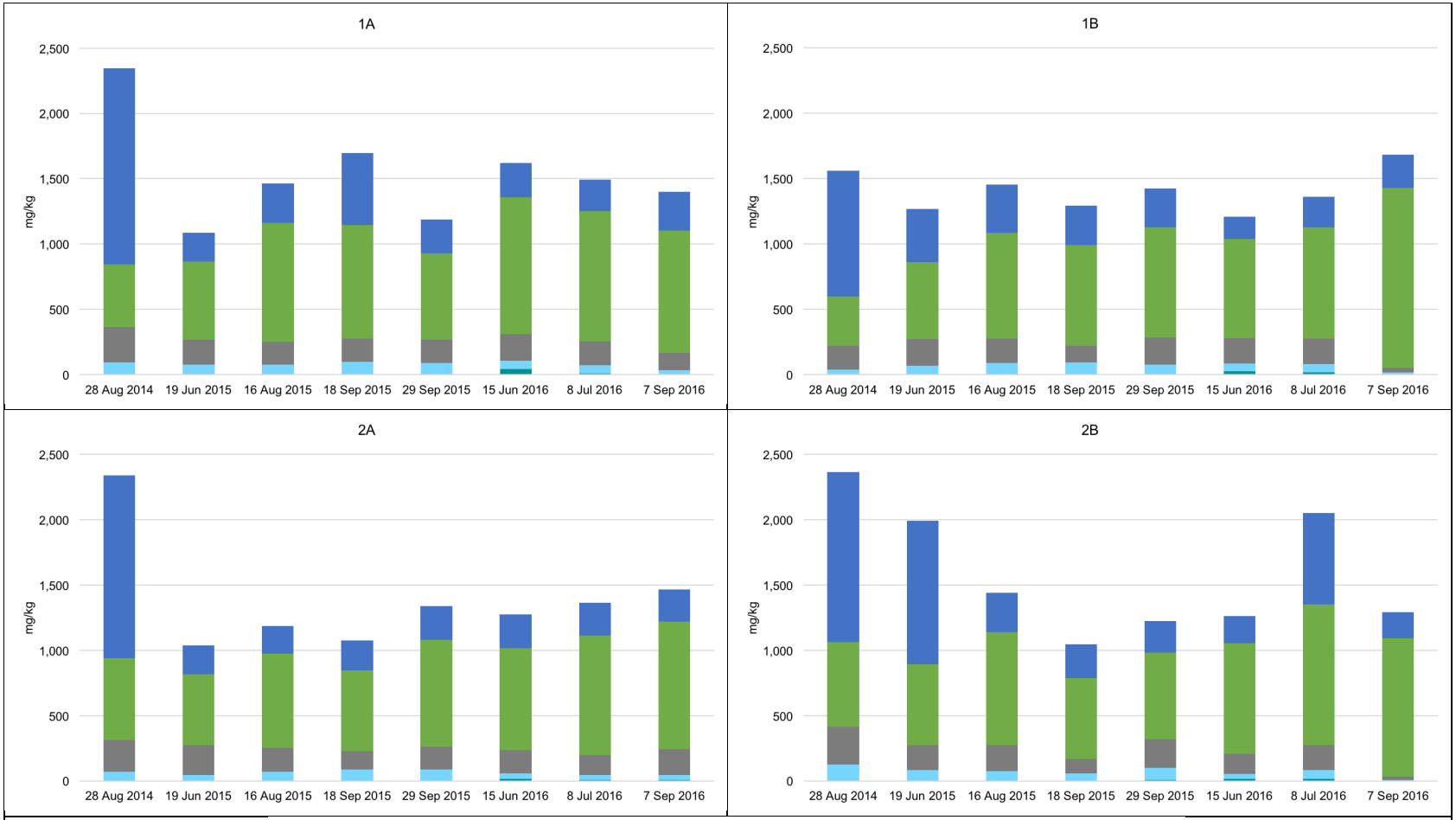



**Figure B6 – Fraction distribution of copper expressed as mg/kg over time (2015, 2016).**

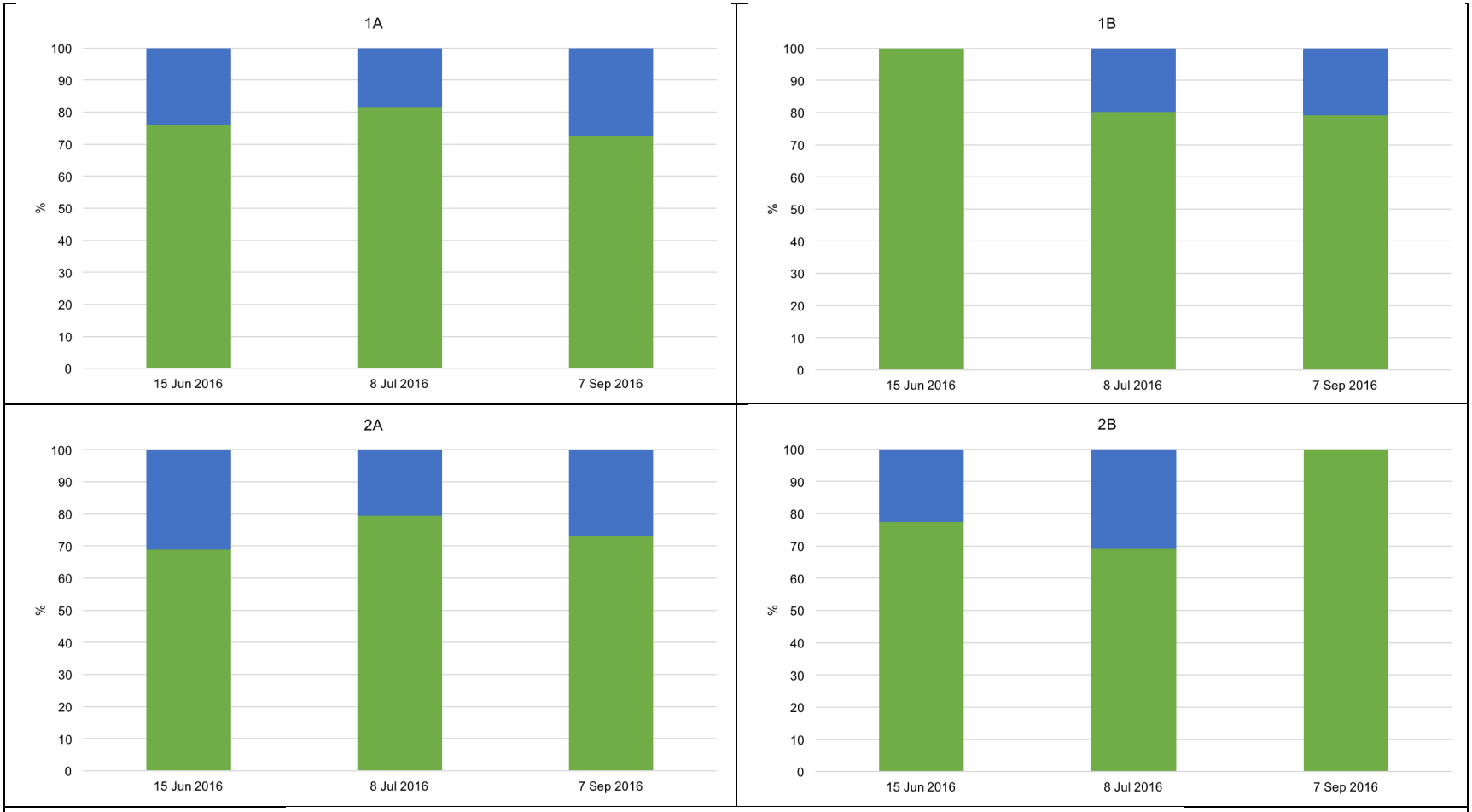



**Figure B7 – Fraction distribution of selenium expressed as percent over time (2016).**
Data in 2014 and 2015 was below detection limits.

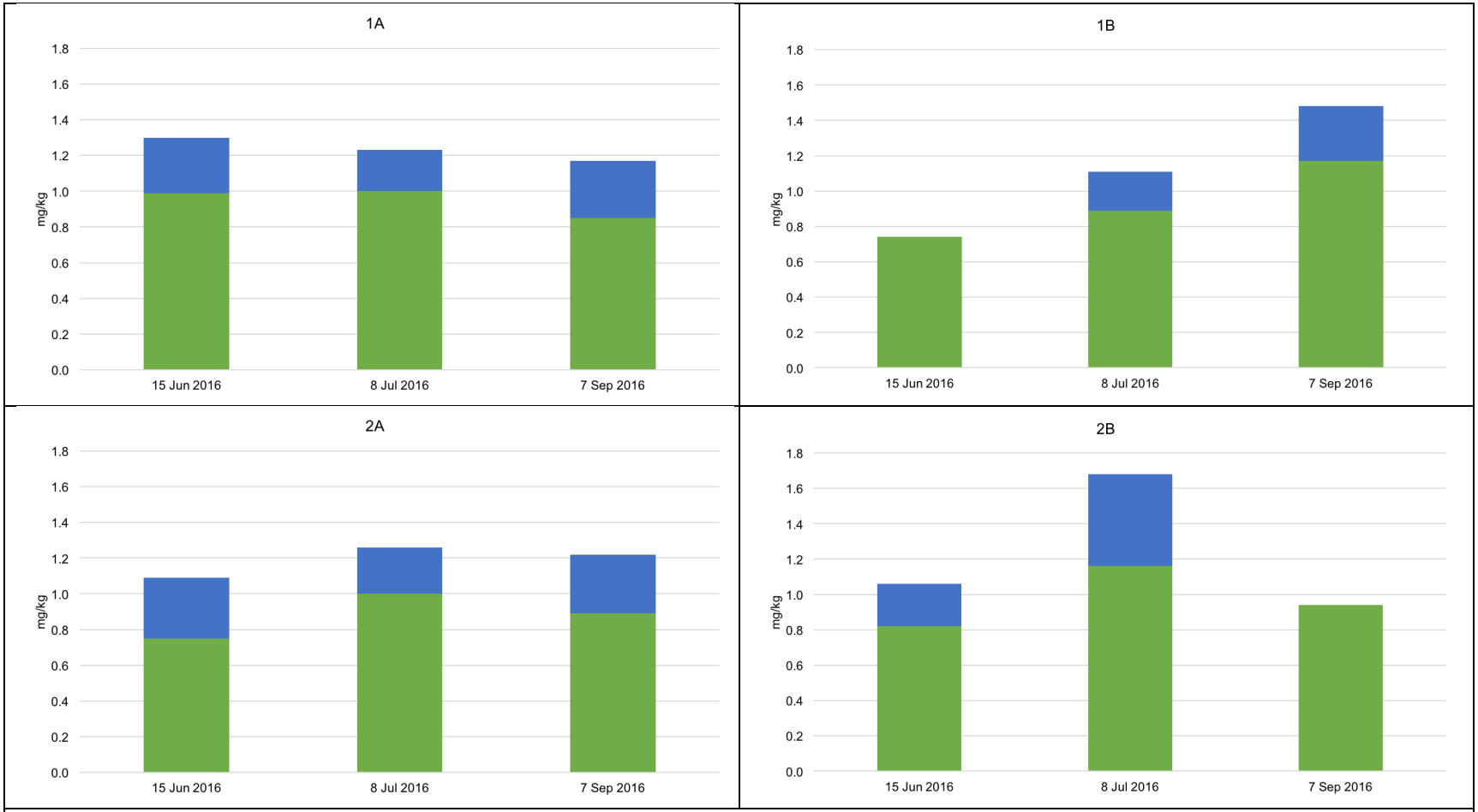



**Figure B8 – Fraction distribution of selenium expressed as mg/kg over time (2015, 2016).**
Data in 2014 and 2015 was below detection limits.

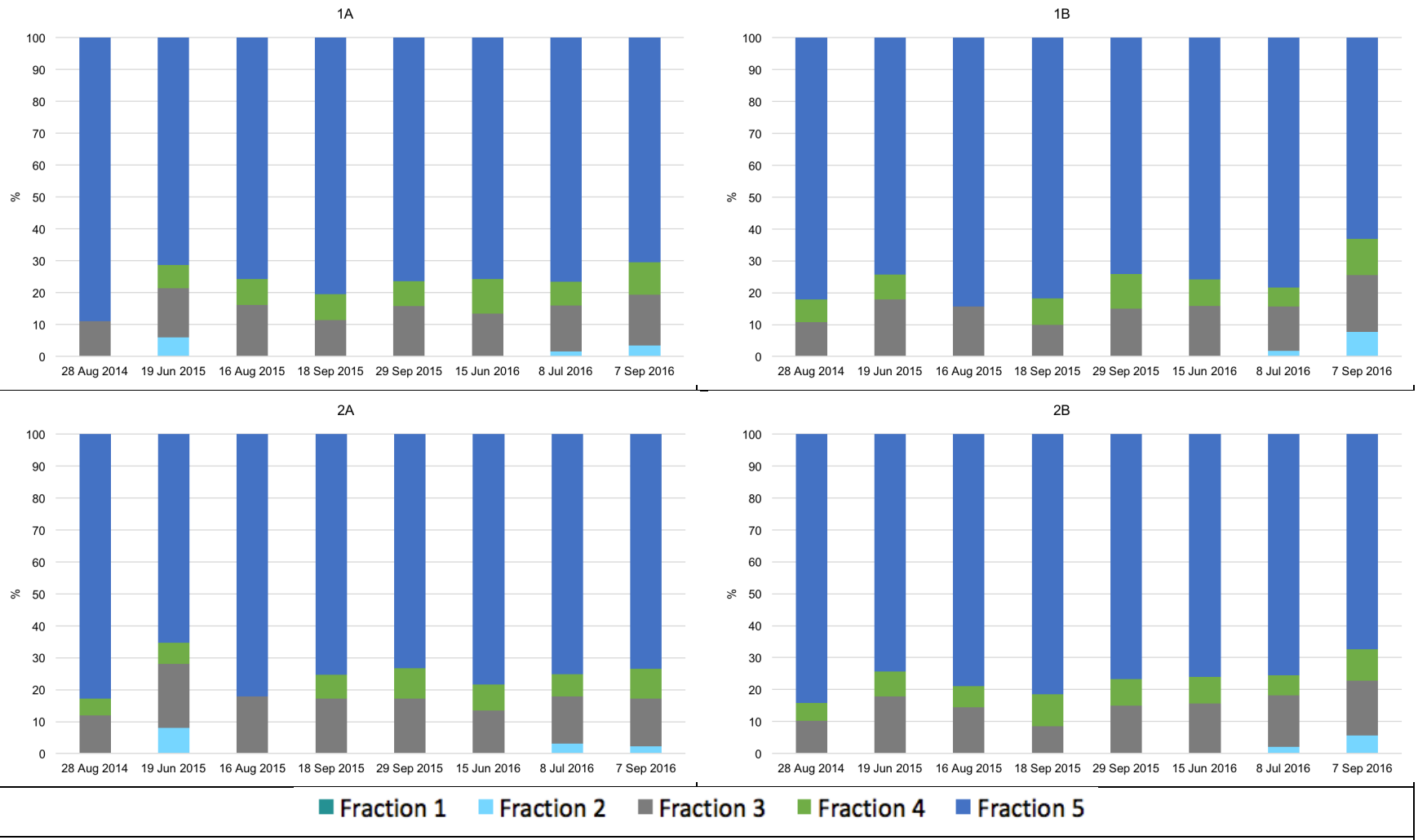



**Figure B9 – Fraction distribution of zinc expressed as percent over time (2015, 2016).**

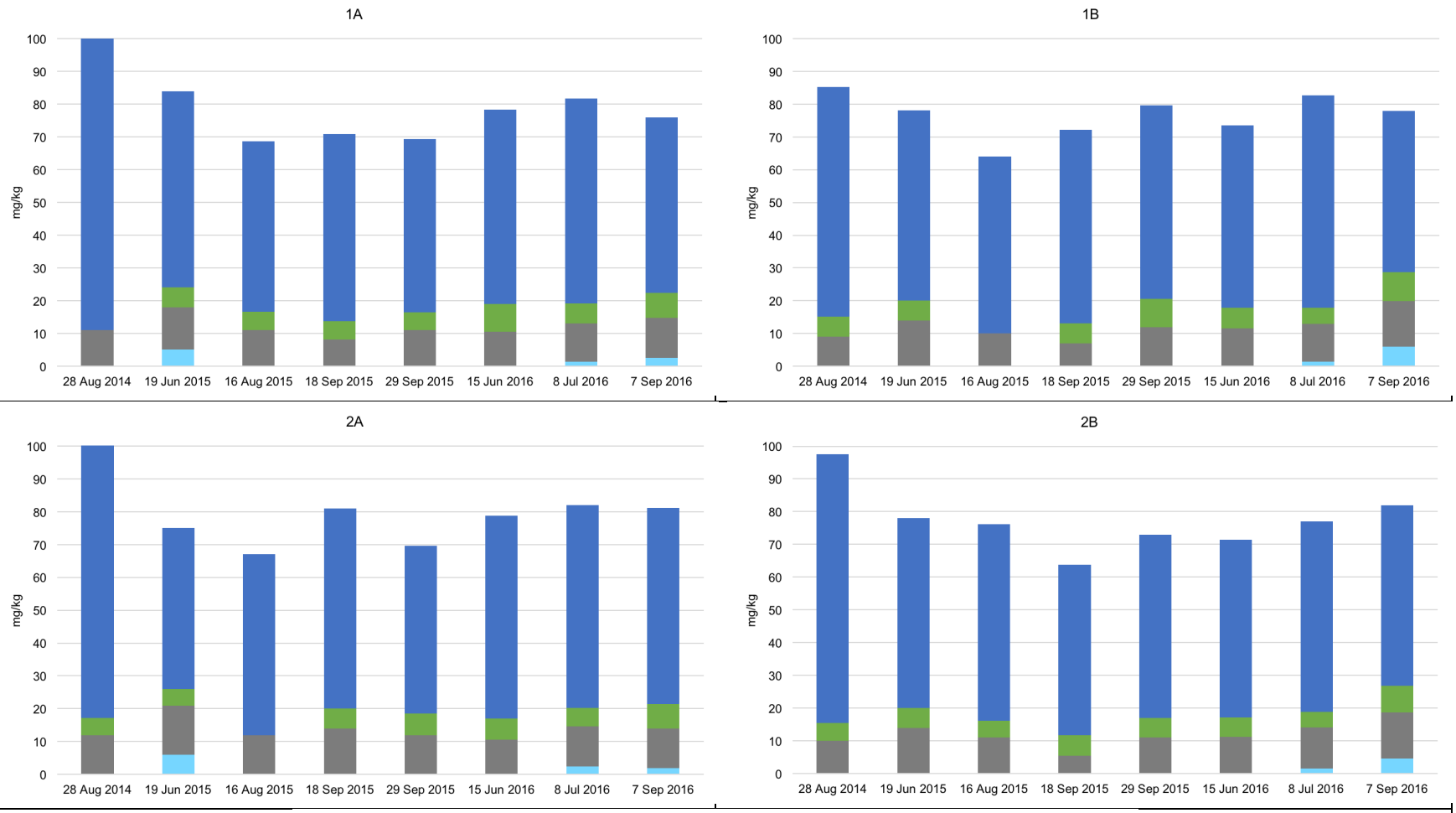
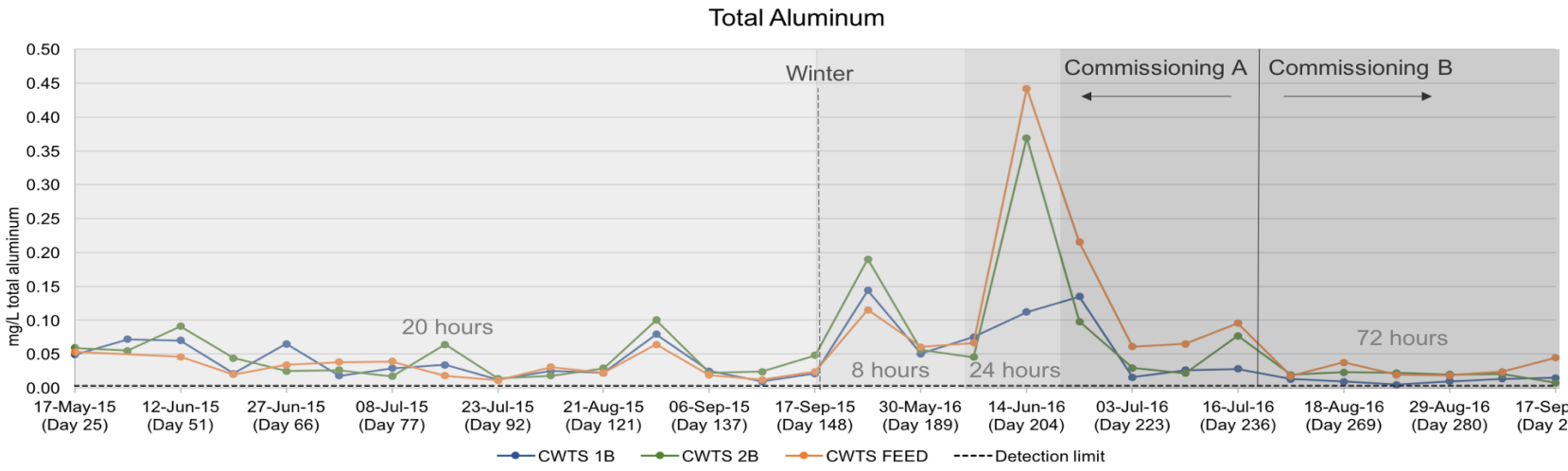



**Figure B10 – Fraction distribution of zinc expressed as mg/kg over time (2015, 2016).**



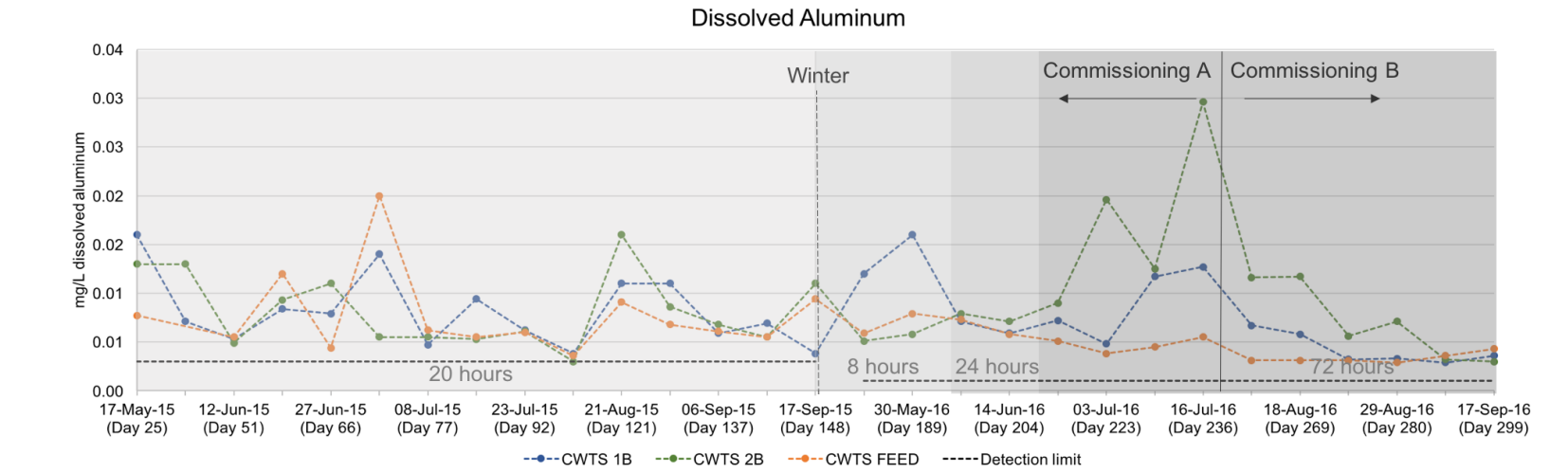
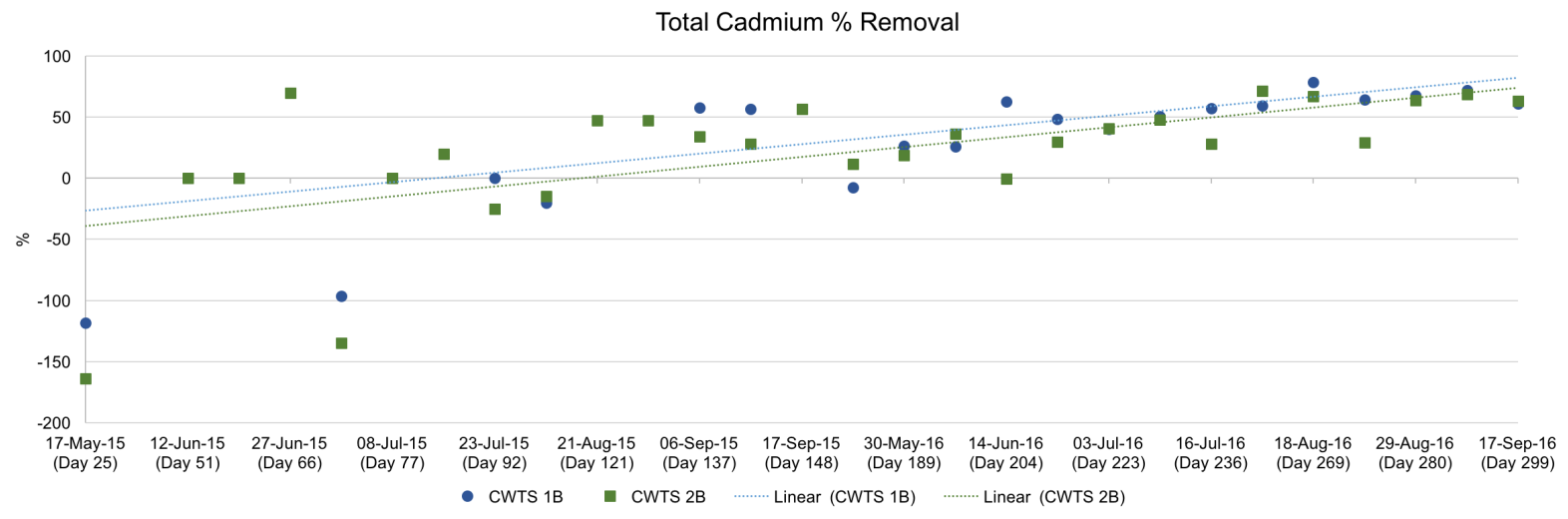




**Figure B11 – Aluminum concentrations in the demonstration scale wetland from May 17, 2015 to Sept 7, 2016.**
The HRT is indicated by grey shading and the duration in hours. The Maxxam (2015 results) measurement uncertainty (MU) for aluminum is +/- 0.0030 mg/L. The ALS (2016 results) MU is +/- 0.0010 mg/L. Timepoints where the dissolved concentration is higher than the total concentration are within the limit of uncertainty.



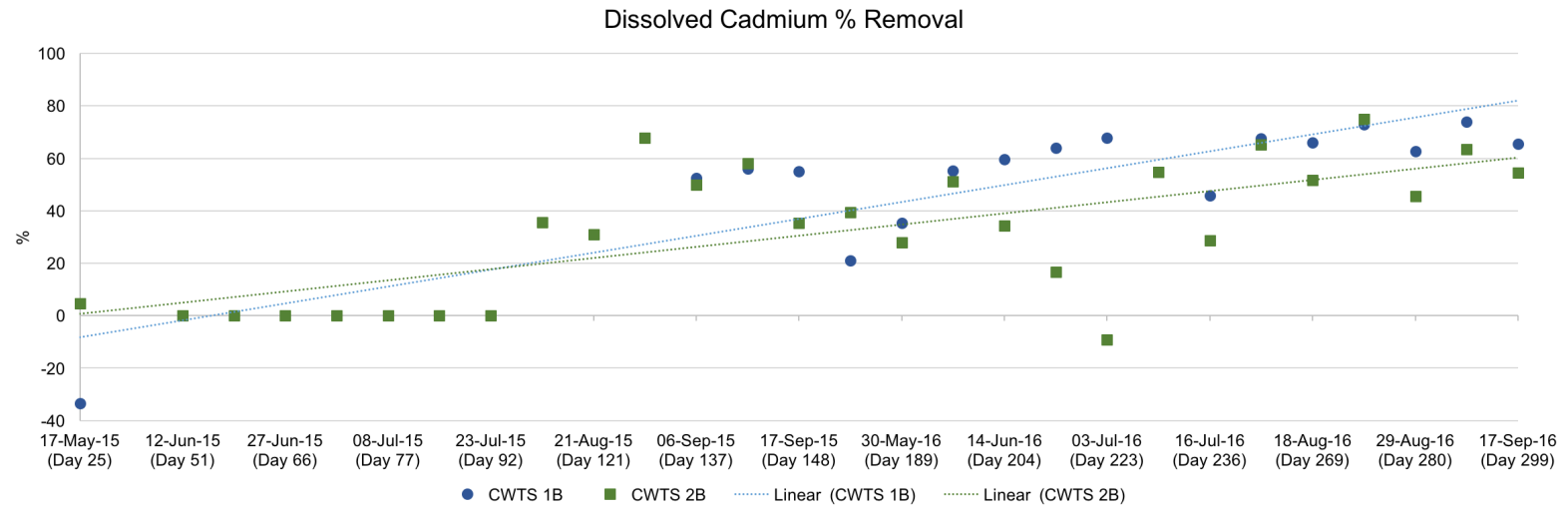
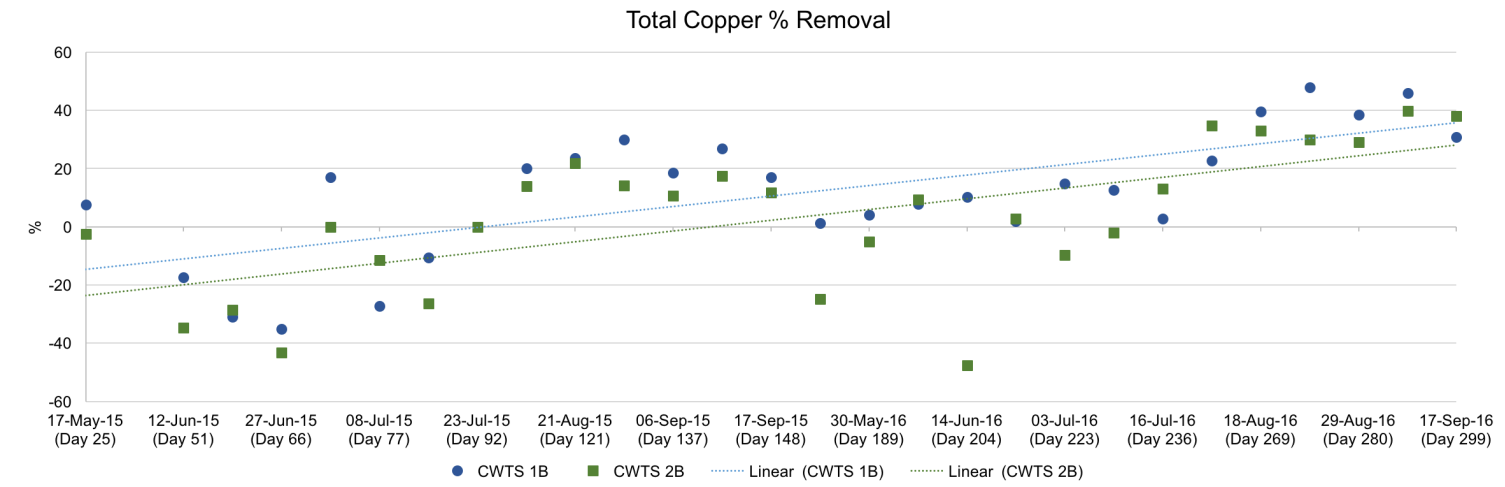




**Figure B12 – Percent removal of cadmium in the demonstration scale wetland.**
If the concentration was below the detection limit of the assay, the detection limit was used to calculate the percent removal. The Maxxam (2015 results) measurement uncertainty (MU) for cadmium is +/- 0.020 µg/L. The ALS (2016 results) MU is +/- 0.005 µg/L. The percent removal calculations for cadmium are therefore estimations within this range of error.



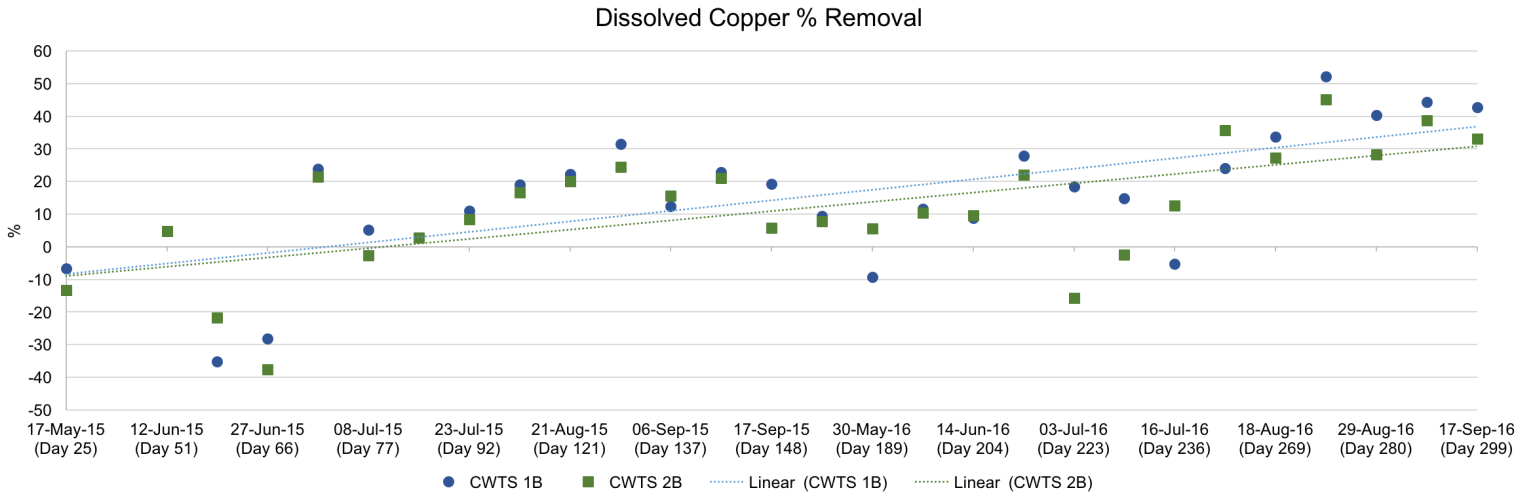
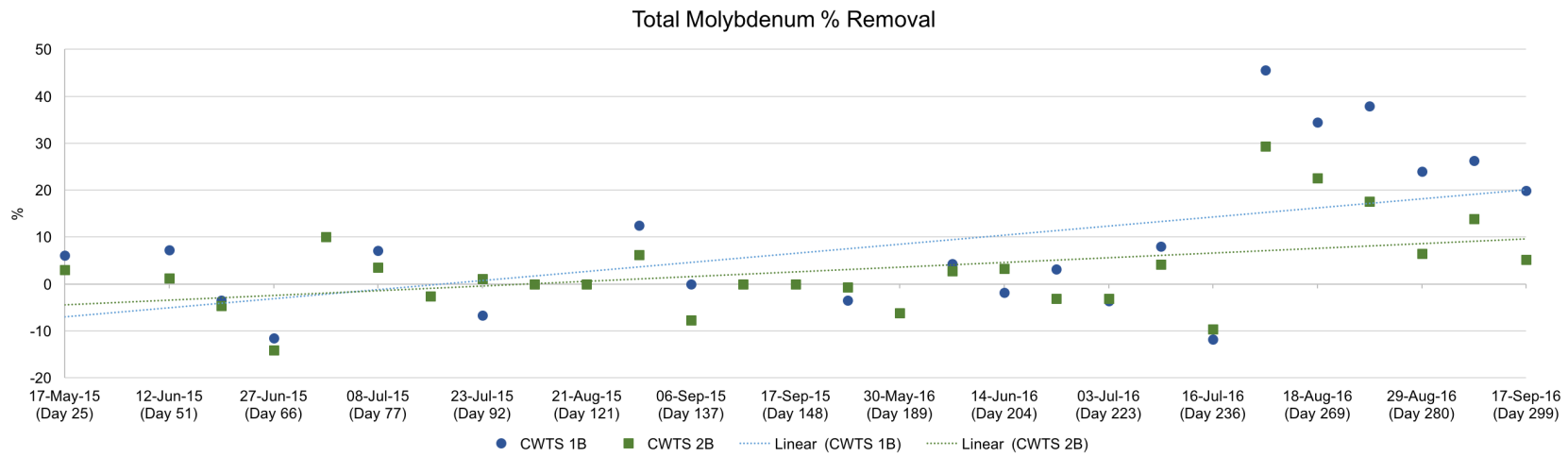




**Figure B13 – Percent removal of copper in the demonstration scale wetland.**
If the concentration was below the detection limit of the assay, the detection limit was used to calculate the percent removal. The Maxxam (2015 results) and The ALS (2016 results) measurement uncertainty (MU) for copper is +/- 0.0002 mg/L.



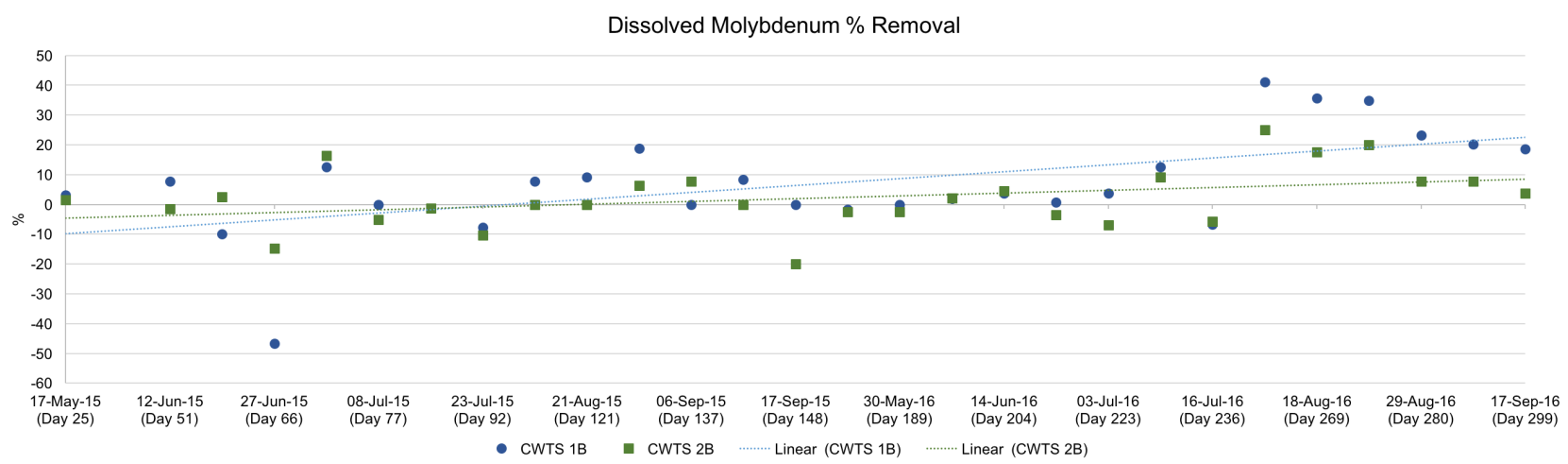
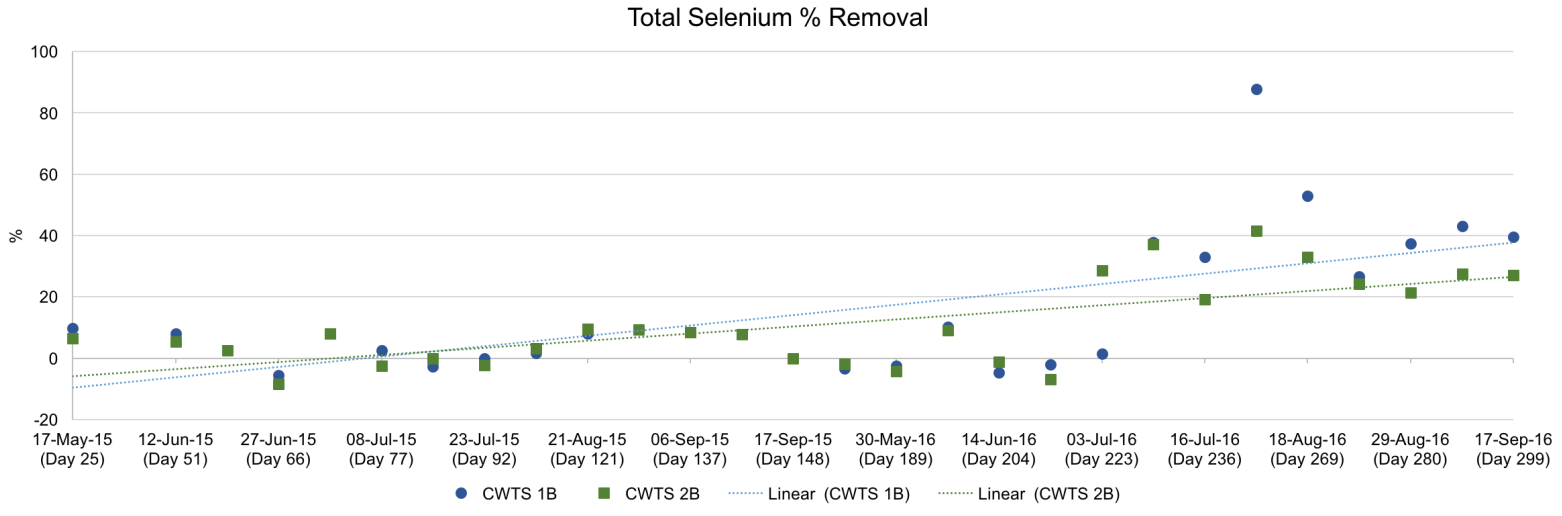




**Figure B14 – Percent removal of molybdenum in the demonstration scale wetland.**
If the concentration was below the detection limit of the assay, the detection limit was used to calculate the percent removal. The Maxxam (2015 results) measurement uncertainty (MU) for molybedenum is +/- 0.0002 mg/L. The ALS (2016 results) MU is +/- 0.000050 mg/L.



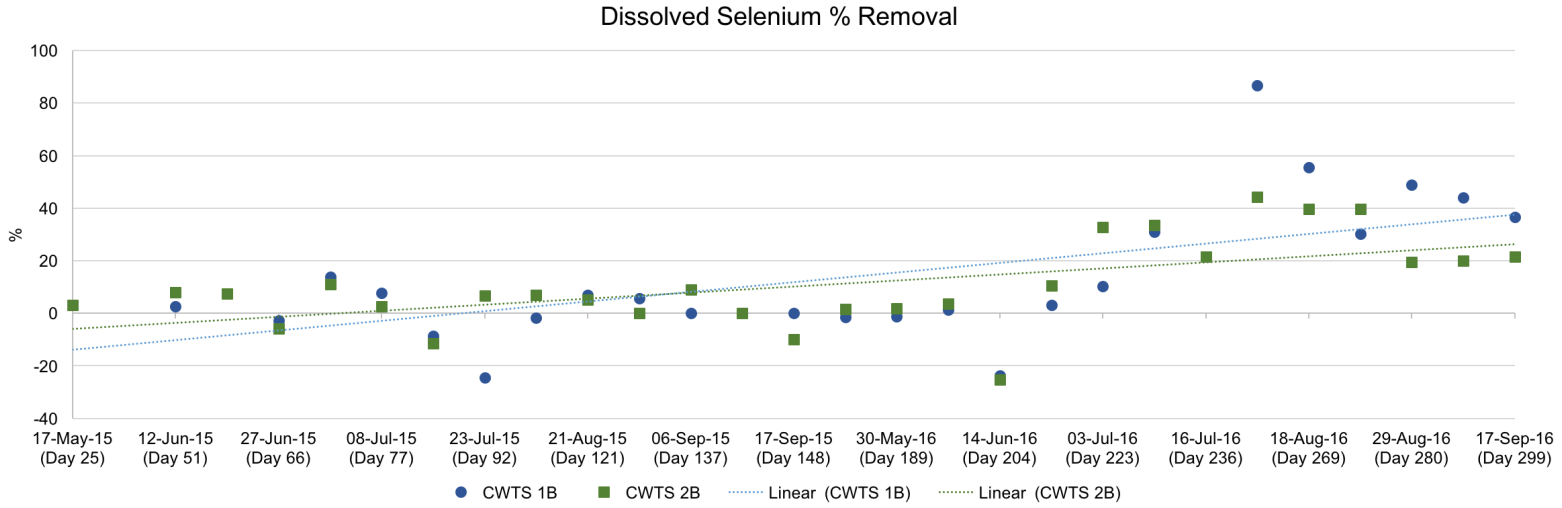
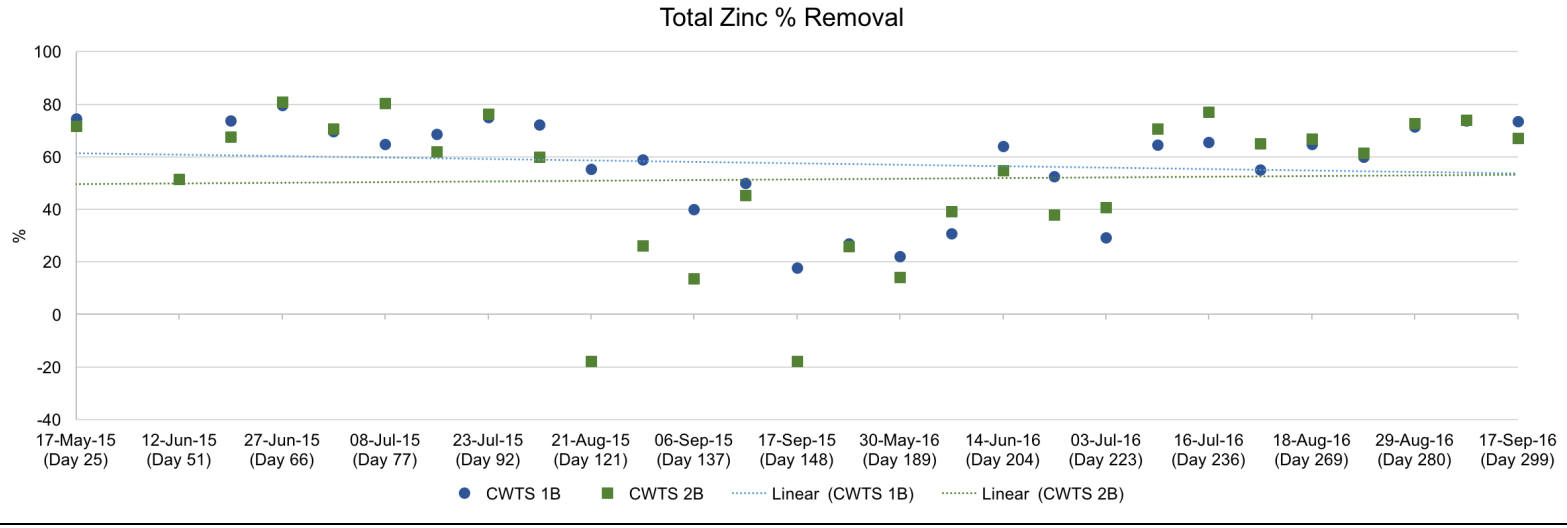




**Figure B15 – Percent removal of selenium in the demonstration scale wetland.**
If the concentration was below the detection limit of the assay, the detection limit was used to calculate the percent removal. The Maxxam (2015 results) measurement uncertainty (MU) for selenium is +/- 0.0002 mg/L. The ALS (2016 results) MU is +/- 0.000050 mg/L.



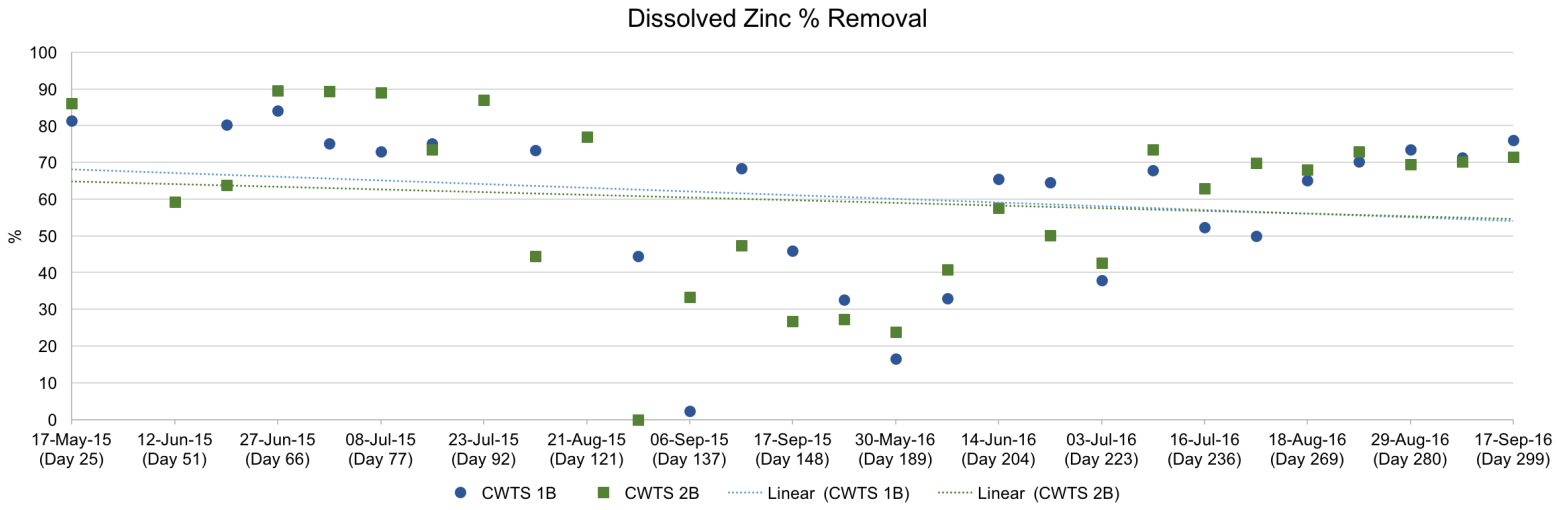




**Figure B16 – Percent removal of zinc in the demonstration scale wetland.**
If the concentration was below the detection limit of the assay, the detection limit was used to calculate the percent removal. The Maxxam (2015 results) measurement uncertainty (MU) for zinc is +/- 0.0030 mg/L. The ALS (2016 results) MU is +/- 0.0010 mg/L.

Contango STRATEGIES LTD.

*Forward looking.* Lateral thinking.

# Minto Mine Constructed Wetland Treatment Research Program – Demonstration-Scale 2017

Document # 011_1117_10B

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Date: November 2017

**Executive Summary**

The Minto Mine is an open pit and subsurface copper mine located 240 km northwest of Whitehorse in the Yukon Territory. As a result of mining activities, cadmium, copper, molybdenum, selenium, and zinc are slightly elevated beyond background concentrations and have been identified as constituents of concern in the Reclamation and Closure Plan for the Minto Mine. As part of the Reclamation and Closure Plan, a constructed wetland treatment system (CWTS) was designed by Contango with the objective of attaining suitable passive treatment of water quality at mine closure.

A phased approach is being followed to guide the site-specific design and implementation of a constructed wetland treatment system at closure. The phased approach for Minto Mine was initiated with a site assessment in 2013 that identified plants suitable for a CWTS as well as natural treatment processes that were already occurring on-site. Following the site assessment, pilot-scale testing was undertaken to confirm and provide proof-of-concept before constructing the on-site demonstration-scale wetland.

The demonstration-scale constructed wetland treatment system was constructed at Minto in 2014 and commissioned from 2015 through mid-2017 during which time the system matured and operational adjustments were made. Commissioning successfully established plant and microbial populations and achieved conditions conducive for treatment of constituents of concern. The demonstration-scale CWTS operational period ran for a month from mid-August to mid-September 2017. Various aspects of the system were measured in 2017 and are detailed in this report including operating conditions, water treatment performance, fate and distribution of treated metals, evapotranspiration, detritus decomposition rates, microbial community characterization (catalyzing treatment reactions), and pest control.

Throughout the operational period, the demonstration-scale CWTS successfully achieved an average decrease in concentrations of 0.0169 µg/L for cadmium (from 0.0261 µg/L to 0.0092 µg/L), 31.8 µg/L for copper (from 49.1 µg/L to 17.3 µg/L), 3.6 µg/L for molybdenum (from 6.3 µg/L to 2.7 µg/L), 3.5 µg/L for selenium (from 4.0 µg/L to 0.5 µg/L), and 47.3 µg/L for zinc (from 49.2 µg/L to 1.9 µg/L). Leaching of copper and other constituents from the mineralized soils used in the construction decreased by the end of 2017 with constituents showing a shift into stable reduced mineral forms in the soil (as the CWTS was designed to do for constituents from the water, but also has now done for the elements in the soil). Additional positive results were also documented; plant uptake of constituents remained minimal throughout operation and high abundance of beneficial sulphide-producing bacteria for treatment of Cu, Cd, Zn, as well as nitrate- and selenium-treating bacteria associated with plant roots.

The operational period of the demonstration CWTS confirmed that the predicted water quality for the Minto Mine at closure is amenable to treatment by these methods. Results from ongoing monitoring of the system in future years will be used to optimize performance and inform the designs for the full-scale constructed wetland treatment system.

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**Abbreviations and definitions**

**Acid volatile sulphides (AVS)** – Sulphide complexed with Fe (FeS) where the sulphide can preferentially exchange Fe for heavy metals (e.g., Ni, Zn, Cd, Pb, Cu, Hg) which are then more stably bound.

**Amendment** – A chemical or organic material added to encourage specific conditions (e.g., aerobic/anaerobic, pH, ORP) or as a source of something that is needed for passive treatment (e.g., nutrients, alkalinity, binding sites, etc).

**Carbon source** – A source of carbon (energy/electrons) for microbes (see **electron donors**). Examples include ethanol, methanol, acetate, sugar (glucose), molasses, wood chips, detritus (dead plant matter).

***Carex aquatilis*** – A plant (emergent macrophyte) commonly known as water sedge.

**Contango** – Contango Strategies Ltd.

**Constructed wetland treatment system (CWTS)** – Wetlands that are designed and constructed to remove compounds from water, using natural processes to sequester them into the soils rendering them less bioavailable. They are different from wetlands that provide habitat for wildlife.

**Constituent of Concern (COC)** – Specific elements that have been identified for evaluation, including cadmium, copper, molybdenum, selenium, and zinc.

**Denitrification** – Where nitrate ($NO_3^-$) is reduced by microorganisms to form nitrite ($NO_2^-$), nitric oxide (NO), or nitrous oxide ($N_2O$), or nitrogen gas ($N_2$) (see **nitrate reduction**).

**Dissolved oxygen (DO)** – Diatomic oxygen ($O_2$) dissolved in water; oxygen can dissolve in water by diffusion from surrounding air, as a product of photosynthesis, or through forced aeration.

**Electron donor(s)** – A chemical compound that donates electrons to another compound (see **carbon source**). An electron donor is a reducing agent, which that by virtue of it donating electrons, is itself oxidized (see **oxidation** and **reduction**).

**Explanatory parameters** – Quantifiable parameters that indicate the type of water treatment reactions that are likely to take place (i.e., dissolved oxygen, pH, soil redox).

**Evapotranspiration** – The combined effects of open water evaporation and plant transpiration (Beebe *et al*, 2014).

**Genetic analysis** – Analysis to assess the presence, identity, and diversity of different microbes in a sample.

**ICP-MS** – Inductively coupled plasma mass spectrometry.

**Macrophytes** – An aquatic plant, large enough to be seen by eye. Can be emergent, submergent, or floating.

**Microbes** – Microscopic organisms that can be uni- or multi-cellular. This includes algae, bacteria, fungi, viruses, and yeast.

**Most probable number (MPN)** – A statistical value representing the viable population of microbes in a sample through use of dilution and multiple inoculations.

**Oxidation** – The loss of electrons, or increase in valence state, by a molecule, atom, or ion. Can be driven by microbes. Process is complementary to chemical reduction.

**Oxidation-reduction potential (ORP)** – A measure of the tendency of a chemical species to acquire or donate electrons, thus becoming reduced or oxidized, respectively, measured in millivolts.

**Passive or semi-passive treatment system(s) (PTS)** – General term used to refer to both passive and semi-passive treatment systems that use processes coupling transformations (e.g., chemical and biogeochemical reactions) with physical transfers (e.g., sorption, filtration) to remove constituents from water, often operationally passive with little long-term management required.

**Redox** – Oxidation-reduction potential (in sediment), a measure of the tendency of a chemical species acquire or donate electrons, thus becoming reduced or oxidized, measured in millivolts. This measurement is relative to the water ORP.

**Reduction** – The gain of electrons, or a decrease in valence state, by a molecule, atom, or ion. Can be catalyzed by microbes. Process is complementary to chemical oxidation.

**Simultaneously extracted metals (SEM)** – Amounts of heavy metals such as Ni, Zn, Cd, Pb, Cu, Hg in sediment, assessed in the context of AVS for excess sulphide. (also see **acid volatile sulphide**)

**Sorption** – The physical and/or chemical process by which one substance becomes attached to another substance.

**Specific conductivity (SPC)** – A measurement of electrical conductivity in water that is typically expressed in µs/cm, which has been adjusted for temperature (25°C).

**Species (sp.)** – One of the basic units of biological classification and a taxonomic rank. Rank in the classification of organisms below genus and above strain. Also can be used to refer to the oxidation state of a mineral (e.g., selenate and selenite are species of selenium).

**SPLP** – Synthetic precipitation leachate procedure.

**Sulphide** – An inorganic anion of sulphur that can form stable complexes with metals and make them insoluble in water (remove them from the water).

**Sulphide producing bacteria (SPB)** – Microbial reduction of sulphur compounds, such as sulphate, sulphite, thiosulphate, and sulphur, which produces sulphides and alkalinity. (see also **SRB**).

**Sulphate reducing bacteria (SRB)** – A form of sulphide producing bacteria that specifically uses sulphate for reduction (see **sulphide producing bacteria**).

**Sulphide production** – Microbial reduction of sulphur compounds, such as sulphate, sulphite, thiosulphate, and sulphur, which produces sulphides and alkalinity.

**Thermodynamic minimum** – The minimum concentration of a contaminant of concern that is consistently achievable.

**Total dissolved solids (TDS) –** A measure of the combined organic and inorganic salts dissolved in water.

**Total organic carbon (TOC)** – A measurement of the total organic carbons present in water.

**Transfer –** Processes that treat water by transferring a constituent to another location without changing its form. For example: absorption, adsorption, dilution, dispersion, filtration, precipitation (aqueous to solid), and volatilization.

**Transform –** Processes that change the chemical form or state of a constituent. For example: biodegradation, biotransformation, hydrolysis, ionization, oxidation, photolysis, and reduction.

# 1. Introduction

The Minto Mine, owned and operated by Capstone Mining Corp., is located 240 km northwest of Whitehorse on the west side of the Yukon River. The Minto property lies within the eastern part of the Dawson Range, with elevations from 700 to 1,000 m above mean sea level. The landscape has rounded mountains intersected by broad valleys and drainages that are part of the Yukon River watershed.

The Minto Mine has been in commercial operation since October 2007 and the deposits being mined are copper sulphide mineralized zones. Surface and groundwater water quality is a key consideration in the evaluation of potential effects of mining and mineral development projects and changes to water quality parameters have the potential to affect aquatic and human use of water resources. A Reclamation and Closure Plan (RCP) is required under both the Water License and the Quartz Mining License. The RCP is intended to address the long-term physical and chemical stability of the site and closure of the proposed features and disturbances associated with the mine. As a part of the RCP, a Constructed Wetland Treatment System (CWTS) is being designed, evaluated, and optimized for water treatment at closure through a phased program approved during the Minto Phase V/VI Expansion Project (Yukon Online Registry Project Number 2013-0100). Constituents of concern that are being evaluated through the CWTS program include cadmium, copper, molybdenum, selenium, and zinc.

## 1.1. Purpose and Objectives

The primary objective for operation of the demonstration-scale CWTS in 2017 was to complete commissioning and progress into operational performance. Once operational performance is achieved, the removal rate coefficients (RRC; $k$) can be assessed to evaluate and refine full-scale designs. To achieve the operational performance, it was recognized that the remaining copper in the soils used in construction needed to be converted into metal-sulphide form; therefore, this was addressed in the early months of 2017 and paired with evapotranspiration trials to make best use of this time.

In 2017, the monitoring program shifted focus from commissioning to testing of operational performance. Activities carried out in 2017 to achieve these objectives were:

- Monitor explanatory parameters and performance to determine when commissioning is complete and the operational period has begun;
- Assess removal of constituents from the water;
- Determine the hydraulic retention time (HRT) by tracer trial and associated correction factor to apply to the nominal (calculated) HRT;
- Evaluate CWTS performance, and determine achievable concentrations of contaminants of concern (thermodynamic minimums);
- Update site-specific removal rate coefficients (from commissioning period) with data from operational period;
- Determine amount of water loss due to evapotranspiration and effect on outflow concentrations;
- Monitor metals leaching from mineralized soils used in construction;

- Assess stability of constituents of concern in soils;
- Determine the rate and extent of detritus decomposition (*C. aquatilis* leaves) in the CWTS over time;
- Assess treatment mechanisms (including microbes); and
- Determine an appropriate method for insect pest control (aphids) in the CWTS.

### 1.2. Overall CWTS Project Approach

For a CWTS to be effective, it must be designed, piloted (tested), optimized, implemented, and maintained in a site-specific manner. A phased approach allows for improvements and optimization at each step. The phases used at the Minto Mine include:

1) site assessment and information gathering;
2) technology selection and conceptual design;
3) pilot-scale testing and optimization (controlled environment, off-site);
4) demonstration-scale confirmation and optimization (on-site); and
5) full-scale implementation.

Phases 1 to 3 are complete at Minto. This work is summarized in the Research Program, Pilot Plant and Demonstration reports completed by Contango (2014a and 2014b). Phase 4 of the project is underway, with the on-site demonstration CWTS constructed at the Minto Mine during fall 2014 (Contango, 2015). Commissioning of the CWTS occurred from 2015-2017 with operations beginning in late 2017. Performance results of the demonstration CWTS indicate that the CWTS is maturing as expected (Contango, 2015; 2016; 2017). This document reports on the 2017 on site demonstration-scale CWTS data, with focus on results from the operational period from August 18 – September 22, 2017.

## 2. Demonstration-Scale Constructed Wetland Treatment System Design

### 2.1. CWTS Layout and Dimensions

The demonstration-scale CWTS is located on the northeast side of the mine site, perched on the MVFE area as shown in Figure 1.

Construction of the demonstration-scale CWTS was completed in 2014 and includes two series in parallel with two cells in each series and a final catchment basin (Figure 1). Water flows from the feed tank through the A cells, through the B cells and into the final combined catchment basin. Water from the catchment basin of the demonstration-scale CWTS is not discharged off-site, rather it is collected in a sump at the toe of the Mill Valley Fill Extension (MVFE). Series 1 and series 2 flow independently of each other and are intended as replicates for analytical testing and operation confirmation. Additional details can be found in the Minto Demonstration-Scale Report (Contango, 2015) and Appendix A of this report.




**Figure 1 – Picture of demonstration-scale CWTS at Minto Mine.**
Demonstration-scale CWTS location in relation to its surroundings. To the far right is the mine camp while below is the tree line. This photo was taken on September 24, 2017.

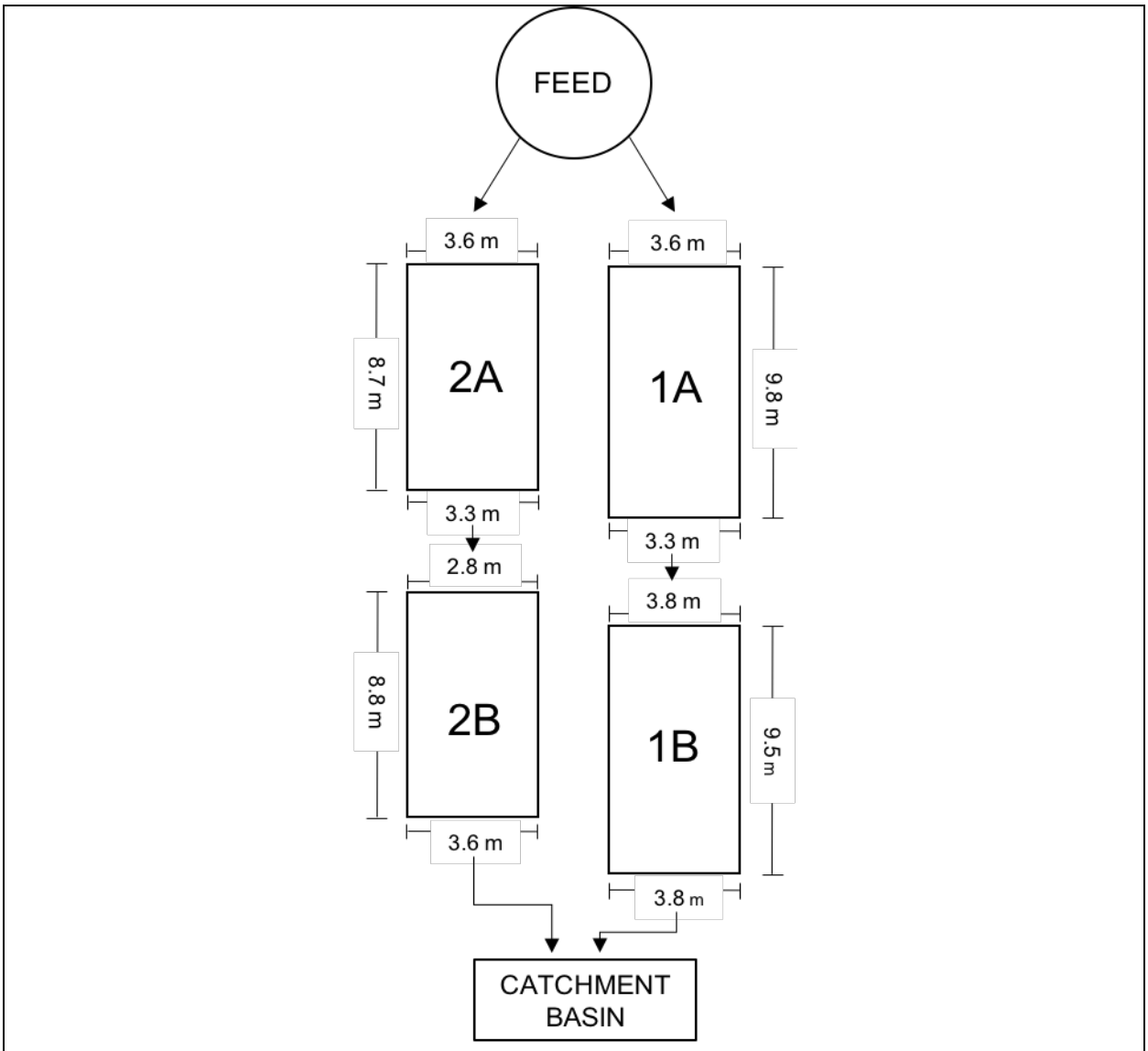



**Figure 2 – Diagram of demonstration-scale CWTS.**
Dimension measurements are indicated at soil surface. Water flows are indicated with black arrows. Water flows from the feed tank into the A cells, into the B cells then into the final catchment basin. Series 1 and series 2 flow independently of each other, and serve as replicates.

### 2.2. Soils

Soils used to construct the CWTS are described in Appendix A of this report and in the initial report that outlines construction (Contango, 2015). In brief, the recommended soil for the CWTS was sand, with 2-7% by volume organic material (e.g., woodchips, peat). The material used in the construction of the demonstration-scale CWTS was an organic peat, and analyses received after construction indicated an elevated concentration of leachable copper (Appendix A, Table A2). This leachable copper has affected the CWTS performance results. Therefore, this has been a focus of efforts through the commissioning period to transition these leachable copper minerals into stable sulphide minerals which will not leach from the CWTS.

### 2.3. Vegetation

The demonstration-scale CWTS was planted with *Carex aquatilis* (aquatic sedge) and aquatic mosses (bryophytes) from the W10 area of the Minto Site. The plant selection and borrow source were identified during the site assessment in 2014 (Contango, 2014a) and pilot-scale testing (Contango, 2014b).

### 2.4. Water Source

The water source for the demonstration-scale CWTS is seepage from the toe of the Mill Valley Fill Extension (MVFE) and was selected for the demonstration-scale CWTS as the seepage is similar to that expected upon closure in the MVFE area. Zinc concentrations were elevated in the water being used in the CWTS in 2016, and it was uncertain if this was due to a culvert used for water collection in the area or seasonal variation. However, zinc concentrations remained elevated in 2017, suggesting that the culvert is contributing to elevated zinc concentrations. Further details can be found in Appendix A and Contango's 2016 update report (Contango, 2017).

## 3. Commissioning and Operations

The period between the construction of the CWTS and achieving the expected treatment performance is referred to as the commissioning period. During this period, several criteria are monitored to determine when the commissioning period has been successfully completed. Criteria that were achieved that indicated the end of the commissioning period and the beginning of the operational period for the Minto Mine demonstration-scale CWTS include the following and are further discussed in the sections listed:

- Plant establishment and maturation such that the plants have grown in to densities visually similar to natural wetlands in the area, but in monoculture (Section 3.2),
- Establishment of reducing conditions within the CWTS (i.e., average soil redox was below -100 mV consistently in 2017; Section 5.1),
- No increase in aqueous copper concentrations through the CWTS (due to copper containing soils used in construction;Sections 5.2.1 and 5.6), and
- Microbial population establishment and maturation to levels similar or better to pilot-scale (Section 5.9).

Once the above criteria were met, the CWTS was deemed to be in the operational period. The same criteria, other than the copper leaching, could be used for the full-scale CWTS. The on-site demonstration-scale CWTS was commissioned from 2015 to 2017, comprising of 135 days in 2015, 150 days in 2016 and 82 days in 2017 (Table 1). The CWTS then proceeded to the operational period and operated for 35 days in 2017 (Table 1).

**Table 1 – Days of operation of demonstration-scale CWTS.**

| Scale | Year | Period (days) | Date | |
|---|---|---|---|---|
| | | | Start | End |
| **Commissioning-A[2]** | **2014[1]** | 23 | Aug 27 | Sept 19 |
| | **2015** | 135 | May 16 | Sept 29 |
| | **2016** | 87 | May 2 | Jul 28 |
| **Commissioning-B[3]** | **2016** | 63 | Jul 29 | Sept 30 |
| | **2017** | 82 | May 27 | Aug 17 |
| **Operational Period** | **2017** | 35 | Aug 18 | Sept 22 |

[1] The CWTS was constructed in 2014, but no water testing occurred during this first month of commissioning-A.
[2] The end of the commissioning-A period and the beginning of the commissioning-B period was marked by the addition of organics on July 28, 2016.
[3] The end of the commissioning-B period and the beginning of the operational period was marked by stabilization of flow rates and resolution of feed water delivery complications.

For the demonstration-scale CWTS the commissioning period was divided into two periods, commissioning-A, and commissioning-B. The end of the commissioning-A period and the beginning of the commissioning-B period was marked by the addition of organics on July 28, 2016. These organics (straw and wood chips) were added to further aid the copper in the soils to transition into sulphide mineral forms, and represents an amount of organic material similar to what would be produced by the CWTS once fully established with *Carex aquatilis*.

The end of the commissioning-B period was expected to be between July 16 and August 2, 2017. However, due to issues with feed-water pumps and flow meters, the end of the commissioning-B period was extended to August 17, 2017 and was marked by stabilization of flow rates and resolution of feed water delivery complications. Additionally, sandbags were added at the end of each cell on August 11, 2017 to increase the water depth and further promote reducing conditions. Therefore, the operational period began on August 18, 2017 and ran until September 22, 2017. Flow was turned off to prepare for winter freeze-up on September 30, 2017, and the last sampling date used was September 22, 2017. Discussions in this document are focused on the operational period and further details on commissioning in 2015 and 2016 can be found in Contango's past reports (2015 and 2016).

## 3.1. Flow Rates

The targeted flow rates were varied during commissioning of the demonstration-scale CWTS to target desirable conditions for establishment of the CWTS. Since the cells in series 2 are smaller than cells in series 1, a faster flow rate is used for series 2 to obtain an equal HRT to series 1.

In 2017, a long HRT was selected to aid in generating reducing conditions in the CWTS and, therefore, flow rates were set to as slow as they could operate. The nominal HRT was targeted to be 5 days. The operational ranges of the flow meters used in the CWTS were 0.3 to 3 gallons per minute (GPM). To obtain this long HRT, the targeted flow rates used during the commissioning and operational periods of the CWTS in 2017 were 0.37 and 0.31 GPM for series 1 and series 2, respectively. Due to pump and flow meter issues, the actual flow rates varied from the target flow rates throughout 2017 commissioning and operational periods. Table 2 summarizes known pump and flow meter issues that occurred in 2017. The average flow rate for the 2017 operational period was a calculated flow rate of 0.38 GPM and 0.29 GPM for series 1 and series 2, respectively. Additional information on flow rates and associated HRT calculations are provided in Appendix A.

## 3.2. Health and Establishment of CWTS Vegetation

### *3.2.1. Carex aquatilis*

During the commissioning period, plants establish and mature, with density expected to increase over time. From planting in 2014 to the last site visit in 2017 *C. aquatilis* thrived in the CWTS creating a dense emergent macrophyte monoculture, supplemented with aquatic mosses (Figure 3). This suggests that *C. aquatilis* are very robust and reaffirms that they are a good candidate for use in the full-scale CWTS at Minto. In July 2017, an aphid infestation occurred in the CWTS which affected the *C. aquatilis*. The biomass above water appeared to partially die off, however the plants continued to send out new shoots suggesting the *C. aquatilis* were resilient to the infestation. Further discussion about the aphids and the control measures in 2017 is presented in Section 6.

### *3.2.2. Moss*

Aquatic mosses have continued to mature and expand in size from 2014 through 2017. The mature mosses are beginning to show characteristics of the desired coupled transfer (sorption, filtration) and transformation (mineralization, reduction) processes. The top of the moss is growing and producing new green biomass that provides transfer sites, and the older, bottom of the moss is turning black and beginning to decompose which creates sulphide reducing zones that allow for transformation (Figure 4 and Figure 5).

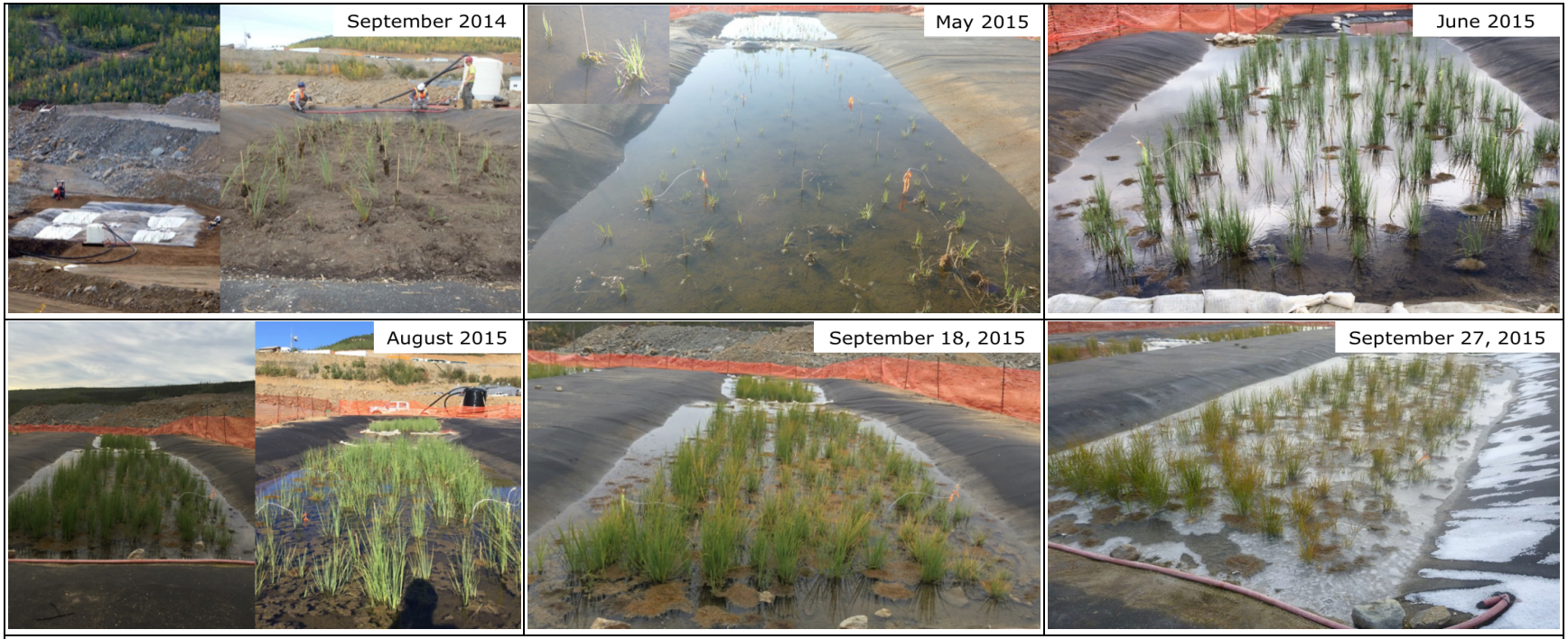



**Figure 3 – Maturation of the CWTS from construction through operations.**
2015 pictures show cell 2A.

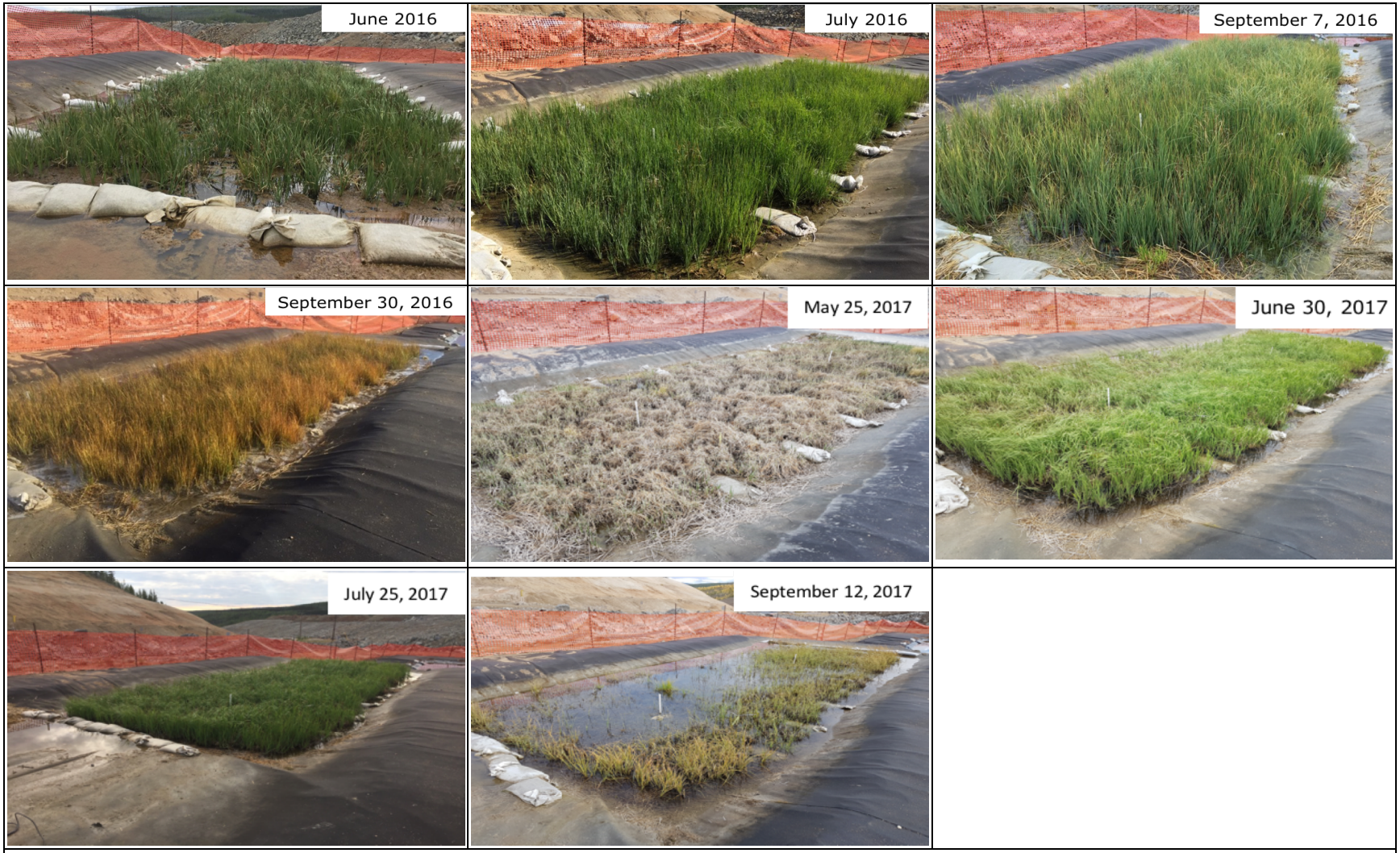



**Figure 3 continued – Maturation of the CWTS from construction through operations.**
2016 and 2017 pictures show cell 1B. September 12, 2017 shows increased yellowing and die off in cell 1B due to aphid infestation.




**Figure 4 – Moss maturation in CWTS through 2016.**




**Figure 5 – Moss top and bottom view in June 2016 and September 2017.**

## 4. Timeline and Sampling Schedule

Major events and operational adjustments or amendments for 2017 are listed in Table 2. Details for events up to 2017 can be found in the Minto Demonstration-scale 2016 Update Report (Contango, 2017). The actual dates as well as effective days of operation are provided, which adjusts for time that the CWTS was not receiving water when it was frozen. The effective days of operation allows for comparison to expected timelines from the pilot-scale testing, and for planning and scheduling to be done for full-scale construction and commissioning. The sampling schedule for 2017 was conceptually developed prior to beginning construction of the demonstration-scale CWTS (Appendix A). Actual dates of sampling were adjusted for timing of spring thaw and winter freeze-up, and the associated ability to have the pumps operating at the W62 sump to supply water to the demonstration-scale CWTS.

**Table 2 – Events and sampling activities since construction.**

| Event | Key Activity | Flow Rate Setting $m^3$/day (gal/min) | | Dates | Effective Days of Operation |
|---|---|---|---|---|---|
| | | CWTS Series 1 | CWTS Series 2 | | |
| CWTS constructed and planted | First sampling, water started. | * | * | August 27 – 31, 2014 | 0-4 |
| Freeze up for winter | Feed water pumps turned off. | * | * | September 19, 2014 | 23 |
| Winter 2014/2015 | | | | | |
| Commissioning-A[2] | | | | May 16 – September 29, 2015 | 136 |
| Winter 2015/2016 | | | | | |
| Commissioning-A[2] | | | | May 2 – July 27, 2016 | 86 |
| Commissioning-B[2] | | | | July 28 – September 30, 2016 | 64 |
| Winter 2016/2017 | | | | | |
| Flow started | Flow started. | 2.18 (0.40) | 1.85 (0.34) | May 27, 2017 | 312 |
| Evaporation Study | Flow stopped. | - | - | June 8, 2017 | 324 |
| End of Evaporation Study | Flow re-started. | 4.80 (0.88) | 4.58 (0.84) | June 15, 2017 | 331 |
| Flush CWTS | Flow increased. | 5.07 (0.93) | 4.20 (0.77) | June 15 – 19, 2017 | 331-335 |
| Contango Site Visit #7 (Spring Sampling) | Microbiology, soils, and water tested. | 2.07 (0.38) | 1.42 (0.26) | June 20-22, 2017 | 336-338 |
| | Detritus decomposition trial started. | | | June 21, 2017 | 337 |
| Saline Tracer Study | Salt added to cells for tracer study. | 1.74 (0.32) | 0.55 (0.10) | June 21 – July 2, 2017 | 337-348 |
| Flow interruptions | Flow rates increased causing feed tank to collapse, and flow stoppage. | * | * | July 16, 2017 | 362 |
| Contango Site Visit #8 (Summer Sampling) | Microbiology and soils tested. Detritus bags collected.[3] | * | * | July 25 – 26, 2017 | 371-372 |
| Flow interruptions | Pump issues. Repairs required and new totalizer installed on CWTS 1. | * | * | July 25 - August 16, 2017[1] | 371-393 |
| Sprayed for aphids | Insecticide applied 7 times to CWTS. | N/A | N/A | July 25 – September 13, 2017 | 371-421 |
| Water level raised | Sand bags were added to the ends of each cell. | * | * | August 11, 2017 | 388 |
| **Beginning of operational period** | | | | August 18, 2017 | 395 |
| Summer Water Sampling | Not completed during Contango Site Visit #8 due to flow interruptions. | 2.40 (0.44) | 1.64 (0.30) | | |
| Fall Sampling | Completed by Minto. Microbiology, soils, water, and plants tested. Detritus bags collected. | 2.02 (0.37) | 1.42 (0.26) | September 11, 2017 | 419 |
| Freeze up for winter | Flow stopped. | - | - | September 30, 2017 | 438 |

* This indicates no flow rate was given, flow rate was unmeasurable or variable; however, cells remained flooded throughout.
[1] Resolution of the flow interruptions marked the end of commissioning-B and the beginning of the operational period.
[2] Detailed information for Commissioning-A and Commissioning-B in 2015 and 2016 can be found in the Minto Demonstration-Scale 2016 Update Report (Contango, 2017).
[3] Due to flow interruptions during the Contango site visit, the summer seasonal water sampling occurred on August 18, 2017 when flows had re-started.

# 5. Performance

## 5.1. Monitoring Explanatory Parameters

The following are key findings regarding explanatory parameters, which are detailed further below:

- Dissolved oxygen (DO) decreased from an average of 8.4 mg/L during commissioning-B in 2016, to an average of 5.3 mg/L during operations in 2017. This elevated DO in the water column is likely the result of photosynthesis of algae and mosses. Despite this DO level in the water column being in oxidizing ranges, stable reducing conditions were achieved in CWTS soils within the targeted soil redox range (-100 to -250 mV).

Average water temperature of the demonstration-scale CWTS in 2017 were similar to those in 2015 (12.9°C) and 2016 (10.2°C). The average water temperature during the operational period in 2017 was 9.7°C, ranging from 5.3°C to 14.9°C. As expected, conductivity did not change from previous years and pH remained circumneutral.

DO concentrations in the CWTS cells were on average 5.3 mg/L, which is lower than commissioning-A and slightly higher than commissioning–B (Table 3). Reducing conditions are needed for nitrate and selenium treatment processes, and for creating metal sulphides that remove copper and cadmium from the water. Water oxidation-reduction potential (ORP) also decreased compared to 2016 by 73 mV, which is also indicative of reducing conditions in the CWTS.

**Table 3 – Average in situ measurements from the pilot scale and demonstration-scale CWTS.**

| Testing Period | | DO (mg/L) | Conductivity (µS/cm) | pH | ORP (mV) | Soil redox (mV) |
|---|---|---|---|---|---|---|
| Demonstration-scale 2015 | | 10.0 | 817.9 | 8.11 | 147.9 | -52 |
| Demonstration-scale 2016 | Commissioning-A[1] | 15.9 | 890.9 | 7.79 | 143.7 | -85 |
| | Commissioning-B[2] | 8.4 | 1020 | 7.59 | 157.6 | -89 |
| Demonstration-scale 2017 | Commissioning-B[3] | 4.3 | 795.9 | 7.43 | 18.7 | -162 |
| | Operational period[4] | 5.3 | 879.7 | 7.36 | 124.9 | -152 |

[1] Data for commissioning-A period is from May 2-July 28, 2016.
[2] Data for commissioning-B period is from July 29-September 30, 2016.
[3] Data for commissioning-B period is from May 27-August 17, 2017.
[4] Data for operational period is from August 18-September 22, 2017.

A key explanatory parameter used to monitor maturation of the CWTS during the commissioning period is the soil redox potential, which is measured using platinum tip probes (in soil) and Calomel electrodes (in water). This measurement offers insight into the direction of electron flux between the sediment/soil/pore water and overlying water column (Faulkner et al., 1989; Huddleston & Rodgers, 2008), and can be used to confirm reducing conditions

in the soil. Based on the information gathered in pilot-scale testing, the targeted soil redox for the demonstration-scale CWTS is between -100 and -250 mV. In these redox ranges, bacterial sulphide-production through reduction of sulphur compounds (e.g., sulphate) is expected. Sulphide production directly results in metals and metalloid treatment for constituents such as cadmium, copper, molybdenum, nickel, lead, and zinc by precipitation as metal sulphides (Figure 6).

This maturation period is necessary for sufficient quantities of microbes to populate the CWTS and become active in decomposing organic material. It is the electrons produced by the decomposition of organic material that is reported by the soil redox measurements. The decomposition of organic material then feeds the sulphate-reducing bacteria the type of energy they need to produce the sulphides that remove the copper, cadmium, molybdenum, and zinc from the water. The microbial activity of the CWTS is discussed further in Section 5.3.2.

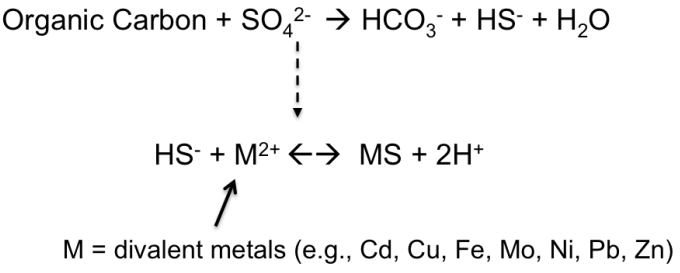



**Figure 6 – Example equation of sulphate reduction and resultant metals mineralization and treatment.**
Equation is not balanced; demonstrates sulphate reduction with creation of alkalinity and sulphides, which can then form metal sulphide complexes.

As expected from the pilot-scale testing, the soil redox in all the demonstration-scale CWTS cells has decreased and stabilized over time, indicating maturation of the CWTS (Figure 7). At the end of 2016, the demonstration-scale CWTS had begun achieving soil redox values that are conducive to sulphide production due to the decomposition of the organics that were added on July 28, 2016 (Contango, 2017). By the end of 2017, soil redox values had decreased to within the targeted range, even without additional organics added to the CWTS. It is therefore evident that the commissioning period was successful and the CWTS has matured and become self-sufficient in producing organic matter to provide electrons to generate reducing conditions upon decomposition. Soil redox will continue to be monitored throughout operation in 2018.

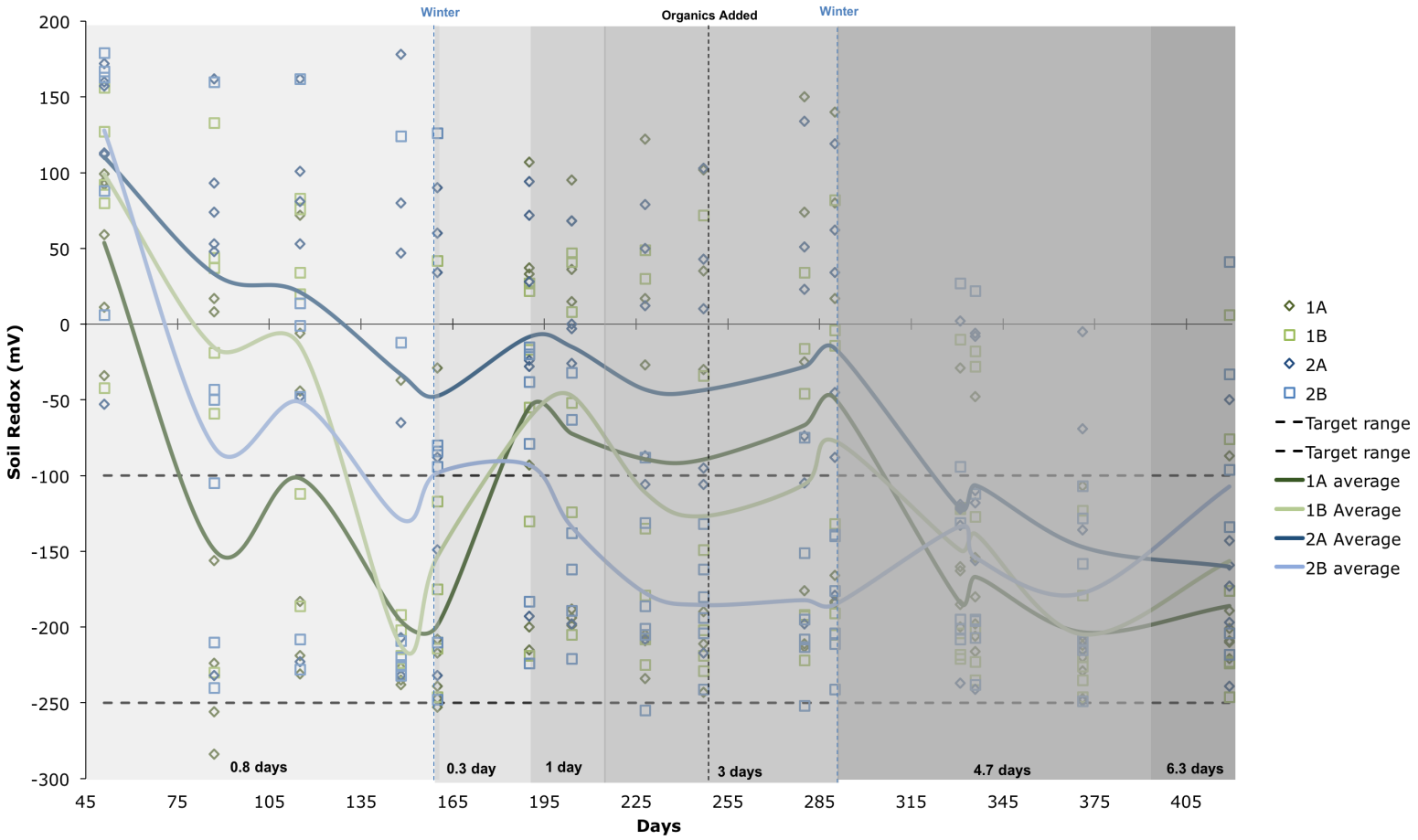



**Figure 7 – Soil redox potential of each CWTS cell over time.**
All demonstration-scale CWTS soil redox measurements are plotted. Targeted soil redox values based on pilot-scale testing are indicated with dotted lines. The blue dotted line indicates break in measurements for winter 2015 and 2016. Days and associated grey shading in 2015 and 2016 indicate the nominal HRT. Days and associated grey shading in 2017 indicate the actual HRT (average of series 1 and 2) using recorded water depths and flow rates during those time periods.

## 5.2. Water

The following are key findings regarding constituents in the water, which are detailed further below:

- Copper treatment in the CWTS was masked by leaching from the soils used in construction of the CWTS into the water, but this has mostly been remedied now by the wetland treating this copper and turning it into more stable sulphide forms in the soil.
- During the operational period the demonstration-scale CWTS successfully achieved an average decrease in concentrations of 0.0169 µg/L for cadmium (from 0.0261 µg/L to 0.0092 µg/L), 31.8 µg/L for copper (from 49.1 µg/L to 17.3 µg/L), 3.6 µg/L for molybdenum (from 6.3 µg/L to 2.7 µg/L), 3.5 µg/L for selenium (from 4.0 µg/L to 0.5 µg/L), and 47.3 µg/L for zinc (from 49.2 µg/L to 1.9 µg/L).
- Molybdenum and selenium treatment in the operational period is notable as the removal rates were negligible within the margins of error of the testing method in the commissioning-A period.

### *5.2.1. Metal Leaching from Soils into Overlaying Water*

Although treatment improved through commissioning as the CWTS matured, copper and aluminum leaching from the soils into the overlaying water, masking the effects of treatment (Contango, 2017). Therefore, additional sampling was performed through the CWTS to identify these fluctuations. Details of the sampling methods can be found in Appendix A of this document and Figure A4 in Appendix A shows the sampling locations in series 2 of the demonstration-scale CWTS. Graphs showing concentrations of copper and selenium throughout the CWTS are presented below (Figure 8 and Figure 9, respectively) while graphs for the remaining constituents can be found in Appendix B (Figures B1 to B4).

Since the beginning of operations of the demonstration-scale CWTS, significant concentrations of copper have been leaching from the CWTS soils used in construction (Contango, 2016 and 2017; Section 5.6). Moreover, aluminum (which could not be accounted for by the influent water chemistry) was elevated in the CWTS. Because of metals leaching from the soils, the treatment occurring within the CWTS was far greater than what was being observed by simply measuring the inflow and outflow points (Contango, 2017). These soils first needed to be treated, before significant treatment could occur for the influent waters.

In early 2017 (June 20, 2017 sampling date), copper was still leaching from the soils into the water (Figure 8). However, at later sampling dates in 2017 copper was no longer leaching at a rate that the treatment wetland could not keep up with for treatment. Copper concentrations decreased by the end of the A cells and stabilized through B cells, indicating that treatment of copper is occurring and that copper leaching from the soils has subsided. Leaching of constituents from the soils is further described in Section 5.6.

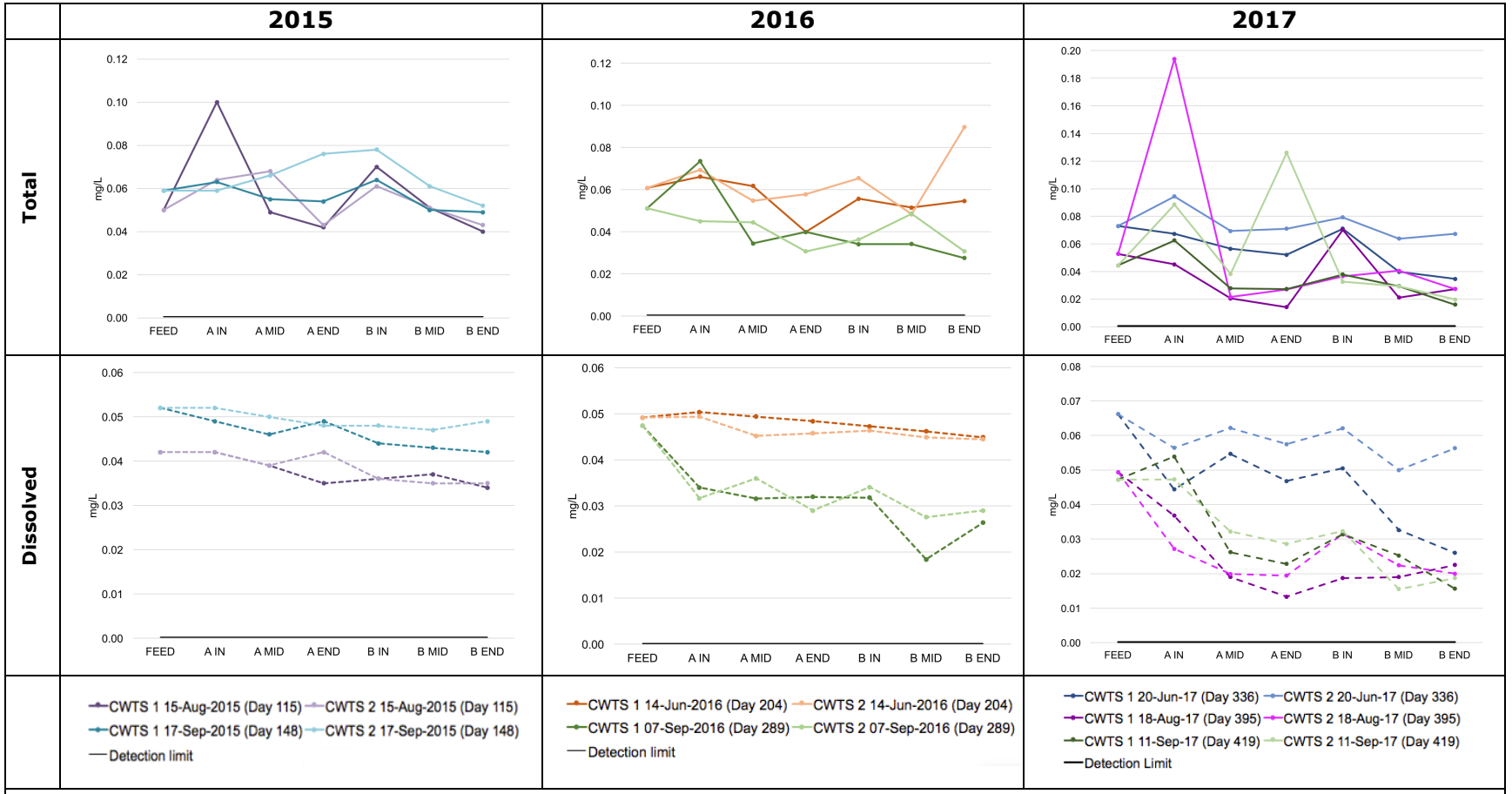



**Figure 8 – Copper concentrations through the CWTS.**
2015 (left), 2016 (middle), and 2017 (right) total (top) and dissolved (bottom) copper concentrations. Data shown for seven timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the CWTS, or possible leaching of constituents from the soils into the CWTS. The Maxxam (2015 results) detection limit (DL; black line) for copper is 0.0002 mg/L. The ALS (2016 and 2017 results) DL for copper is 0.0005 mg/L. Spikes in copper concentrations were observed in early sampling points in the CWTS indicating leaching from the soils is occurring; however, later sampling points do not show any copper spikes and, therefore, leaching has subsided. The 2017 graphs are on different y-axes than previous graphs due to one data point from 18-Aug-17 for total copper and two data points from 20-Jun-17 for dissolved copper that are higher than previous axes.

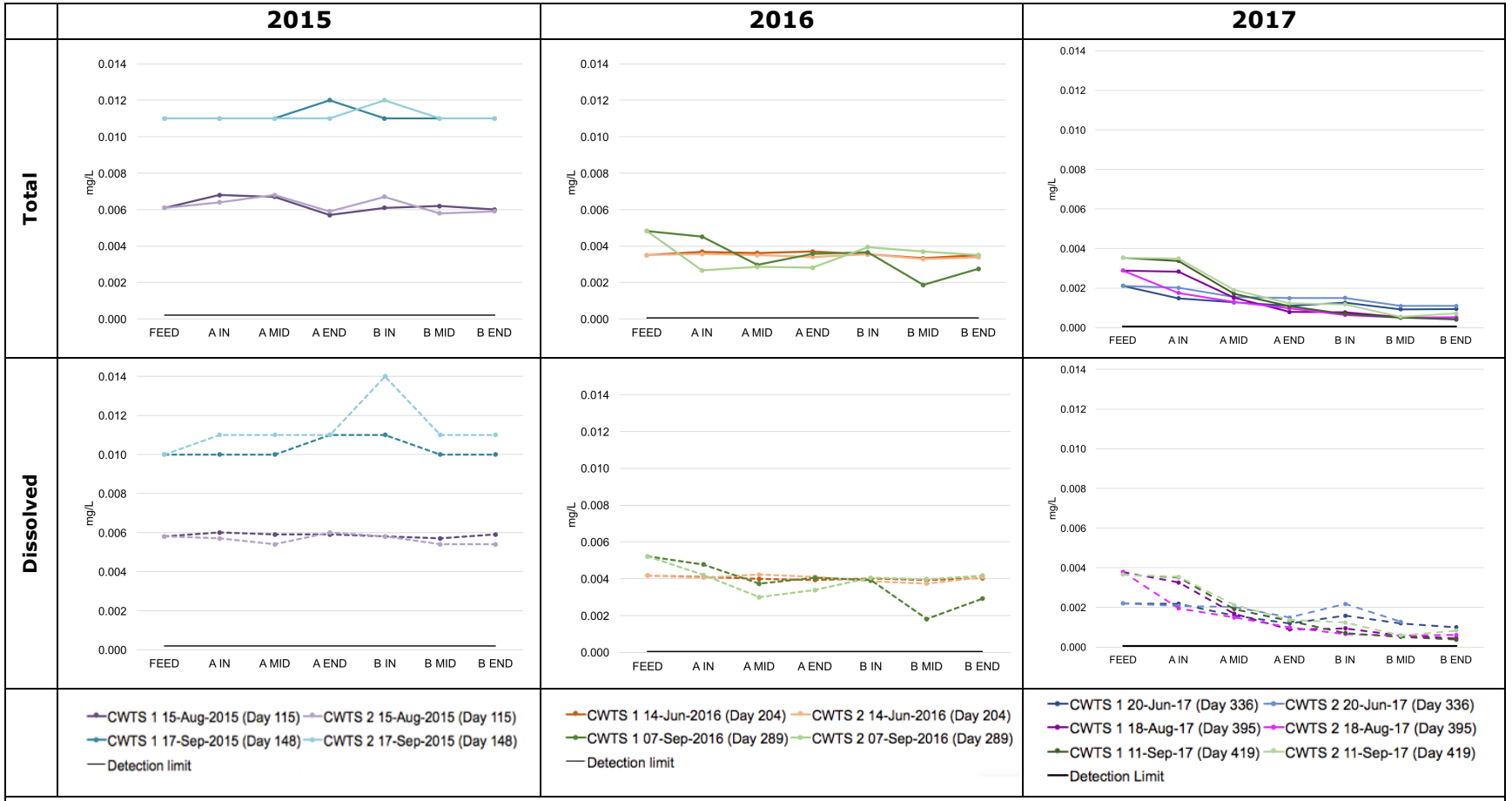



**Figure 9 – Selenium concentrations through the CWTS.**
2015 (left), 2016 (middle), and 2017 (right) total (top) and dissolved (bottom) copper concentrations. Data shown for seven timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the CWTS, or possible leaching of constituents from the soils into the CWTS. Y-axes are set to be the same for total and dissolved. The Maxxam (2015 results) detection limit (DL; black line) for selenium is 0.0002 mg/L. The ALS (2016 and 2017 results) DL is 0.000050 mg/L. This graph indicates that leaching is not occurring as there are no spikes in selenium concentrations throughout the CWTS.

### *5.2.2. Performance during Commissioning-A*

The commissioning-A period occurred from May 16 to September 29 in 2015 and May 2 to July 28 in 2016. Details regarding the results of the commissioning-A period can be found in Demonstration-Scale 2016 Update Report (Contango, 2017).

### *5.2.3. Performance during Commissioning-B*

The beginning of commissioning-B was marked by the addition of organics to the CWTS and ran from July 29 to September 30 in 2016 and from May 27 to August 17 in 2017. These organics (straw and wood chips) were added to further aid the copper in the soils to transition into sulphide mineral forms, and represents an amount of organic material similar to what would be produced by the CWTS once fully established with *Carex*. Treatment of constituents was similar through 2016 and 2017 for commissioning-B. An evapotranspiration trial was also completed during commissioning-B to allow water to stagnate and provide time for copper in the soils to convert to sulphide mineral forms more readily.

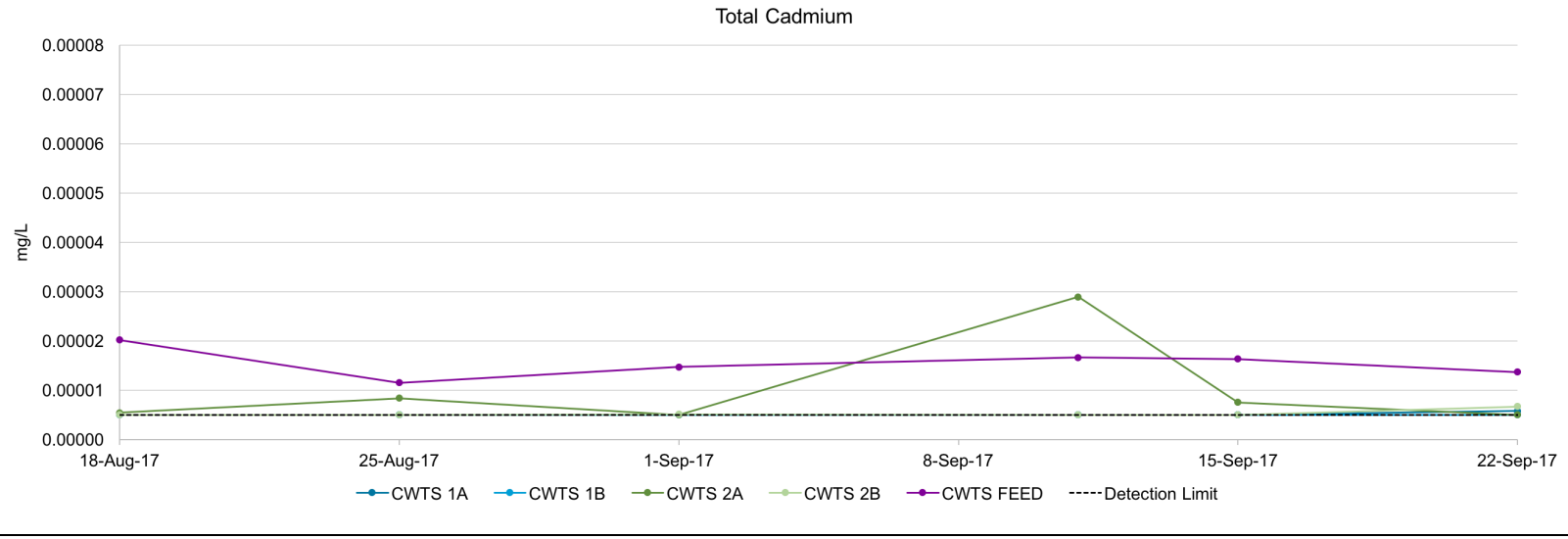
### *5.2.4. Performance during Operations*

Figures showing performance of the demonstration-scale CWTS in 2017 (commissioning-B and operational period) can be found in Appendix B (Figures B5 to B12). In the operational period from August 18 to September 22, 2017, dissolved cadmium, copper, selenium, and zinc treatment improved from the 2017 commissioning-B period. Dissolved metals concentrations were used for the discussion in this report instead of total metals concentrations, as total values were highly variable and not representative of the metals concentrations in the CWTS. The variability of the total metals concentrations is likely owing to particulate material containing metals being part of the grab sample collection method. During the operational period the CWTS achieved an average decrease of 0.0169 µg/L for cadmium (from 0.0261 µg/L to 0.0092 µg/L), 31.8 µg/L for copper (from 49.1 µg/L to 17.3 µg/L), 3.5 µg/L for selenium (from 4.0 µg/L to 0.5 µg/L), and 47.3 µg/L for zinc (from 49.2 µg/L to 1.9 µg/L; Table 4, Figure 10, Figure 11, Figure 12, and Figure 13, respectively). In contrast, molybdenum removal was fairly constant through 2017 (both commissioning-B and operations) with a decrease of 3.9 µg/L (5.7 µg/L to 1.8 µg/L) during commissioning-B and a decrease of 3.6 µg/L (from 6.3 µg/L to 2.7 µg/L) during operations (Table 4). The percent removal of molybdenum and selenium in 2017 is notable, as it has increased from 0% removal during commissioning-A in 2015 and 2016 (Contango, 2016 and 2017) (Table 4). Furthermore, nitrite and nitrate outflow concentrations also decreased from feed water concentrations throughout the demonstration-scale CWTS. Nitrite and nitrate are therefore being removed through treatment in the CWTS (Figure 15 and Figure 16). These results indicate that the commissioning periods were successful in establishing beneficial conditions for the removal of constituents in the CWTS and treatment of these constituents should continue through 2018.

**Table 4 – Percent removal of dissolved constituents in the demonstration-scale CWTS.**

| COC (µg/L) | | Commissioning period | | | | Operational period |
|---|---|---|---|---|---|---|
| | | 2015[1] | 2016[2] | 2016[3] | 2017[4] | 2017[5] |
| **Cd** | In | 0.0505 | 0.0240 | 0.0185 | 0.0163 | 0.0261 |
| | Out | 0.0248 | 0.0142 | 0.0066 | 0.0093 | 0.0092 |
| | **%** | **49** | **40** | **64** | **41** | **66** |
| **Cu** | In | 54.5 | 61.6 | 46.1 | 59.5 | 49.1 |
| | Out | 45.0 | 56.7 | 28.8 | 35.5 | 17.3 |
| | **%** | **17** | **8** | **37** | **36** | **65** |
| **Mo** | In | 11.0 | 7.6 | 7.3 | 5.7 | 6.3 |
| | Out | 11.3 | 7.6 | 5.7 | 1.8 | 2.7 |
| | **%** | **0** | **0** | **21** | **62** | **57** |
| **Se** | In | 11.0 | 3.7 | 5.7 | 2.5 | 4.0 |
| | Out | 11.3 | 3.4 | 3.3 | 0.9 | 0.5 |
| | **%** | **0** | **8** | **41** | **61** | **87** |
| **Zn** | In | 12.3 | 92.8 | 37.6 | 135.3 | 49.2 |
| | Out | 6.8 | 49.0 | 11.6 | 4.9 | 1.9 |
| | **%** | **42** | **47** | **69** | **95** | **96** |

[1] Values calculated from end of last two sampling event in 2015 before the addition of EDTA (September 9 and 17, 2015; during commissioning-A).
[2] Commissioning-A (May 2, 2016 to July 28, 2016).
[3] Commissioning-B (July 29, 2016 to September 30, 2016).
[4] Commissioning-B (May 27, 2017 to August 17, 2017).
[5] Operational period (August 18, 2017 to September 22, 2017).



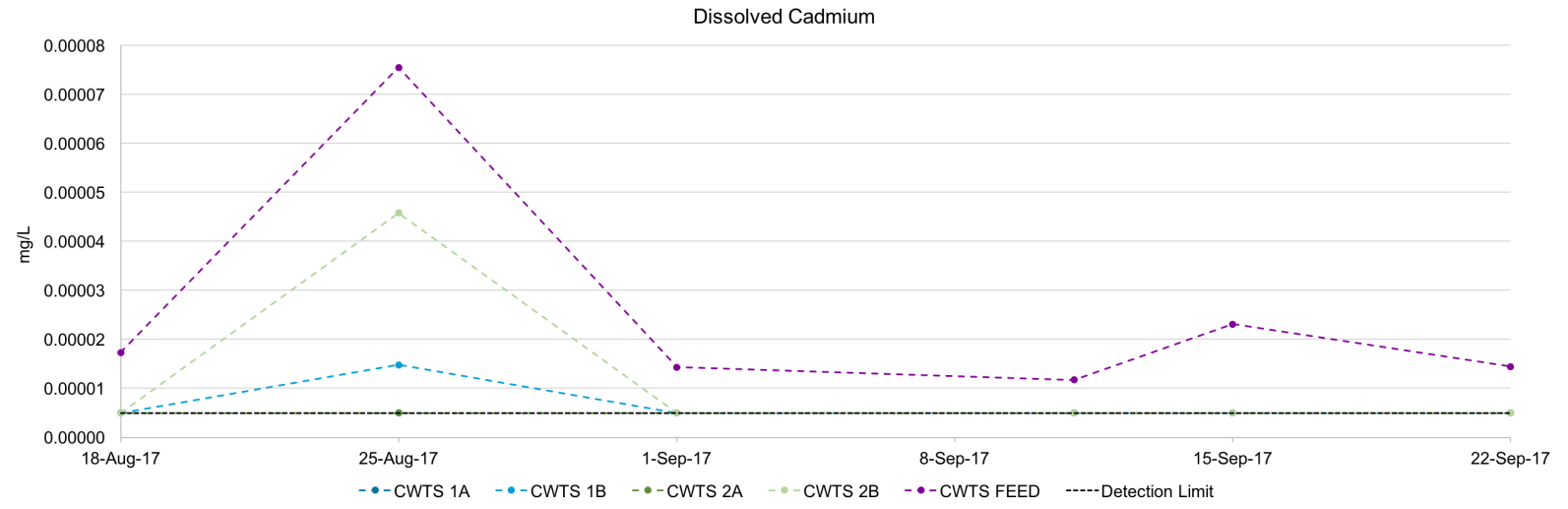
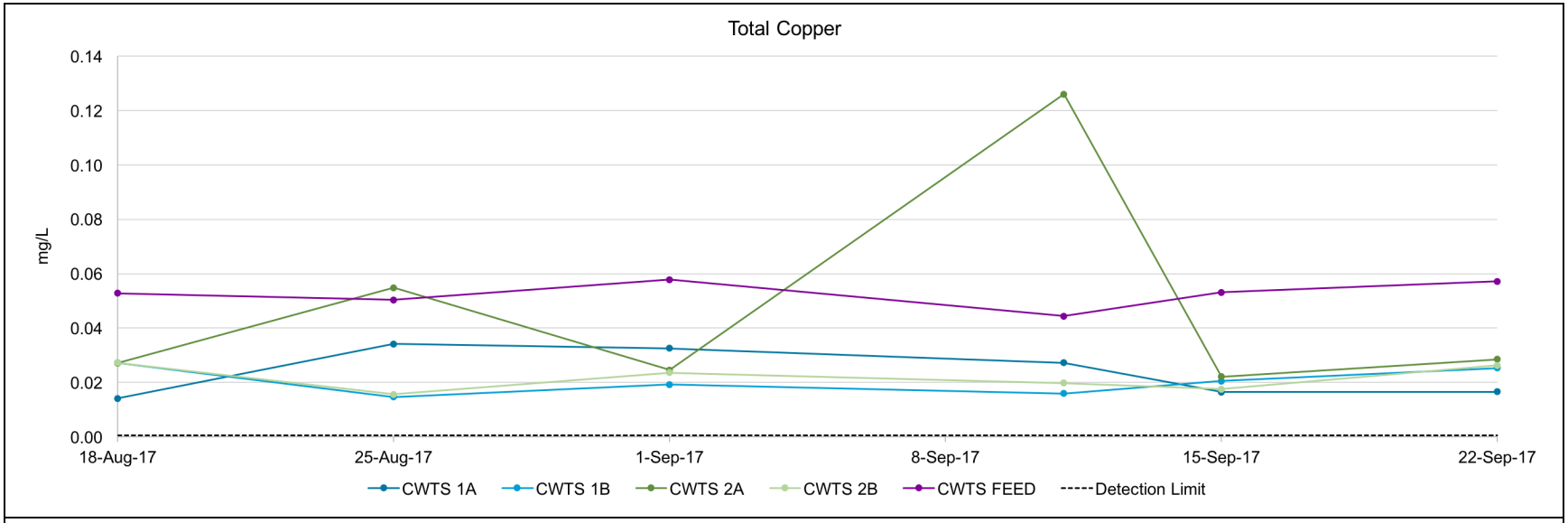




**Figure 10 – Cadmium concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for cadmium is 0.000005 mg/L.



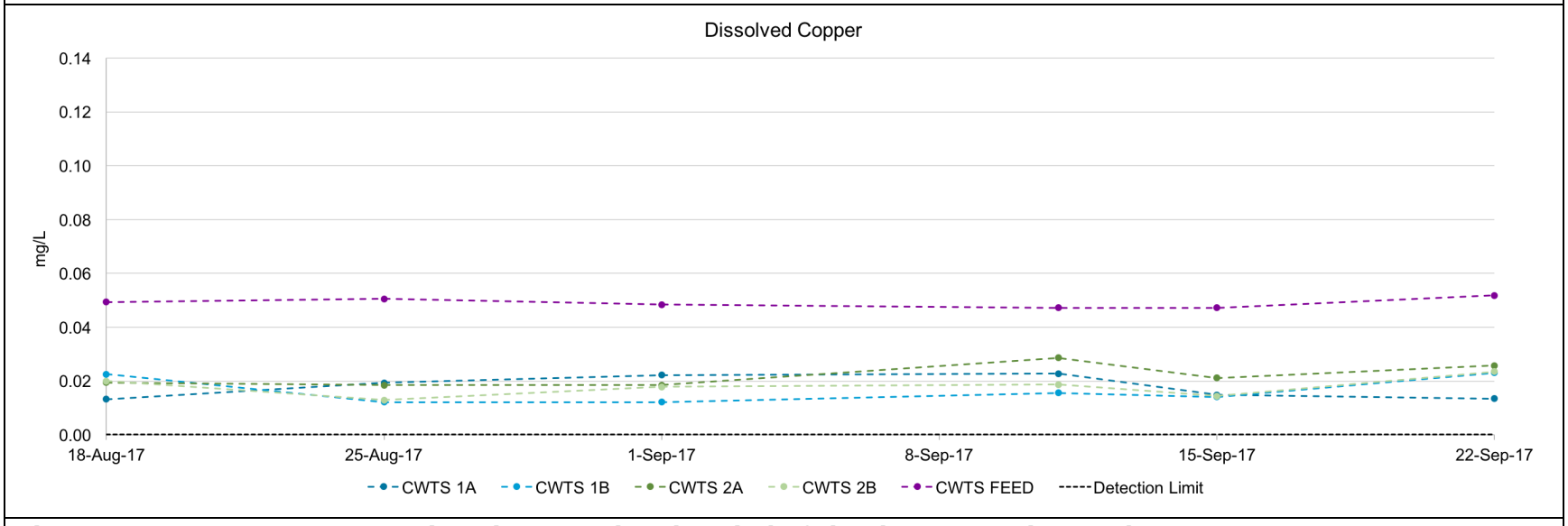




**Figure 11 – Copper concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for dissolved and total copper is 0.0002 mg/L and 0.0005 mg/L, respectively.

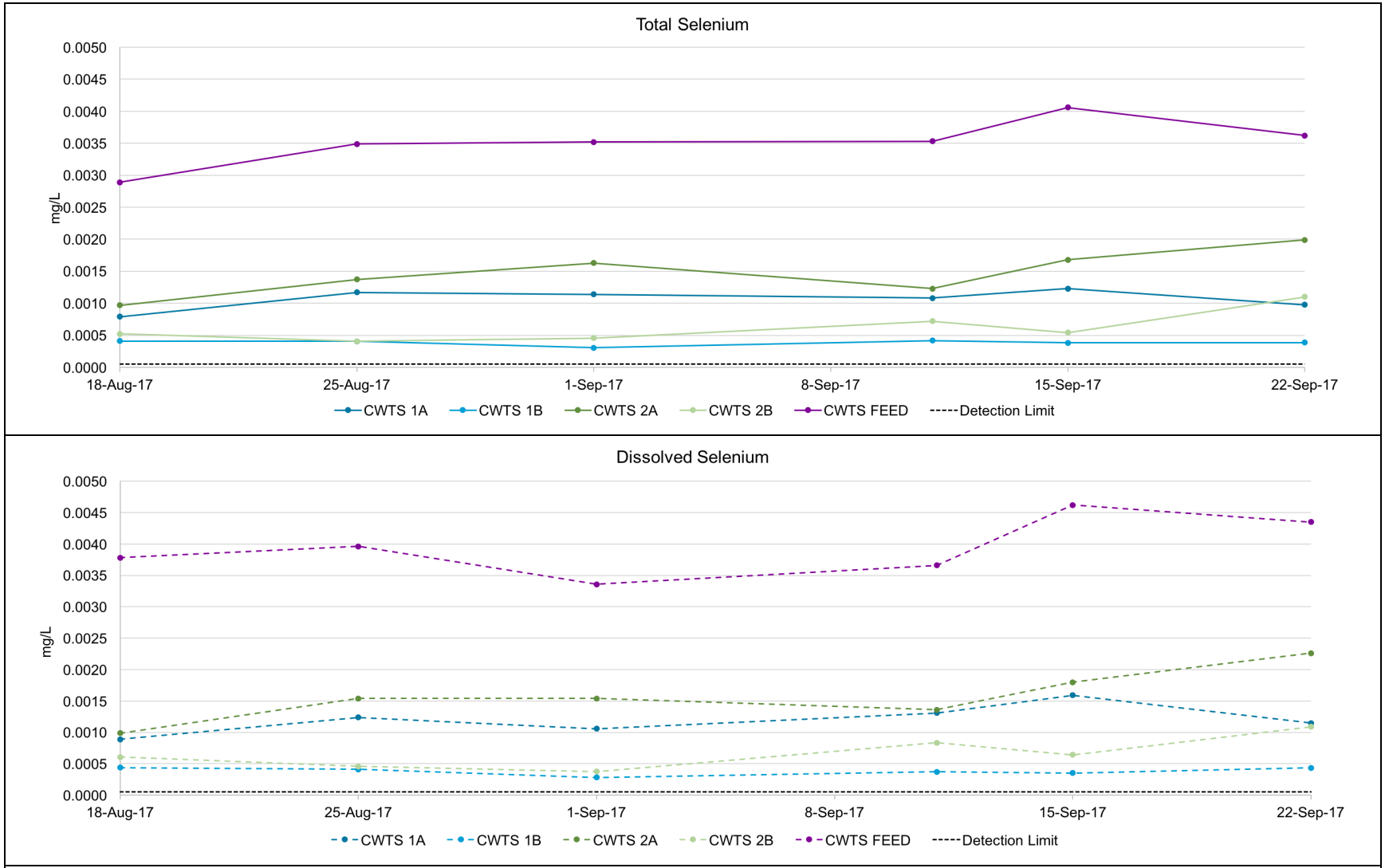
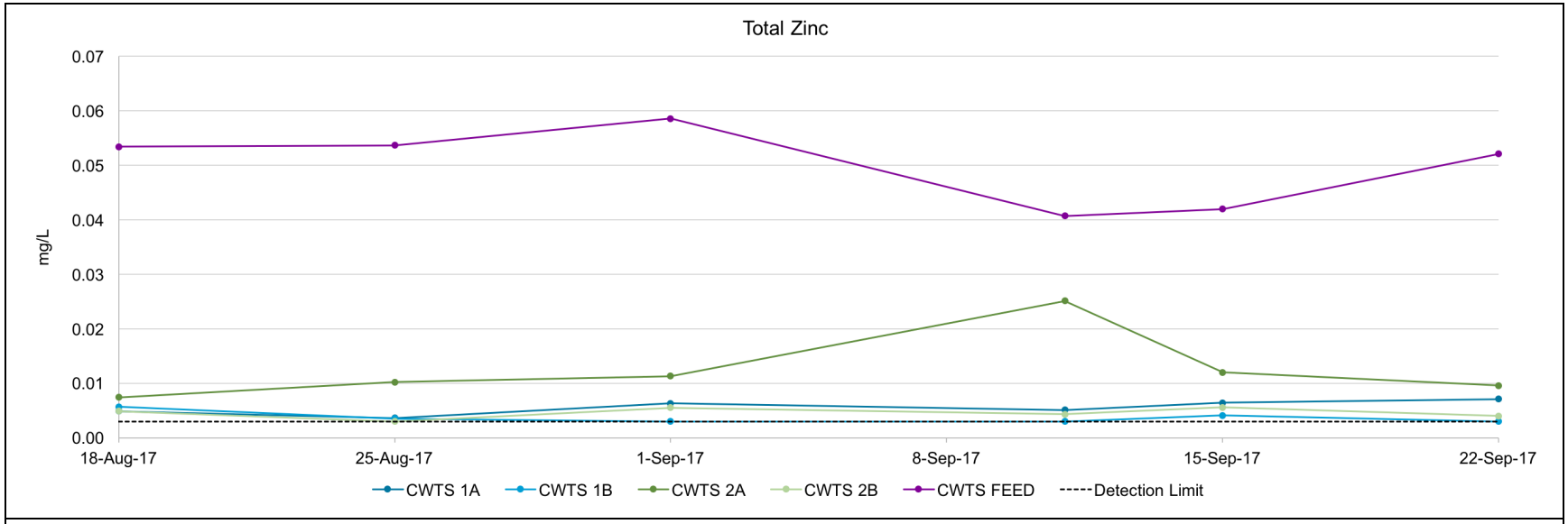



**Figure 12 – Selenium concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for selenium is 0.000050 mg/L.



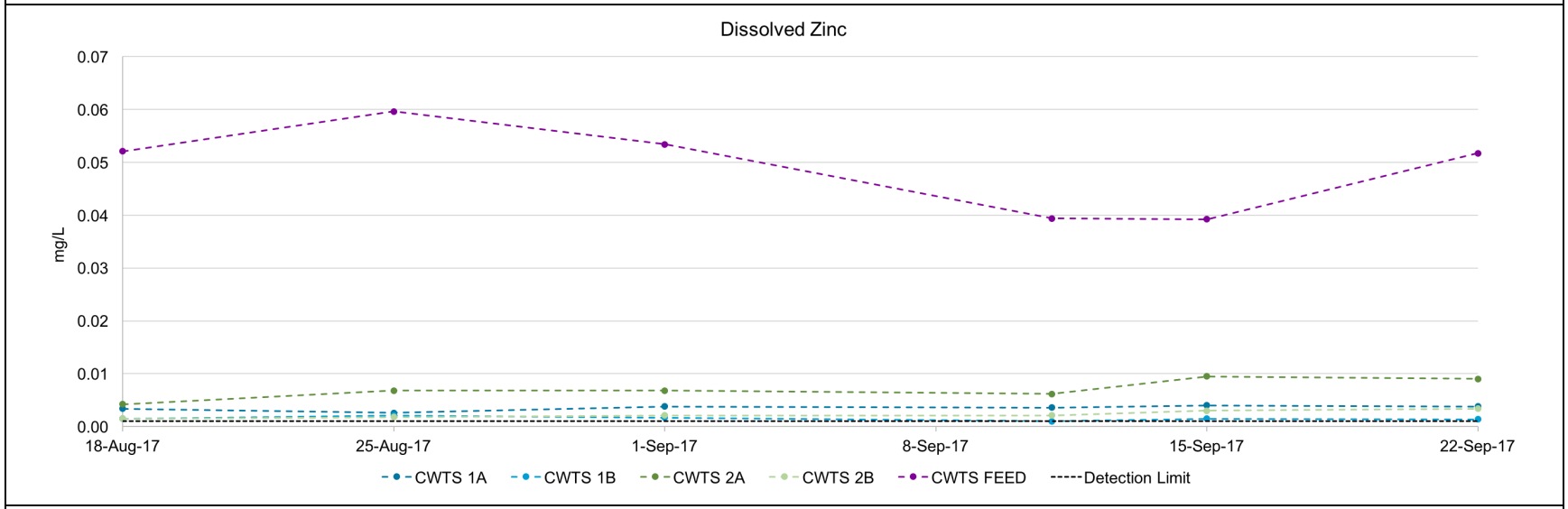
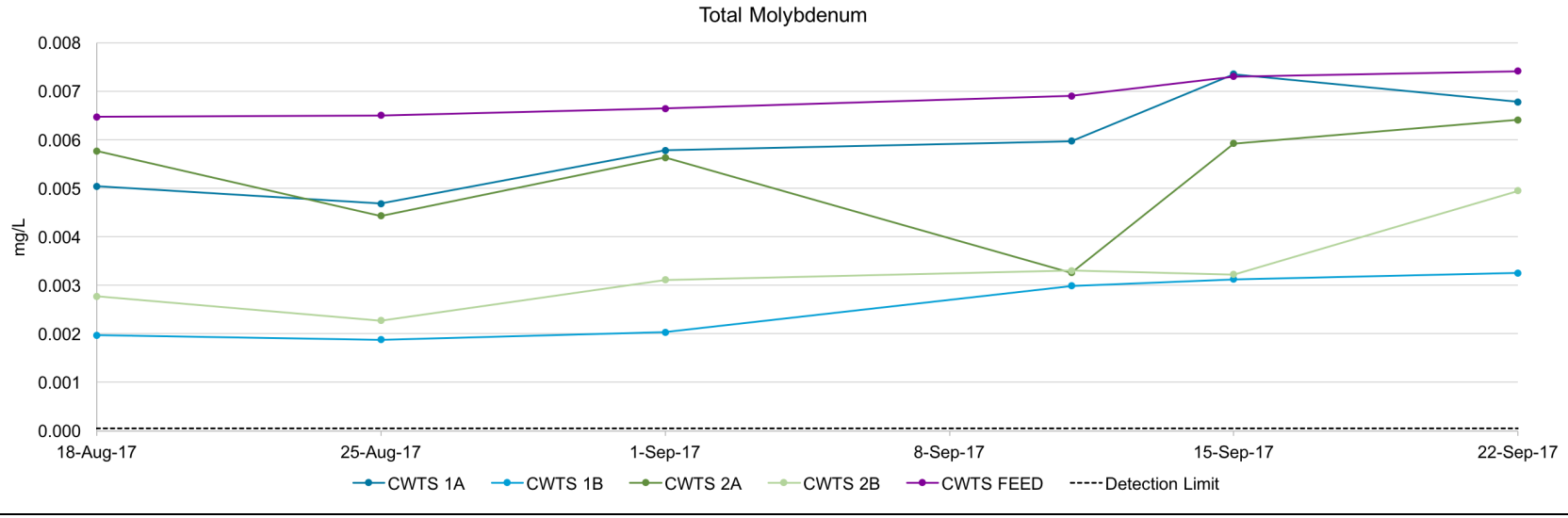




**Figure 13 – Zinc concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for dissolved and total zinc is 0.001 mg/L and 0.003 mg/L, respectively.



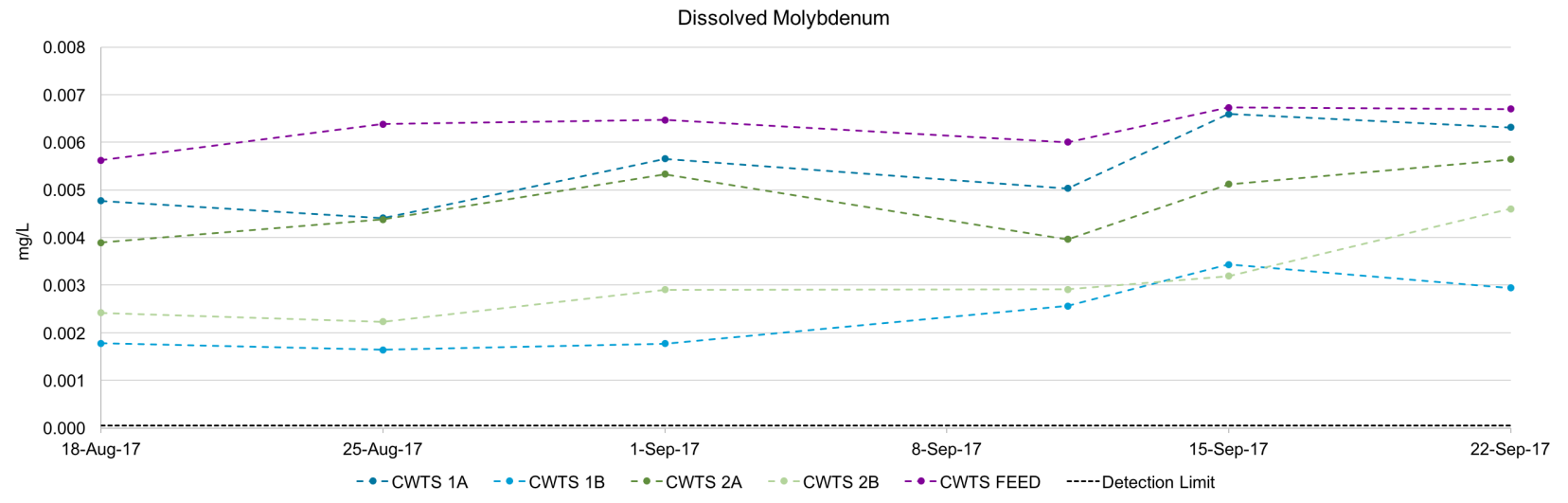




**Figure 14 – Molybdenum concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for molybdenum is 0.000050 mg/L.

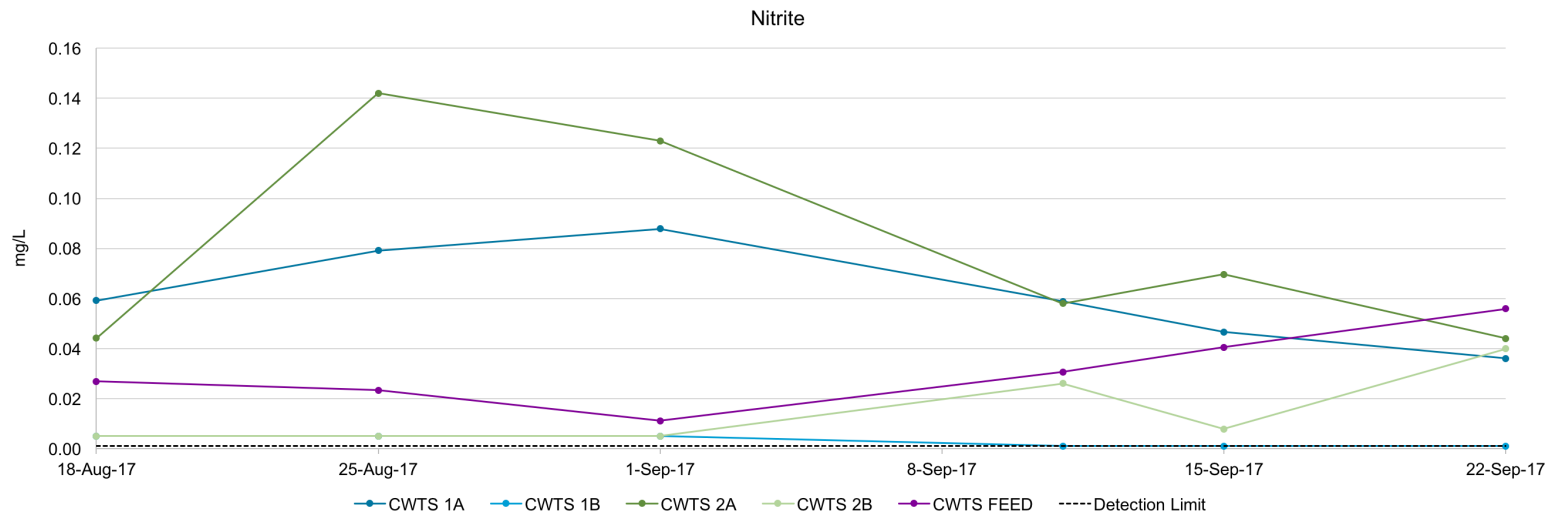



**Figure 15 – Nitrite as N ($NO_2$) concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for nitrite is 0.0050 mg/L.

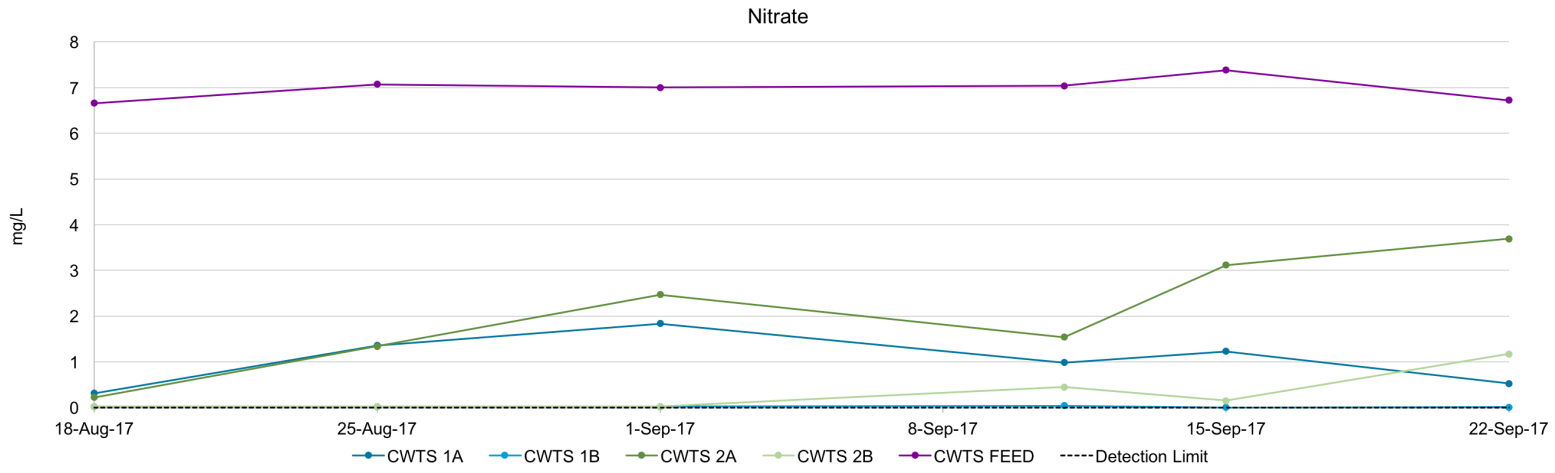



**Figure 16 - Nitrate as N ($NO_3$) concentrations in operational period of the demonstration-scale CWTS.**
The ALS detection limit for nitrate is 0.025 mg/L.

## 5.3. Hydraulic Retention Time

The following are key findings regarding the hydraulic retention time, which are detailed further below:

- The tracer study effectively demonstrated the HRT and flow symmetry through the CWTS.
- There was a single flow path in the CWTS (shown by a single peak in the tracer study)
- Water is incorporating in to the CWTS soils (shown by the long tail for depletion of the tracer).
- The nominal HRT is calculated from the area of the CWTS and the depth at the in situ measuring points. This nominal HRT does not account for depth variations, embankment slopes, vegetation (using space in the water), or substrate pore space involvement. It was found that once all of these factors are in play, the correction factor from nominal to actual is only 0.01 added to the depth of the CWTS, which is incorporated into the HRT calculation as expressed in Equation 3.

### *5.3.1. Tracer Study*

A tracer study was conducted in cell 1A of the CWTS in 2016 (June 13-15, 2016) and in 2017 (June 21-July 2, 2017). Results from the 2016 tracer study can be found in the 2016 demonstration-scale CWTS report (Contango, 2017). The methods of the 2017 tracer study were refined from the 2016 tracer study methods and are further discussed in Appendix A. The nominal HRT is calculated from the area of the CWTS and the depth at the in situ measuring points. This nominal HRT does not account for depth variations, embankment slopes, vegetation (using space in the water), or substrate pore space involvement. The purpose of the tracer studies was to determine the actual hydraulic retention time (HRT) that occurs in the CWTS with a known inflow rate and depth measurement. Then, using this actual HRT form the tracer study, a correction factor can be developed for future CWTS HRT calculations.

Salt (NaCl) was used as the tracer in these tracer studies. By adding a salt solution at the inflow of the CWTS, and placing a YSI meter at the outflow of the CWTS, it could be determined how long it took for the salt to pass through the CWTS by monitoring the specific conductance (SPC) in situ (as salt raises the SPC). The actual HRT of the CWTS was determined by calculating the amount of time that passed between the addition of the salt tracer at the inflow of the CWTS and the peak in SPC at the outflow.

The nominal HRT at the time of the tracer study was calculated based on the flow rate at the time of the tracer study, the known area of cell 1A, and measured depth of cell 1A obtained from the depth sticks that were installed in the CWTS in June 2016 (Appendix A, Figure A5). The results from the 2017 HRT tracer study suggests that the actual HRT of cell 1A is 2.25 days while the nominal HRT of cell 1A is 2.05 days. Therefore, the actual HRT was approximately 10% slower than the nominal HRT. The actual HRT of 2.25 days obtained from the 2017 tracer study was used to solve Equation 1, implying 0.14 m of water involvement

as the "depth", which was 0.01 m greater than the measured depth of 0.13 m of water. This results in a correction factor of 0.01 (Equation 2). Therefore, the correction factor can be applied to the operational HRT as shown in Equation 3 in order to more accurately estimate HRT of the CWTS.

This HRT correction factor has been incorporated into calculations for the operational HRT for the demonstration-scale CWTS in 2017. The correction factor was incorporated into the operational HRT calculations in Section 5.3.2 and used to determine the 2017 removal rate coefficients in Section 5.4.2.

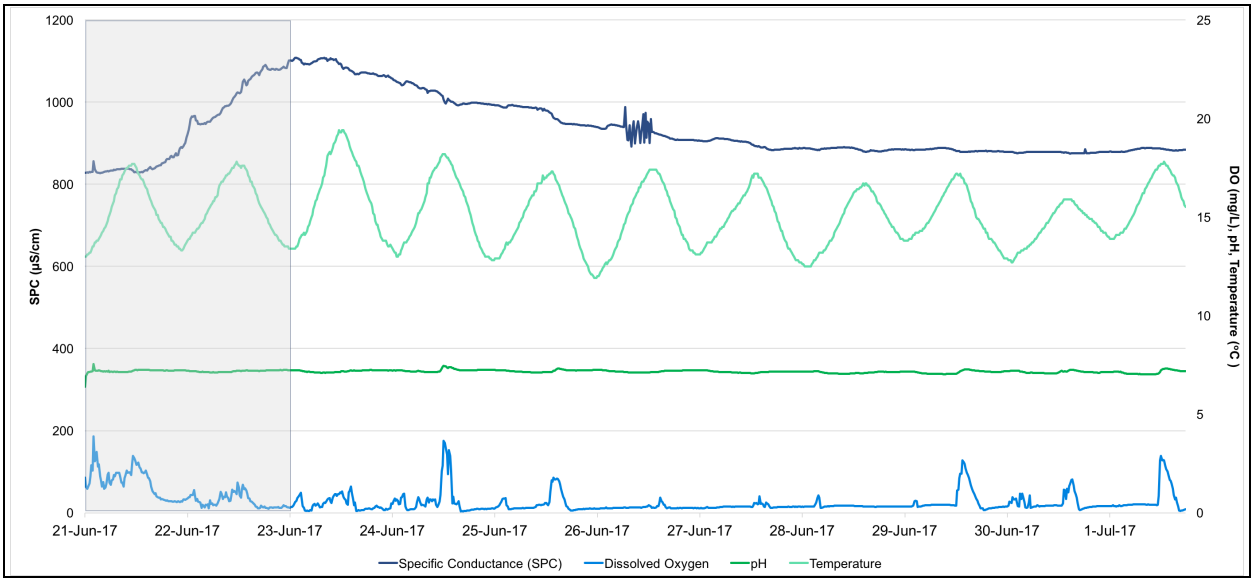



**Figure 17 – Hydraulic retention time tracer study results.**
Specific Conductance (SPC; µS/cm) on primary y-axis. Dissolved oxygen (mg/L), pH, and temperature (°C) on secondary y-axis. Grey shading indicates time from when CWTS was dosed to the peak of tracer breakthrough, which was used as the actual HRT. The fluctuation in temperature correspond to day (peaks) and night (lows). The dates on the x-axis are at 24 hr intervals, beginning from 7:52 am on June 21, 2017.

$$\text{Actual depth} = \frac{(Q \times \text{actual HRT})}{A}$$

**Equation 1 – Equation for calculation of the actual CWTS depth including the correction factor.**
$Q$ is the flow rate; actual HRT is the HRT obtained from the tracer study (2.25 days); $A$ is the area of cell 1A.

$$\text{Correction factor} = \text{Actual depth} - \text{measured depth}$$

**Equation 2 – Equation for calculation of the correction factor.**
The actual depth was calculated via Equation 1 (0.14 m); measured depth is the depth of cell 1A during the tracer study (0.13 m).

### *5.3.2. Operational Hydraulic Retention Time*

The operational HRTs of the demonstration-scale CWTS for 2017 were calculated for each series using Equation 3. Equation 3 uses the volume of a CWTS series including a correction factor (calculated from the results of the tracer study in Equation 2; Section 5.3) and the flow rate from the operational period under consideration. For the operating period in 2017, the average HRT was calculated for August 17 – September 22, 2017 as the flows and depths were relatively stable during this time. The operational HRTs calculated were 5.85 days and 6.82 days for series 1 and series 2, respectively. The operational HRTs were then averaged and used in the calculation of removal rate coefficients in Section 5.4.2.

$$\text{Operational HRT} = \frac{A \times \text{actual depth}}{Q}$$

**Equation 3 – Equation for calculation of hydraulic retention time.**
Operational HRT is the confirmed hydraulic retention time; *A* is the area of the CWTS; actual depth was calculated using Equation 1 (0.14 m); *Q* is the flow rate.

## 5.4. Treatment Effectiveness

The following are key findings regarding treatment effectiveness of the CWTS, which are detailed further below:

- All targeted constituents are being treated by mineralization and sequestered to the soils (minimal plant uptake).
- The lowest concentrations consistently achievable for the treatment design (thermodynamic minimums) were reached by the end of the A cells for cadmium and copper.
- RRCs for cadmium and zinc in the 2017 demonstration-scale CWTS were artificially low because low flow rates did not provide the resolution needed to determine a RRC.
- Removal rate coefficients (RRCs, *k*) have been developed that can be used for full-scale sizing.
- Copper leaching from soils has decreased, but is still likely making the RRC artificially low in this CWTS; however, the RRC is expected to improve once copper leaching has subsided.

### *5.4.1. Thermodynamic Minimums*

The thermodynamic minimum is the lowest concentration consistently achievable for a given treatment design and water chemistry. Once reached, making the CWTS bigger will not result in further decrease of outflow concentration (although outflow load may continue to decrease). Therefore, thermodynamic minimums are useful parameters to aid in developing appropriate RRCs, and determining appropriate sizing and outflow water quality objectives of a CWTS. The thermodynamic minimum was determined for each constituent in the demonstration-scale CWTS. The thermodynamic minimum was calculated by comparing the A cell and the B cell concentrations in a series to determine if the concentrations were significantly different or not. If a concentration had stabilized between the A and B cell in a series, the thermodynamic minimum was considered to have been met. To determine when concentrations had stabilized, statistical analyses were done (paired t-test, one-tailed, $\alpha$=0.05) to determine if the concentrations were significantly different or not. These analyses were then also visually compared to the concentrations of constituents at seven sampling locations throughout the CWTS from two time points, to further evaluate and confirm whether concentrations appeared to have leveled off (Figure 8 and Figure 9 for copper and selenium, respectively; Figures B1 to B4 in Appendix B for remaining constituents). However, there was not enough time points in the operational period for this data to be used in the statistical analyses to further refine the expected HRT for the thermodynamic minimums. This can be refined in 2018, by varying flow rates.

Based on the results of the t-test for the A cell and B cell concentrations, it was determined that the thermodynamic minimum was achieved for cadmium and copper by the end of the A cells in the demonstration-scale CWTS. The detection limit was reached for cadmium prior to the outflow of cell A, suggesting that faster flows would be needed to accurately determine the HRT at which the thermodynamic minimum was met (Figure 18). The thermodynamic minimum for molybdenum, nitrate, and selenium were not yet statistically achieved,

suggesting that a larger CWTS would achieve lower concentrations of these constituents (Appendix B, Figures B13 to B17). The thermodynamic minimum for zinc was not statistically achieved, however, the majority of zinc load was removed within the beginning of cell A, with minimal load removal in the remainder of the CWTS (Figure 18). Furthermore, outflow concentrations of both cell A and B for zinc are at or near detection limit (Figure B17), so it is not necessarily beneficial to build a larger CWTS for zinc.

As shown by the graphs previously mentioned, concentrations in A cells and B cells were very similar for cadmium and copper. This shows that treatment is occurring in the A cells and has reached a thermodynamic minimum which does not decrease further for the B cells. However, these results for copper should be taken with consideration that there is still some residual copper in the soils from construction that is being treated, and therefore, there is more copper treatment ongoing that can be noted by just the water concentrations.

Interestingly, once cadmium, copper and nitrate are treated, zinc and molybdenum begin to have an increase in treatment. This phenomenon is referred to as a treatment front, which generally abides by reaction orders (i.e., nitrate treatment before sulphate, etc.; Murray-Gulde, 2008).

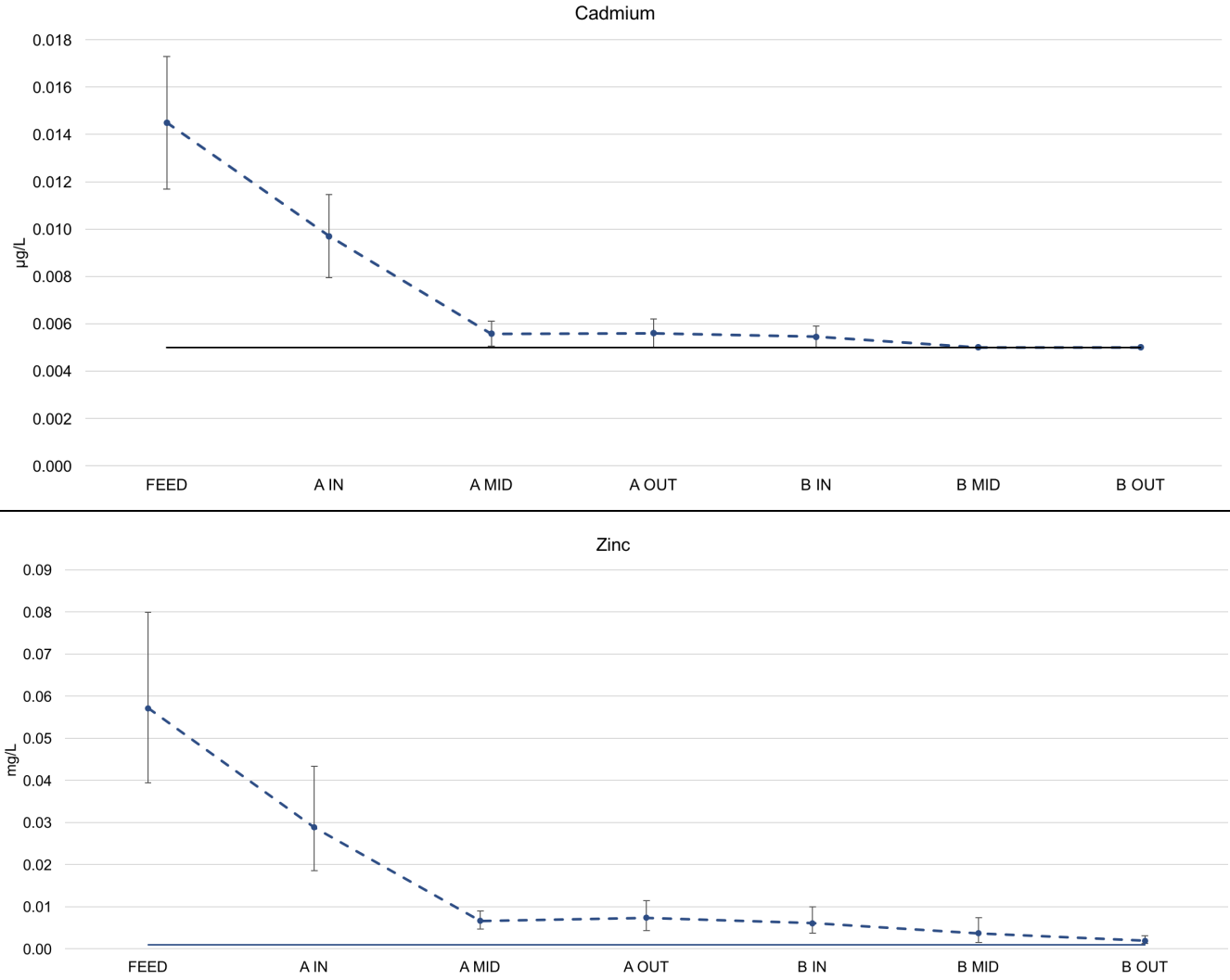



**Figure 18 – Average dissolved cadmium and zinc concentrations through the CWTS during the operational period.** Data shows the average of series 1 and series 2 for two sampling points during the operational period (August 18 and September 11, 2017). Error bars show minimum and maximum concentrations at each sampling point. The black horizontal line shows the detection limit of 0.005 µg/L for cadmium and 0.001 mg/L for zinc.

### *5.4.2. Removal Rate Coefficients*

An important factor for CWTS design is the rate of treatment, also known as the removal rate coefficient (RRC; *k*). The RRC is based on the treatability of a specific compound and the hydraulic retention time of the CWTS, both of which are site-specific based on water chemistry, CWTS designs, and characteristics of the CWTS. A RRC was calculated and applied for cadmium, copper, molybdenum, selenium, zinc, and nitrate which can be used to refine future sizing and performance estimations of a full-scale CWTS (Table 5). In pilot-scale testing specific for the Minto CWTS, the RRC for selenium was a zero-order reaction kinetic, however, optimizations of the operation of the system through the demonstration-scale commissioning have enabled a first-order RRC to be maintained. Therefore, cadmium, copper, selenium, zinc, and nitrate are calculated as first-order kinetics, but molybdenum followed a zero-order kinetic. In other words, the reaction rate for molybdenum is a constant rate and does not depend on concentration, whereas the reaction rates for cadmium, copper, selenium, zinc, and nitrate are proportional to concentration (a half-life type of reaction).

In Equation 4 and Equation 5, *Cf* is the final concentration, *Ci* is the initial concentration, and *HRT* is the operational hydraulic retention time calculated in Equation 3 (Section 5.3.2) using the CWTS depth and correction factor calculated from the tracer study (Equation 1 and Equation 2; Section 5.3).

$$k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{HRT}$$

**Equation 4 – Equation for calculation of first-order removal rate coefficient.**
*k* is the removal rate coefficient; *Cf* is the final concentration; *Ci* is the initial concentration; *HRT* is the operational hydraulic retention time.

$$k = \frac{(Ci - Cf)}{HRT}$$

**Equation 5 – Equation for calculation of zero-order removal rate coefficient.**
*k* is the removal rate coefficient; *Cf* is the final concentration; *Ci* is the initial concentration; *HRT* is the operational hydraulic retention time.

RRCs were calculated for each constituent (dissolved and total) and series 1 and series 2 were averaged for the operational period in 2017 and compared to RRCs calculated to the commissioning period of 2016, and pilot-scale RRCs (Table 6). In 2016, all RRCs were calculated using outflow concentrations from the B cells while in 2017, cadmium and copper RRCs were calculated using outflow concentrations and HRTs from the A cells as they had reached their thermodynamic minimum at the end of cells 1A and 2A (Section 5.4.1). The RRCs for the remaining constituents did not reach their thermodynamic minimum in the A cells and, therefore, outflow concentrations and HRTs from the B cells were used. RRCs for cadmium and zinc in the 2017 demonstration-scale CWTS were artificially low because low flow rates did not provide the resolution needed to determine a RRC. Additionally, RRCs for copper in demonstration-scale CWTS are also artificially low due to copper leaching from soils used in construction of the system. Therefore, the RRCs for copper are expected to improve

once leaching has subsided. In general, RRCs improved from those calculated in 2016 (Table 5; Contango, 2017).

Applying the removal rate coefficients ($k$) from Table 5 to Equation 3 above, parameters can be rearranged to solve for those of interest, such as the volume needed, that in turn determines the area of CWTS required which is dependent upon the design. Analytical results from August 17 – September 22, 2017 were chosen to calculate $k$ because this is the operational period after commissioning-B was completed and flow rates were stable and at targeted values. The treatment rate coefficients applied here are intended to be conservative estimates for conceptual sizing purposes, and will need to be refined through further demonstration-scale (on site) testing.

**Table 5 – Removal rate coefficients (*k*) for constituents of concern.**

| COC | Pilot[1] *k**day$^{-1}$ | 2016 Demonstration[2] (Commissioning) *k**day$^{-1}$ | | 2017 Demonstration[3] (Operational) *k**day$^{-1}$ | | Recommended[4] *k**day$^{-1}$ |
|---|---|---|---|---|---|---|
| | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| **First order removal rate coefficients** | | | | | | |
| **Cd** | 1.142 | 0.172 | 0.174 | >0.521[5] | >0.226[5] | 1.142 |
| **Cu[6]** | 1.171 | 0.0778[6] | 0.0740[6] | >0.3100[6] | >0.1356[6] | 1.171 |
| **Mo** | 0.1010 | 0.0416 | 0.0468 | N/A | N/A | N/A |
| **Se** | N/A | N/A | N/A | 0.3186 | 0.3069 | 0.3186 |
| **Zn** | 1.144 | 0.195 | 0.183 | 0.512[5] | 0.394[5] | 1.144 |
| **Nitrate** | 0.559 | 0.0914 | N/A | 0.591 | N/A | 0.591 |
| **Zero order removal rate coefficients** | | | | | | |
| **Mo** | N/A | N/A | N/A | 0.0006 | 0.0006 | 0.0006 |
| **Se** | 0.00181 | 0.000357 | 0.000316 | N/A | N/A | N/A |

[1] Values calculated from data in Contango, 2014b (pilot-scale report) for *Carex aquatilis* + moss with low nitrogen scenario.
[2] Analytical results from August 10 – September 17, 2016 were used.
[3] Analytical results from August 18 – September 22, 2017 were used.
[4] Cadmium, copper, and zinc recommended RRCs are developed from total concentrations in pilot-scale testing and are conservative proxies for dissolved concentrations.
[5] RRCs for cadmium and zinc in the 2017 demonstration-scale CWTS were artificially low because low flow rates did not provide the resolution needed to determine a RRC, so the lowest potential *k* value based on available data is reported here.
[6] RRC's for copper in demonstration-scale CWTS are artificially lowered due to copper leaching from soils used in construction of the system and are therefore expected to improve once leaching has subsided.
N/A = an RRC is not available. All RRCs are for first-order reaction kinetics except for selenium in the 2016 demonstration-scale CWTS and molybdenum in the 2017 demonstration-scale CWTS, which are zero-order reaction rate kinetics. All RRCs in 2016 and 2017 used outflow concentrations for the B cells in the CWTS.

### 5.5.Evapotranspiration in the Demonstration-Scale CWTS

The following are key findings regarding the evapotranspiration studies, which are detailed further below:

- The evapotranspiration studies revealed a significant loss of water, which will impact calculations of loads to the receiving environment (making them lower than previously estimated).
- In May and June, an average water loss of 5.3 L/day/$m^2$ was observed, which is equivalent to 18-20% of water (~700 L/day lost in the demonstration CWTS).
- During the evapotranspiration trials, copper leached into the water as it was transformed from an oxide mineral to a sulphide mineral (because of the copper in the soils used for construction). This is not representative of what would occur during periods with no flow in a full-scale CWTS, where soils with minimal leachable copper are used and copper is deposited in sulphide form (fraction 4) by the biogeochemical activity of the CWTS (Section 5.6).

Total evapotranspiration from a CWTS is measured as the combined effects of open water evaporation and plant transpiration (Beebe et al., 2014). The purpose of calculating the evapotranspiration of a CWTS is to understand the amount of water lost per day over the surface area of a wetland, which in turn concentrates constituents, and should be considered in the context of the decrease in outflow concentration (or not) and outflow load reduction. It should also be noted that evapotranspiration will vary depending on temperature, humidity, and wind on-site and, therefore, will fluctuate over time. This should be considered when interpreting evapotranspiration rates, however, for conceptual calculation purposes, a set rate is applied here.

The off-site evapotranspiration study conducted in 2016 suggested that approximately 15.5 L/day/$m^2$ could be lost due to evapotranspiration (Contango, 2017). The results of the 2017 on-site evapotranspiration studies were intended to provide more accurate estimates at the CWTS than the off-site study and had an average water loss of 5.3 L/day/$m^2$ (Table 6). These results are consistent with pilot-scale results from another CWTS planted with *Carex* where 5.1 L/day/$m^2$ were lost through evapotranspiration. Although the off-site study can be informative, the on-site study is more representative of what would occur during operation of the full-scale CWTS in the spring. The difference in the two rates is expected to be due to temperature difference of the trial. The on-site during the evapotranspiration study were on average 9.6°C in May and 13.7°C in June while temperatures in the off-site study were on average 22°C during the day (12 hr) and 16°C during the night (12 hr) which is less representative of site conditions. Temperatures in July and August at Minto were only slightly higher than June temperatures and were on average 15.8°C and 13.9°C, respectively. Therefore, we would expect marginally higher rates of evapotranspiration in these months.

Table 7 shows the amount of water lost to evapotranspiration during the operational period (August 18 – September 22, 2017) in each cell of the demonstration-scale CWTS. The amount of water lost in the CWTS during each flow rate period tested is calculated using Equation 6.

$$Water\ loss\ (\%) = \frac{ET}{Q} \times 100$$

**Equation 6 – Equation for the calculation of the water loss due to evapotranspiration.**
*Q* is the flow rate (L/day); *ET* is the evapotranspiration rate (L/day).

**Table 6– Water loss through evapotranspiration in the CWTS.**

| Study | Cell | Water loss[1] (L/day) | Water loss[2] (L/day/m$^2$) |
|---|---|---|---|
| Trial 1: May 16 – 24, 2017 | 1A | 575.0 | 8.3 |
| | 1B | 143.7 | 2.1 |
| | 2A | 509.0 | 8.8 |
| | 2B | 152.7 | 2.6 |
| | | **L/day/m$^2$ Average** | **5.4** |
| Trial 2: June 8 – 11, 2017 | 1A | 580.8 | 8.3 |
| | 1B | 116.2 | 1.7 |
| | 2A | 775.7 | 13.3 |
| | 2B | 339.4 | 5.8 |
| | | **L/day/m$^2$ Average** | **7.3** |
| Trial 3: June 11 – 15, 2017 | 1A | 292.7 | 4.2 |
| | 1B | 27.9[3] | 0.4 |
| | 2A | 273.4 | 4.7 |
| | 2B | 203.6 | 3.5 |
| | | **L/day/m$^2$ Average** | **3.2** |
| | | **L/day/m$^2$ Overall Average** | **5.3** |

[1] Water loss (L/day) = (initial depth (m) – final depth (m)) * area of CWTS (m$^2$) * 1000 L/m$^3$/days.
[2] Water loss (L/day/m$^2$) = Water loss (L/day) / area of CWTS (m$^2$).
Total days of study in trials 1, 2, and 3 were 8, 3, and 5 days, respectively. The area of series 1 is 69.7 m$^2$ and the area of series 2 is 58.2 m$^2$.
[3] Depths in this cell had minimal change throughout trial 3.

Table 7 shows how this water loss likely affected the load leaving the wetland. The average ambient temperature on-site for this time period was 9.9°C, and so the evapotranspiration rates from the trials are expected to be relevant to the operational period. The information in Table 7 is calculated based on Equation 7 and Equation 8.

Evapotranspiration has a significant effect on the calculation of constituent load to the receiving environment. Therefore, future models for assimilative capacity in the downstream receiving environment should take into account not only the predicted outflow concentrations from the CWTS using removal rate coefficients (Section 5.4.2), but also adjust the load accounting for evapotranspiration.

Concentrations of copper (and other metals) were measured in the water during the evapotranspiration studies to determine if any leaching occurred during periods of no flow because the soils used in construction contained oxidized copper minerals. In the 2017 study, this is noted by an average decrease of 63.3 µg/L copper after flow was restarted and treatment of copper resumed. This is not representative of what would occur during periods

with no flow in a full-scale CWTS, where soils with minimal leachable copper are used and copper is deposited in sulphide form (fraction 4) by the biogeochemical activity of the CWTS (Section 5.6). In a full-scale CWTS, lower flows and stagnation will result in greater treatment of constituents into sulphide mineral forms.

The demonstration-scale evapotranspiration studies were conducted to inform evapotranspiration rate estimates for full-scale CWTS design. However, these results are fortuitous because the study was conducted during the commissioning-B period, rather than the operational period when the CWTS was running optimally. Additionally, since the studies were conducted in the spring, they do not capture the seasonality of evapotranspiration rates and are therefore conservative numbers. Thus, it is recommended that another evapotranspiration study be conducted on-site in 2018.

$$Load_{in} = C_i \times V$$

**Equation 7 – Equation for the calculation of load of a constituent into a CWTS over a period of time.**

$Load_{in}$ is the mass of a constituent that enters a CWTS over a period of time; $C_i$ is the inflow concentration of the constituent; $V$ is the volume of water that enters a CWTS over a period of time.

$$Load_{out(ET)} = Water\ Out_{ET} \times C_f$$

**Equation 8 – Equation for the calculation of the load out of a constituent over a period of time, adjusted for evapotranspiration.**

$Load_{out(ET)}$ is load out of a constituent over a period of time, adjusted for evapotranspiration; $Water\ Out_{ET}$ is the outflow water volume over a period of time, adjusted for evapotranspiration; $C_f$ is the outflow concentration of the constituent.

**Table 7 – Average constituent load in, load out, load out adjusted for evapotranspiration and load removed adjusted for evapotranspiration in the demonstration-scale CWTS.**

| COC | Form | Load in (mg/ day) | Load out[1] (mg/day) | Load out Adjusted for evapotranspiration[2] (mg/day) | Load removed adjusted for evapotranspiration (mg/day) | Load removed[3] (%) |
|---|---|---|---|---|---|---|
| Cd | D | 0.0476 | 0.0162 | 0.0131 | 0.0345 | 71 |
| | T | 0.0283 | 0.0094 | 0.0076 | 0.0207 | 73 |
| Cu | D | 89.7 | 31.4 | 25.4 | 64.3 | 72 |
| | T | 96.2 | 38.4 | 31.1 | 65.1 | 67 |
| Mo | D | 11.5 | 4.8 | 3.9 | 7.6 | 65 |
| | T | 12.6 | 5.2 | 4.2 | 8.3 | 66 |
| Se | D | 7.2 | 0.9 | 0.7 | 6.5 | 89 |
| | T | 6.4 | 0.9 | 0.7 | 5.7 | 88 |
| Zn | D | 90.0 | 3.4 | 2.8 | 87.2 | 97 |
| | T | 91.6 | 7.5 | 6.0 | 85.5 | 93 |

[1] Inflow volume was used for the calculation of load out using outflow concentrations without adjusting for evapotranspiration (Appendix A, Equation A2).
[2] Outflow volume adjusted for evapotranspiration was used for the calculation of load out adjusted for evapotranspiration.
[3] Load Removed (%) = (Load out adjusted for evapotranspiration)/(Load in) * 100
Water loss for each flow period is an average of all time points and is calculated using Equation 7. Average water loss in series 1 and 2 is 377.9 L/day/m2 (18%) and 315.4 L/day/m2 (20%), respectively. D = dissolved, T = total. Results in the table are from the operational period only (August 18 – September 22, 2017) and are therefore not representative of what would occur year-round. Ambient temperature on-site for this period was on average 9.9°C.

### 5.6.Soils

The following are key findings regarding constituents in the soil, which are detailed further below:

- In 2017, leachable copper concentrations in soils decreased in the top 0-10cm while total copper concentrations increased.
- Most constituents, including copper, have shifted primarily into stable reduced and residual minerals fractions in the soil.
- Acid volatile sulphides (AVS) were non-detectable in the CWTS in 2016. In 2017 small amounts of AVS were detected in cells 1A and 2A which indicates that residual sulphides are starting to become available for metal treatment and that copper in the soils are becoming rendered inert through sulphide mineralization.

Although unintentional, the high initial leachable copper concentrations in the CWTS soils (Appendix A, Table A2) allowed for additional testing to be carried out on these CWTSs. Because the soil substrates used for construction of the CWTS were from overburden sources, the copper was in oxidized form rather than in a mineral form that would typically be found in a reducing CWTS (i.e., soils with negative redox). Therefore, there was some initial leaching of copper from the soils into the water.

To assess the effect of the elevated metals in the soils used in construction on CWTS functionality, four soil analytical test methods were used and are described in Appendix A. Analytical methods tested for total metals, leachable metals, and metal speciation. Results of these test methods during the operational period are discussed in the following sections. Table 8 shows the definitions of extractable fractions from the sequential extraction procedure for the speciation of metals (Tessier et al., 1979).

**Table 8 - Summary of extractable fractions from sequential extraction procedure for the speciation of metals[1].**

| Fraction | Description | When COCs Become Unstable and Release to the Water Column |
|---|---|---|
| **1** | Exchangeable fraction for adsorbed minerals | Readily released (i.e., soluble and exchangeable) |
| **2** | Mineral fraction bound to carbonates or solubilized at pH 5 | Decreased pH |
| **3** | Oxidized mineral fraction bound to Fe-Mn oxides | Reducing conditions |
| **4** | Reduced mineral fraction and sulphides | Oxidizing conditions |
| **5** | Residual mineral fraction (primary and secondary minerals) | Not expected to be released in solution over time under conditions normally encountered in nature |

[1]Method based on Tessier et al., 1979.

Analysis of leachable metals in 2017 used the same leach method as in 2016 and results can be found in Appendix B, Table B2. When compared to early 2016 results, leachable copper concentrations in 2017 soils decreased throughout the CWTS (Figure 19) while total copper concentrations increased overall as copper shifted from its leachable to mineral form (Figure 20). In general, soils in the demonstration-scale CWTS appear to be reaching a steady-state with concentrations of leachable copper changing little throughout 2017. We expect leachable copper decrease further in 2018.

Sequential extraction procedure for the speciation of particulate trace metals was conducted for all constituents of concern and results and figures can be found in Appendix B (Tessier et al., 1979). The analysis shows that despite elevated initial leachable copper concentrations, the soils have become more stable (less leachable) over time in the CWTS setting as the soils have aged, shifting from oxidized to reduced, mineral forms (Figure 21; Figures B18 and B19). This beneficial aging of soils to a less soluble mineralized form of sulphide is expected for this type of treatment CWTS design. It should also be noted that copper leached from the original substrate into the water put additional treatment demands on the CWTSs.

For the CWTS to treat the copper from the soils, additional organic carbon is needed beyond that necessary for the waters alone. Organic carbon is contributed to the CWTS through decomposition of plant material as the CWTS matures. Organic carbon is used as food by the microbes, which in turn produce sulphides which drive metals treatment through mineralization that is helped by biogeochemical processes. Presently, as there is excess copper in the soils in oxidized forms transitioning to reduced forms, these will bind to and consume the sulphides produced, transforming them to the sulphide-bound fraction 4 (Table 7). This in turn impacts the ability to treat water, as it uses the available sulphides that would otherwise treat metals in the water. When the mineral fractions of the soils have completed their transformation into sulphide-bound minerals, the soils will no longer be "sulphide hungry", allowing for the soil-produced sulphides to be utilized for metals treatment in the water. This progress can be tracked in results from the sequential extraction tests, the appearance of acid volatile sulphides (AVS) in the soils (iron sulphates, which will only occur after the copper is transformed), and the change of sulphate concentrations in the water.

Additional reserve treatment capacity can be stored in a CWTS through creation of a reserve of AVS (newly formed amorphous iron sulphides). AVS are referred to as such because of the testing method, which is also done alongside simultaneously extracted metals (AVS:SEM; at Minto, cadmium, copper, and zinc were tested for) to determine the ratio of iron sulphides to free metals. An excess of AVS suggests the metals would be non-bioavailable and not likely to leach. In the case of Minto, where the soils used in construction had excess copper, the appearance of measurable AVS would also indicate that the copper in the soils is nearing an endpoint of transformation to sulphide forms.

AVS was tested for in 2016 prior to adding the straw and wood chips and was non-detectable (hence, the decision to add the straw and wood chips). The appearance of small amounts of measurable AVS over time (cell 1A in June and cell 2A in September, 2017) indicates that the amount of sulphide produced in the soils is beginning to exceed the total amount of copper

placed with the original soils and the CWTS should eventually start performing the way it should have if substrates with high leachable copper had not been used. However, the AVS:SEM ratio is indicating there is significant copper in the soils still consuming the sulphides, and treatment performance is expected to improve as that continues to be remedied over time. An AVS:SEM ratio greater than one indicates excess copper in the soils has been reduced to sulphide form and is no longer consuming excess sulphides, allowing for AVS to form. Once the AVS:SEM ratio of all cells is consistently greater than one, we do not expect any further copper leaching to occur, and copper treatment within the CWTS should improve until this time.

Zinc (Figures B20 and B21) mineral forms have become stable over time, with most of these constituents found in the reduced or mineral form (fraction 4 and 5) by the end of 2017. Cadmium concentrations are at or near detection limits for all fractions (Figures B22 and B23). Molybdenum was mostly found in the most stable residual mineral fraction 5, which contained around 40% of the total molybdenum in the samples (Figures B24 and B25). Selenium was at or near the detection limit for all fractions and at the end of 2017, and was barely detectable for the stable fractions 4 and 5 (Figures B26 and B27).

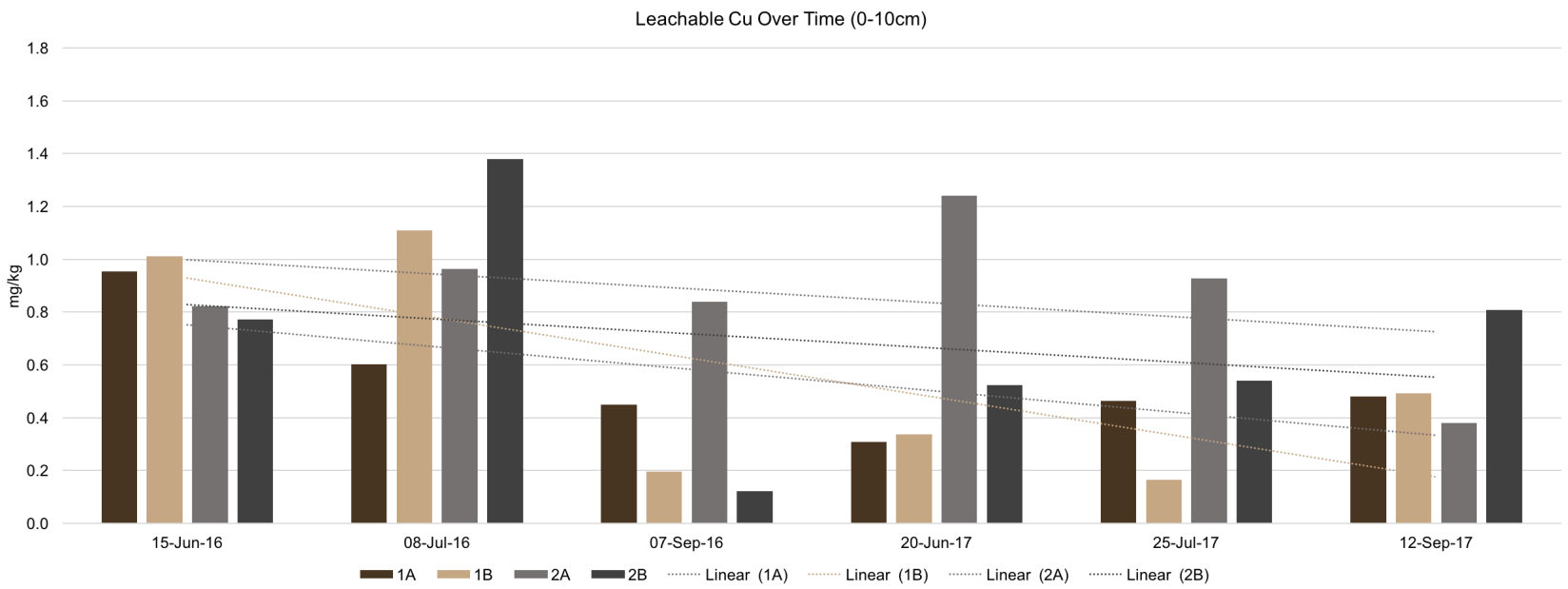



**Figure 19 – Leachable copper concentrations in soils over time in the demonstration-scale CWTS.**
Figure shows concentrations in shallow soil (0-10 cm). Trendlines (dotted lines) show a general decrease in leachable copper over time.

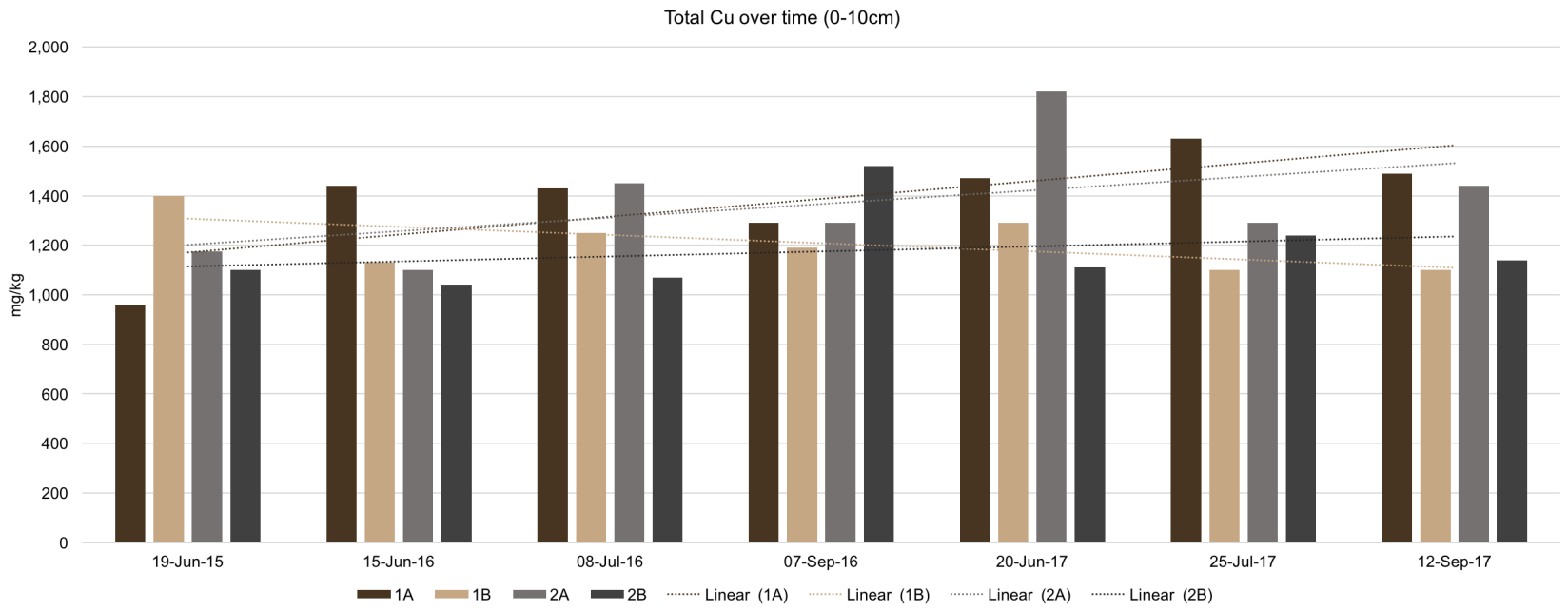



**Figure 20 – Total copper concentrations in soils over time in the demonstration-scale CWTS.**
Figure shows concentrations in shallow soil (0-10 cm). Trendlines (dotted lines) show a general increase in total copper over time.

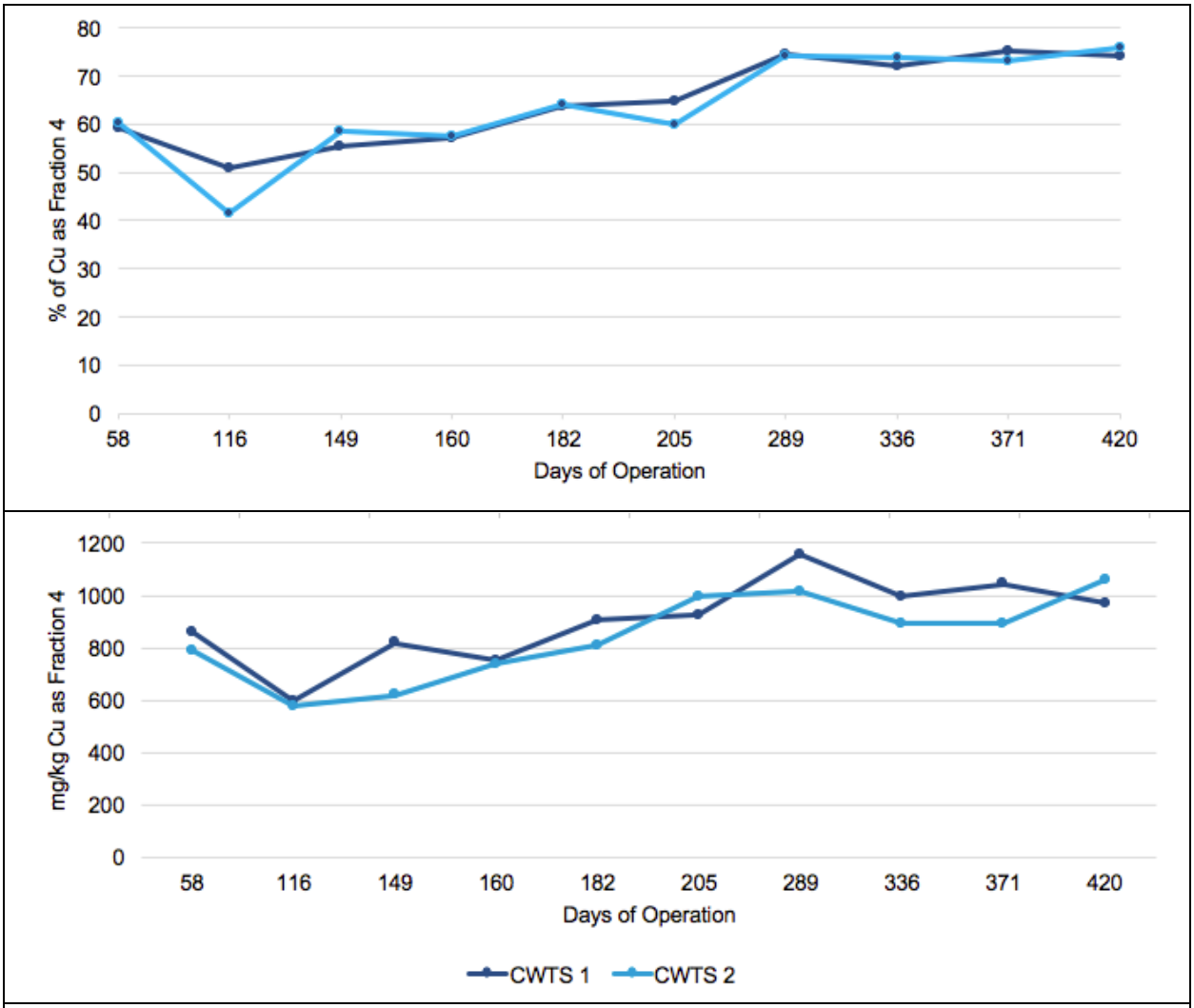



**Figure 21 – Copper as sequential leach fraction 4 over time.**
Copper in the form of the targeted Fraction 4 (sulphide mineral form and bound to organics), increased in the CWTS over time as the soils matured. Additional information can be found in Appendix B.

### 5.7.Metals Uptake

The following are key findings regarding metals uptake, which are detailed further below:

- Overall, uptake of metals in *C. aquatilis* was low and generally lower in 2017 than in 2016 demonstration-scale CWTS results.
- Targeted treatment mechanisms are becoming more robust, rendering elements non-bioavailable.

Concentrations of the constituents of concern in *C. aquatilis* and moss from the demonstration-scale CWTS in 2017 were compared to those from 2016. *C. aquatilis* and moss in the demonstration-scale CWTS had greater copper concentrations than the pilot CWTSs, likely reflecting the bioavailable copper that was in the soils used for construction. Concentrations of copper in the *C. aquatilis* at the end of 2017 were similar or lower than 2016 concentrations (Figure 22). The moss had higher copper concentrations in the A cells than in 2016, but lower concentrations in B cells, indicating more treatment earlier in the CWTS as it matures (Figure 22). Over time, constituents sorbed to mosses will form reduced minerals, rendering them less bioavailable.

Cadmium concentrations in *C. aquatilis* and moss were similar in 2017 and 2016, except for higher concentrations in cell 1B where concentrations were higher for *C. aquatilis*, (Figure 23). Similar selenium concentrations were observed in both plant types in 2017 as in 2016, (Figure 24; Contango, 2016 and 2017). Concentrations of molybdenum in moss generally decreased from 2016 to 2017, while concentrations of molybdenum in *C. aquatilis* decreased significantly and now remain around the detection limit (Figure 25). In 2017, overall concentrations of zinc decreased in *C. aquatilis* and moss from 2016, except for cell 1B in *C. aquatilis* and cell 2A in moss where concentrations of zinc remained the same (Figure 26).

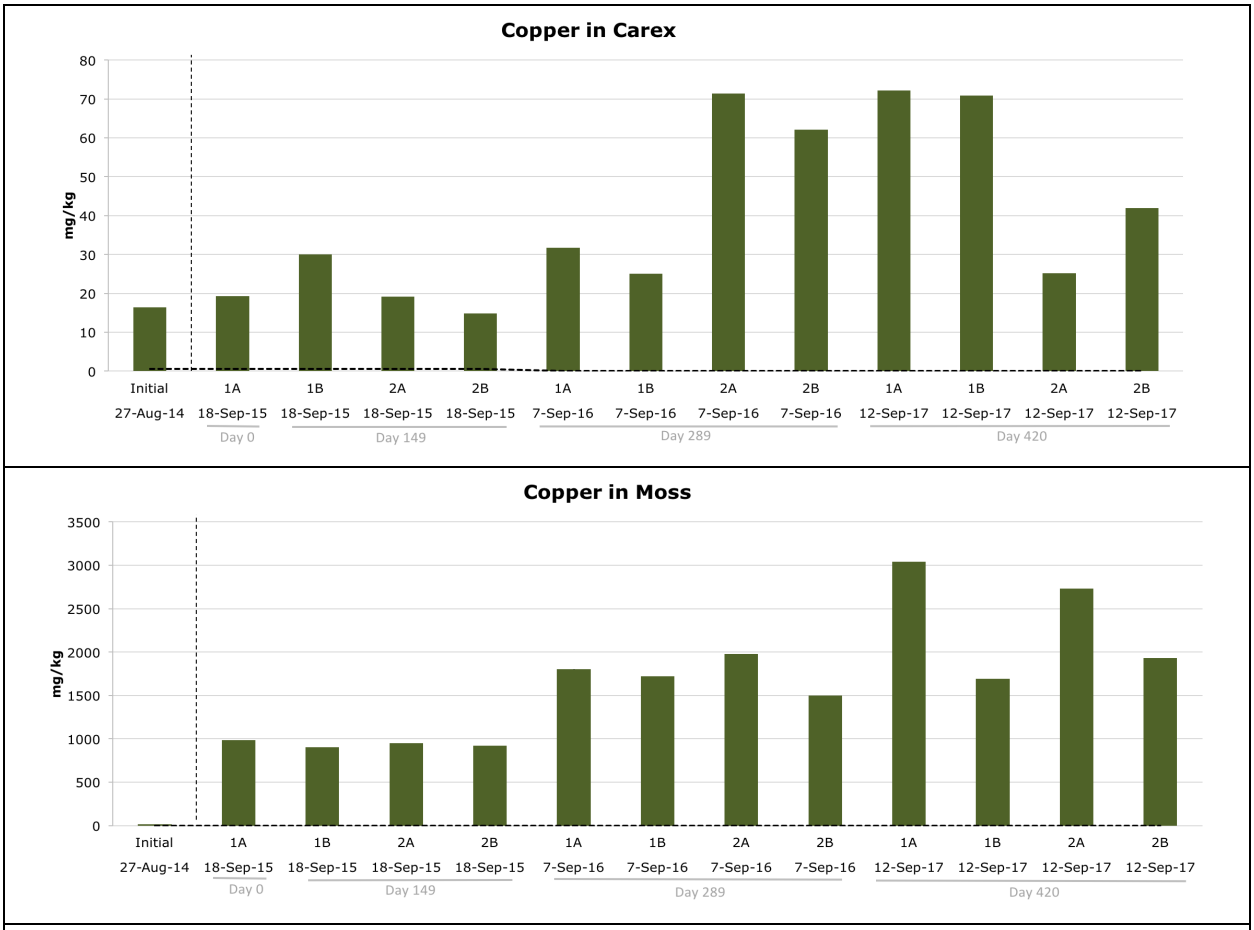



**Figure 22 – Copper concentrations in plants.**
The 2014 detection limit (DL; horizontal dotted line) for copper is 0.5 mg/kg, the 2015 DL is 0.1 mg/kg, and the 2016 and 2017 DL is 0.05 mg/kg. The initial data set is the average of three *Carex* replicates at construction.

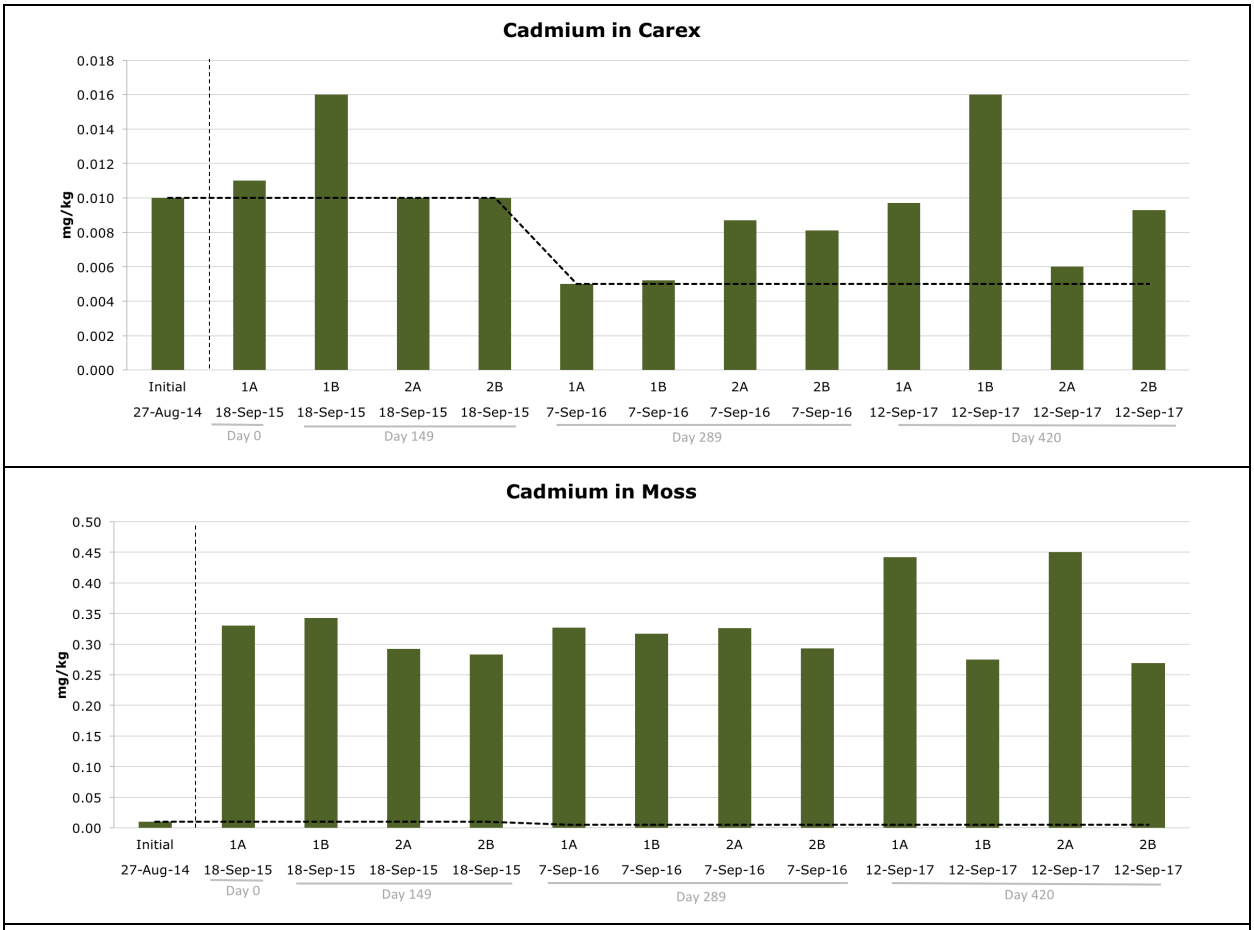



**Figure 23 – Cadmium concentrations in plants.**
The 2014 and 2015 detection limit (DL; horizontal dotted line) for cadmium is 0.10 mg/kg. The initial data set is the average of three *Carex* replicates at construction.

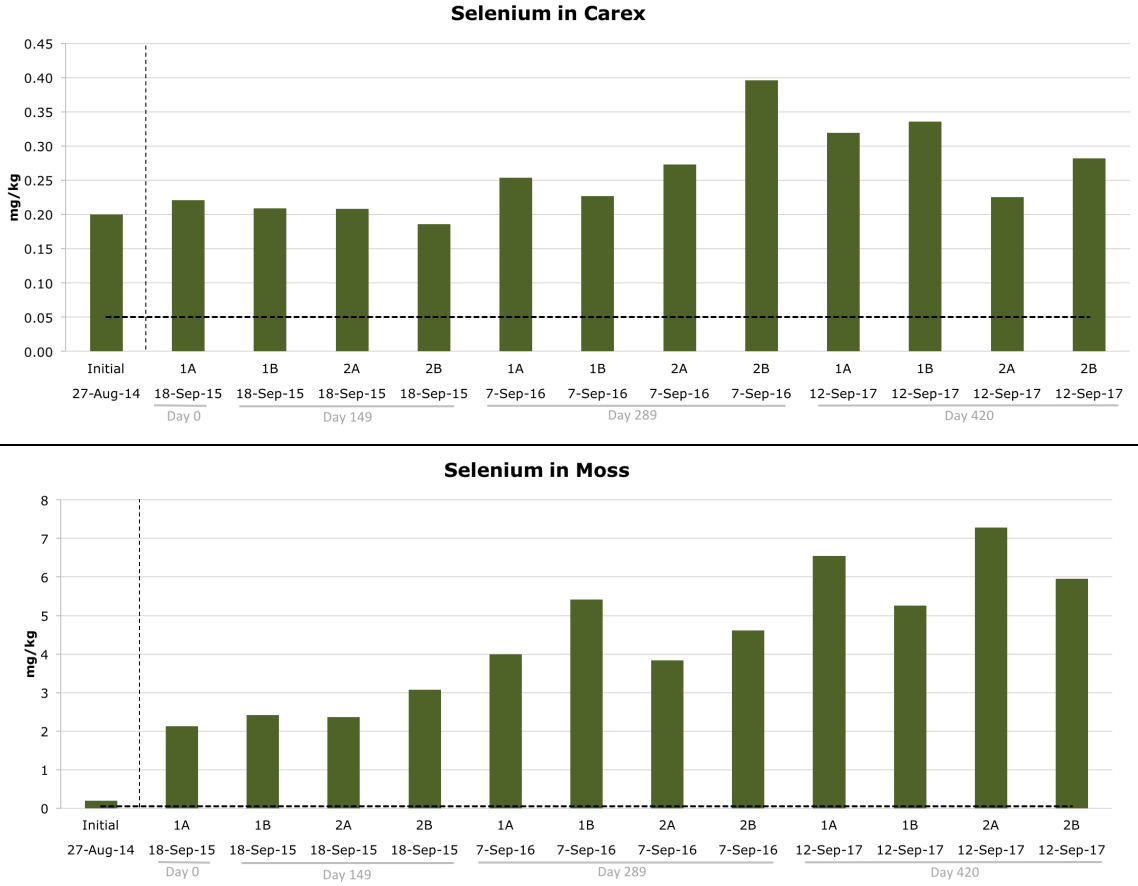
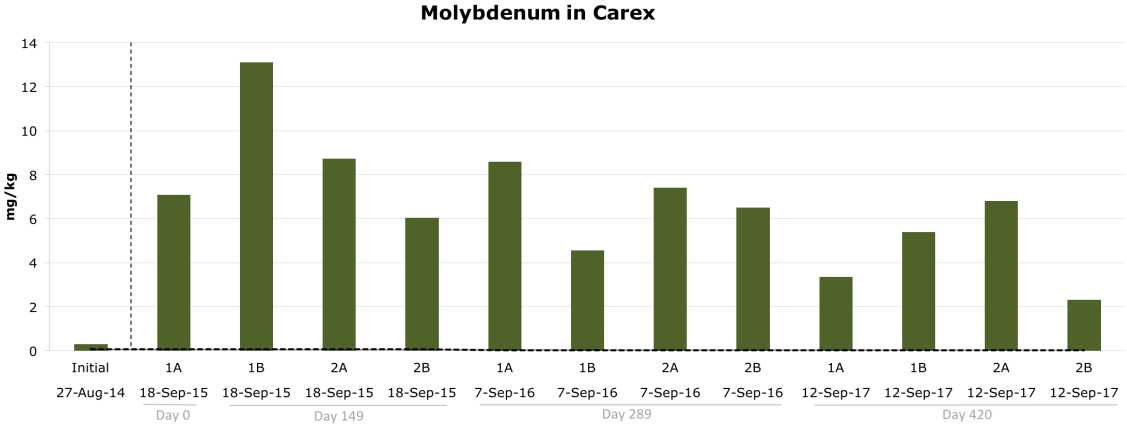



**Figure 24 – Selenium concentrations in plants.**
The method detection limit (DL; horizontal dotted line) for selenium is 0.2 mg/kg. The initial data set is the average of three *Carex* replicates at construction.



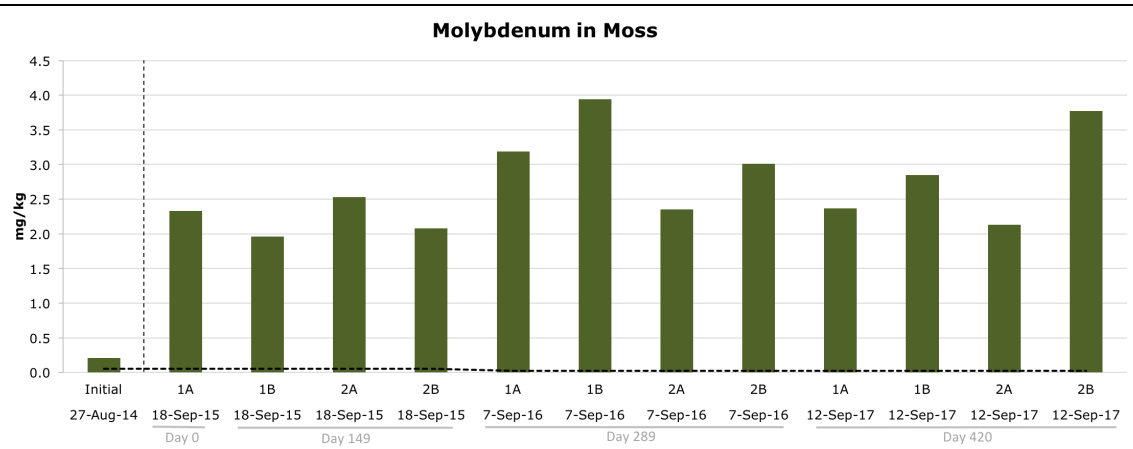




**Figure 25 – Molybdenum concentrations in plants.**
The 2014 and 2015 detection limit (DL; horizontal dotted line) for molybdenum is 0.05 mg/kg, the 2016 and 2017 DL is 0.020 mg/kg. The initial data set is the average of three *Carex* replicates at construction.

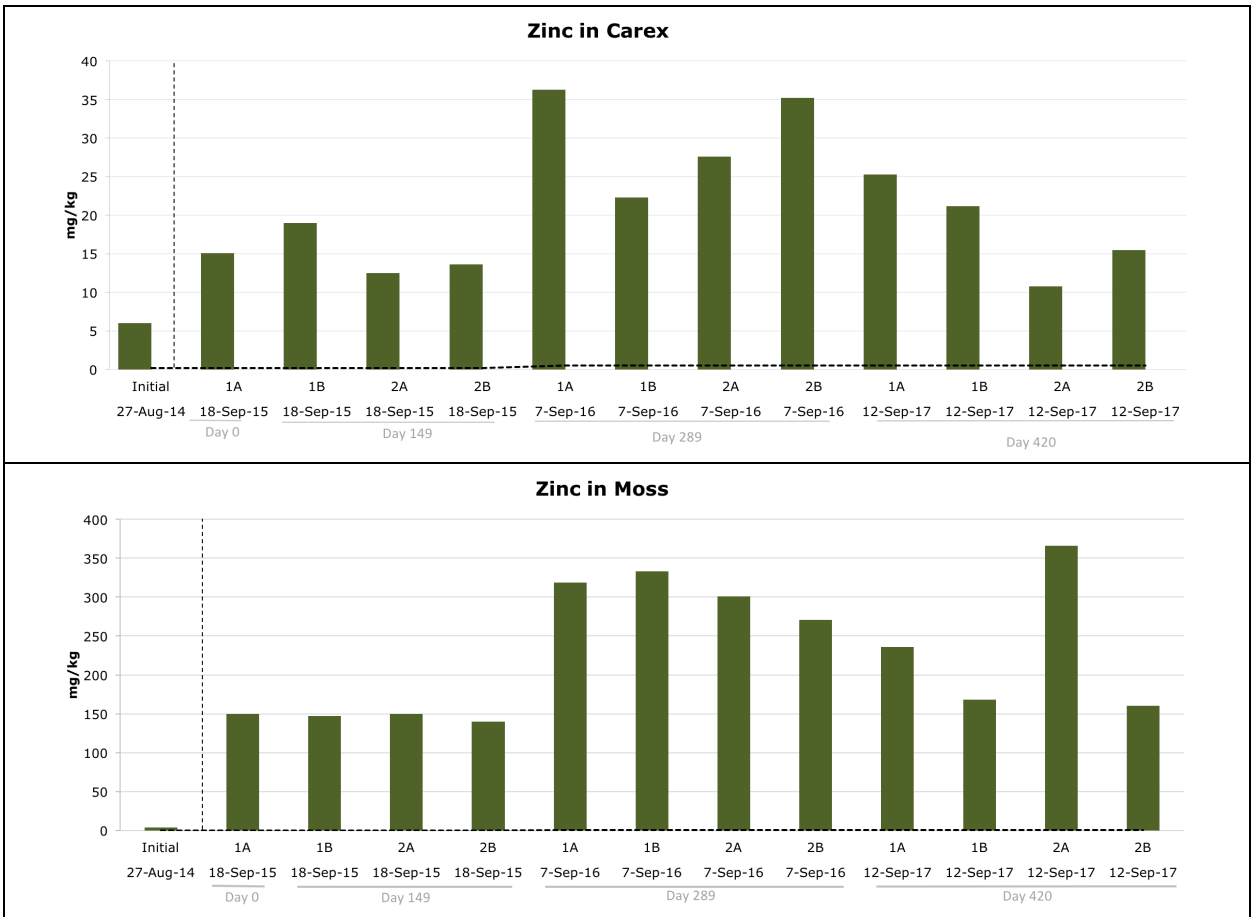



**Figure 26 – Zinc concentrations in plants.**
The 2014 detection limit (DL; horizontal dotted line) for zinc is 2.0 mg/kg, the 2015 DL is 0.002 mg/kg, and the 2016 and 2017 DL is 0.5 mg/kg. The initial data set is the average of three *Carex* replicates at construction.

### 5.8. Detritus Study

The following are key findings regarding the detritus study, which are detailed further below:

- The detritus study suggested that algae growth on the assay devices had reached a steady state (growth vs decomposition) by ~23 days of the study.
- After 83 days submerged in the CWTS, *C. aquatilis* decomposed on average 64%.

A detritus study was conducted in 2017 to assess decomposition rates of *C. aquatilis* in the CWTS over time as well as to determine the steady state of carbon contribution from algae growth on CWTS materials (Chimney and Pietro, 2006; Hammerly et al., 1989). Additional details describing the methods can be found in Appendix A. The study began on June 21, 2017 when six bags filled with 5g of oven dried *C. aquatilis* were submerged into each CWTS cell to determine the decomposition rate of *C. aquatilis* (Figure 27). Variability between samples are indicated by error bars (minimum and maximum values) in Figure 28. Six additional bags filled with 3.8 g of polyester filter fiber material were submerged into each cell of the CWTS to determine the algae growth rate. On July 25, 2017 and September 11, 2017 (after 34 and 83 days of submersion in the CWTS, respectively) one bag filled with *C. aquatilis* and one bag with the polyester fiber were sacrificed from each CWTS cell and the dried weights compared to initial sample weights (Table 9). This resulted in four replicates for each treatment and sampling date.

The weight of the polyester fiber bags increased by an average 23% after 34 days, and by 21% after 83 days, suggesting that the algae growth had reached a steady state prior to 34 days. After being submerged for 34 days in the CWTS, *C. aquatilis* decomposed on average 56% from the initial weight (decreasing from 5 g to 2.2 g), and continued to decompose to an average of 64% (decreasing from 5 g to 1.8 g) after submersion for 83 days in the CWTS (Table 9). There was little variability between cells. These detritus decomposition rates have been adjusted for by subtracting the weights of algal growth of the corresponding polyester fiber filled bag (Appendix A).

Four bags of each material remain in each cell for future sampling. The detritus study will continue in 2018 to enable monitoring and calculation of decomposition and accretion rates.



**Figure 27 – Detritus study bags.**
Left are mesh bags filled with sedges and polyester fiber fill stuffing. Left are mesh bags with *C. aquatilis* and control polyester prior to addition to the CWTS, middle are bags submerged in a CWTS cell and attached to depth stick, and right is a mesh bag with decomposed sedges and polyester fiber fill stuffing.

**Table 9 – Results of the *C. aquatilis* detritus study.**

| | Initial weight of *C. aquatilis* (g) | Dry weight after 34 days (g) [2] | Decrease in weight after 34 days (%) | Dry weight after 82 days (g) [2] | Decrease in weight after 83 days (%) |
|---|---|---|---|---|---|
| 1A | 5.0[1] | 2.1 | 57% | 1.7 | 65% |
| 1B | | 2.1 | 59% | 1.7 | 67% |
| 2A | | 2.3 | 54% | 2.0 | 61% |
| 2B | | 2.4 | 52% | 1.9 | 63% |
| **Average** | | **2.2** | **56%** | **1.8** | **64%** |

[1] Initial weight prior to bags being placed in CWTS.
[2] Weights of *C. aquatilis* corrected by subtracting the increase in weight from the polyester fiber fil to account for algae growth.

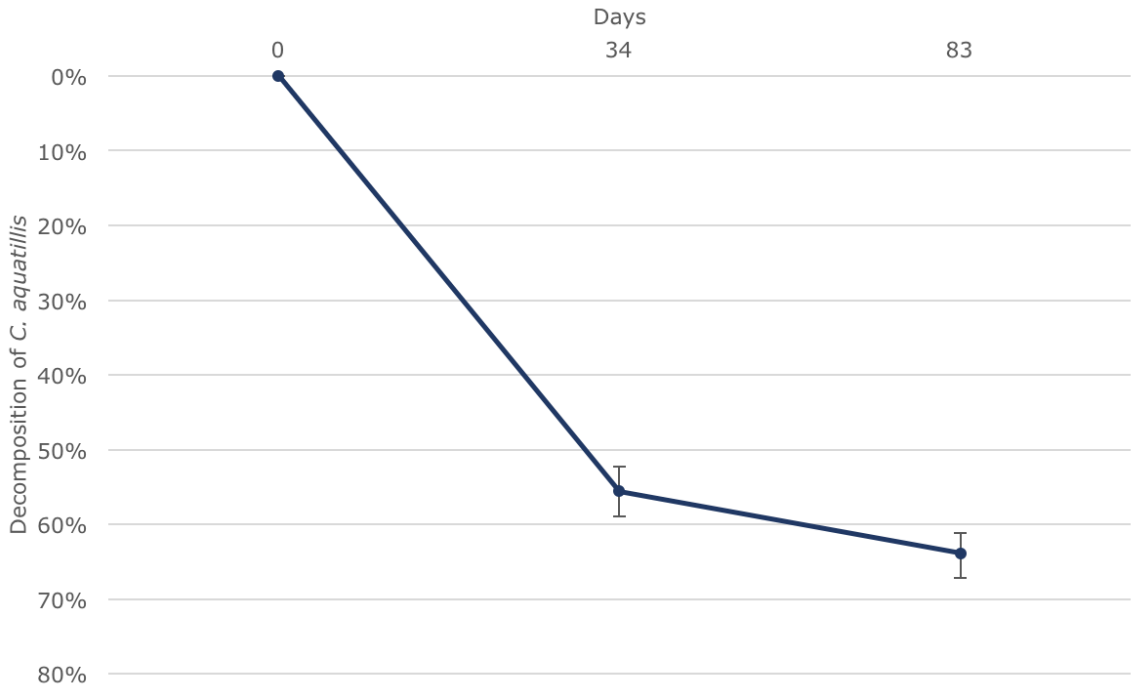



**Figure 28 – *C. aquatilis* decomposition over time.**
Decomposition was measured by the decrease in weight over time of the *C. aquatilis* samples compared to the initial weight. The decomposition rate was corrected for algae growth by subtracting the increase in weight of the polyester filter foam from the dry weight of the *C. aquatilis* samples over time. Error bars indicate the variation in results for each time point.

## 5.9. Beneficial Microbes

The following are key findings regarding beneficial microbe establishment in the CWTS, which are detailed further below:

- Establishment of sulphide-producing bacteria (SPB) increased throughout 2017 and was highest after commissioning was completed.
- SPB were found in highest abundance in root and soil samples.
- The average number of different types of sulphide-producing bacteria increased over time in all sample types tested (root, soil, detritus, and moss).
- Selenium-reducing and nitrate-reducing bacteria increased over time with the highest abundances found in *C. aquatilis* roots.

Microbes are the driving force of many treatment pathways that are targeted in CWTSs. The beneficial microbes in these CWTSs catalyze biogeochemical processes that remove specific constituents of concern from the water column. Careful design of CWTSs can create the environmental conditions needed to enhance the abundance and metabolic activity of these beneficial microbes. Accordingly, complimentary methods of genetic and growth-based testing were used to characterize the microbial populations associated with a range of microbial habitats in the demonstration-scale CWTS (e.g., soils, sediment, biofilms, aquatic mosses, and plant roots).

In the context of the Minto Mine CWTS, beneficial microbes include those that are involved in the reduction of selenium (i.e., selenate and selenite), nitrate, and sulphur compounds. Reduced sulphur can in turn treat copper, cadmium, molybdenum, and zinc through geochemical interactions. Information on each of these mechanisms and the associated microbial populations in the demonstration-scale CWTS is outlined in the following sections.

### *5.9.1. Sulphide-producing Bacteria*

Treatment of metals and metalloids can be achieved by targeting the lithic biogeochemical sequestration of divalent metals through sulfide (i.e., $S^{2-}$, $HS^{-}$) precipitation as mineralized species (e.g., chalcocite [CuS], covellite [$Cu_2S$]). These sulfide-bound species are relatively insoluble (CuS; $K_{sp}=10^{-16}$; Stumm and Morgan 1996), and are transferred from the water column into the CWTS soil as non-bioavailable fractions (Murray-Gulde et al., 2003; Huddleston et al., 2008). Moreover, similar reactions occur with cadmium and zinc, rendering them non-bioavailable. As such, sulphide production is a key biogeochemical mechanism for water treatment at Minto Mine. Sulphides can be created by beneficial microorganisms through the reduction of sulphur-containing compounds, such as sulphate, sulphite, thiosulphate, and elemental sulphur.

Based on the information gathered in pilot-scale testing, the targeted soil redox for the demonstration-scale CWTS is between -100 and -250 mV to facilitate these reactions. This is in agreement with literature that indicates anaerobic conditions with relatively low ORP (-250 to -100 mV) are necessary to promote anaerobic metabolism in bacteria which oxidizes

organic matter and produces electrons, which in turn reduces sulfate to hydrogen sulfide ($H_2S$) and other sulfide species (i.e., bisulfide ion ($HS^-$), sulfide ion [$S^{2-}$]; Mitsch and Gosselink 2007). In these redox ranges, bacterial sulphide-production through reduction of sulphur compounds is expected, alongside increases in the proportion (percentage) and abundance of these microbes.

As expected, diversity (Table 10), proportion, and inferred abundance of sulphide-producing bacteria (SPB) increased as the soil redox decreased in the demonstration-scale CWTS with the highest proportions observed in 2017 compared to 2016, as the CWTS has matured (Figure 29, Figure 30, Figures B28 and B29 in Appendix B; Contango, 2017). Proportions of SPB increased in all sample types (soil, roots, moss, and detritus) over time through 2017 (Table 10). As observed in 2016, the *C. aquatilis* roots were again found to harbour the highest proportions and abundances of beneficial SPB, followed by the soil, detritus, and moss. Furthermore, the highest proportions were observed in the operational period for both soil and root samples. Root, detritus, and soil samples harboured the highest average number of different SPB types, followed by moss (Table 10). However, the average number of different types of SPB increased over time in every sample type tested.

The microbial analysis of various sample types in the CWTS has therefore confirmed that the commissioning period proceeded as expected and was successful in establishing beneficial SPB populations alongside reducing conditions. Monitoring of soil redox as well as microbial populations will continue to be monitored for stability or further improvement in 2018.

**Table 10 – Average number of different types of sulphide-producing bacteria in 2014/2015, 2016, and 2017.**

| Sample Type | 2014 & 2015 | 2016 | 2017 |
|---|---|---|---|
| detritus | NT | 6 | 9 |
| moss | 3 | 4 | 8 |
| root | 6 | 8 | 9 |
| soil | 4 | 8 | 9 |

NT – not tested. The number of different types is based on counting the number of operational taxonomic units (clustered at 97% identity) that are classified as known sulphide-producing bacteria.

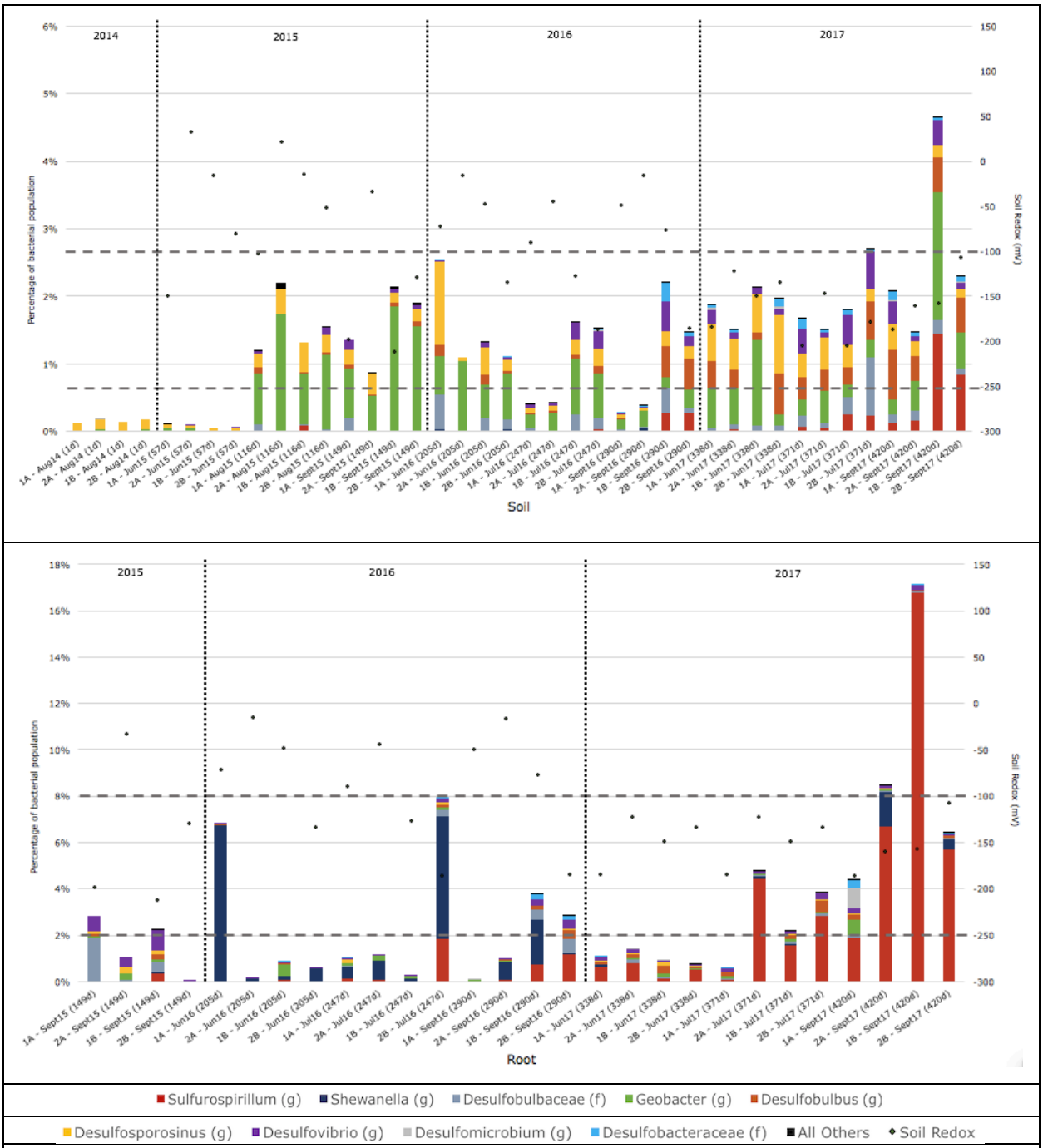



**Figure 29 – Percentage and identity of sulphide-producing bacteria in soil (top) and roots (bottom) demonstration-scale CWTS.**

The horizontal dashed lines indicate the targeted soil redox range. Organism classifications and data analysis methods have been updated from Contango (March 2016). The y-axis provides the percentage of the bacterial community (relative abundance) that corresponds to sulphide-producing bacteria through the reduction of sulphate, sulphite, thiosulphate, and sulphur. Percentage is based on identification via genetic sequencing. Organisms are either classified to the genus (g) or family level (f). The root y-axis is different from the soil y-axis as the % SPBs is much higher in one sample of root (1B – Sept17 (420d)).

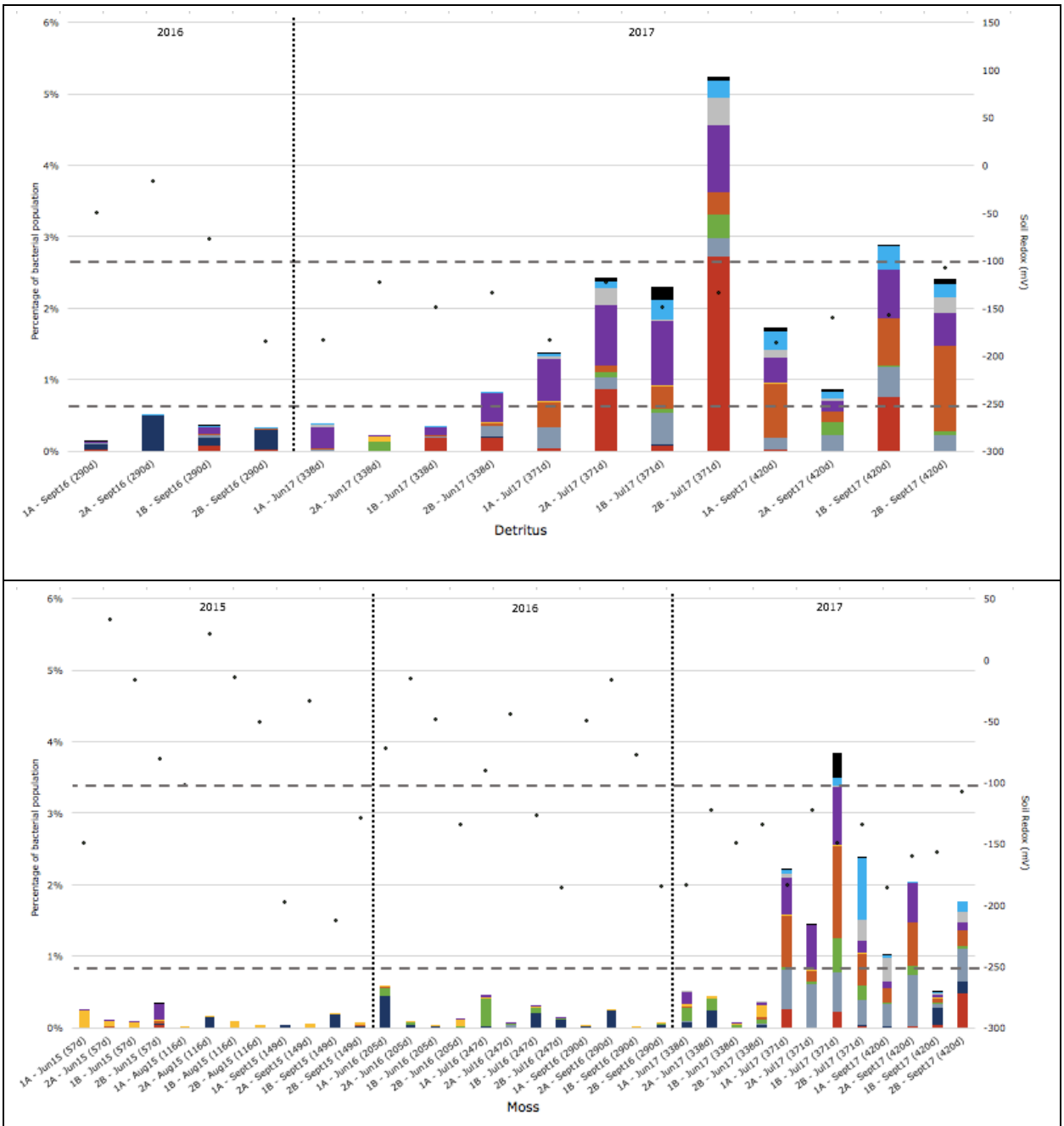



**Figure 30 – Percentage and identity of sulphide-producing bacteria in detritus (top) and moss (bottom) demonstration-scale CWTS.**

The horizontal dashed lines indicate the targeted soil redox range. Organism classifications and data analysis methods have been updated from Contango (March 2016). The y-axis provides the percentage of the bacterial community (relative abundance) that corresponds to sulphide-producing bacteria through the reduction of sulphate, sulphite, thiosulphate, and sulphur. Percentage is based on identification via genetic sequencing. Organisms are either classified to the genus (g) or family level (f).

### *5.9.2. Selenium-reducing Bacteria*

The targeted selenium treatment pathways in the Minto CWTS include sorption to moss and soils, and subsequent microbial reduction of soluble (sorbed) selenate (Se(VI)) and selenite (Se(IV)) to insoluble elemental selenium (Se(0)). This reductive process can also be achieved directly in the water column, but is more effective when associated with mosses and biofilms due to their sorptive properties that bring the selenium in contact with beneficial selenium-reducing bacteria. Selenium reduction biogeochemical processes are achieved within the range of soil redox conditions targeted for sulphate-reduction as suggested by pilot-scale testing and literature (Contango, 2014).

Selenite-reducing organisms are ubiquitous in nature and as expected, were detected in all sample types, including algae, biofilm, moss, soil, sediment, roots, and detritus. Although organisms that reduce selenate to elemental selenium (rather than intermediary selenium compounds) are generally less abundant in the environment, they were found associated with all sample types, indicating that the conditions conducive to their proliferation have been created within the CWTS. Moreover, the abundance of selenite- and selenate-reducing organisms generally increased or remained stable over time in the demonstration-scale CWTS through the commissioning and operational periods in (Figure B30 in Appendix B). Aquatic mosses were found to initially host the highest abundance of both selenate- and selenite-reducing organisms, affirming the importance of the inclusion of moss in the CWTS. Over time, as the vegetation has established, selenium-reducing bacteria have increased in abundance on the roots of *C. aquatilis* (Figure B30 in Appendix B).

These findings indicate the commissioning period was successful and the demonstration-scale CWTS has established and maintained beneficial selenium-reducing microbes. Selenium is removed as it is sorbed to moss or detritus or by interacting directly with selenium in water that has been drawn into the root zone by plants. Abundance of selenium-reducing bacteria is similar to that found through 2016 and during pilot-scale soil testing, suggesting they have established as expected. Selenium-reducing microorganisms will continue to be monitored in 2018, alongside performance testing.

### *5.9.3. Nitrate-reducing Bacteria*

Nitrate is sometimes a constituent of concern during operations and early closure owing to residuals from blasting activities. Even if not in exceedance of water quality guidelines in terms of receiving environment objectives, nitrate often requires treatment in order to subsequently achieve treatment of other constituents such as selenium and metals through sulphide production. Nitrate can be removed from water through denitrification by different types of microbes, including nitrate reducing bacteria which can reduce nitrate ($NO_3$) to nitrite ($NO_2$), and also denitrifying organisms that are capable of fully reducing nitrate to nitric oxide (NO), nitrous oxide ($N_2O$), and dinitrogen gas ($N_2$, which is the most abundant gas in air). Most-probable number (MPN) analysis was therefore used to quantify these organisms.

As observed in 2016, nitrate-reducing and denitrifying organisms were found associated with all sample types in the demonstration-scale CWTS (Figure 31; Contango, 2017). Roots and detritus had a high abundance of both nitrate and denitrifying organisms, with soil being similar to or slightly less than what was found during pilot-scale testing. These results indicate nitrate reducers have established in the CWTS during the commissioning period as expected. Nitrate-reducing microorganisms will continue to be monitored in 2018, alongside performance testing.

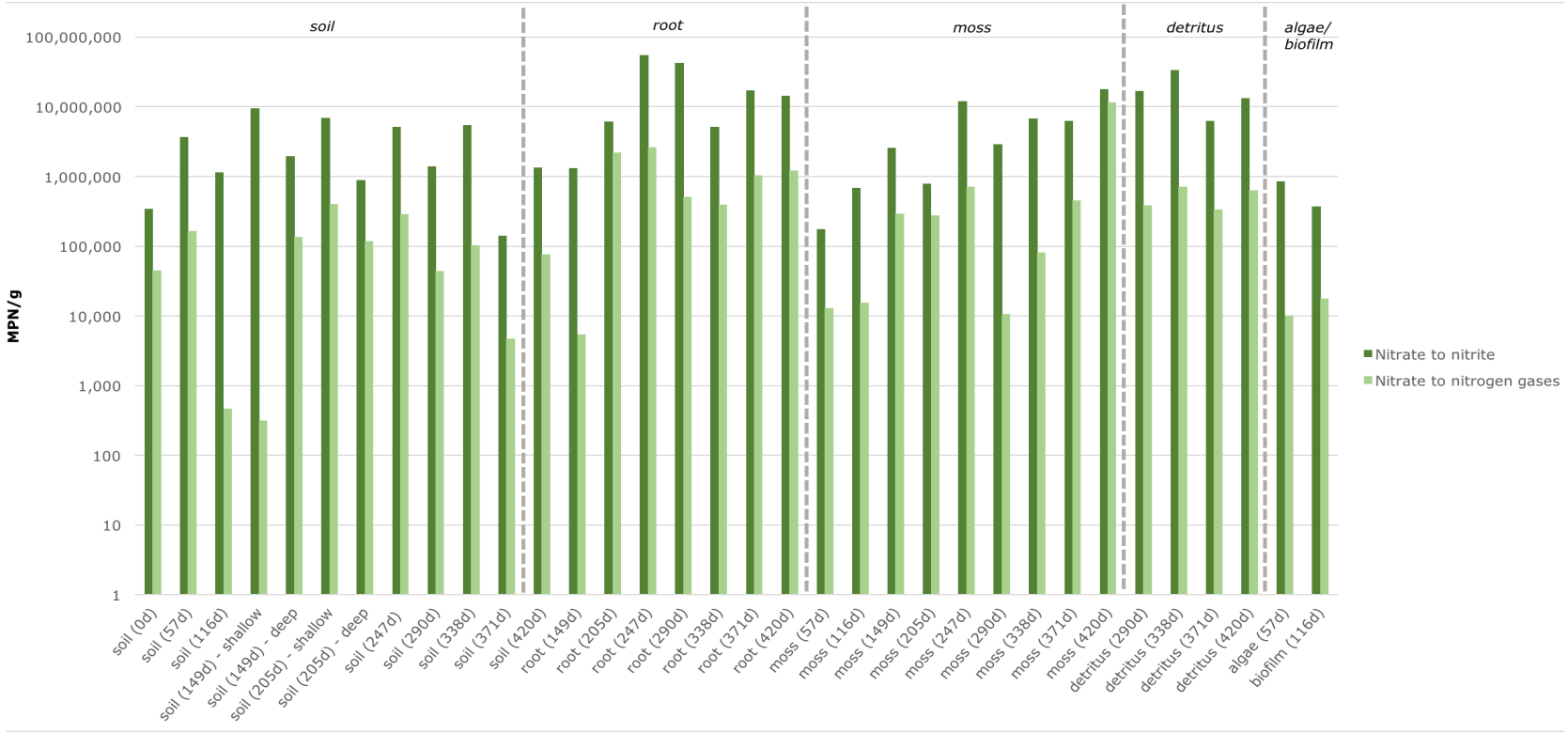



**Figure 31 – Abundance of nitrate-reducing and denitrifying organisms in various CWTS sample types over time.**
Nitrate-reducing = reduction of nitrate to nitrite; denitrifying = reduction of nitrate to nitrogen gases.
Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of CWTS.

## 6. Operational Challenges

The following are key findings regarding operational challenges, which are detailed further below:

- Aphids were again found in abundance on *C. aquatilis* in 2017.
- Efforts to control the aphid population on-site were made but an ongoing spraying regiment was not maintained and, therefore, aphids remained. However, no short-term detrimental effect on *C. aquatilis* viability was observed, despite the persistence of aphids.
- Damage to the above water vegetation was observed however new shoots were emerging in the CWTS and treatment COCs was not impacted by damage to the above water vegetation.
- Effects of aphids on *C. aquatilis* did not affect treatment.
- These issues with aphids are likely owing to the isolated nature of the demonstration-scale CWTS and not expected to affect the full-scale CWTS.

The Minto Mine's demonstration-scale CWTS, which is constructed of an emergent macrophyte monoculture of *Carex aquatilis*, experienced an aphid infestation in 2016 and 2017. The demonstration-scale CWTS is located in a relatively isolated area, away from other vegetation and potential sources of insects. It is known that aphids can migrate on air currents (Dixon, 1971), possibly over great distances (Riley et. al., 1995), which may be how they reached the demonstration-scale CWTS. Aphids are often monophagous, meaning they feed on one species of plant (Foottit and Maw, 1997) and it is likely that having additional vegetation available will not reduce the level of infestation on the *Carex* species planted in the CWTS. However, if additional surrounding vegetation is available, it could provide habitat for natural predators of aphids. With the demonstration CWTS currently located 50 m away from trees or other vegetation, there is little to no opportunity for natural predators to inhabit the area or incentive to travel the distance to the CWTS. The large buffer area (MVFE) around the demonstration-scale CWTS allows the aphids to colonize more robustly than anticipated in the full-scale CWTS onsite, which would not have the same buffer zone. This would not be an issue in the full-scale CWTS.

Aphids can be controlled, naturally, by predatory insects such as ladybugs, lacewings, and parasitic wasps (Flint, 2001). Ladybugs were observed in very small numbers on the *Carex* plants but in insufficient numbers to control the aphid population. Lacewings are found throughout North America and would be expected to be present in the Minto Mine region (Russel and Diaz, 2015). Several types of parasitic wasps that prey on aphids are known to be present in the Yukon (Finnamore, 1997). Other control methods involve the use of insecticidal soaps, which are recommended as they are non-toxic to most other insects and kill aphids through contact (the soft bodies are suffocated by the fatty acids in the soap; Ubl and Munnerlyn, 2009).

To quantify the aphid population on-site, sticky, yellow insect traps were installed at W10 and W15 as well as eight (two per cell) in the CWTS in 2017 (Figure 32). However, none of the traps at any of the locations were successful in trapping aphids and instead trapped numerous

other insects. It was observed that the sticky traps at W10 and W15 trapped a larger quantity and diversity of insects compared to the traps installed in the CWTS. This suggests that the larger population and diversity at the W10 and W15 areas assisted with keeping aphid populations under control in these areas. Due to the isolated area of the CWTS, away from other vegetated areas, the CWTS hosted a smaller quantity and diversity of insects which were not able to keep the aphid population under control.

Efforts were made in 2017 to control the aphid population by applying a mild insecticidal soap (Scott's EcoSense Bug B Gone Insecticidal Soap concentrate mixed with water) or a soap solution using a hand-held sprayer. Although the insecticidal soap was more effective than the soap solution, an ongoing spraying regiment was not maintained long enough to decimate the population. Care must be taken when using insecticidal soap to spray all surfaces of plant leaves, as aphids frequently inhabit the underside of leaves. Applications should be repeated every 4-7 days (follow label instructions) until pests are eliminated (Ubl and Munnerlyn, 2009). A stronger insecticidal soap (Trounce's Yard and Garden Insecticide) was applied on September 13, 2017 in another effort to reduce aphid populations; however, no discernable change was noticed, perhaps due to the lateness in the season. Insecticidal soaps with natural plant-based pyrethrins may provide control with fewer negative impacts than insecticides like malathion, permethrin, and acephate because pyrethrins break down quickly (Flint, 2001).

Series 1 of the CWTS appeared to have a larger aphid infestation and resulted in more damage to the above water vegetation. Regrowth will be monitored in 2018 and replanting of Series 1 may be required. The aphids will continue to be monitored in 2018 and compared with other background areas (e.g., W10 and W15) to see if increases in aphid populations are specific to the CWTS, or general to the area. In 2018, it is recommended that a stronger insecticide be applied early in the season and on a frequent, predetermined schedule.



**Figure 32 - Insect traps.**
Insect traps installed in CWTS cells (left and right), insect trap installed at W15 (center) in 2017.




**Figure 33 – Aphids observed in cell 1A and 2A in 2016 (top) and 2017 (bottom).**
Left pictures are of cell 1A. Right pictures are of cell 2A. Note the increased yellowing in cell 1A (2017) and cell 2A (2016, 2017) due to a denser aphid population.



**Figure 34 – Aphids observed on *C. aquatilis.***
The left picture was taken in 2016 and the right picture was taken in 2017. Note the small green and black aphids on *C. aquatilis* leaves.

## 7. Summary of Results

When designed and implemented in a strategic and scientifically guided manner, CWTS can mitigate risks posed by many constituents. A treatment plan including processes to precipitate insoluble species of these constituents for sequestration into the soils of the wetland are very desirable as this mechanism captures the constituents and stores them in stable form in the soil, rather than transferring the constituents to an indeterminate fate (e.g., through plant uptake that can potentially bio accumulate in wildlife or be re-released in plant decomposition). This study addressed several important design considerations regarding implementation of a CWTS at full-scale for the treatment of metals and metalloids to meet the overriding objective of completing commissioning of the CWTS and progress through operational performance. A summary of key findings from the 2017 studies and recommendations to meet the objectives are listed below.

Monitor explanatory parameters and performance to determine when commissioning is complete and the operational period has begun:

- Dissolved oxygen (DO) decreased from an average of 8.4 mg/L during commissioning-B in 2016, to an average of 5.3 mg/L during operations in 2017. The DO in the water column is likely the result of photosynthesis of algae and mosses.
- Despite this DO level in the water column being in oxidizing ranges, stable reducing conditions were achieved in the CWTS soils within the targeted soil redox range (-100 to -250 mV).

Assess removal of constituents from the water:

- Copper treatment in the CWTS was masked by leaching from the soils used in construction of the CWTS into the water, but this has mostly been remedied now by the wetland treating this copper and turning it into more stable sulphide forms in the soil.
- During the operational period the demonstration-scale CWTS successfully achieved an average decrease in concentrations of 0.0169 µg/L for cadmium (from 0.0261 µg/L to 0.0092 µg/L), 31.8 µg/L for copper (from 49.1 µg/L to 17.3 µg/L), 3.6 µg/L for molybdenum (from 6.3 µg/L to 2.7 µg/L), 3.5 µg/L for selenium (from 4.0 µg/L to 0.5 µg/L), and 47.3 µg/L for zinc (from 49.2 µg/L to 1.9 µg/L).
- Molybdenum and selenium treatment in the operational period is notable as the removal rates were negligible within the margins of error of the testing method in the commissioning-A period.

Determine the hydraulic residence time (HRT) by tracer study and associated correction factor to apply to the nominal (calculated) HRT:

- The tracer study effectively demonstrated the HRT (2.25 days) and flow symmetry through the CWTS.
- There was a single flow path in the CWTS (shown by a single peak in the tracer study)
- Water is incorporating into the CWTS soils (shown by the long tail for depletion of the tracer).

- The nominal HRT is calculated from the area of the CWTS and the depth at the in-situ measuring points. This nominal HRT does not account for depth variations, embankment slopes, vegetation (using space in the water), or substrate pore space involvement. It was found that once all of these factors are in play, the correction factor from nominal to actual is only 0.01 added to the depth of the CWTS, which is incorporated into the HRT calculation as expressed in Equation 3.

Evaluate CWTS performance, and determine achievable concentrations of contaminants of concern (thermodynamic minimums):

- All targeted constituents are being treated by mineralization and sequestered to the soils (minimal plant uptake).
- The lowest concentrations consistently achievable for the treatment design (thermodynamic minimums) were reached by the end of the A cells for cadmium and copper.
- RRCs for cadmium and zinc in the 2017 demonstration-scale CWTS were artificially low because low flow rates did not provide the resolution needed to determine a RRC.
- Removal rate coefficients (RRCs, *k*) have been developed that can be used for full-scale sizing.
- Copper leaching from soils has decreased, but is still likely making the RRC artificially low in this CWTS; however, the RRC is expected to improve once copper leaching has subsided.

Update site-specific removal rate coefficients (from commissioning period) with data from operational period:

- Removal rate coefficients (RRCs, *k*) have been developed that can be used for full-scale sizing.
- Copper leaching from soils has decreased, but is still likely making the RRC artificially low in this CWTS.

Determine amount of water loss due to evapotranspiration and effect on outflow concentrations:

- The evapotranspiration studies revealed a significant loss of water, which will impact calculations of loads to the receiving environment (making them lower than previously estimated).
- In May and June, an average water loss of 5.3 L/day/$m^2$ was observed, which is equivalent to 18-20% of water (~700 L/day lost in the demonstration CWTS).
- During the evapotranspiration trials, copper leached into the water as it was transformed from an oxide mineral to a sulphide mineral (because of the copper in the soils used for construction). This is not representative of what would occur during periods with no flow in a full-scale CWTS, where soils with minimal leachable copper are used and copper is deposited in sulphide form (fraction 4) by the biogeochemical activity of the CWTS (Section 5.6).

Monitor metals leaching from mineralized soils used in construction:

- In 2017, leachable copper concentrations in soils decreased in the top 0-10cm while total copper concentrations increased.

Assess stability of constituents of concern in soils:

- Most constituents, including copper, have shifted primarily into stable reduced and residual minerals fractions in the soil.
- Acid volatile sulphides (AVS) were non-detectable in the CWTS in 2016. In 2017, small amounts of AVS were detected in cells 1A and 2A which indicates that residual sulphides are starting to become available for metal treatment and that copper in the soils are becoming rendered inert through sulphide mineralization.

Determine the rate and extent of detritus decomposition (*C. aquatilis* leaves) in the CWTS over time:

- The detritus study suggested that algae growth on the assay devices had reached a steady state (growth vs decomposition) by ~23 days of the study.
- After 83 days submerged in the CWTS, *C. aquatilis* decomposed on average 64%.

Assess treatment mechanisms (including microbes):

- Establishment of sulphide-producing bacteria (SPB) increased throughout 2017 and was highest after commissioning was completed.
- SPB were found in highest abundance in root and soil samples.
- The average number of different types of sulphide-producing bacteria increased over time in all sample types tested (root, soil, detritus, and moss).
- Selenium-reducing and nitrate-reducing bacteria increased over time with the highest abundances found in *C. aquatilis* roots.

Determine an appropriate method for insect pest control (aphids) in the CWTS:

- Aphids were again found in abundance on *C. aquatilis* in 2017.
- Efforts to control the aphid population on-site were made but an ongoing spraying regiment was not maintained and, therefore, aphids remained. However, no short-term detrimental effect on *C. aquatilis* viability was observed, despite the persistence of aphids.
- Damage to the above water vegetation was observed however new shoots were emerging in the CWTS and treatment COCs was not impacted by damage to the above water vegetation.
- Effects of aphids on *C. aquatilis* did not affect treatment.
- These issues with aphids are likely owing to the isolated nature of the demonstration-scale CWTS and not expected to affect the full-scale CWTS.

## 8. Next Steps for 2018

A conceptual testing plan was developed at the beginning of the demonstration-scale CWTS program, and has been refined and adapted based on performance and scientific findings during the commissioning and operational periods of the demonstration-scale CWTS. The demonstration-scale CWTS is expected to run until at least the end of 2018 to assess performance under a wider range of conditions. In 2018, a flow rate schedule will be developed targeting different HRTs based on predicted HRTs for full-scale performance. The overriding objective of the demonstration-scale program in 2018 is to assess performance under conditions that would be similar to the full-scale CWTS. Table 11 outlines the action plan for CWTS optimization and testing for 2018 based on the performance results through 2017.

A multi-year plan is provided in Appendix C, and includes work performed to date as well as a schedule of activities for 2018.

**Table 11 – Minto 2018 CWTS demonstration-scale action items.**

| Timing | Task | Purpose |
|---|---|---|
| April 2018 | Develop a flow rate schedule for 2018. | The flow rates will fluctuate based on expected amounts of water for full-scale wetland (scaled to size) in order to evaluate the performance of the wetland at different key periods. |
| | Develop sampling plan for 2018 | The sampling plan will include sampling types, parameters, frequency, and locations. These results will inform the performance of the CWTS. Monthly sampling of the in, mid, and out locations will be added to the 2018 sampling plan to better assess removal of constituents through the CWTS cells. |
| | Develop aphid control and monitoring and plan for 2018 | A consistent control and monitoring plan will aid efforts to control the aphid population residing in the demonstration-scale CWTS. |
| April/May 2018 | Start water flow to CWTS | Begin 2018 demonstration-scale CWTS program |
| | Add sandbags on top of existing sandbags along edges of CWTS | Adding sandbags along edges of CWTS will minimize flow short circuiting. Use the sand that was confirmed to be a good borrow source in 2016 (i.e., low copper) |
| | Add sandbags to the end of the CWTS cells to increase the water depth to ~20 cm | Raising the water levels will promote the desired reducing conditions in the CWTS. |
| | Implement aphid control using insecticide on a routine schedule | Begin applications in early May when vegetation begins to become green, in order to control the aphid population before an infestation occurs. |
| Ongoing through 2018 sampling season | Routine sampling program | Follow sampling plan from May to September 2018 for routine collection of water, soil, microbial, plant, and detritus samples. |
| | Monitor for the presence of aphids in the CWTS and surrounding areas (W10 and W15 areas). | Determine if the aphid presence is isolated to the CWTS. Determine if more aggressive control measures are needed. |

| | | |
|---|---|---|
| July/Aug 2018 | Conduct a vegetation plot harvest. Collect all above water biomass of *C. aquatilis* in a 1m x 1m plot | To determine quantity of biomass per $m^2$ |
| | Conduct evapotranspiration study | Although 2017 data suggests minimal release of metals from soils, another evapotranspiration trial during the operational period needs to be conducted to confirm metals leaching has subsided. Completing the evapotranspiration study in July/Aug in 2018 will provide information on evapotranspiration rates in warmer months and the effects of seasonality. |
| Sept 2018 (If needed) | Replant CWTS | Replant areas of the CWTS that were impacted by aphids if needed. |
| December 2018 | Report | 2018 Update Report |

## 9. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Respectfully submitted,

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# APPENDIX A - Methods

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## A1. Demonstration-Scale Constructed Wetland Treatment System Design

### A1.1. System Layout and Dimensions

The demonstration-scale CWTS includes two systems in parallel with two cells in each series and a final catchment basin that both systems flow into (Figure A1). Dimensions and construction details are available in the Minto Demonstration Scale Report Document 011_0315_01A (Contango, 2015). The two parallel systems serve as a replicate for data analysis, and as testing has progressed, the two systems have also allowed for comparison of different management techniques. Dimensions of the systems are provided here in Table A1.

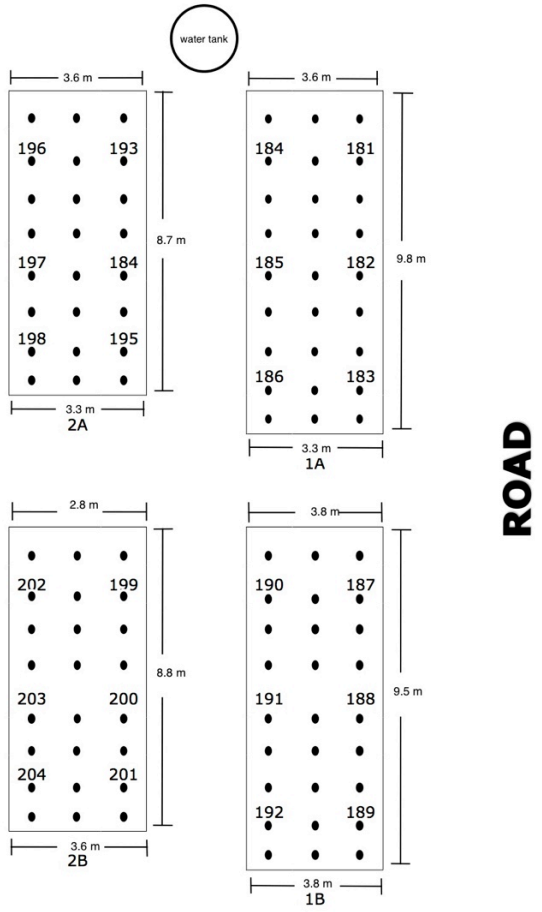


**Figure A1 – Diagram of demonstration-scale CWTS.**
Dimension measurements are indicated at soil surface. Black dots indicate initial construction grid marked by moss stakes, and locations of soil redox probes with identifying numbers.

**Table A1 – Dimensions of demonstration-scale CWTS cells at soil surface and resultant areas of treatment systems.**

| Measurement | | Series 1 | | Series 2 | |
|---|---|---|---|---|---|
| | | 1A | 1B | 2A | 2B |
| Width (m) | Inflow | 3.6 | 3.8 | 3.6 | 2.8 |
| | Outflow | 3.3 | 3.8 | 3.3 | 3.6 |
| Length (m) | | 9.8 | 9.5 | 8.7 | 8.8 |
| Approximate surface area at soil ($m^2$) | | 33.8 | 36.1 | 30.0 | 28.2 |
| Total area of system at soil ($m^2$) | | 69.9 | | 58.2 | |

### A1.2. Soils

Soils used to construct the CWTS are described in the initial report that outlines construction (Contango, 2015). In brief, the recommended soil for the CWTS was sand, with 2-7% by volume as organic material (e.g., woodchips, peat). In the pilot-scale systems, this resulted in a total organic carbon (TOC) content by weight of 0.2-0.6% (the sand itself was at 0.1% TOC prior to adding amendment). Ideally, this percentage could be higher, approximately 2-10% by weight to stimulate the desired reducing conditions. For the demonstration-scale system, the soil added to each of the four cells during construction was from a local borrow site. As is expected in a mining area, the soils are likely mineralized. Although a potential borrow source was tested prior to construction ("Tested Soil"; Table A2), a different borrow source was available upon construction of the demonstration-scale CWTS ("Soil used"; Table A2). The material used in the construction of the demonstration-scale CWTS was an organic peat, and analyses received after construction indicated an elevated concentration of leachable copper (Table A2). It should be noted that in a full-scale system, the variability in soil would be normalized by the larger volume of soil used. The soil in the CWTS (composed of the organic peat soil, wood chips, and straw) had a total organic carbon (TOC) content of 1.8-3.1%.

**Table A2 – Comparison of copper concentrations in soils of pilot- and demonstration-scale CWTS.**

| Test method | Pilot-scale | Demonstration-scale | |
|---|---|---|---|
| | Initial soil | Tested soil (June, 2014) | Soil used (August, 2014) |
| SPLP Copper (mg/L)[1] | - | 0.00546-0.0296[2] | 0.148-0.608 |
| Total Copper (mg/kg) | 5.3-5.5 | 210-1400[2] | 960-1400[3] |

[1] SPLP - Synthetic Precipitation Leaching Procedure.
[2] For the June 2014 samples, the soil with the highest total copper concentration also had the lowest leachable copper concentration, and was therefore deemed acceptable for use.
[3] Total copper value for soils used was taken in June 2015 (no data for August 2014).

### A1.3. Vegetation

The demonstration-scale CWTS was planted with *Carex aquatilis* (aquatic sedge) and aquatic mosses from the W10 area of the Minto Site. The plant selection and borrow source was previously determined through the site assessment (Contango, 2014a). Five *C. aquatilis* plants were planted per square meter, with moss tied to stakes that outlined the 1 m x 1 m grid for planting (details provided in Contango, 2015).

### A1.4. Water Source

Water from the W36 area receiving seepage from the toe of the Mill Valley Fill Extension (MVFE) was selected for the demonstration-scale CWTS testing as the leachate is similar to that expected upon closure in the MVFE area. The chemistry of this water at the time of bringing the demonstration-scale CWTS online (September 18, 2014) is provided in Contango, 2015. In 2015 the water for the CWTS was pumped out of the sump at the toe of the MVFE. As the Mill Valley Fill Extension Stage 2 (MVFE2) progressed a new collection sump (W62 sump) was constructed as a replacement for the sump used in 2015. The W36 sump was decommissioned in February 2016 as part of the MVFE2 construction. The new sump approximately 30 m downslope was the supply water for the CWTS for the summer of 2016 and was the same source for 2017 (Figure A2).




**Figure A2 – Water source for the demonstration-scale CWTS in 2017.**

## A2. Flow Rates

Flow rates as well as the totalizer values were recorded from the flow meter that feeds the demonstration-scale CWTS periodically throughout 2017. The flow rates (recorded by Minto) represent the flow that occurred at the time the flow rate was recorded off the flow meter and is represented by blue bars in Figure A3 below. The totalizer value was also recorded periodically and is the cumulative amount of water that passes through the flow meter between two given dates. Actual flow rates were also calculated based on the totalizer values and are represented by green dots in Figure A3 below. The flow rates calculated from the totalizer values represent the actual flow rates. The average actual flow rates calculated from the totalizer values during the operational period were 0.38 gallons per minutes (GPM) for series 1 and 0.29 GPM for series 2. Figure A3 shows the fluctuation in actual versus targeted flow rates throughout the 2017 operational period.

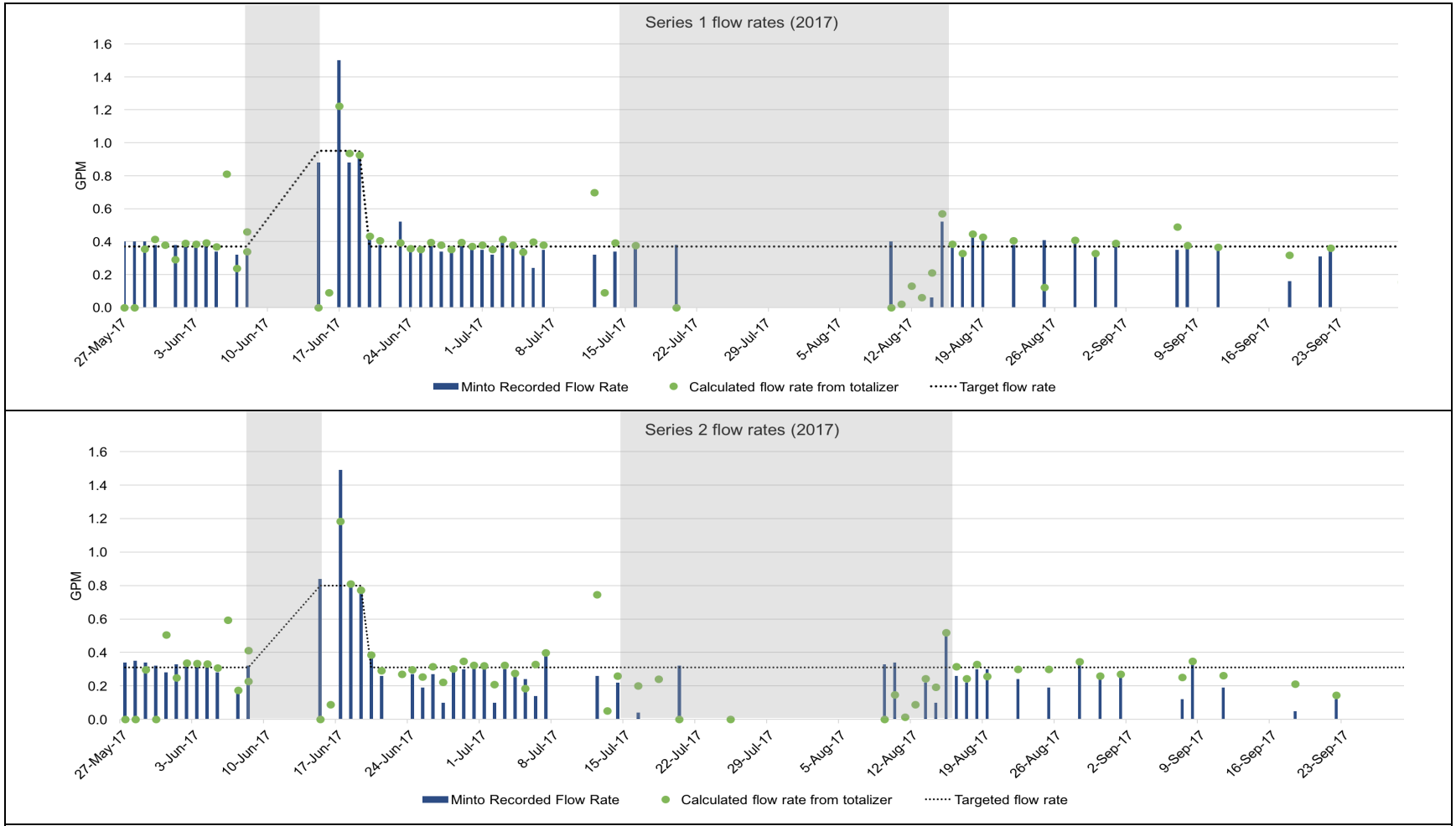


**Figure A3 – Flow rates during CWTS operations in 2017.**
Blue bars indicate flow rates displayed on flow meter, while green dots are flow rates calculated from the totalizer values (values from meter were recorded by Minto personnel). Targeted flow rates for series 1 and 2 were 0.37 and 0.31 gallons per minutes (GPM), respectively. Targeted flow rates are different for each series because the series differed in size. Series 2 was smaller than series 1 and therefore needed a slower flow rate to obtain the same HRT as series 1. The totalizer value is the cumulative volume of water passing through the flow meter between two measurement dates. Areas with no blue bars or green dots are time periods where flow rates and totalizer values were not recorded. Areas shaded grey indicate dates of interrupted flow. Further details can be found in Table 3 of the main report.

### A2.1. Demonstration-Scale Commissioning Periods

Performance monitoring continued during commissioning although full treatment functionality of the demonstration-scale system was not expected. The information aided in guiding future development of the full-scale system in the following ways:

- Evaluated construction effectiveness and potential optimizations.
- Assessed timelines to reach targeted operational parameters to allow for effective phasing of implementation (e.g., soil redox, percentage and abundance of sulphate reducing bacteria).
- Assessed the effectiveness of *Carex aquatilis* and aquatic moss transplantation to assess planting density, time period to full density, and if plant propagation and/or a replanting schedule is necessary.

However, there were aspects of the demonstration-scale CWTS that were not directly transferrable to the planned construction of the full-scale CWTS. Notably, the demonstration-scale CWTS was built with a different soil type and chemistry than recommended for the full-scale system. Therefore; it took longer to commission the demonstration-scale system as the copper in the soils needed to be treated in addition to the copper and other constituents in the water.

Based on pilot-scale testing (Contango, 2014b), the estimated commissioning period for the Minto demonstration-scale CWTS was four months (i.e., period when water is flowing). In 2014, the demonstration-scale CWTS operated for less than one month prior to freezing, and was restarted along with spring thaw (freshet) in mid-May 2015. Based on these timelines, September 2015 was month four of commissioning, and the demonstration-scale system trended towards performance as expected during the commissioning period (Contango, 2016). However, as discussed further in sections 2.2 and 6.1 of the 2016 update report (Contango, 2017), the soil used in the CWTS had high concentrations of leachable copper, and therefore optimization opportunities were evaluated throughout 2015, and adjustments were implemented in 2015 and 2016. The last operational adjustment during the commissioning period was the addition of organic material in 2016, which marked the end of the commissioning-A period and the beginning of the commissioning-B period. Organic material will also be added during construction of the full-scale design to enhance desired reducing conditions to establish in the CWTS until vegetation is sufficient to provide for this required component. The end of the commissioning-B period was expected to be between July 16 and August 2, 2017. However, due to issues with the totalizer, the end of the commissioning-B period was August 17, 2017 and was marked by stabilization of flow rates and resolution of totalizer complications. Additionally, sandbags were added to the end of each cell on August 11, 2017 in order to raise the water level to obtain better treatment through enhancing reducing conditions. The operational period therefore began on August 18, 2017 and ran until September 22, 2017. Discussions in this report are based on the operational period.

# A3. Sampling and Analyses

## A3.1. Routine Monitoring of Explanatory Parameters

Explanatory parameters are quantifiable aspects of a CWTS environment that can be used to assess feasibility of treatment for a range of constituents, and therefore 'explain' the performance of a CWTS. These parameters, which often include acidity, alkalinity, conductivity, dissolved oxygen (DO), pH, oxidation-reduction potential (ORP), ion balance, available electrons donors (e.g., organic carbon, reduced elements), and temperature, can be used to predict, promote, and/or optimize the ability of the system to treat different constituents (Haakensen et al., 2015). A YSI ProPlus meter was used in the field to test for water temperature, DO, conductivity (and specific conductivity; SPC), pH, and ORP. In situ field readings were taken weekly in conjunction with water sampling using the YSI ProPlus.

## A3.2. Water Sampling and Analyses

Water sampling occurred on a weekly basis from spring thaw in May 2017 to freeze up in September 2017. Frequencies and sampling parameters are outlined in Table A3. Grab samples were collected at the feed and outflow of each cell. Care was taken to avoid collecting plant matter, invertebrates, and other debris in the grab samples. Samples were collected from downstream to upstream to ensure that water sampling did not affect sample collection from the next cell (e.g., disrupting flow rates or suspending solids).

Due to copper and aluminum being found to be released from the CWTS substrates into the water in 2015, an additional sampling structure was designed. For two timepoints in 2015 (August 15, 2015 and September 17, 2015), two timepoints in 2016 (June 14, 2016 and September 7, 2016), and three timepoints in 2017 (June 20, 2017, August 18, 2017, and September 11, 2017) water was sampled not only at the feed and the outflow of each cell, but also through the cell. Beginning at the outflow of cell B and working upwards towards the feed, samples were taken at the B cell outflow, B cell mid-point, and B cell inflow, and then the same three points for the A cell (Figure A4). In each case, the sample was taken from within reaching distance of the side shore to ensure that sediments were not suspended in sampling.

**Table A3 – Summary of 2017 analytical water sampling types, frequencies and locations.**

| Water | |
|---|---|
| Dissolved and total metals | Weekly, outflow of each cell and feed |
| Ammonia | |
| Nitrate | |
| Nitrite | |
| Flow rate | Weekly, feed |
| pH, DO, ORP, Conductivity (in situ) | Weekly, all cells and feed |
| Anion Sum | Monthly, outflow of each cell and feed |
| Cation Sum | |
| Hardness ($CaCO_3$) | |
| Ion Balance | |
| Total Dissolved Solids (TDS) | |
| Chloride (Cl) | |
| Sulphate ($SO_4$) | |
| Nitrogen (Total) | |
| Alkalinity | |
| pH | |
| Conductivity | |
| Chemical Oxygen Demand (COD) | |
| Total Organic Carbon (TOC) | |
| Total Kjeldahl Nitrogen (TKN) | |
| Total Suspended Solids (TSS) | |
| Dissolved Organic Carbon (DOC) | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Hydroxide (OH) | |

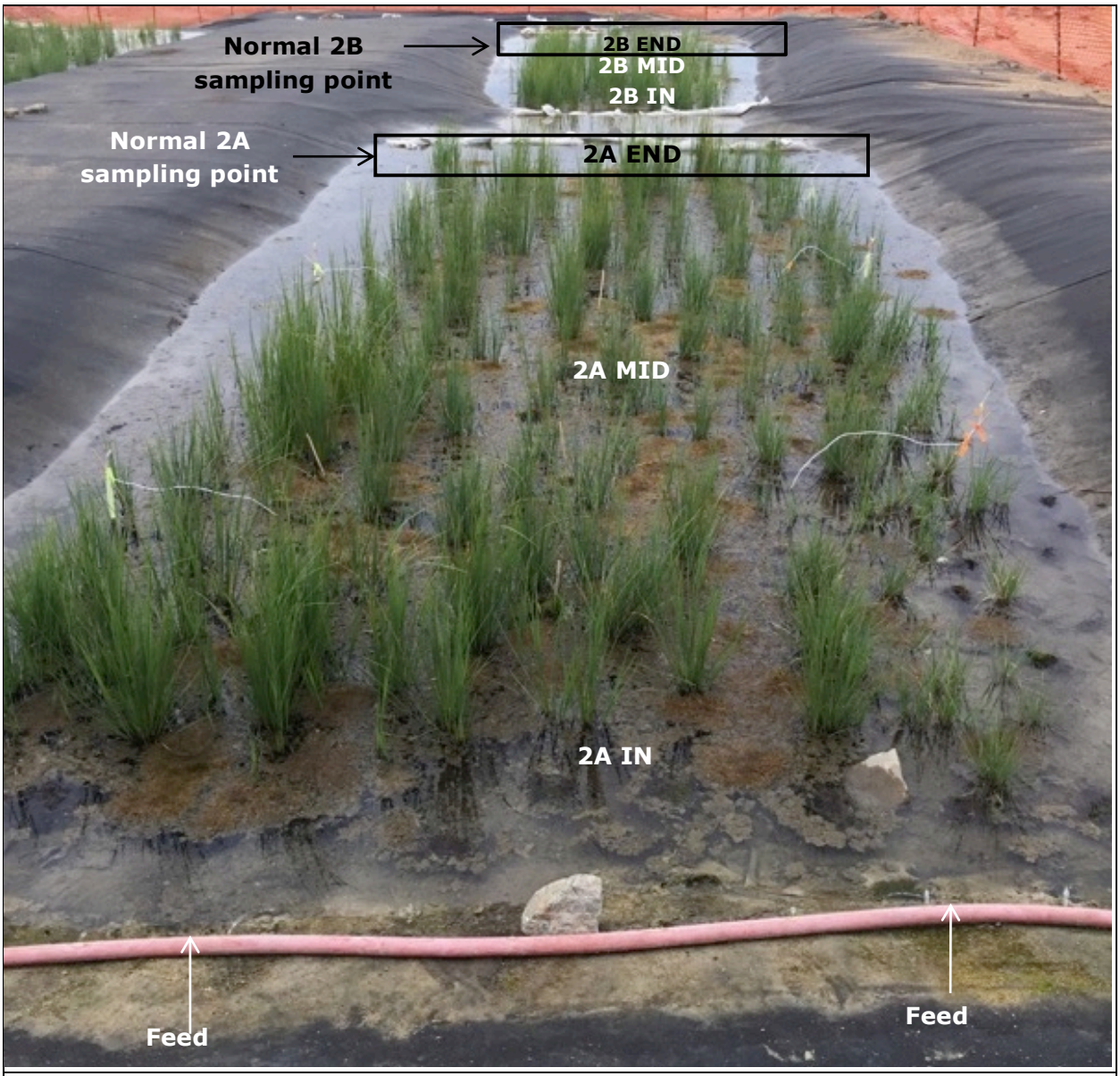


**Figure A4 – Sampling points through the CWTS (Photo taken August 16, 2015).**

### A3.3. Soil Sampling and Analyses

Soil sampling was conducted three times in 2017 (June, July, September). A sample of the top 0-10 cm of CWTS soil was collected into a 1L glass jar for analyses. Analyses are outlined in Table A4. Each CWTS cell was sampled during each sampling event.

**Table A4 – Summary of 2017 analytical soil sampling types, frequencies and locations.**

| **Soil** | |
|---|---|
| Relative soil redox (in situ) | Monthly, all probes (6 per cell) |
| **Analyses completed on soil sample** | |
| SAR, pH, EC, %sat, Ca, F, Mg, Na, K, Cl, SO4 | Seasonally (3x per year) from a depth of 0-10 cm. |
| Available NPK and sulphur | |
| Alkalinity | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Total Organic Carbon (TOC) | |
| Metals Analysis (Total) | |
| Sulfur by LECO | |
| Metals Leach | |
| AVS+SEM | |
| Sequential Leaching (5 Acid Test) | |
| Metals SPLP | Spring Sampling (1x per year). |
| **Analyses completed on special leach** | |
| Bromide (Br) | Seasonally (3x per year) |
| Chloride (Cl) | |
| Sulphate ($SO_4$) | |
| Fluoride (F) | |
| Alkalinity | |
| Bicarbonate ($HCO_3$) | |
| Carbonate ($CO_3$) | |
| Hydroxide (OH) | |
| Dissolved Organic Carbon (DOC) | |
| Ammonia | |
| Nitrate | |
| Nitrite | |
| Total Dissolved Solids (TDS) | |
| Anion Sum | |
| Cation Sum | |
| Cation/EC ratio | |
| Ion Balance | |

Although unintentional, the use of soils in the CWTS with high initial leachable copper concentrations (Table A2) allowed for additional types of testing to be carried out on these systems. To assess the effect of the elevated metals (aluminum and copper) in the soils used in construction on CWTS functionality, four soil analytical test methods were used:

- Total concentration of elements in the soils by CRC ICPMS (EPA 200.2/6020A). This method uses a heated strong acid digestion with $HNO_3$ and HCl and is intended to liberate metals that may be environmentally available.

- In 2015 and 2017, leachable concentrations of elements in the soils by Synthetic Precipitation Leaching Procedure (SPLP), which is a method to assess the mobility of elements in soils at the pH of rain water (i.e., if the CWTS were to entirely dry out, then be subjected to leaching by rain water) (EPA 1312/6010B).
- In 2016 and 2017 a leach method was used (EPA 6020A). This analysis was carried out using a leaching procedure which involved the gentle tumbling of a sample in a specified leaching solution (water from the CWTS) for two hours. This method is typically carried out by tumbling the sample in deionized water, however this method was adjusted to use water from the CWTS to be more representative of the actual leachability of the soils into the overlaying water of the CWTS. The resulting extract is then analyzed by inductively coupled plasma – optical emission spectrophotometry (EPA 300.1). This method was selected in 2016 to determine the concentration of metals that are being released from the soil into the overlying water column. The leach method is more representative of actual potential leachability of the soils into the CWTS than is the SPLP method.
- Sequential extraction procedure for the speciation of particulate trace metals (Tessier et al., 1979, EPA 6020A) to assess the stability and form of elements in soils.

### A3.4. Plant Sampling and Analyses

Both *C. aquatilis* and moss samples were collected for metals analysis at the final sampling period of the demonstration-scale CWTS. Above water vegetation for *C. aquatilis* samples were collected from each cell in the CWTS. Green, living moss samples (rather than black, decomposing moss) were collected from each cell in the CWTS. Analyses are outlined in Table A5. Analyses of the tissue samples followed EPA 200.3/6020A and were reported in mg/kg dry weight. The tissue samples were homogenized and sub-sampled prior to digestion.

**Table A5 - Summary of 2017 analytical plant sampling types, frequencies and locations.**

| **Plant tissue samples** | |
|---|---|
| Total Metals by ICPMS (Co, Cu, Fe, Pb, Li, Mg, Mn, Mo, Ni, P, K, Se, Ag, Na, Sr, Tl, Sn, Ti, U, V, Zn, Zr) | *Carex aquatilis* and aquatic moss, each cell, year end |

### A3.5. Microbial Sampling

Soil, roots, detritus, and moss were collected from each cell in the CWTS for microbial analysis three times in 2017 (June, July, Sept). The soil was collected by scooping the surface, from 0-10 cm, in various parts of the cell and pouring off any excess water after collection. The roots were collected from various plants in each cell at different depths of soil and pooled together in a 50mL falcon tube. Detritus samples were collected from various areas of the cells and included the decomposing straw material within the water. Moss samples were collected from various parts of the cell from the green new growth as well as the decomposing black areas of the moss and pooled together in a 50mL falcon tube. Microbial analyses are outlined in Section A3.6.

## A3.6. Methods for Microbial Analyses

### *A3.6.1. Growth-based Analyses (MPN)*

The most-probable number (MPN) of bacteria was determined for all microbial samples. The MPN test allows for an estimation of the number of bacteria that can grow in a specific laboratory medium (i.e., quantification method). MPN of heterotrophic organisms (grown with R2A medium; HiMedia Labs) were quantified in both aerobic and anaerobic conditions. MPN tests for selenate and selenite reduction were performed as per Siddique et al. (2006). The nitrate reduction MPN was performed as per the Nitrate Reduction Test (supplied by Sigma-Aldrich).

In brief, samples were weighed and/or measured into a 0.1% peptone solution and then serially diluted along a sterile 96-microwell round-bottom plate containing the growth media. All tests were conducted in triplicate. Wells were incubated without light at room temperature (21-22°C) and assessed for visible growth (formation of a pellet) and/or colour change specific to the type of media after 27-29 days. A colour change to red indicated selenite or selenate reduction, while nitrate reduction was assessed per the manufacturer's instructions. The most probable number of microbes was then calculated as described by Blodgett (2010).

### *A3.6.1. DNA-based Analyses*

DNA was extracted from all samples using the MO BIO PowerLyzer PowerSoil DNA Isolation kit. Targeted DNA sequencing was used to identify bacteria present in each sample via polymerase chain reaction (PCR) amplification of the v3/v4 region of the 16S ribosomal RNA gene (Klindworth et al., 2013). Library preparation and sequencing was performed as per the manufacturer's instructions for MiSeq v3 paired-end 300 bp sequencing (Illumina) for all samples and positive and negative controls. After sequencing, the forward and reverse reads were merged and all sequences were quality filtered before processing into Operational Taxonomic Units (OTUs) and classified.

## A3.7. Hydraulic Retention Time Tracer Study

The Minto Demonstration Scale 2016 Update Report (Contango, 2017) provides details on the methods used in the HRT tracer study in 2016. In 2017, a 1 $m^3$ tank was added to the CWTS area, and another HRT tracer study was conducted. The 1 $m^3$ tank provided a way to mix a lower concentration salt solution, and dose it into the CWTS over a longer period at a constant flow using a metering pump. This allowed the flow rate to be calculated for the duration of time the salt solution was dosed into the CWTS. To conduct the HRT tracer study over a longer period, the YSI unit was connected to a power source due to a limited battery life. By conducting the tracer study in 2017 as described above only one breakthrough occurred, as opposed to the two breakthroughs that were observed in 2016, providing more accurate results.

The 1 $m^3$ tank used in the HRT tracer study was filled with 600 L of influent water with 1.26 kg of salt dissolved into the water to create the tracer. The salt solution was mixed thoroughly with a mixing pump in the tank prior to use. The salt solution was dosed into cell 1A at a rate

of 1.8 L/min. The tracer was dosed over a period of approximately four hours, at which time approximately 400 L of salt solution had been dosed into cell 1A. The volume of water and weight of salt was calculated based on the amount required to increase the specific conductance (SPC) of cell 1A to approximately twice its background level (i.e., from 850 µs/cm, to 1,700 µs/cm) (Oakton Instruments, 1997). When using this method in 2016 the SPC was raised by 38% higher than desired, therefore in 2017 38% less salt was used for the tracer. The volume of water used was then selected to ensure the concentration of the salt solution was sufficiently diluted and would mix with the water of the CWTS (i.e., the solution wasn't so dense that it would stratify and sink to the bottom of the CWTS).

In situ monitoring was carried out from June 21, 2017 until July 2, 2017. This time period was selected to allow sufficient time for the entire salt tracer to pass through the CWTS and return to background SPC levels. The YSI unit was placed in the CWTS for approximately two hours prior to dosing of the tracer to record background readings. The background SPC prior to commencing the HRT tracer study was approximately 829 µS/cm, and the SPC peaked at 1107 µS/cm, 2.25 days after the tracer was dosed into the CWTS (Figure 20, in main document). The increase in conductivity did not reach the desired amount of double the background SPC level, however the peak was sufficient to observe the tracer pass through the system and determine the maximum.

### A3.8. Detritus Decomposition Trials

A detritus decomposition trial was developed and conducted in 2017 to assess decomposition rates of *C. aquatilis* in the CWTS over time, as well as the algae growth on CWTS organic materials within the water column (Chimney and Pietro, 2006; Hammerly et al.,1989). Twenty-four 12-inch by 4-inch mesh bags were filled with 5 grams of oven dried *C. aquatilis* material (dried at 50°C). On June 21, 2017, six bags were then submerged into each of the four CWTS cells to determine the rate of decomposition of *C. aquatilis* over time. An additional 24 mesh bags were filled with 3.8 grams of polyester filter fiber material. On the same day (June 21, 2017) six bags were submerged into each of the four CWTS cells to determine the amount of algae growth on material in the CWTS during the course of the trial. On July 25, 2017, after 34 days of submersion in the CWTS, and on September 11, 2017 after 82 days of submersion in the CWTS, one bag filled with polyester filter fiber and one bag filled with *C. aquatilis* was removed from each CWTS cell. The contents of the bags were then rinsed with deionized water to remove any sediment from the sample and dried in an oven at 50$^{o}$C. The dried weights after 34 days and 82 days were compared to the initial weights of the sample. It was assumed that the increase in weight on the polyester fiber fill sample would be representative of the algae that grew on the *C. aquatilis* samples that could not be removed by rinsing the samples. Therefore, the increase in dry weight of the polyester fiber was subtracted from the dry weight of the *C. aquatilis* to determine the amount of decomposition that occurred over a specific time period.

In total, six bags of each material were submerged in each cell and two bags of each material were removed over the 2017 sampling periods. The remaining four bags of each material were left in each cell for future analysis. Each removal of four bags (one from each cell) were treated as replicates for the sample material and date removed.

### A3.9. Evapotranspiration Trials

Total evapotranspiration from the system is the combined effects of open water evaporation and plant transpiration (Beebe et al, 2014). The purpose of calculating the evapotranspiration of a system is to understand the amount of water lost, which in turn concentrates elements and should be considered in the context of the difference of decrease in outflow concentration (or not) and outflow load reduction. In 2016, an off-site and on-site evapotranspiration study was conducted (Contango, 2017); however, rain occurred during the on-site study and the Minto weather station was not functioning, therefore evapotranspiration rates could not be determined and it was recommended the study be repeated in 2017.

To add to the information gathered from the off-site evapotranspiration trials conducted in 2016 (Contango, 2017), three trials were conducted on-site to refine site-specific evapotranspiration rates. In 2017, the evapotranspiration studies were performed on-site from May 16-24 (trial 1), June 8-11 (trial 2), and June 11-15, 2017 (trial 3). Approximately 17.5 mm of rain occurred on-site during trial 2 on June 11, 2017 and therefore trial 2 was terminated and trial 3 began to account for the precipitation. In trial 1, the flow to the CWTS was shut off on May 16 and the water level was recorded in each cell of each series using depth measuring sticks, which were installed at each end of the CWTS in 2016 (Figure A5). The water level was recorded again on May 24 to determine the water lost due to evapotranspiration in the CWTS throughout the study. The same method to determine water lost was also used in trials 2 and trial 3 and the flow to the CWTS was shut off on June 8 to June 11 and June 11 to June 15, respectively.




**Figure A5 – Depth sticks in CWTS cell 1A to record evapotranspiration in 2016 (left) and 2017 (right).**
Depth sticks were installed in all CWTS cells June 2016 and used throughout the demonstration-scale study.

## A4. Thermodynamic Minimum Calculations

The thermodynamic minimum is the lowest concentration consistently achievable for a given treatment design and water chemistry. Once reached, making the CWTS bigger will not result in further decrease of concentration (although it will continue to decrease the load). Therefore, this is a useful parameter to aid in determining appropriate sizing and outflow water quality objectives of a CWTS. The CWTS was analyzed at three points to determine whether the thermodynamic minimum had been reached. Concentrations of constituents were measured at three sampling points (CWTS feed, cell A-outflow, and cell B-outflow) in the series and compared to determine if the thermodynamic minimum had been reached. To determine if a

concentration was significantly different or not, statistical analyses were done (paired samples t-test, α=0.05) to determine if the concentration had stabilized across two sampling points. Once a concentration had stabilized across two points in a series, the thermodynamic minimum was considered to have been met.

## A5. Load Removal Calculations

The load removed shows how much of the load of a constituent entering the pilot-scale CWTS was removed during each flow period. Equation A1, Equation A2, and Equation A3 show how the nominal load in, load out, and load removal (non-evapotranspiration adjusted) is calculated.

$$Load_{in} = C_i \times V$$

**Equation A1 – Equation for the calculation of load of a constituent into a CWTS over a period of time.**

$Load_{in}$ is the mass of a constituent that enters a CWTS over a period of time, $C_i$ is the inflow concentration of the constituent, $V$ is the volume of water that enters a CWTS over a period of time.

$$Load_{out} = C_f \times V$$

**Equation A2 – Equation for the calculation of the load of a constituent out of a CWTS over a period of time.**

$Load_{out}$ is the mass of a constituent that exits a CWTS over a period of time, $C_f$ is the outflow concentration of the constituent, $V$ is the volume of water that enters a CWTS over a period of time.

$$Load\ Removed = Load_{in} - Load_{out}$$

**Equation A3 – Equation for the calculation of the load removed over a period of time.**

### A5.1. Load Removal Calculations Adjusted for Evapotranspiration

The results of the evapotranspiration trial (Section A3.9) were integrated with the load removal calculations (Section A4) to determine the actual amount of load removed taking into consideration the amount of water lost from the pilot-scale CWTS through evapotranspiration (Equation A4). Equation A5 describes how the outflow water volume from a CWTS is adjusted for evapotranspiration. Equation A5 uses a value for evapotranspiration in L/day/m$^2$, which was calculated using the results of the evapotranspiration trial (main report), which is multiplied by the surface area of the CWTS. For series 1 the surface area is 69.7 m$^2$, and for series 2 the surface area is 58.2 m$^2$. Equation A6 describes how the load out adjusted for evapotranspiration is calculated using the evapotranspiration adjusted outflow volume calculated in Equation A5. Equation A7 was used to calculate the outflow concentration (mg/L) adjusted for evapotranspiration using the load out calculated in Equation A6. Equation A8 describes how the load removal adjusted for evapotranspiration is calculated using the load in calculated in Equation A1 and load out adjusted for evapotranspiration in Equation A6.

$$Water\ loss\ (\%) = \frac{ET}{Q} \times 100$$

**Equation A4 – Equation for the calculation of the water loss due to evapotranspiration.**
*Q* is the flow rate (L/day), *ET* is the evapotranspiration rate (L/day).

$$V_{ET} = Q - ET$$

**Equation A5 – Equation for the calculation of the outflow water volume adjusted for evapotranspiration.**
$V_{ET}$ is the outflow water volume adjusted for evapotranspiration, *Q* is the flow rate (L/day), *ET* is the evapotranspiration rate (L/day).

$$Load_{out(ET)} = V_{ET} * C_f$$

**Equation A6 – Equation for the calculation of the load out of a constituent adjusted for evapotranspiration.**
$Load_{out(ET)}$ is the load out adjusted for evapotranspiration, $V_{ET}$ is the outflow water volume adjusted for evapotranspiration, $C_f$ is the outflow concentration of the constituent.

$$Cf_{ET} = \frac{Load_{out(ET)}}{Q}$$

**Equation A7 - Equation for the calculation of outflow concentration adjusted for evapotranspiration.**
$Cf_{ET}$ is the outflow concentration of the constituent adjusted for evapotranspiration, $Load_{out(ET)}$ is the load out adjusted for evapotranspiration, *Q* is the flow rate (L/day).

$$Load\ Removed\ Adjusted\ for\ Evapotranspiration = Load_{in} - Load_{out(ET)}$$

**Equation A8 – Equation for the calculation of the load removed adjusted for evapotranspiration.**
$Load_{out(ET)}$ is the load out adjusted for evapotranspiration

## A6. Removal Rate Coefficients and Calculations

An important factor for CWTS design is the rate of treatment, also known as the removal rate coefficient (*k*). The removal rate coefficient is based on the treatability of a specific compound and the hydraulic retention time of the CWTS, both of which are site-specific based on water chemistry, CWTS designs, and characteristics of the CWTS.

Once hydraulic retention time is calculated (main report), it can be used to solve for the removal rate coefficients (*k*) using the inflow (*Ci*) and outflow (*Cf*) concentrations of a given constituent (Equation A9 and Equation A10). Equation A9 was utilized to calculate first-order removal rate coefficients, while Equation A10 was utilized to calculate zero-order removal rate coefficients.

$$k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{\mathrm{HRT}}$$

**Equation A9 – Equation for calculation of first-order removal rate coefficient.**
*k* is the removal rate coefficient, *Cf* is the final concentration, *Ci* is the initial concentration, and HRT is the hydraulic retention time.

$$k = \frac{(Ci - Cf)}{\mathrm{HRT}}$$

**Equation A10 – Equation for calculation of zero-order removal rate coefficient.**
*k* is the removal rate coefficient, *Cf* is the final concentration, *Ci* is the initial concentration, and HRT is the hydraulic retention time.

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**Table B1 - Summary of extractable fractions from sequential extraction procedure for the speciation of metals[1].**

| Fraction | Description | COCs unstable when |
|---|---|---|
| **1** | Exchangeable fraction for adsorbed minerals | Readily released (i.e., soluble and exchangeable) |
| **2** | Mineral fraction bound to carbonates or solubilized at pH 5 | Decreased pH |
| **3** | Oxidized mineral fraction bound to Fe-Mn oxides | Reducing conditions |
| **4** | Reduced mineral fraction and sulphides | Oxidizing conditions |
| **5** | Residual mineral fraction (primary and secondary minerals) | Not expected to be released in solution over time under conditions normally encountered in nature |

[1]Method based on Tessier et al., 1979.

**Table B2 – Total and leachable soil copper concentrations in first year of operations.**

| CWTS Cell | Sampling Date | Days in Operation | Sample Depth (cm) | Total Cu (mg/kg) | SPLP Cu (mg/L) | Leachable Cu (mg/kg) |
|---|---|---|---|---|---|---|
| 1A | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 960 | 0.055[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 950 | 0.187 | - |
| | 18-Sep-15 | 149 | 10-20 | 1300 | 0.049 | - |
| | 29-Sep-15 | 160 | 10-20 | 910 | 0.069 | - |
| | 15-Jun-16 | 194 | 0-10 | 1440 | - | 0.953 |
| | 15-Jun-16 | 194 | 10-20 | 1210 | - | 0.66 |
| | 8-Jul-16 | 217 | 0-10 | 1430 | - | 0.603 |
| | 8-Jul-16 | 217 | 10-20 | 1730 | - | 0.832 |
| | 7-Sep-16 | 247 | 0-10 | 1290 | - | 0.449 |
| | 20-Jun-17 | 336 | 0-10 | 1470 | 0.315 | 0.308 |
| | 25-Jul-17 | 371 | 0-10 | 1630 | 0.529 | 0.463 |
| | 12-Sep-17 | 420 | 0-10 | 1490 | 0.590 | 0.481 |
| 1B | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 1400 | 0.033[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 1400 | 0.209 | - |
| | 18-Sep-15 | 149 | 10-20 | 830 | 0.065 | - |
| | 29-Sep-15 | 160 | 10-20 | 880 | 0.059 | - |
| | 15-Jun-16 | 194 | 0-10 | 1130 | - | 1.01 |
| | 15-Jun-16 | 194 | 10-20 | 1240 | - | 0.822 |
| | 8-Jul-16 | 217 | 0-10 | 1250 | - | 1.11 |
| | 8-Jul-16 | 217 | 10-20 | 1620 | - | 1.21 |
| | 7-Sep-16 | 247 | 0-10 | 1190 | - | 0.197 |
| | 20-Jun-17 | 336 | 0-10 | 1290 | 0.450 | 0.338 |
| | 25-Jul-17 | 371 | 0-10 | 1100 | 0.290 | 0.165 |
| | 12-Sep-17 | 420 | 0-10 | 1100 | 0.716 | 0.492 |

[1] Samples collected in June 2015 were at a shallow depth (0-5 cm) and copper content had therefore likely already been removed by washing from the faster flows of the CWTS system. The blue shading indicated samples that were taken from a shallower depth (0-10).

**Table B2 continued – Total and leachable soil copper concentrations in first year of operations.**

| CWTS Cell | Sampling Date | Days in Operation | Sample Depth (cm) | Total Cu (mg/kg) | SPLP Cu (mg/L) | Leachable Cu (mg/kg) |
|---|---|---|---|---|---|---|
| 2A | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 1175 | 0.037[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 660 | 0.139 | - |
| | 18-Sep-15 | 149 | 10-20 | 880 | 0.081 | - |
| | 29-Sep-15 | 160 | 10-20 | 1000 | 0.073 | - |
| | 15-Jun-16 | 194 | 0-10 | 1100 | - | 0.823 |
| | 15-Jun-16 | 194 | 10-20 | 1280 | - | 0.900 |
| | 8-Jul-16 | 217 | 0-10 | 1450 | - | 0.963 |
| | 8-Jul-16 | 217 | 10-20 | 1150 | - | 1.68 |
| | 7-Sep-16 | 247 | 0-10 | 1290 | - | 0.838 |
| | 20-Jun-17 | 336 | 0-10 | 1820 | 0.381 | 1.24 |
| | 25-Jul-17 | 371 | 0-10 | 1290 | 0.419 | 0.927 |
| | 12-Sep-17 | 420 | 0-10 | 1440 | 0.389 | 0.381 |
| 2B | 28-Aug-14 | 1 | Initial Composite | - | 0.298 (0.148-0.608) | - |
| | 19-Jun-15 | 58 | 0-5 | 1100 | 0.039[1] | - |
| | 16-Aug-15 | 116 | 10-20 | 1000 | 0.201 | - |
| | 18-Sep-15 | 149 | 10-20 | 830 | 0.078 | - |
| | 29-Sep-15 | 160 | 10-20 | 540 | 0.059 | - |
| | 15-Jun-16 | 194 | 0-10 | 1040 | - | 0.771 |
| | 15-Jun-16 | 194 | 10-20 | 1310 | - | 1.16 |
| | 8-Jul-16 | 217 | 0-10 | 1070 | - | 1.38 |
| | 8-Jul-16 | 217 | 10-20 | 1180 | - | 1.25 |
| | 7-Sep-16 | 247 | 0-10 | 1520 | - | 0.123 |
| | 20-Jun-17 | 336 | 0-10 | 1110 | 0.283 | 0.523 |
| | 25-Jul-17 | 371 | 0-10 | 1240 | 0.477 | 0.540 |
| | 12-Sep-17 | 420 | 0-10 | 1140 | 0.596 | 0.809 |

The blue shading indicated samples that were taken from a shallower depth (0-10).

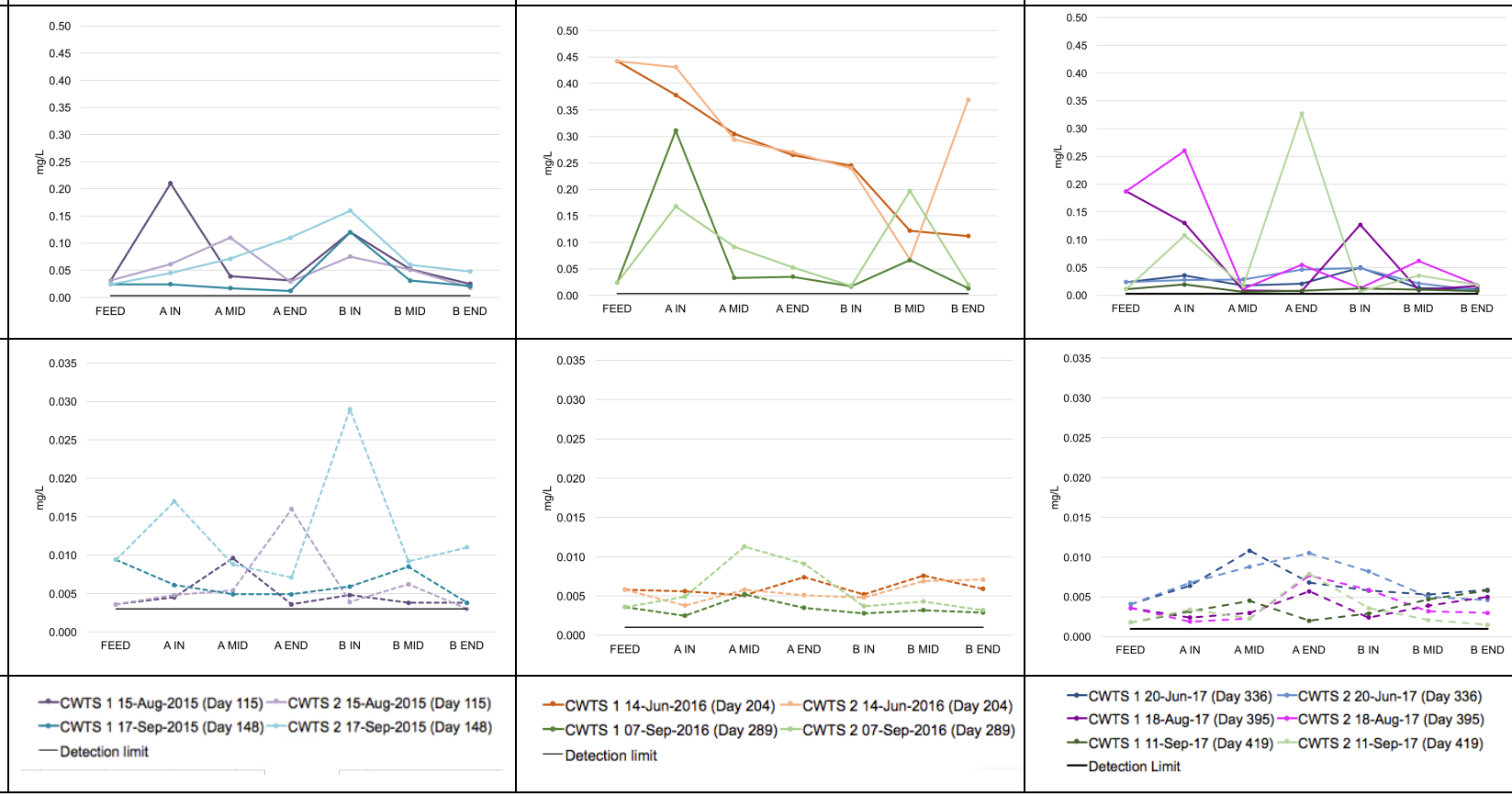



**Figure B1 – Aluminum concentrations through the CWTS.**
2015 (left), 2016 (middle), and 2017 (right) total (top) and dissolved (bottom) aluminum concentrations. Data shown for seven timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. The Maxxam (2015 results) detection limit (DL; black line) for aluminum is 0.0030 mg/L. The ALS (2016 and 2017 results) DL for dissolved and total aluminum are 0.0010 mg/L and 0.0030 mg/L, respectively.

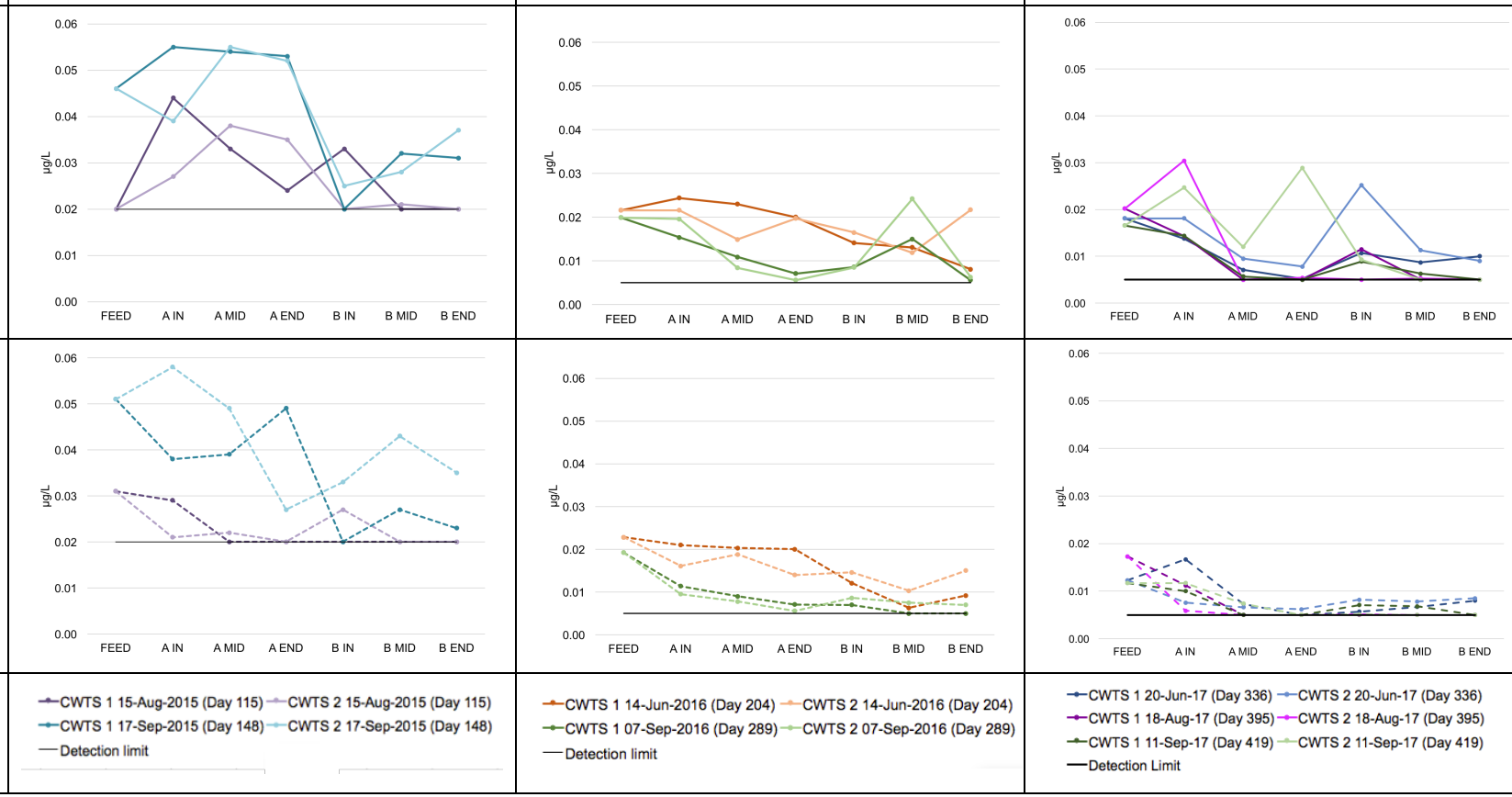



**Figure B2 – Cadmium concentrations through the CWTS.**
2015 (left), 2016 (middle), and 2017 (right) total (top) and dissolved (bottom) cadmium concentrations. Data shown for seven timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. The Maxxam (2015 results) detection limit (DL; black line) for cadmium is 0.020 µg/L. The ALS (2016 and 2017 results) DL for cadmium is 0.005 µg/L.

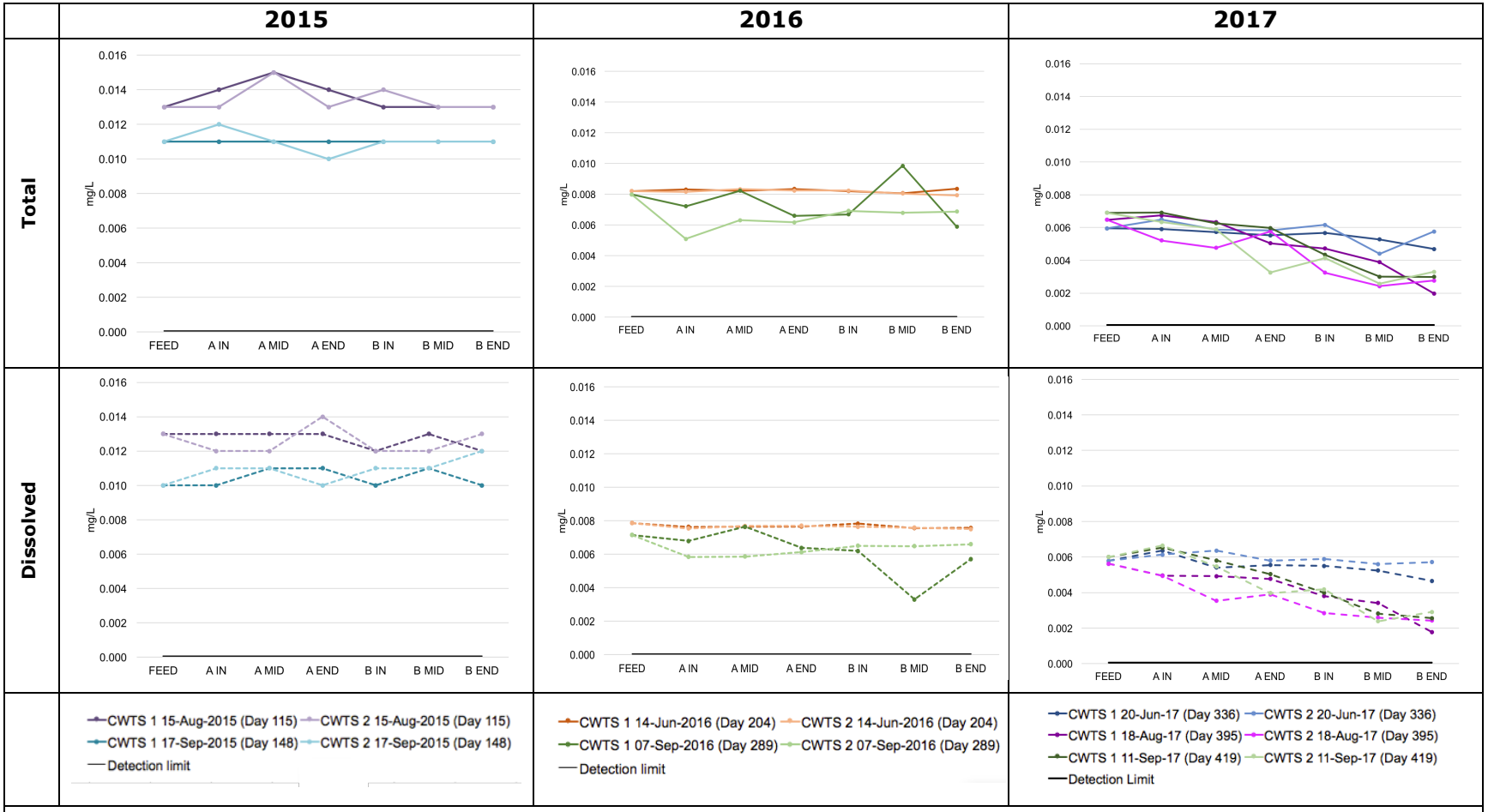



**Figure B3 – Molybdenum concentrations through the CWTS.**
2015 (left), 2016 (middle), and 2017 (right) total (top) and dissolved (bottom) molybdenum concentrations. Data shown for seven timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. The Maxxam (2015 results) detection limit (DL; black line) for molybdenum is 0.0002 mg/L. The ALS (2016 and 2017 results) DL for molybdenum is 0.000050 mg/L.

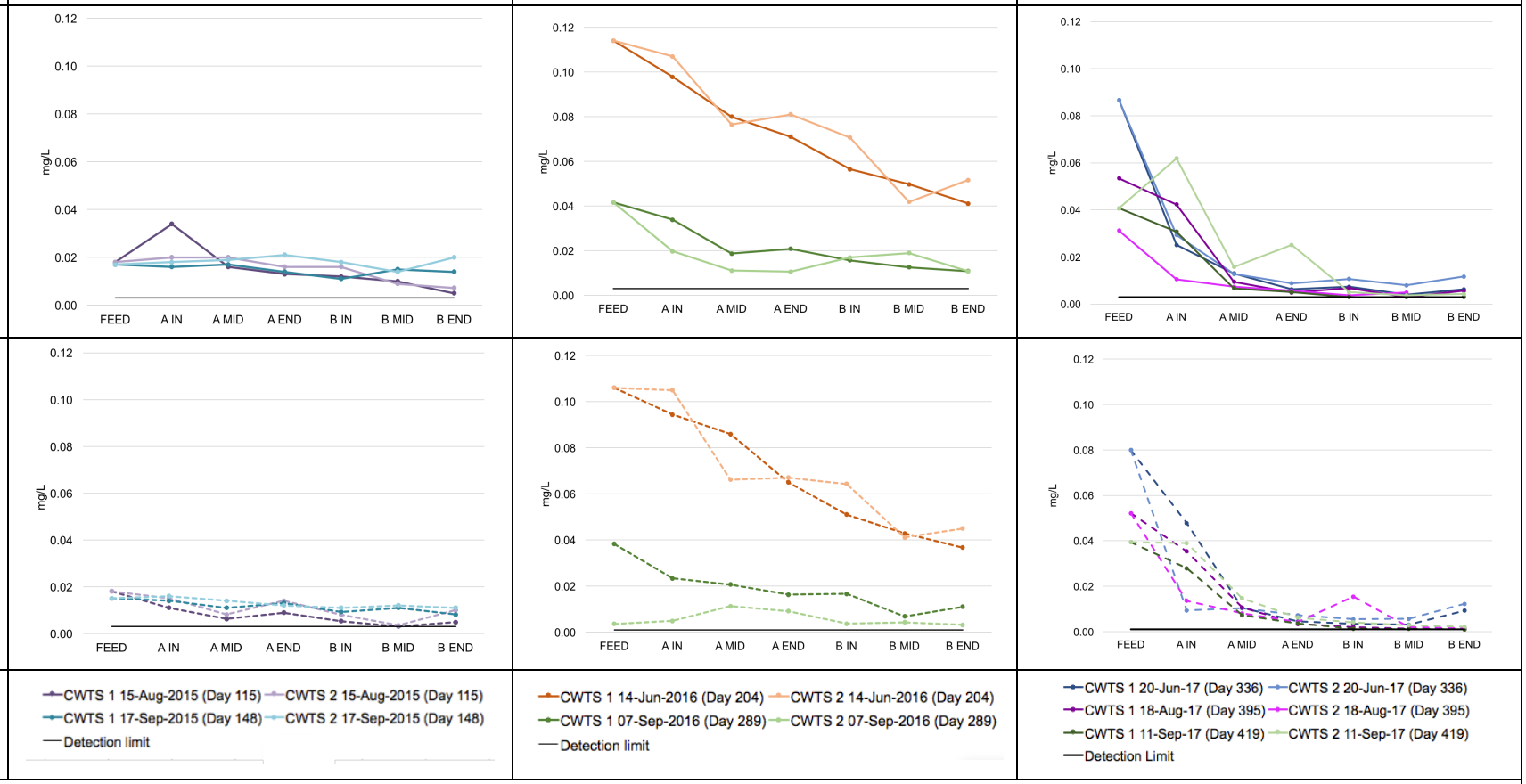
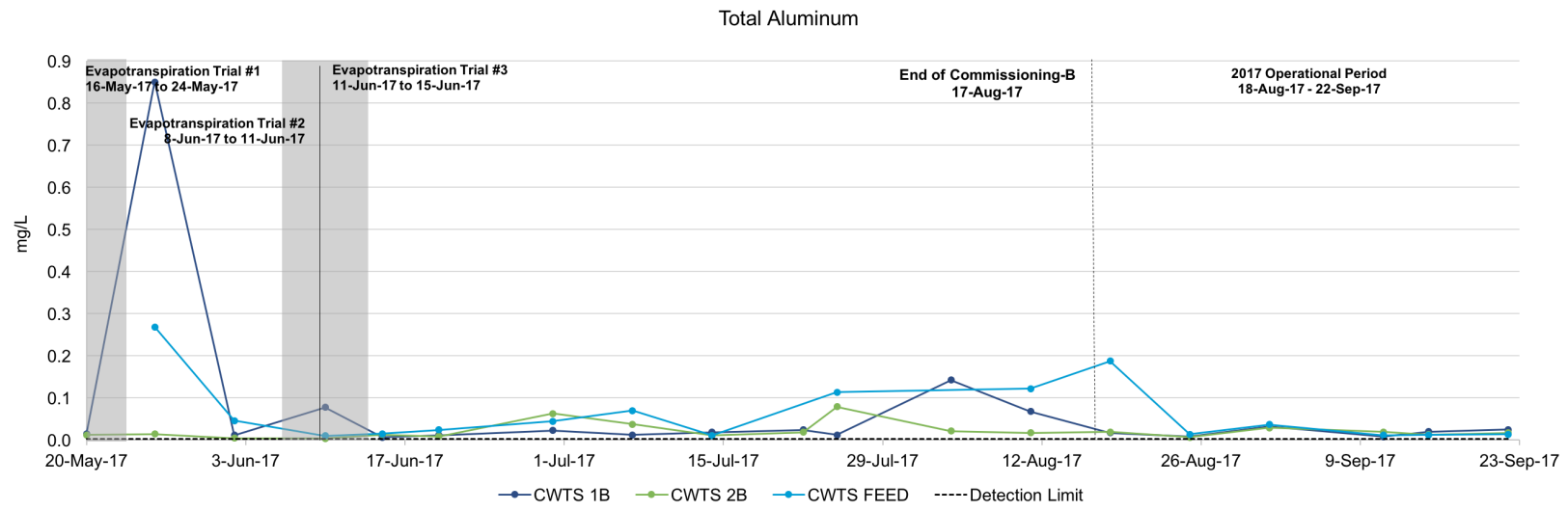



**Figure B4 – Zinc concentrations through the CWTS.**
2015 (left), 2016 (middle), and 2017 (right) total (top) and dissolved (bottom) zinc concentrations. Data shown for seven timepoints, where water was sampled at 7 locations through the flow path of the CWTS to assess for treatment fronts within the wetland, or possible leaching of elements from the soils into the CWTS. The Maxxam (2015 results) detection limit (DL; black line) for zinc is 0.0030 mg/L. The ALS (2016 and 2017 results) DL zinc is for 0.0010 mg/L.



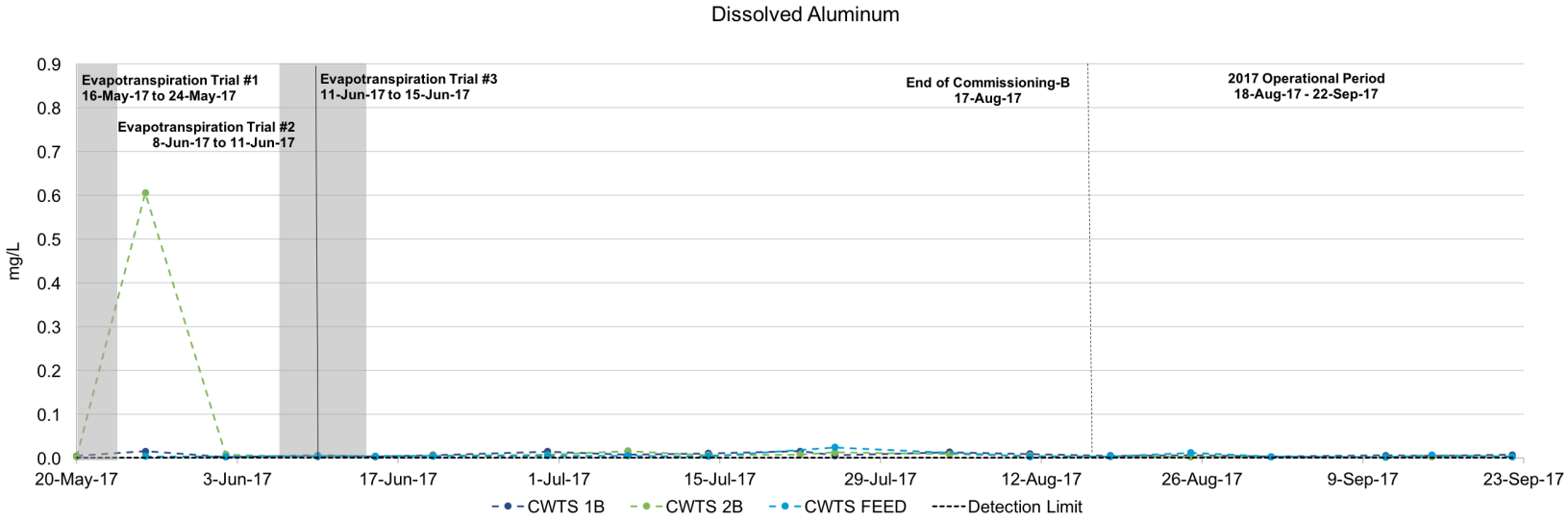
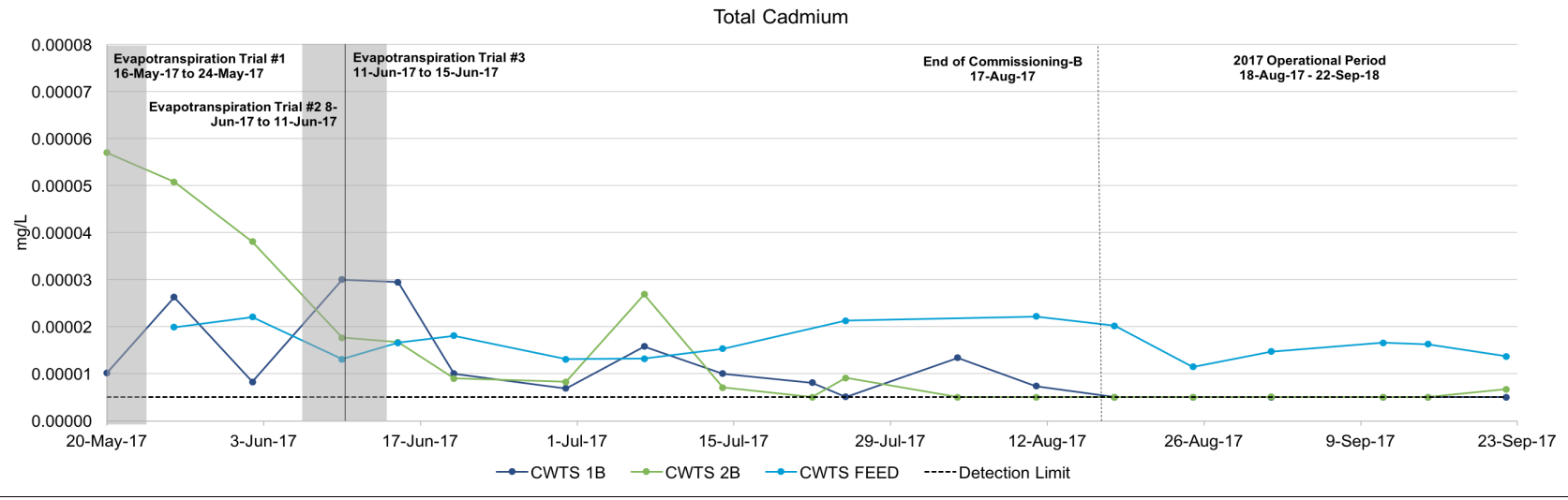




**Figure B5 – Aluminum concentrations in the demonstration-scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for dissolved and total aluminum is 0.001 mg/L and 0.003 mg/L, respectively. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.



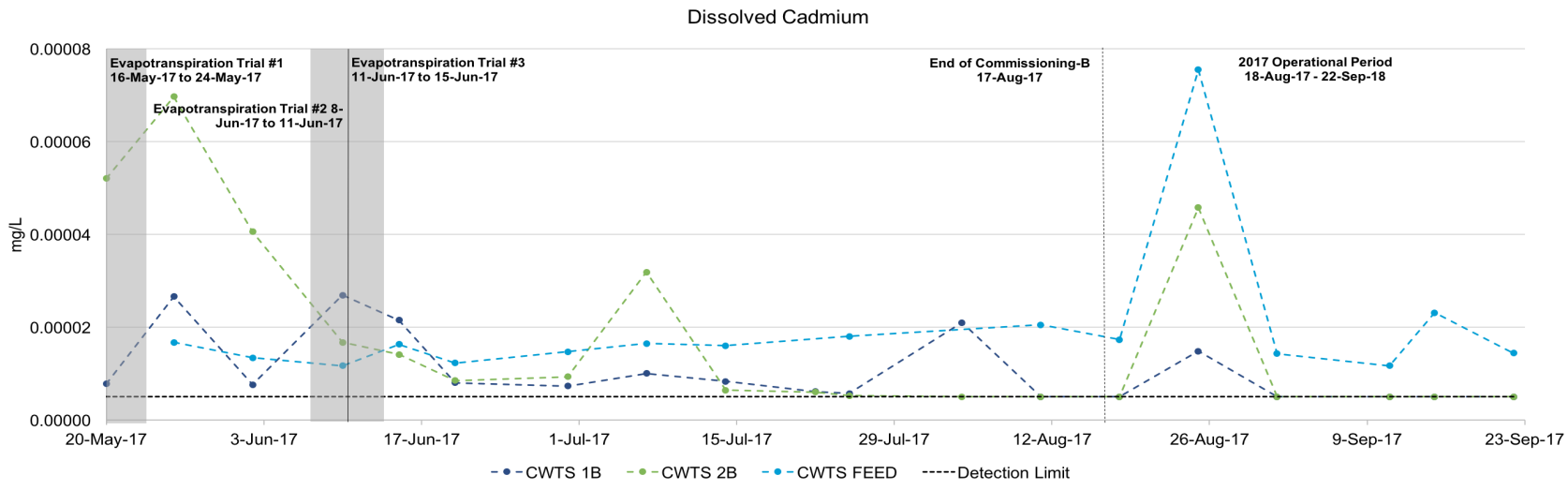
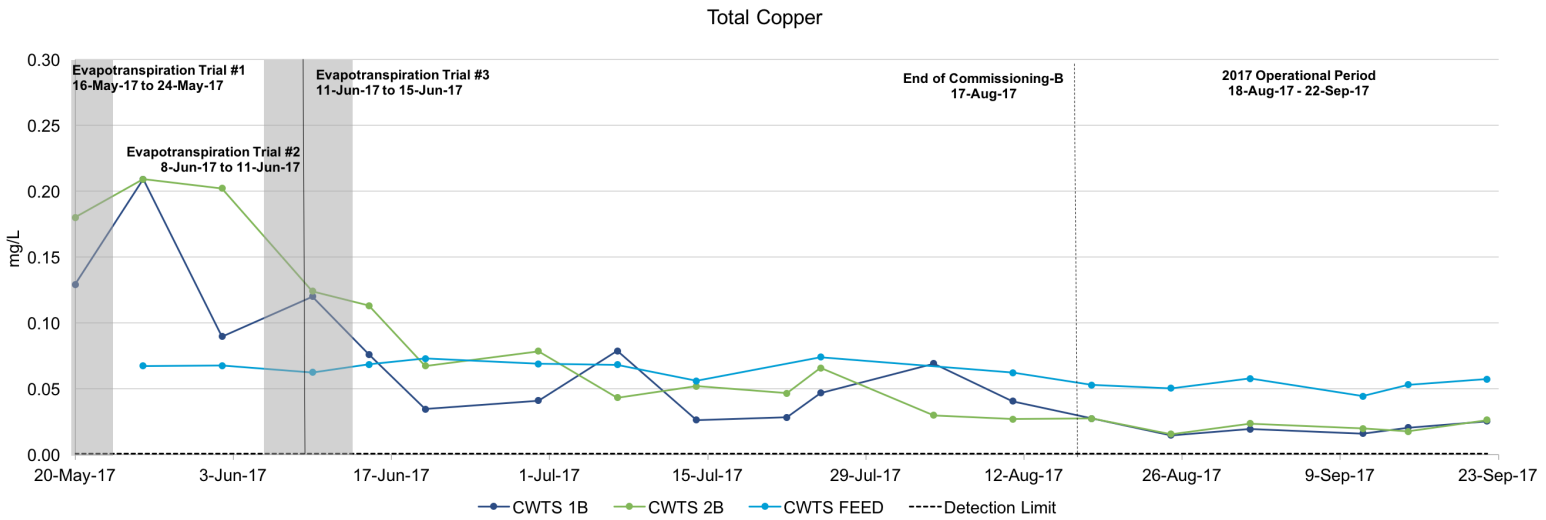




**Figure B6 – Cadmium concentrations in the demonstration-scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for cadmium is 0.000005 mg/L. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.



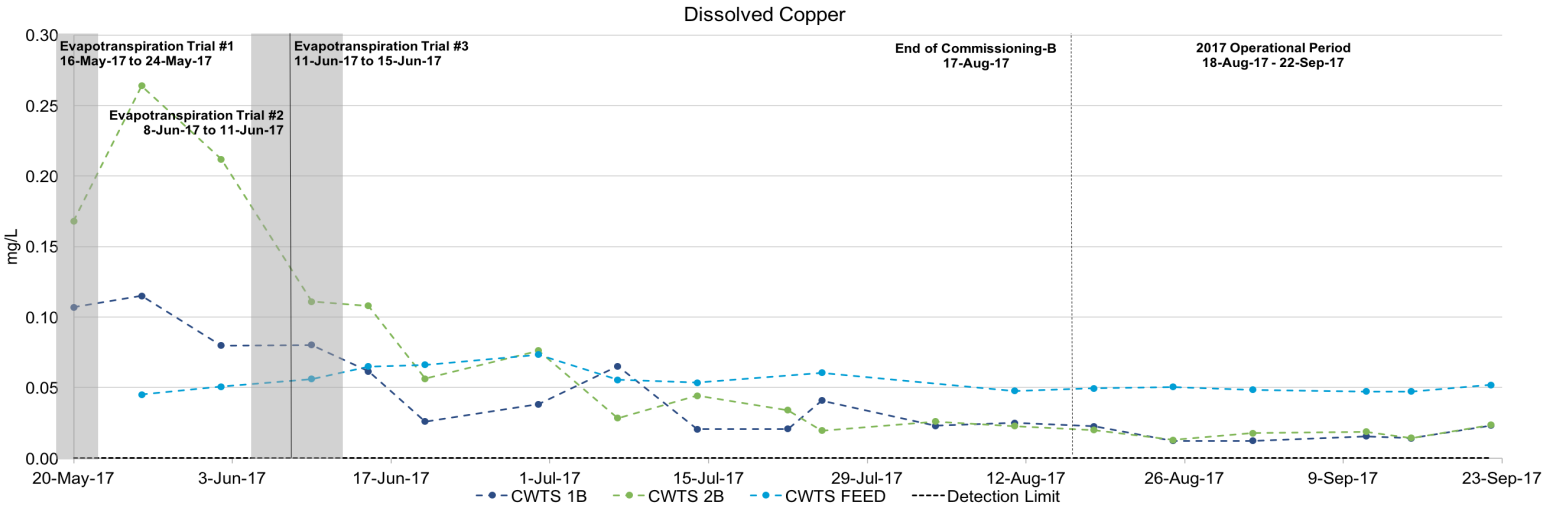
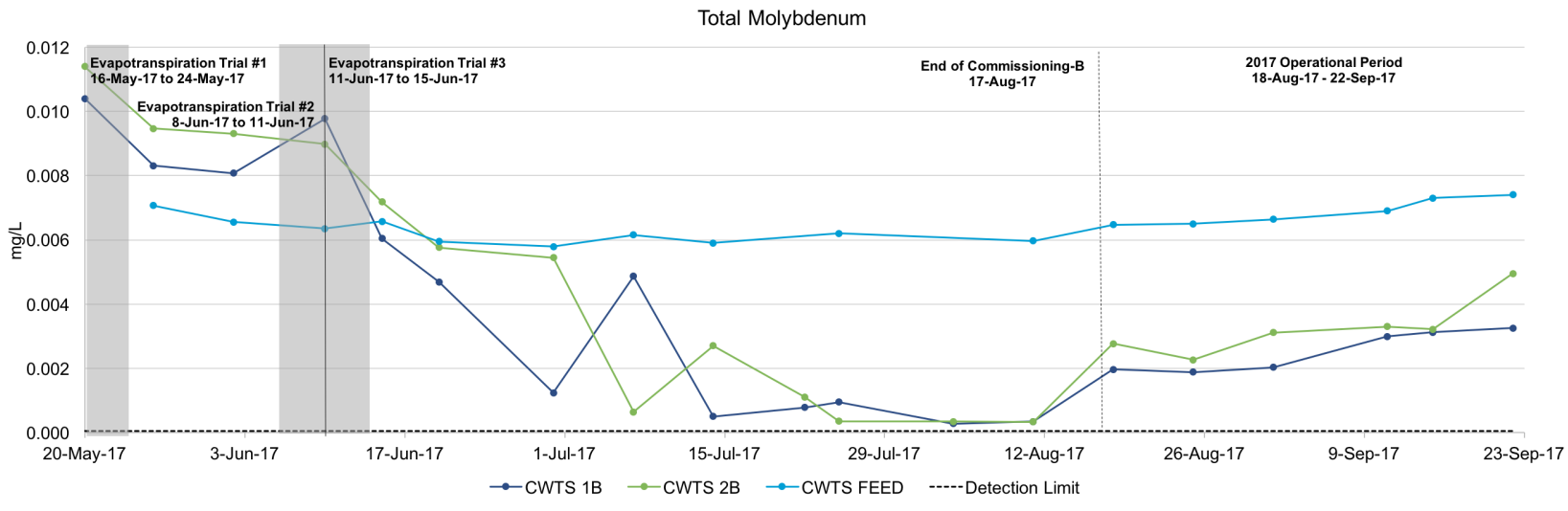




**Figure B7 – Copper concentrations in the demonstration-scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for dissolved and total copper is 0.0002 mg/L and 0.0005 mg/L, respectively. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.



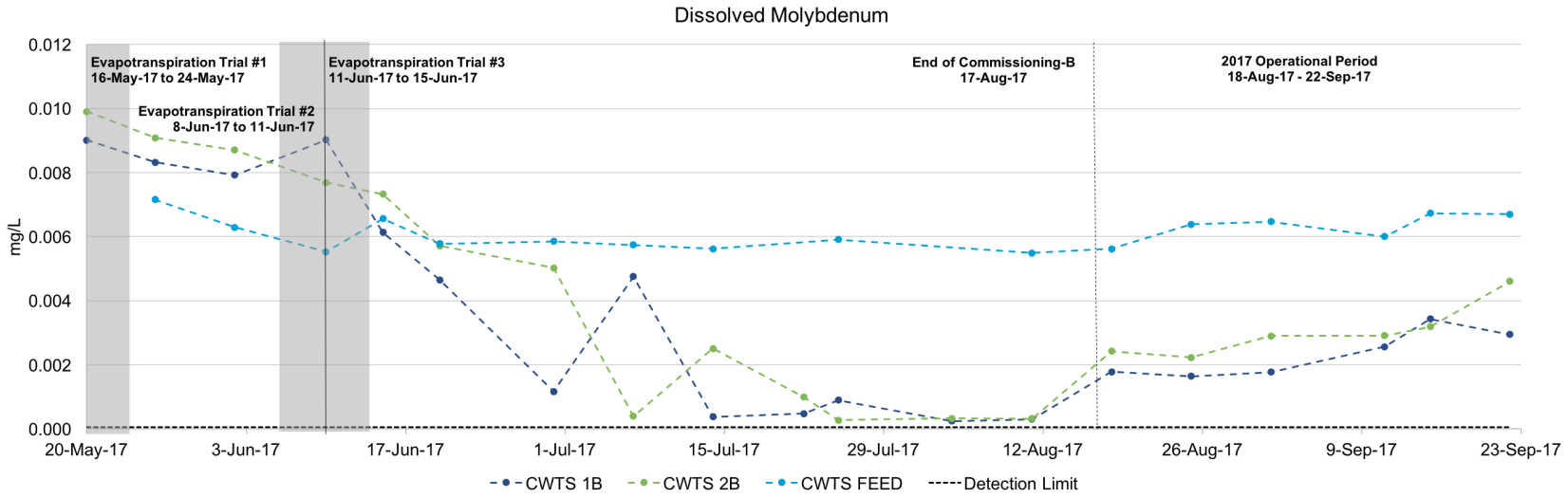




**Figure B8 – Molybdenum concentrations in the demonstration-scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for molybdenum is +/- 0.000050 mg/L. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.

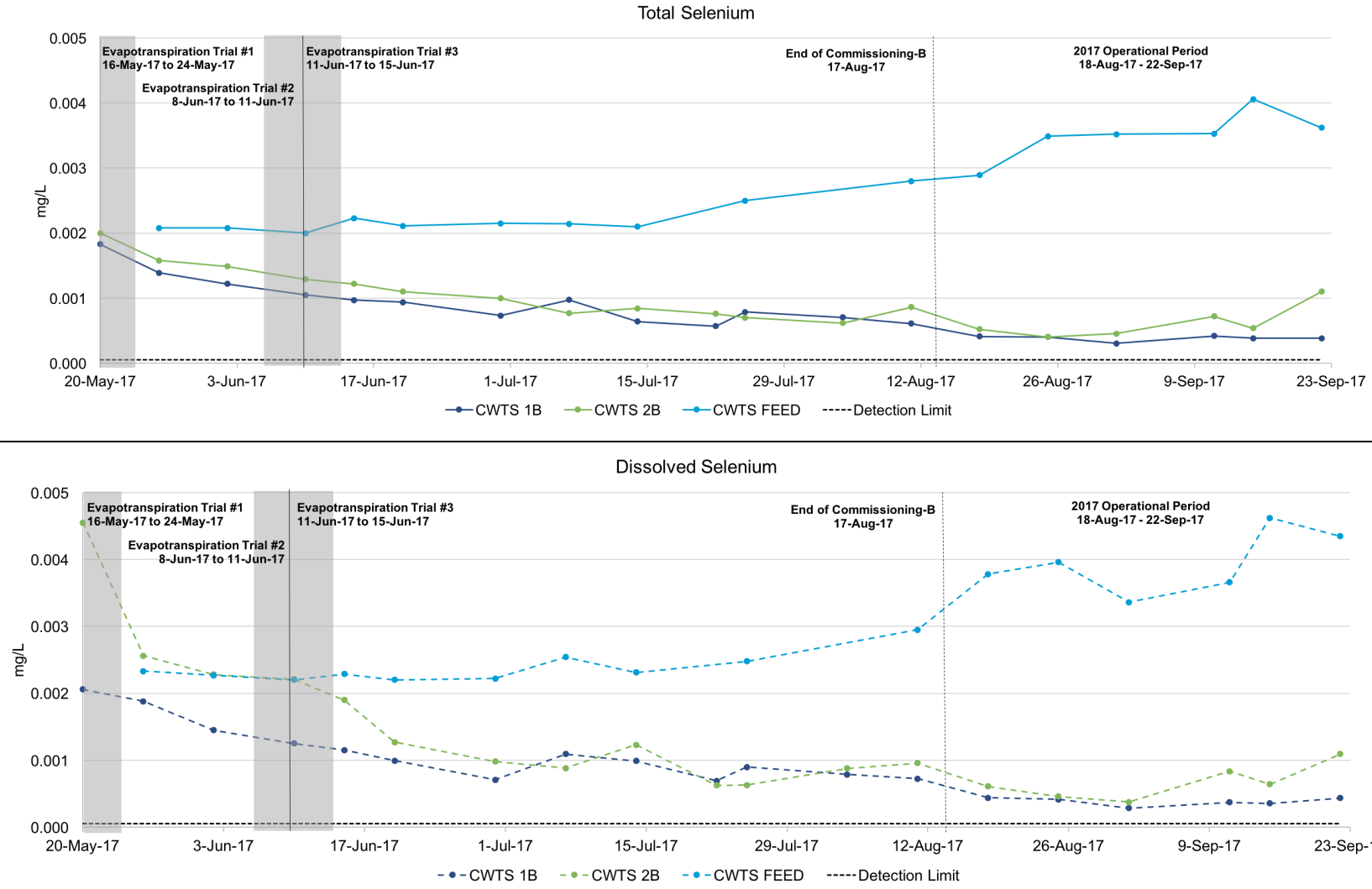



**Figure B9 – Selenium concentrations in the demonstration-scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for selenium is 0.00005 mg/L. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.

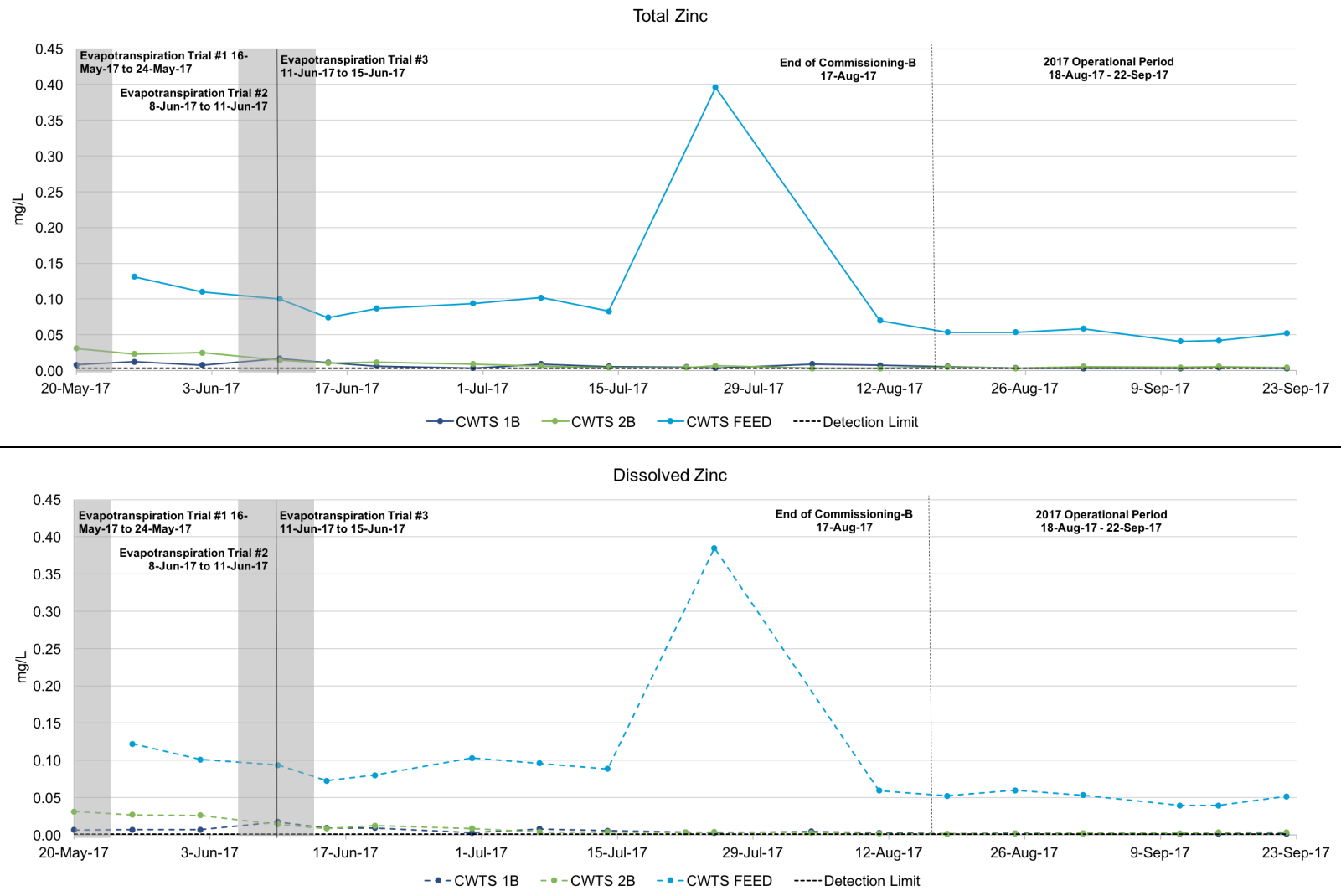



**Figure B10 – Zinc concentrations in the demonstration-scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for dissolved zinc is 0.001 mg/L. The detection limit for total zinc is 0.003 mg/L. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.

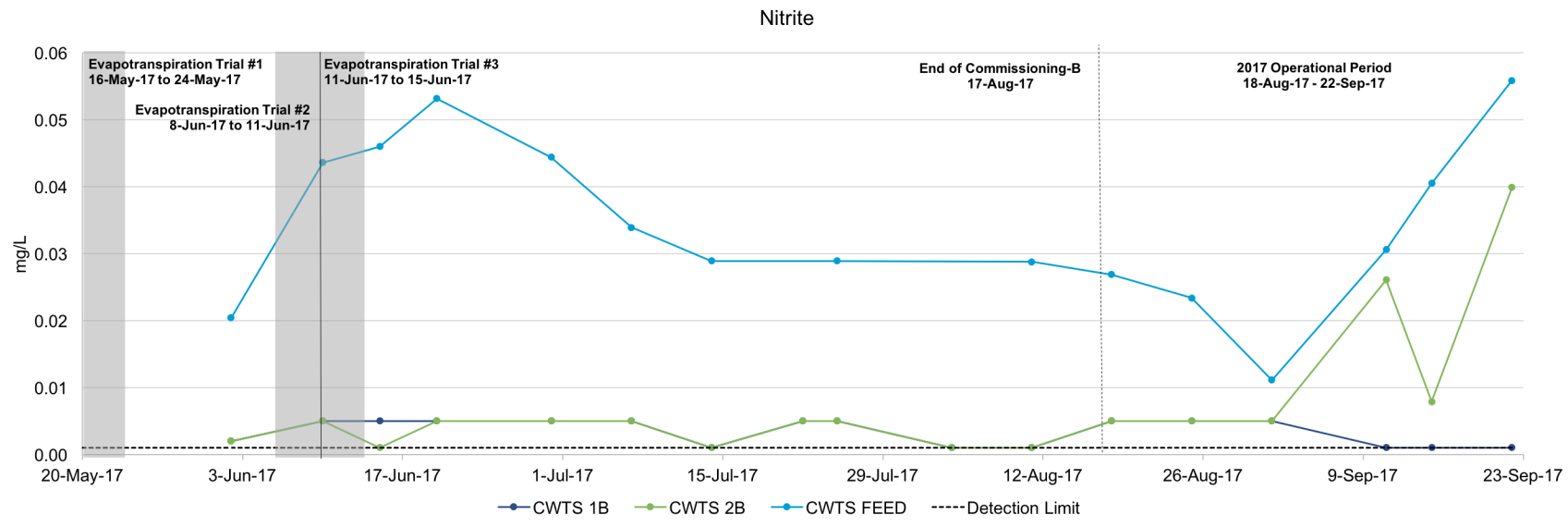



**Figure B11 – Nitrite as N ($NO_2$) concentrations in the demonstration scale wetland in 2017.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for nitrite is 0.0010 mg/L. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.

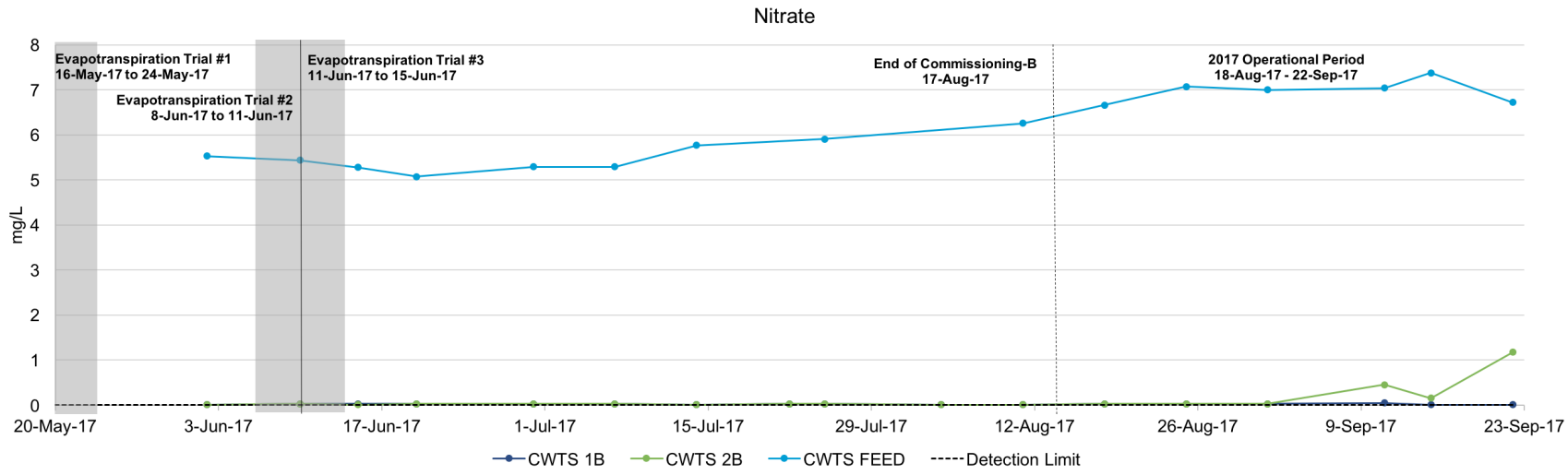
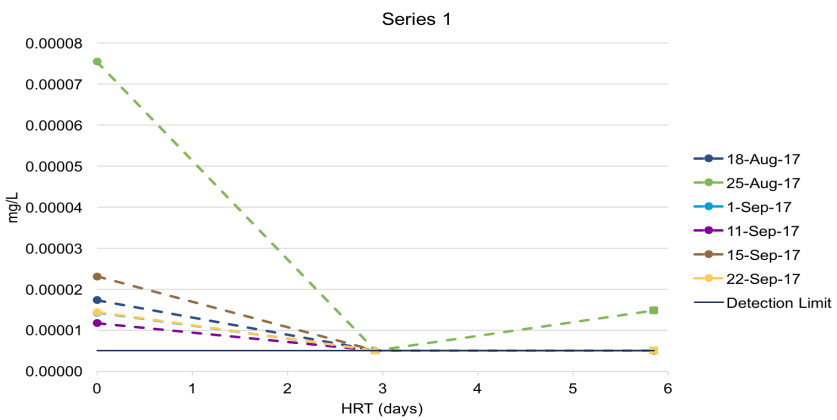
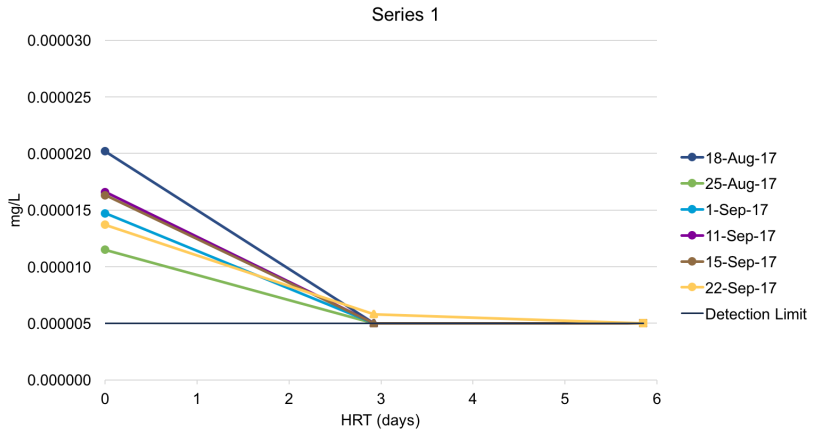
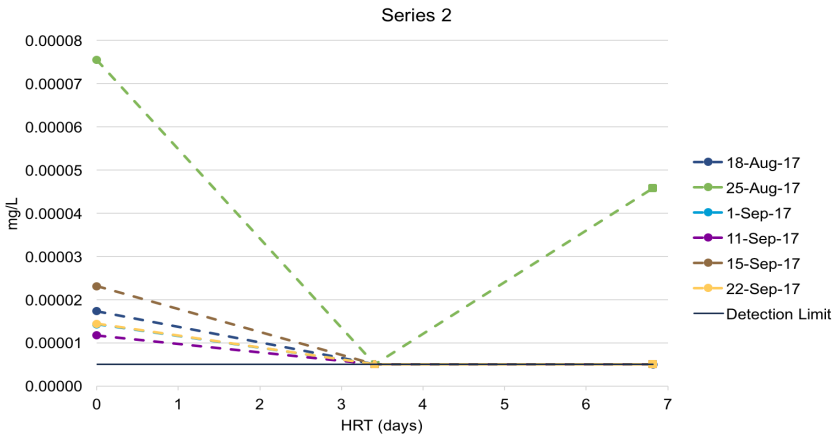



**Figure B12 –Nitrate as N ($NO_3$) concentrations in the demonstration-scale wetland.**
The evapotranspiration trials are indicated by grey shading and the duration in days. The ALS detection limit for nitrate is 0.0050 mg/L. Flow to the CWTS was turned off on September 30, 2017. However, the last sampling date in the operational period was September 22, 2017 due to variable flow rates in the CWTS following this date.



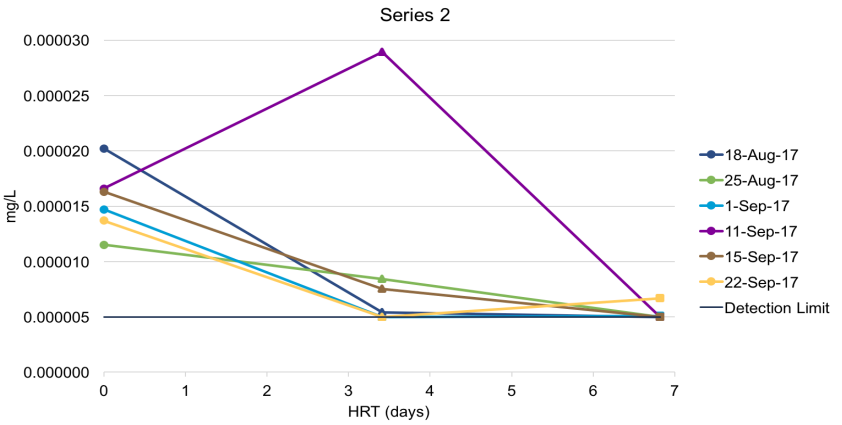
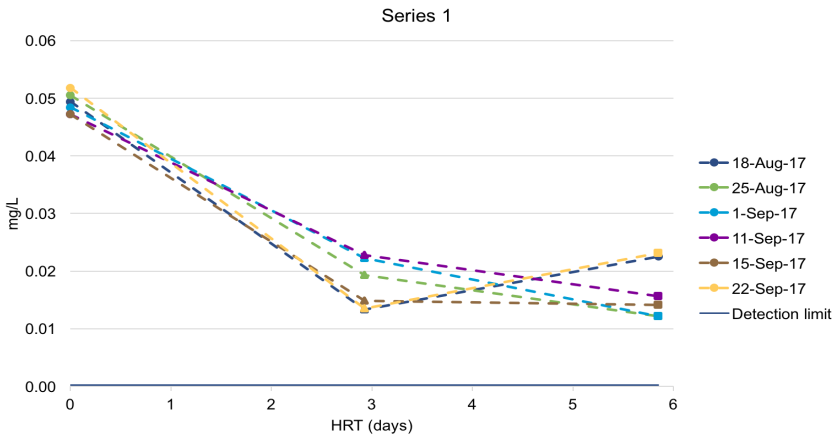
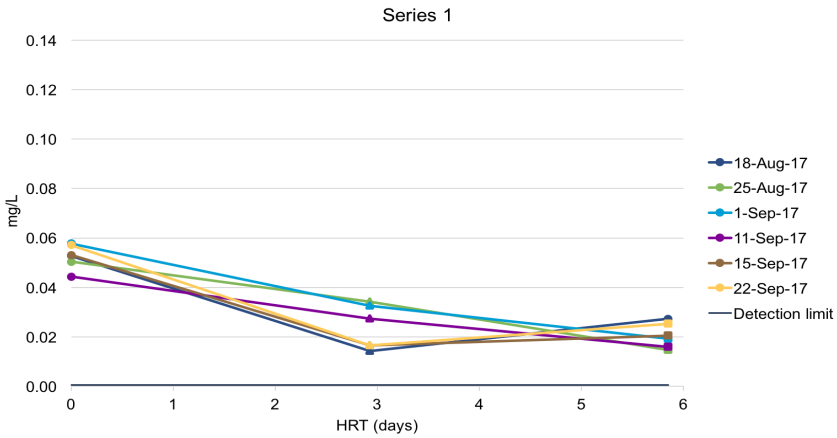
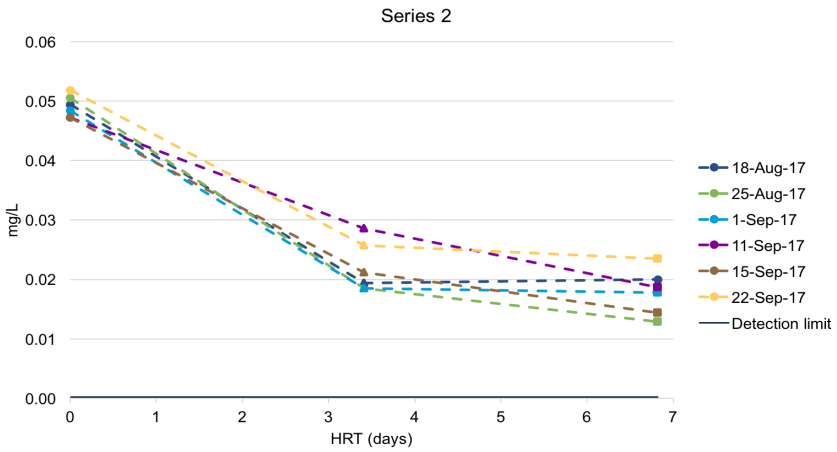




**Figure B13 – Dissolved and total cadmium concentrations through series 1 and series 2.**
Dashed lines represent dissolved concentrations (left) while solid lines represent total concentrations (right). Circles represent the feed water entering the wetland, diamonds represent the outflow of cell A and squares represent the outflow of cell B. The ALS detection limit for cadmium is 0.000005 mg/L.



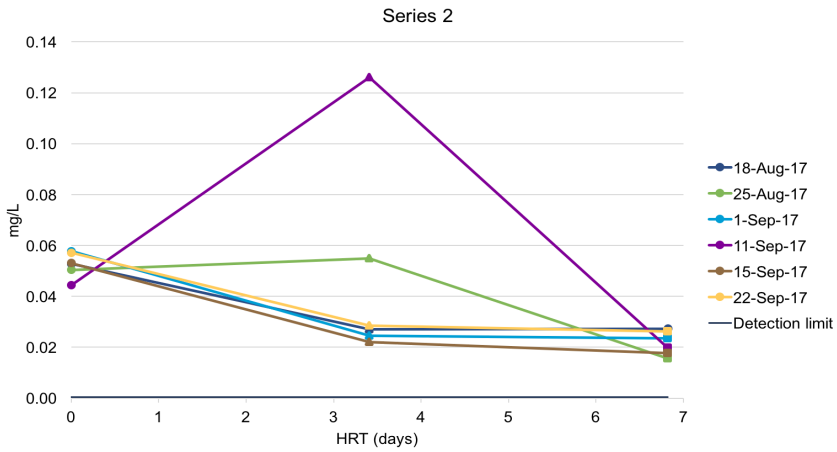
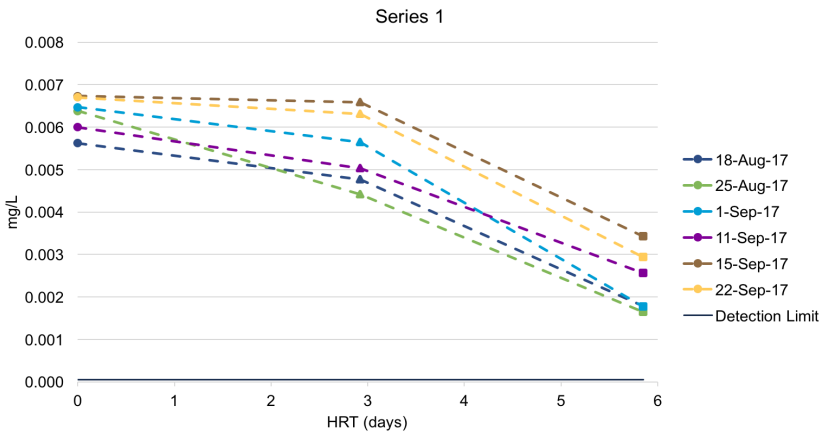
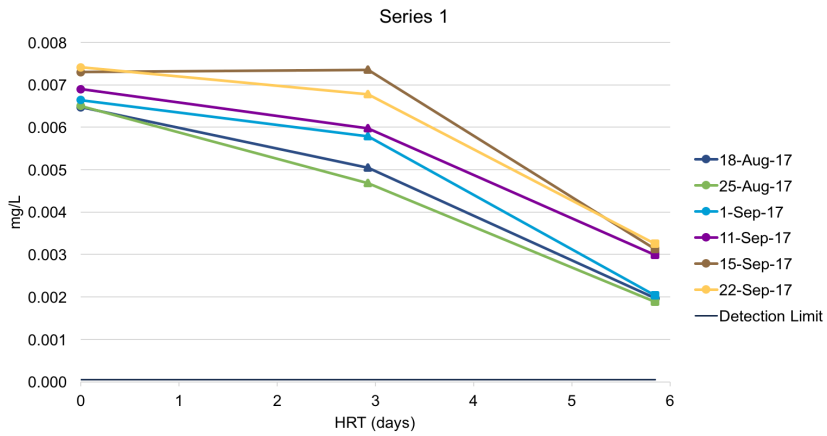
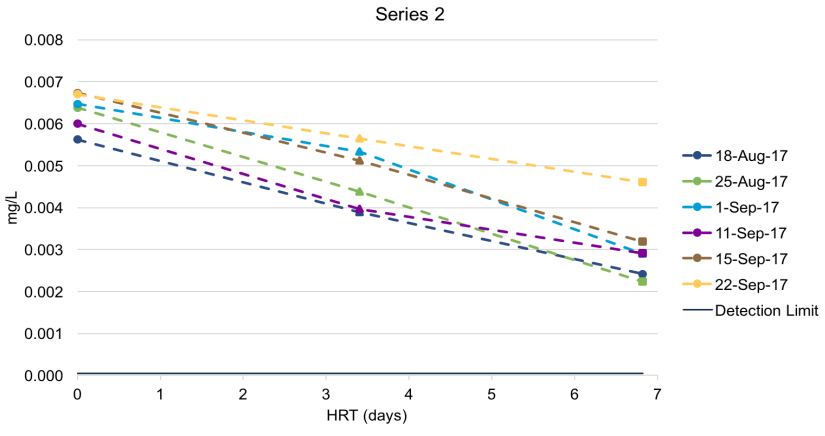




**Figure B14 - Dissolved and total copper concentrations through series 1 and series 2.**
Dashed lines represent dissolved concentrations (left) while solid lines represent total concentrations (right). Circles represent the feed water entering the wetland, diamonds represent the outflow of cell A and squares represent the outflow of cell B. The ALS detection limit for dissolved copper is 0.0002 mg/L. The detection limit for total copper is 0.0005 mg/L.



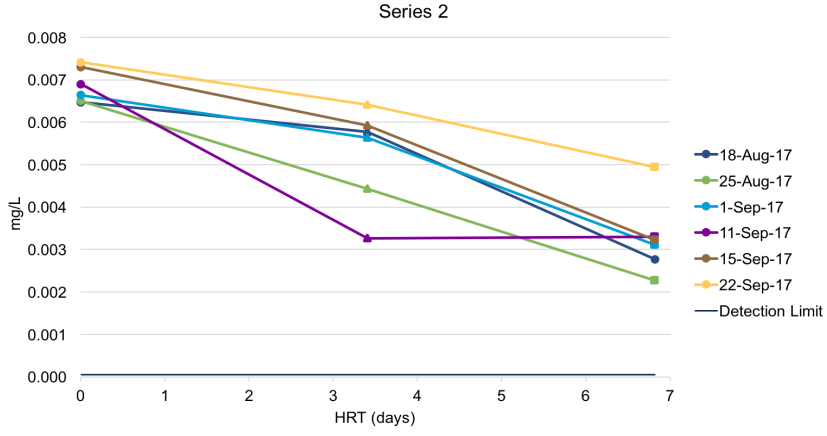
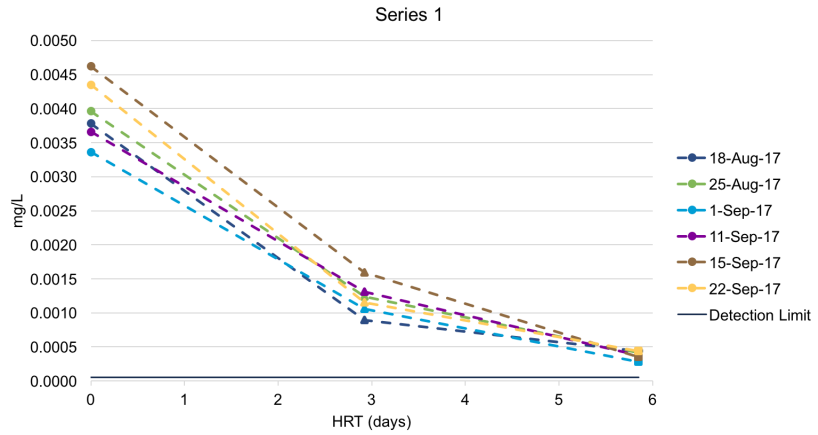
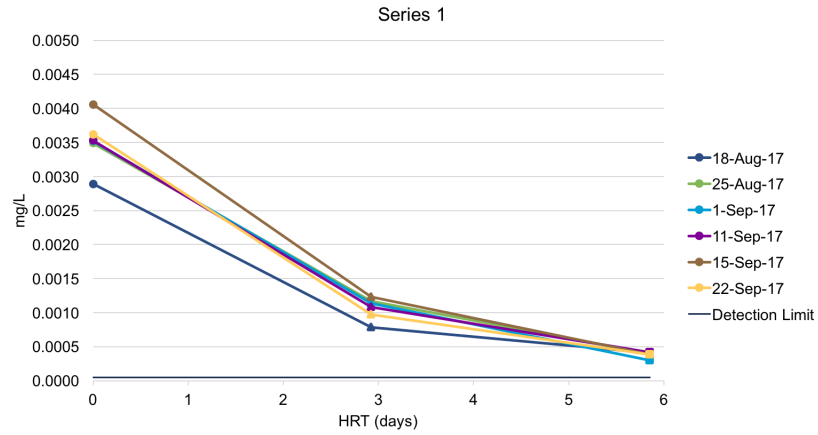
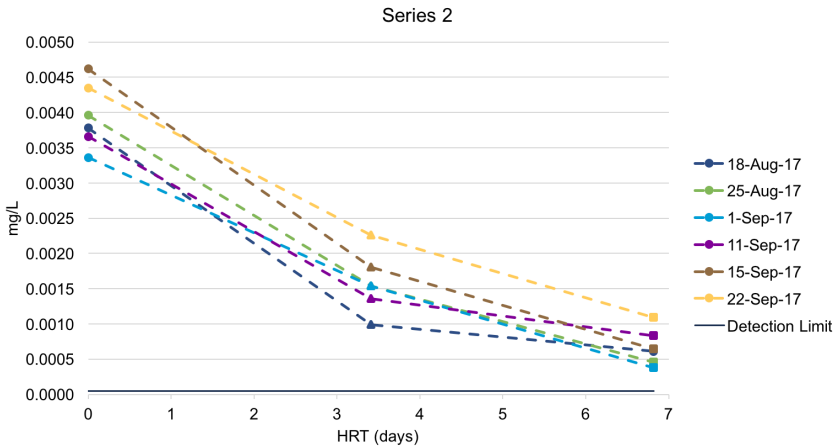




**Figure B15 - Dissolved and total molybdenum concentrations through series 1 and series 2.**
Dashed lines represent dissolved concentrations (left) while solid lines represent total concentrations (right). Circles represent the feed water entering the wetland, diamonds represent the outflow of cell A and squares represent the outflow of cell B. The ALS detection limit for molybdenum is 0.00005 mg/L.



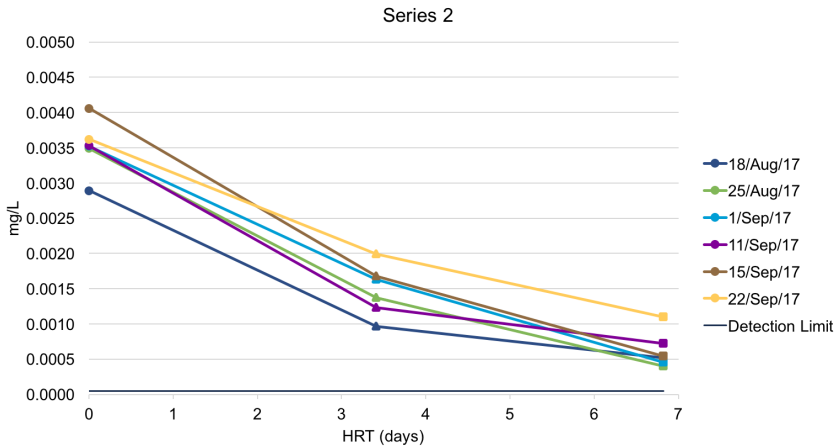
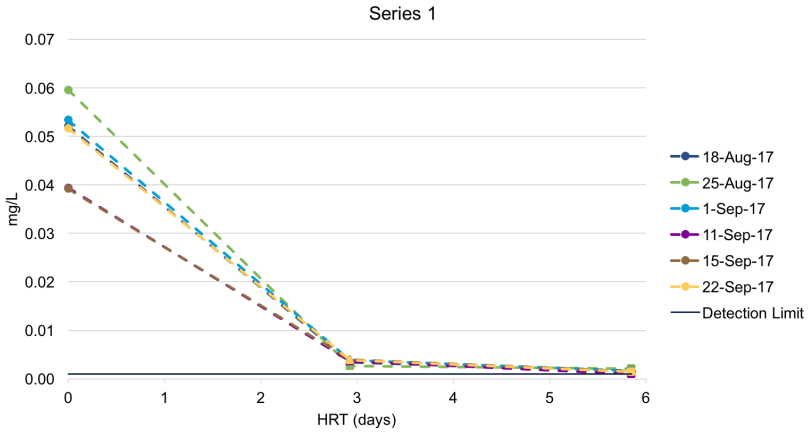
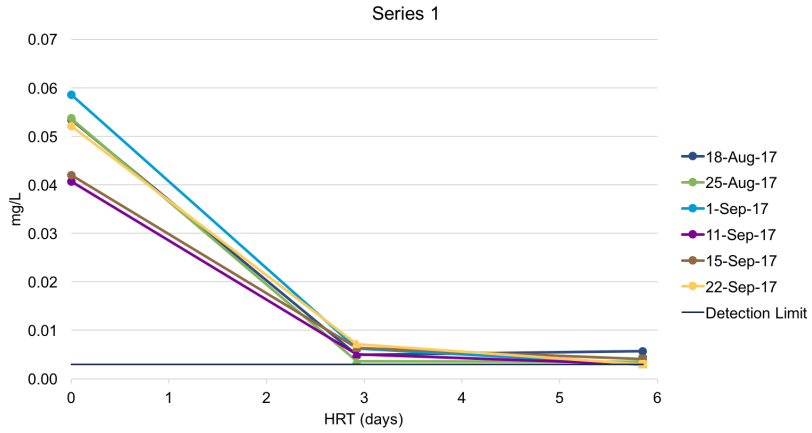
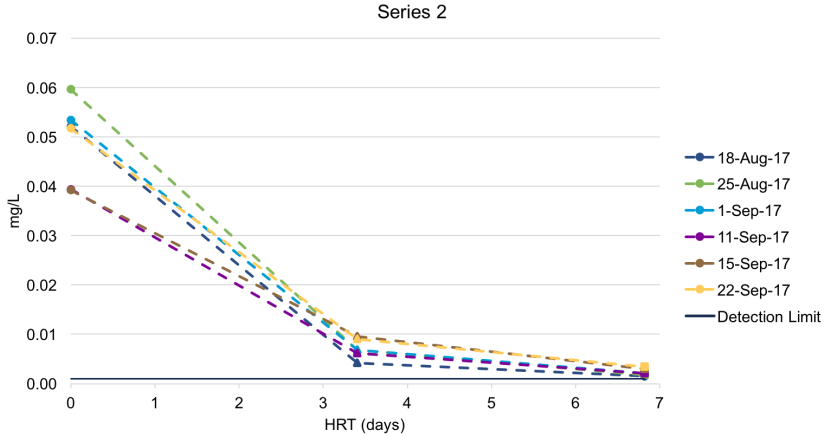




**Figure B16 – Dissolved and total selenium concentrations through series 1 and series 2.**
Dashed lines represent dissolved concentrations (left) while solid lines represent total concentrations (right). Circles represent the feed water entering the wetland, diamonds represent the outflow of cell A and squares represent the outflow of cell B. The ALS detection limit for selenium is 0.00005 mg/L.



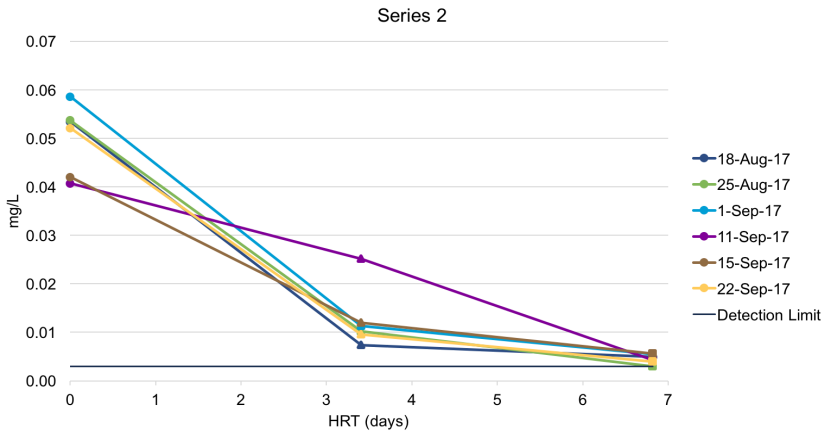




**Figure B17 - Dissolved and total zinc concentrations through series 1 and series 2.**
Dashed lines represent dissolved concentrations (left) while solid lines represent total concentrations (right). Circles represent the feed water entering the wetland, diamonds represent the outflow of cell A and squares represent the outflow of cell B. The ALS detection limit for dissolved zinc is 0.001 mg/L. The detection limit for total zinc is 0.003 mg/L.

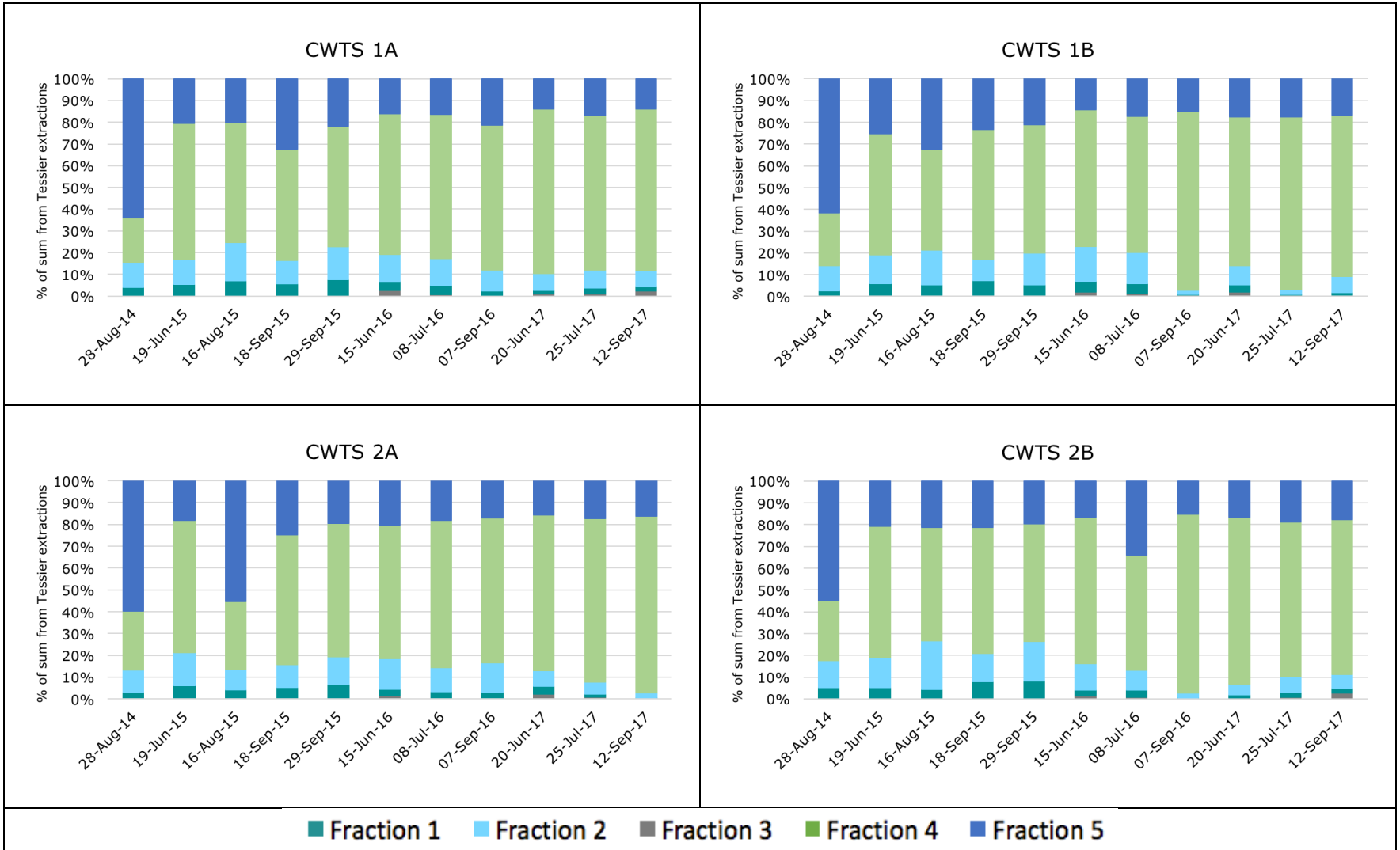



**Figure B18 – Fraction distribution of copper expressed as percent over time (2014 – 2017).**
Fractions are defined in Table B1.

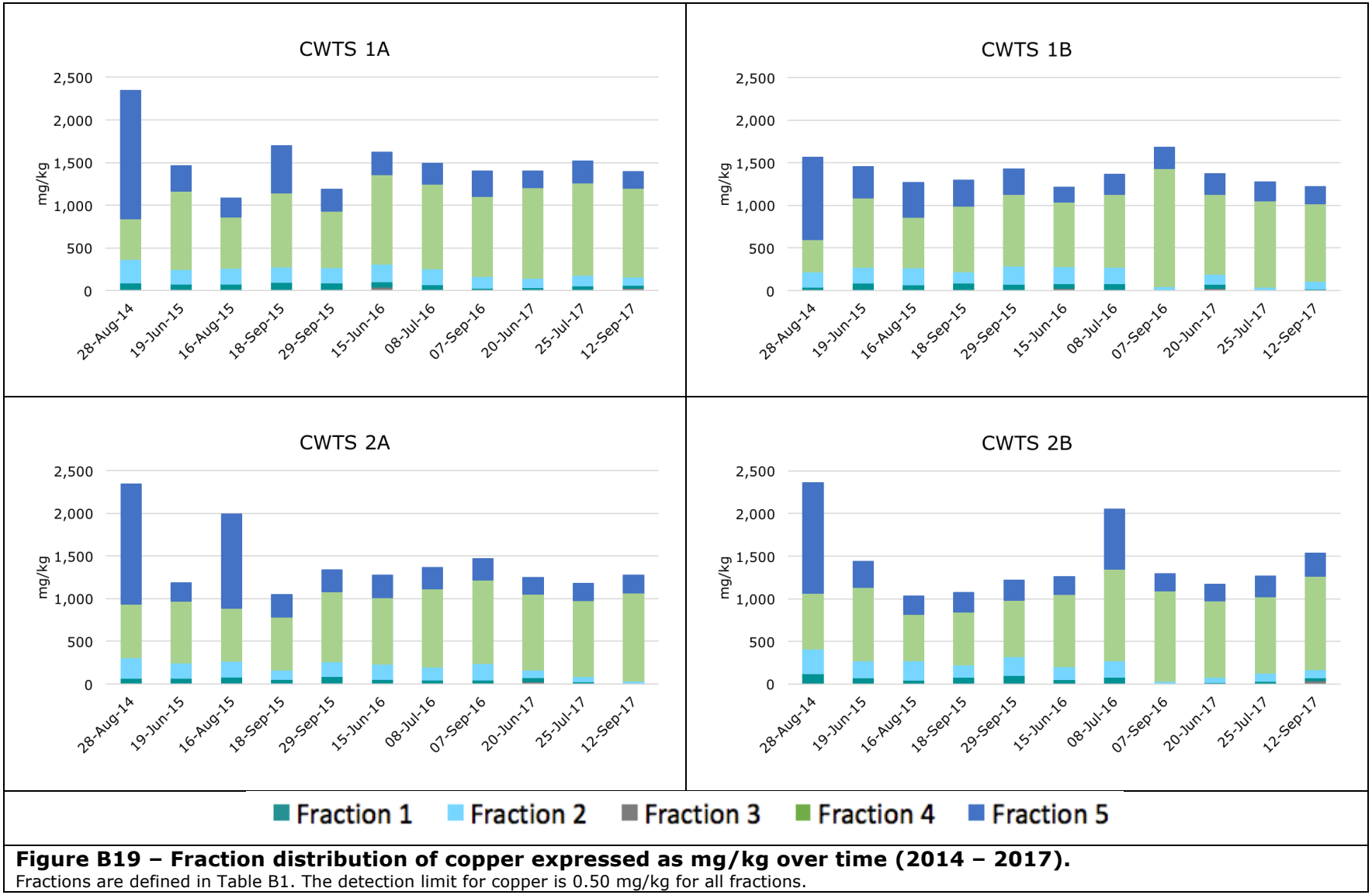



**Figure B19 – Fraction distribution of copper expressed as mg/kg over time (2014 – 2017).**
Fractions are defined in Table B1. The detection limit for copper is 0.50 mg/kg for all fractions.

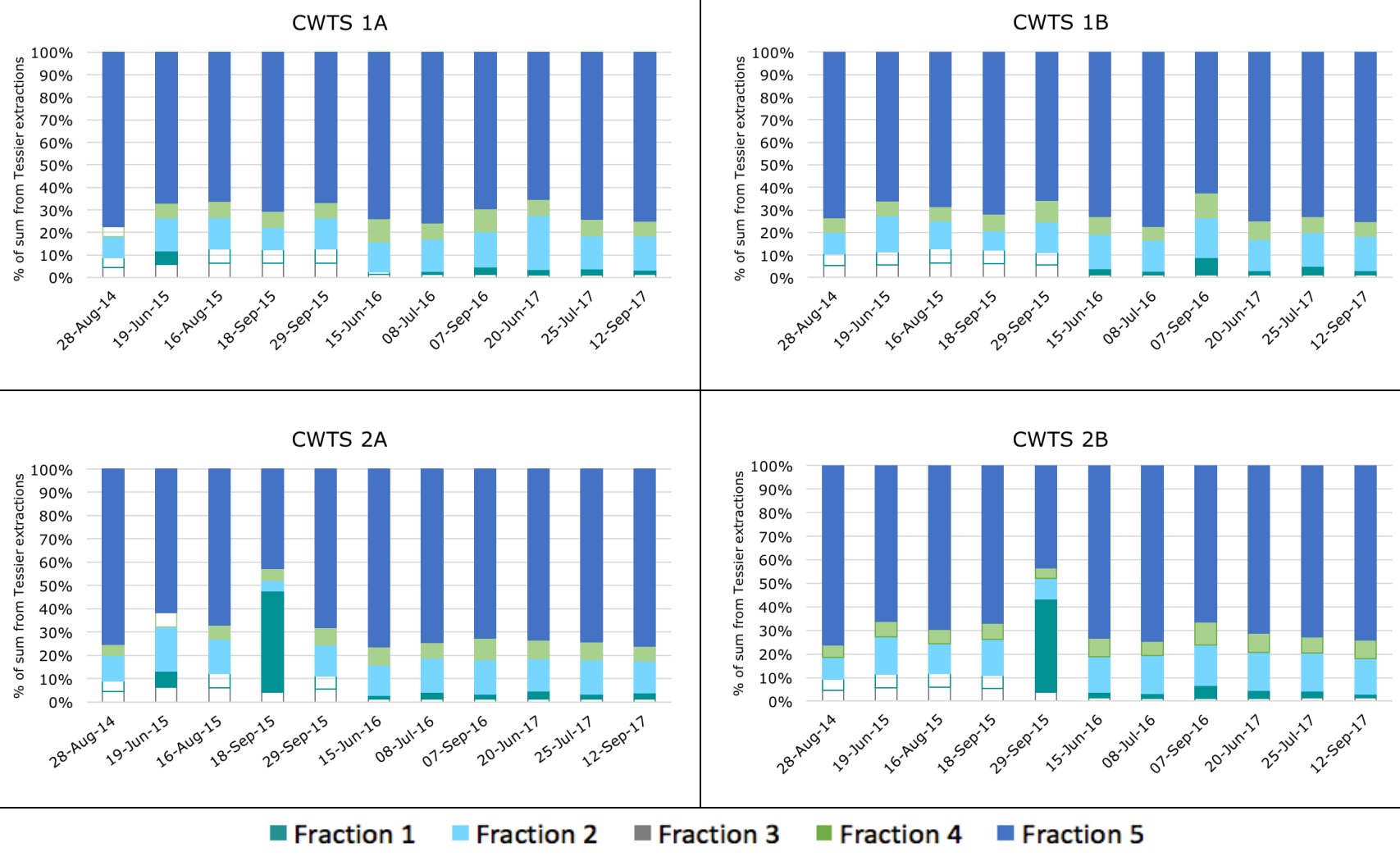



**Figure B20 – Fraction distribution of zinc expressed as percent over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Fractions are defined in Table B1.

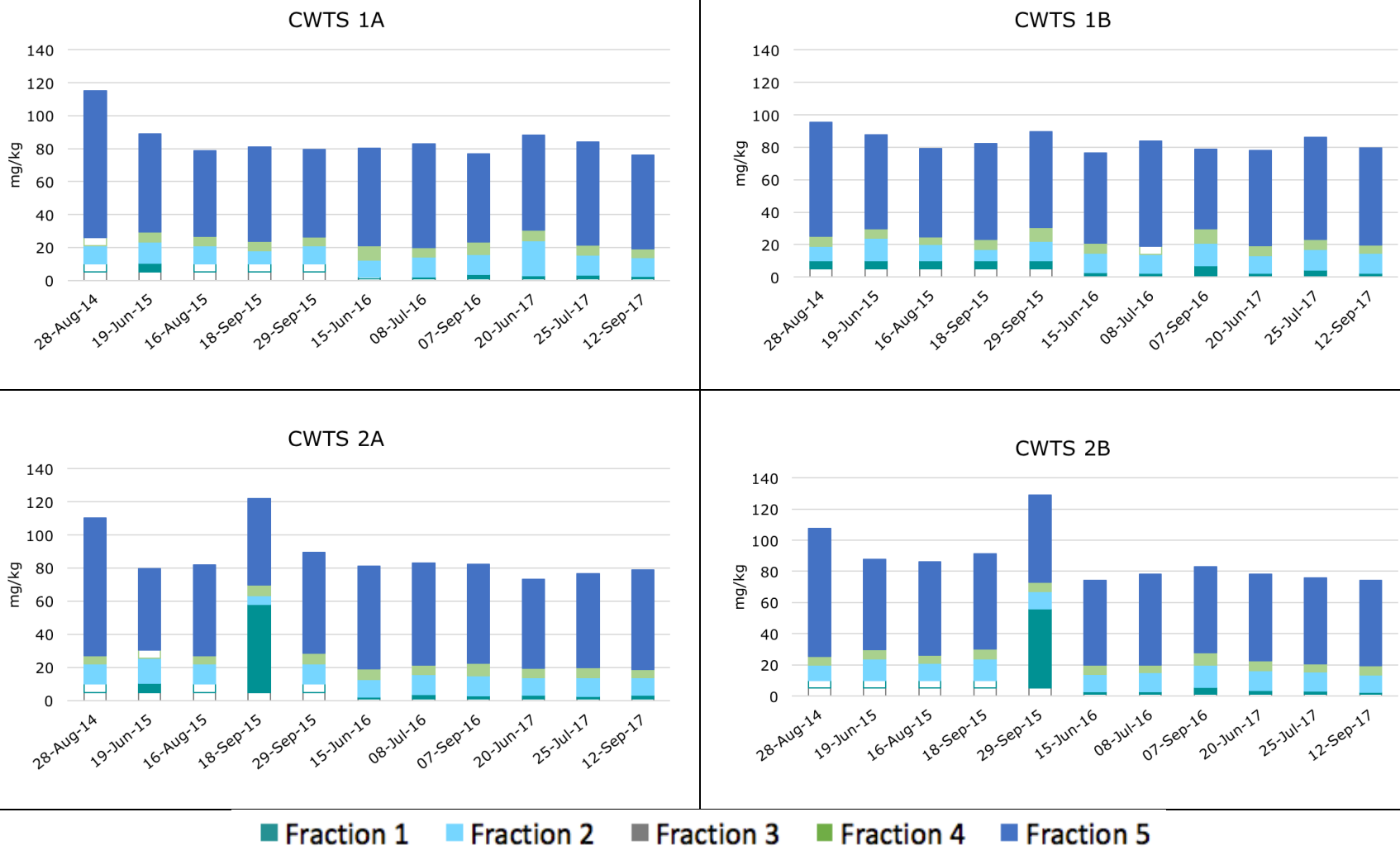



**Figure B21 – Fraction distribution of zinc expressed as mg/kg over time (2014 – 2017).**
A cells and B cells are on different y-axes. Unfilled areas are values at or below detection limits. Fractions are defined in Table B1. The detection limit for zinc is 1.0 mg/kg for all fractions.

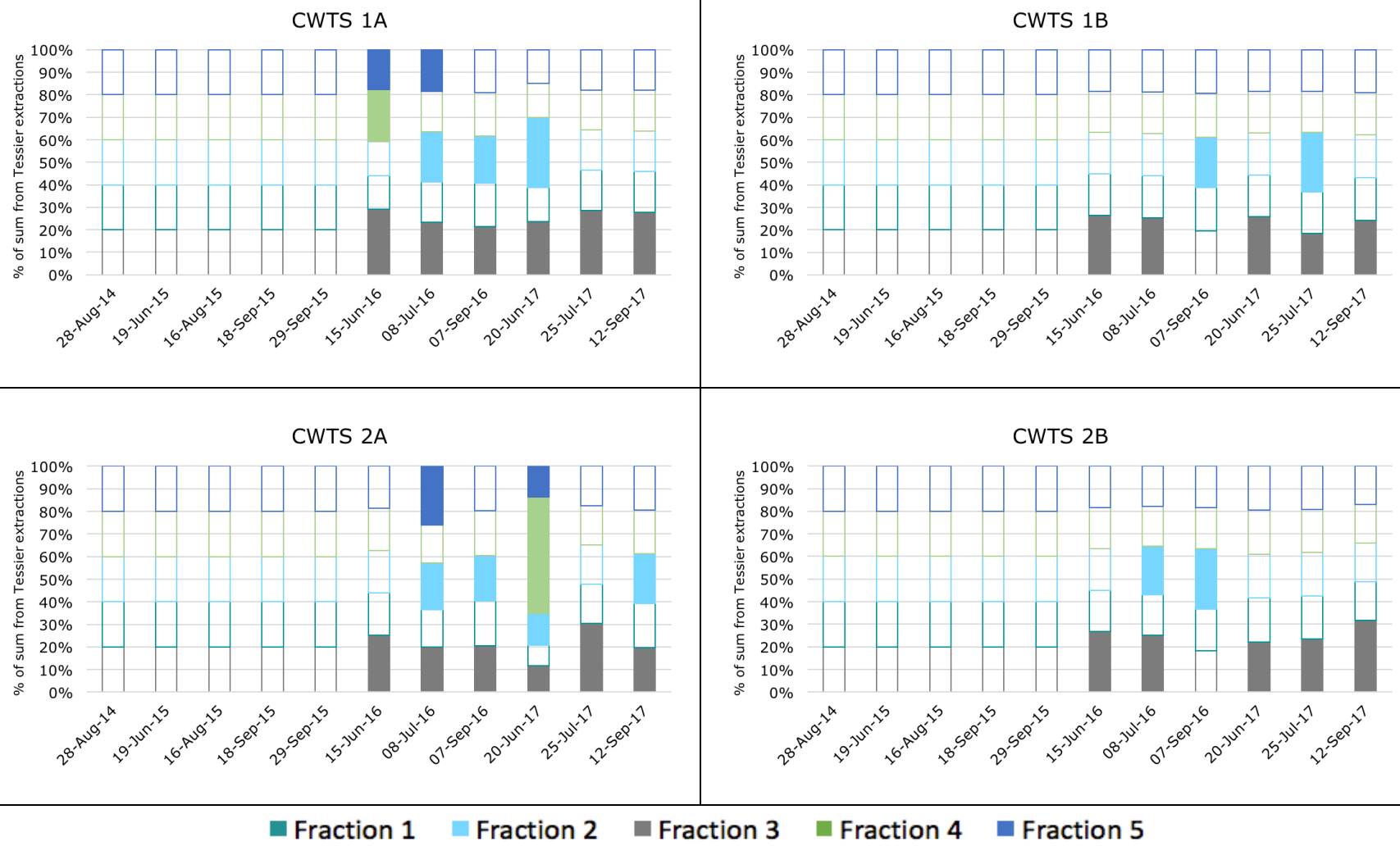



**Figure B22 – Fraction distribution of cadmium expressed as percent over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Fractions are defined in Table B1.

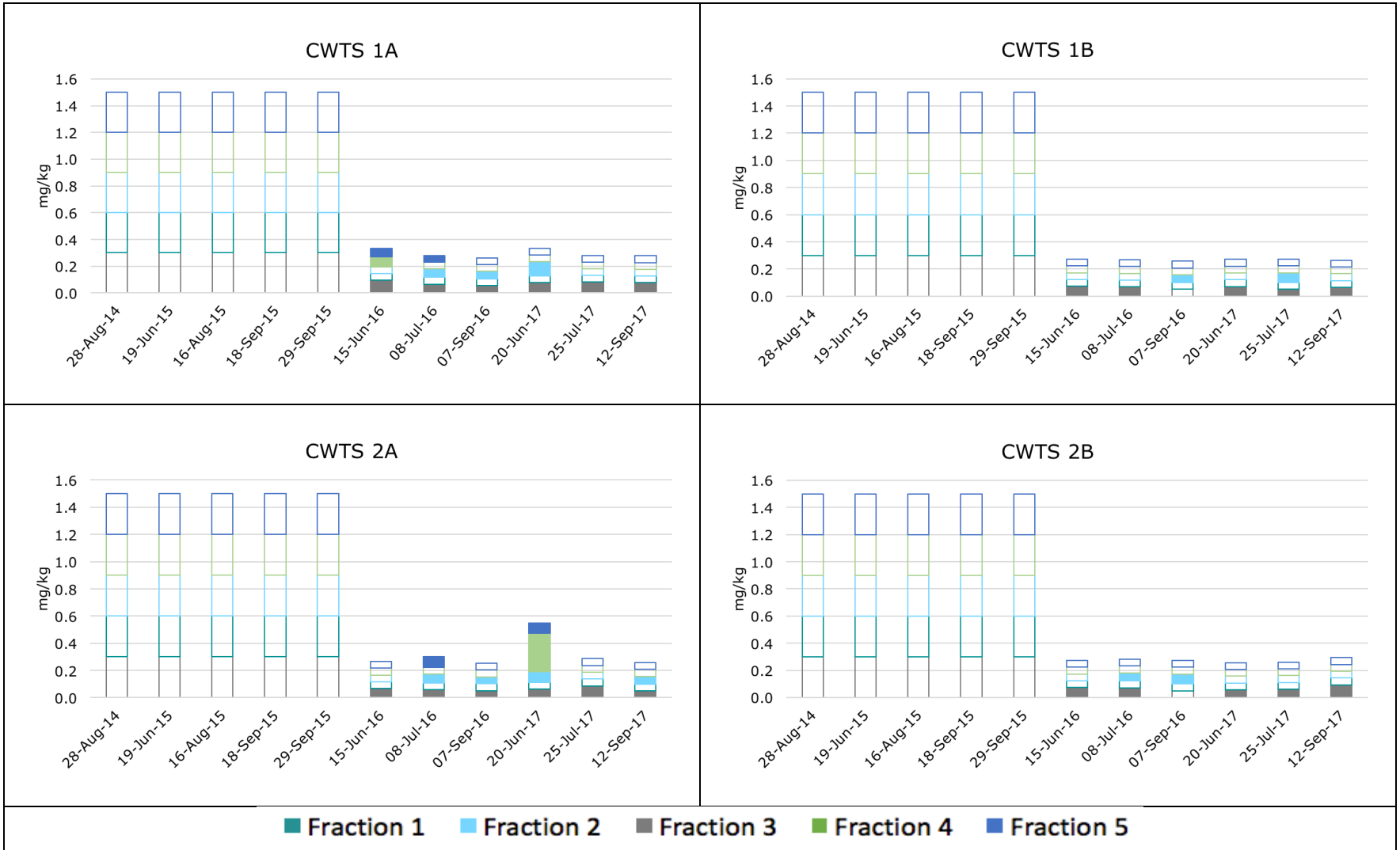



**Figure B23 – Fraction distribution of cadmium expressed as mg/kg over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Detection limits changed in 2016 and 2017, which is indicated by the smaller bars after 2015. The detection limit for cadmium in 2014 and 2015 was 0.30 mg/kg for all fractions. The detection limit for cadmium in 2016 and 2017 is 0.050 mg/kg for all fractions. Fractions are defined in Table B1.

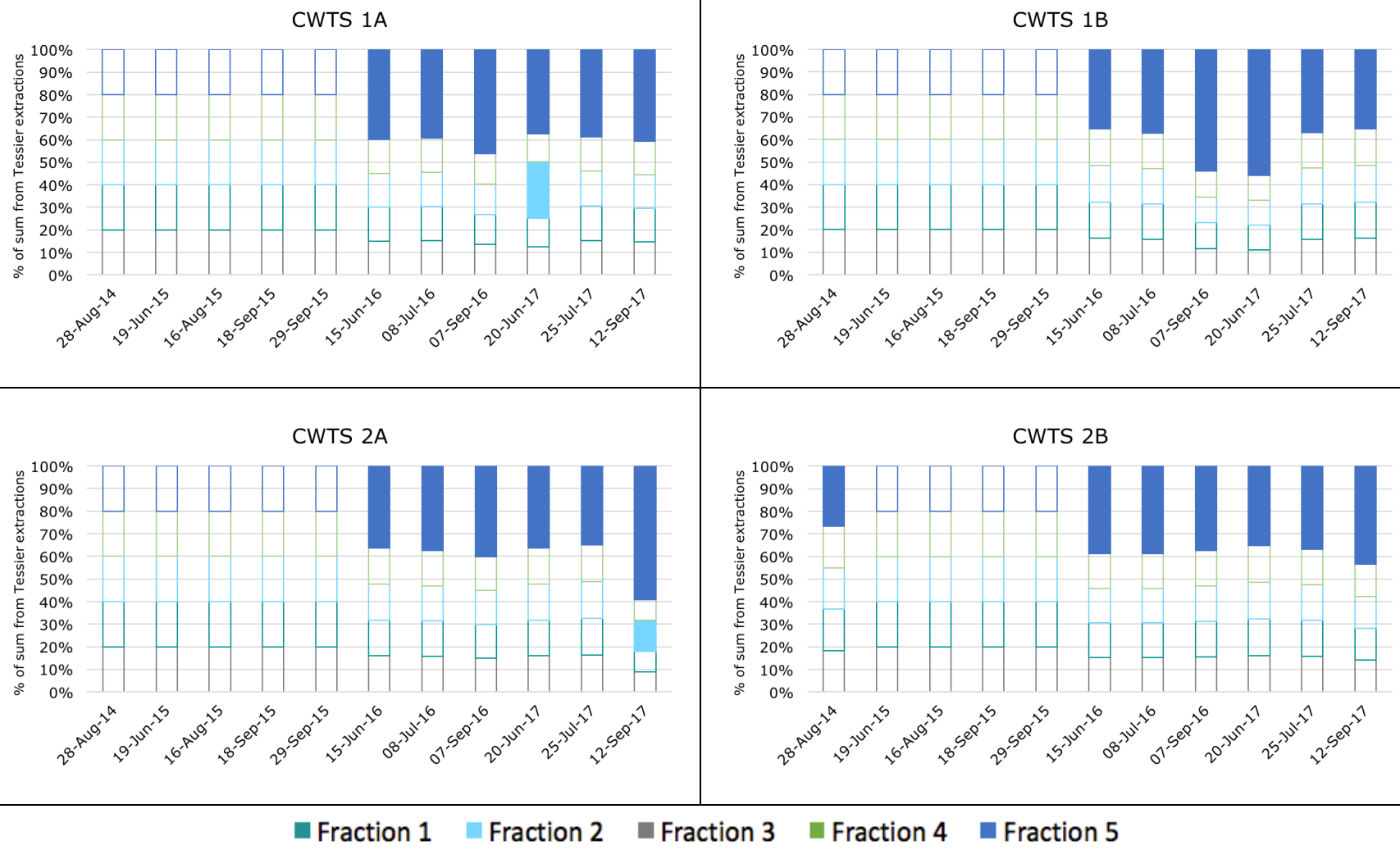



**Figure B24 – Fraction distribution of molybdenum expressed as percent over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Fractions are defined in Table B1.

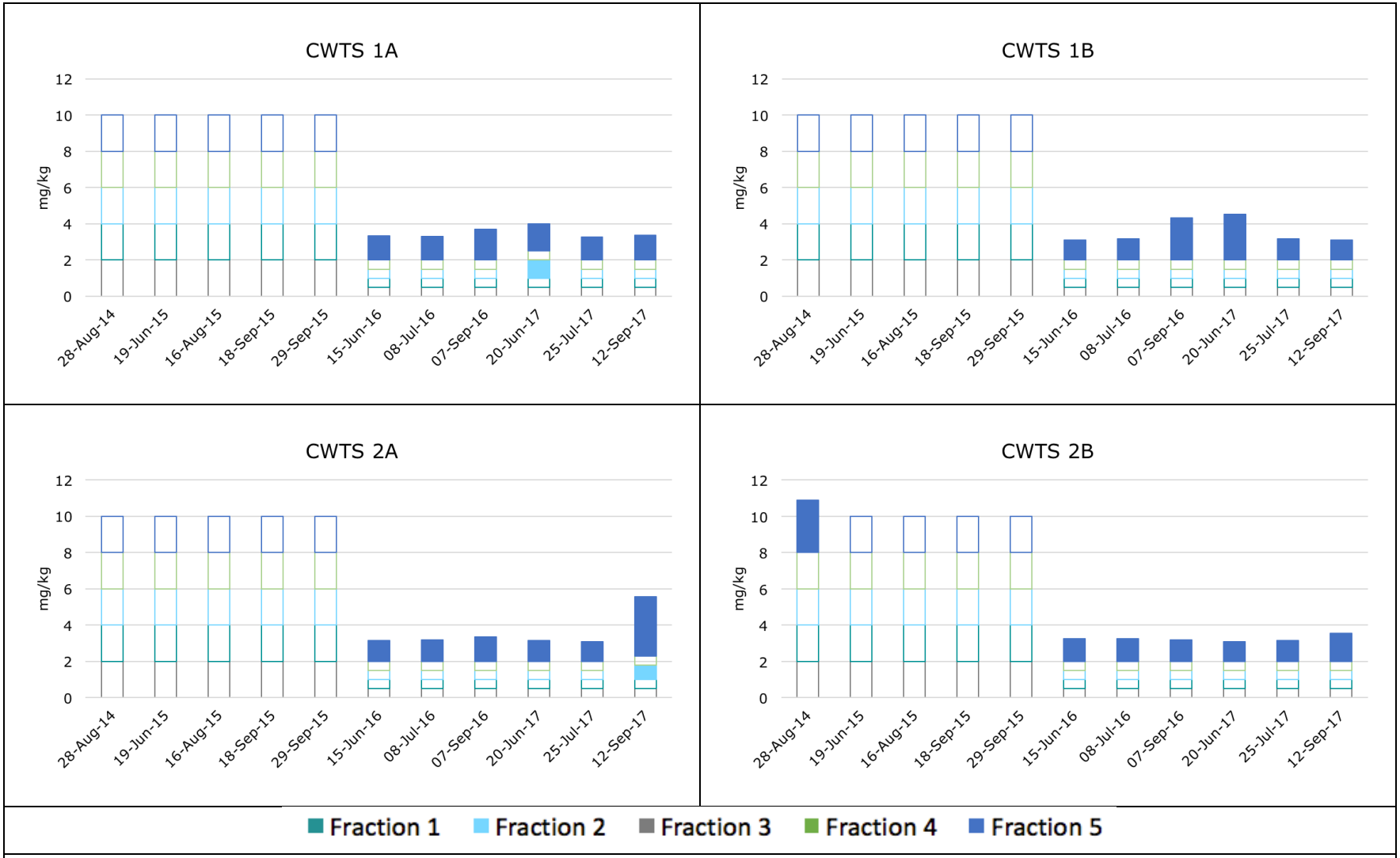



**Figure B25 – Fraction distribution of molybdenum expressed as mg/kg over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Fractions are defined in Table B1. Detection limits changed in 2016 and 2017, which is indicated by the smaller bars after 2015. The detection limit for molybdenum in 2014 and 2015 was 2.0 mg/kg for all fractions. The detection limit for molybdenum in 2016 and 2017 is 0.50 mg/kg for all fractions.

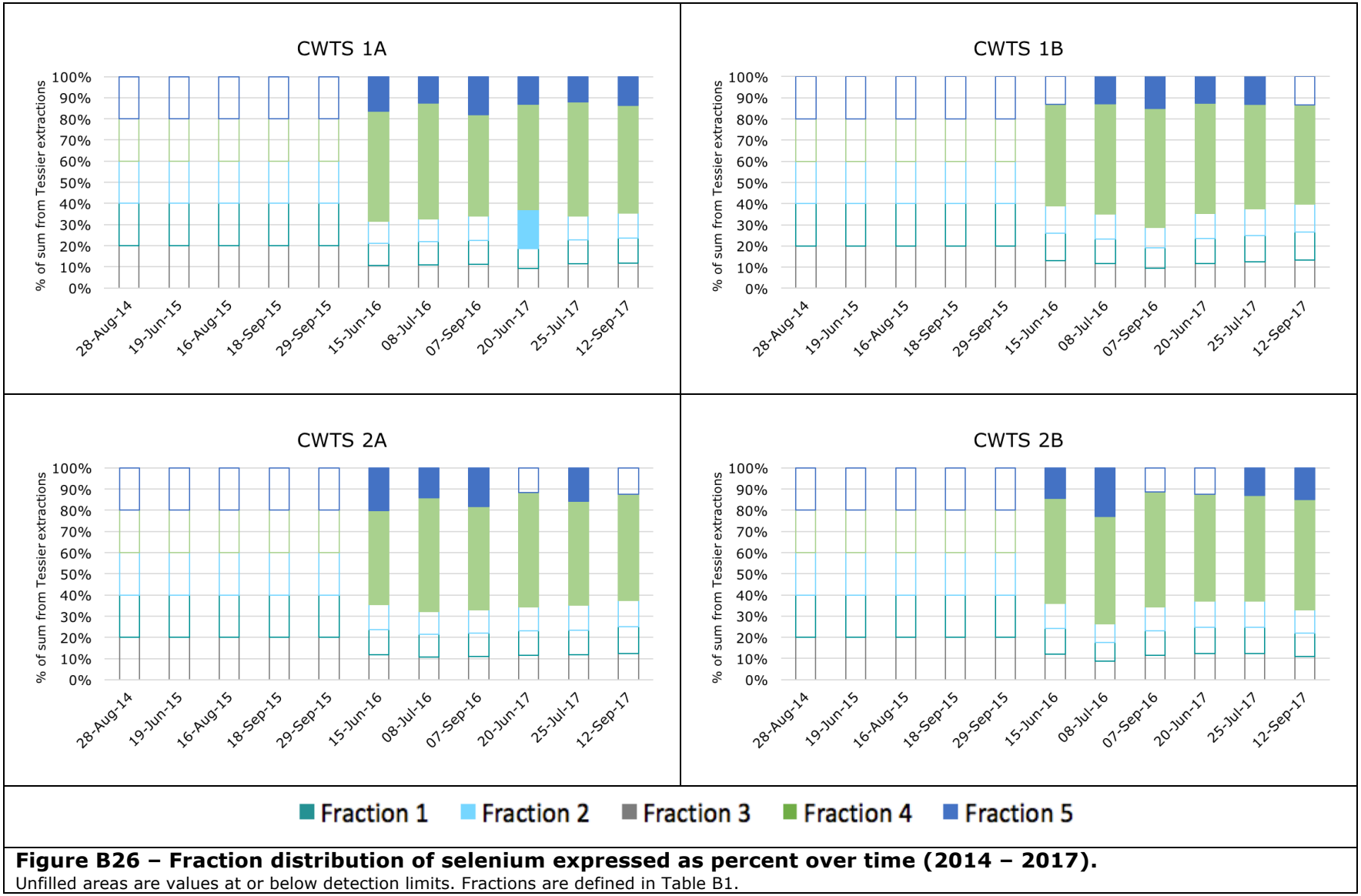



**Figure B26 – Fraction distribution of selenium expressed as percent over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Fractions are defined in Table B1.

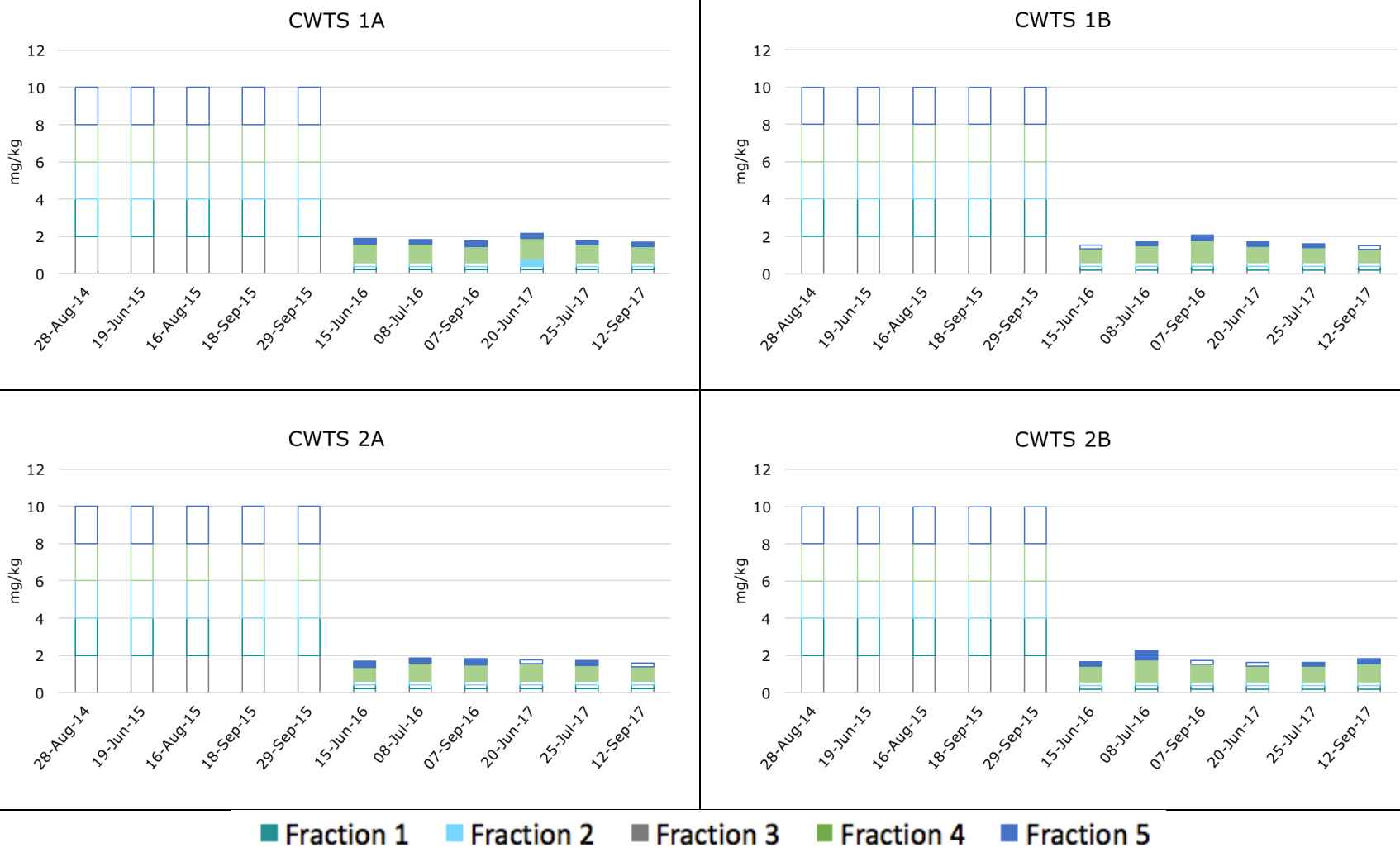



**Figure B27 – Fraction distribution of selenium expressed as mg/kg over time (2014 – 2017).**
Unfilled areas are values at or below detection limits. Detection limits changed in 2016 and 2017, which is indicated by the smaller bars after 2015. The detection limit for selenium in 2014 and 2015 was 2.0 mg/kg for all fractions. The detection limit for selenium in 2016 and 2017 is 0.20 mg/kg for all fractions. Fractions are defined in Table B1.

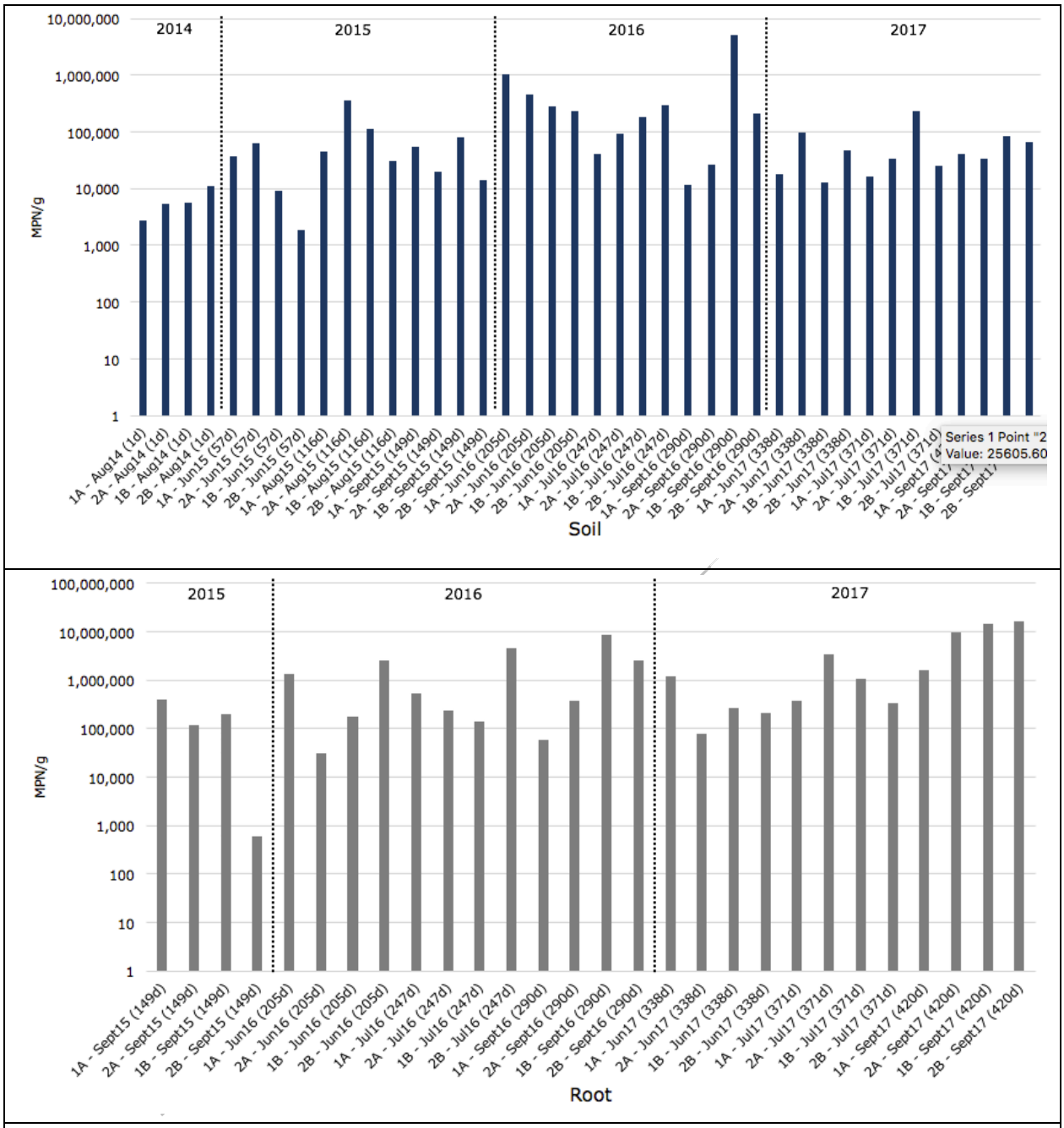
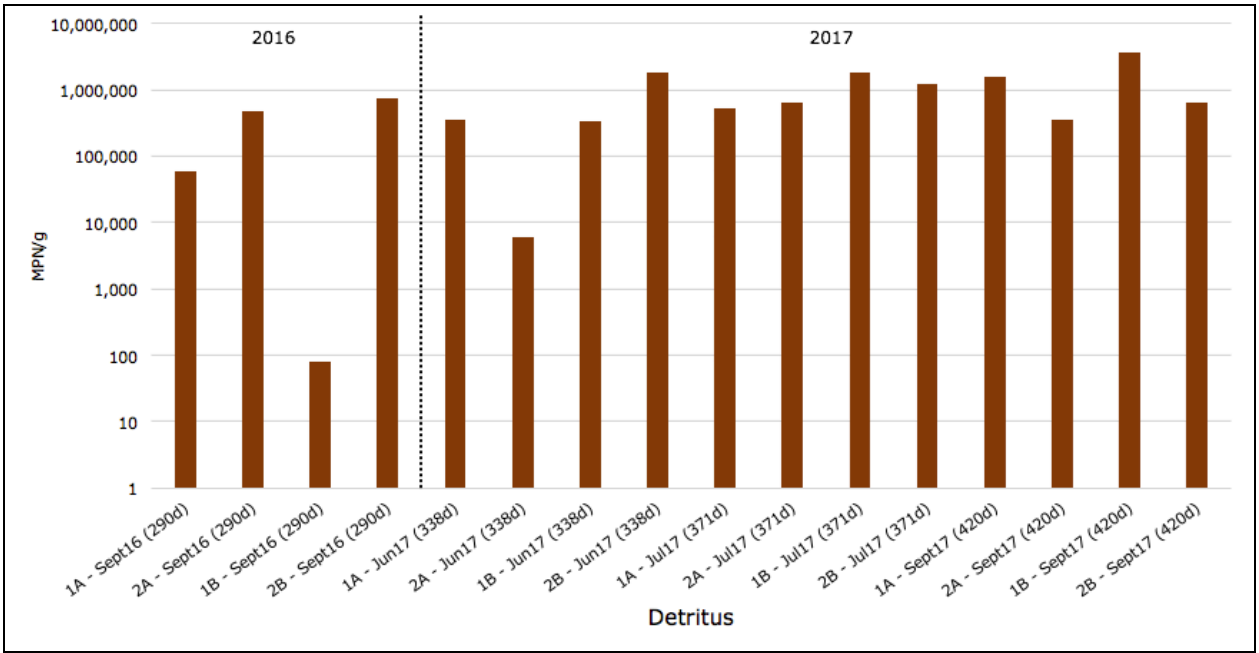



**Figure B28 – Inferred abundance of sulphide-producing bacteria in soil (top) and roots (bottom) of the demonstration-scale CWTS.**

Inferred abundance is calculated based on a combination of genetic and growth-based data. Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of CWTS. The root y-axis is different from the soil y-axis as the inferred abundance is much higher in root.



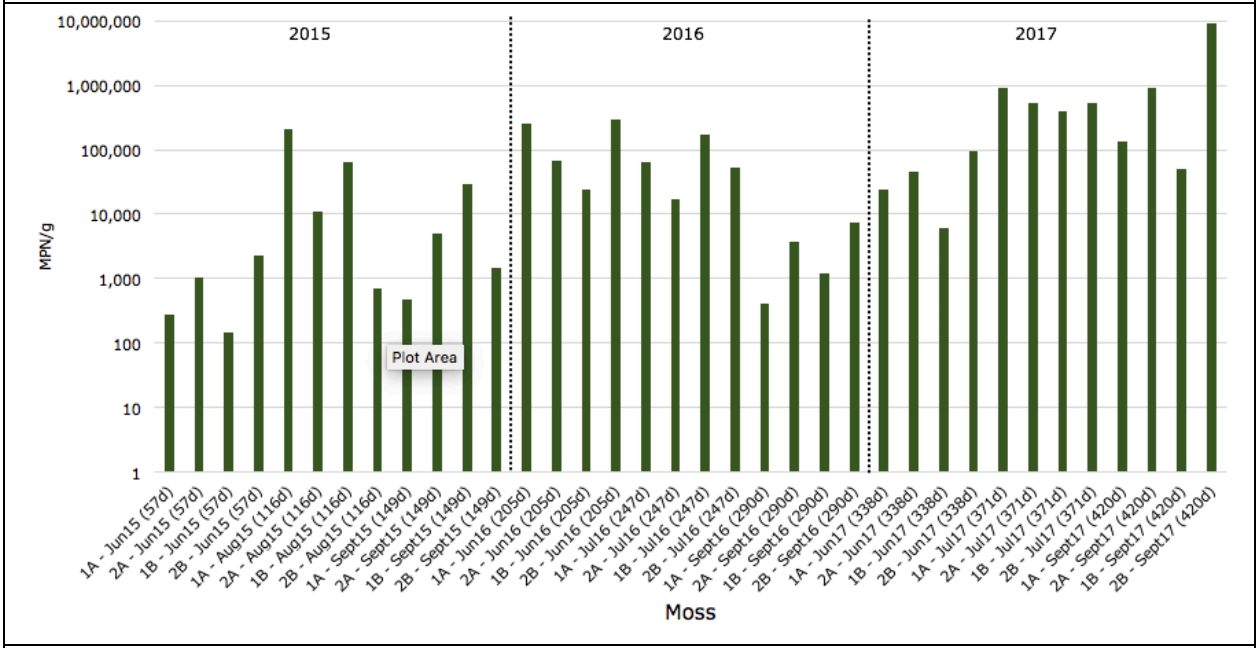




**Figure B29 – Inferred abundance of sulphide-producing bacteria in detritus (top) and moss (bottom) of the demonstration-scale CWTS.**
Inferred abundance is calculated based on a combination of genetic and growth-based data. Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of CWTS.

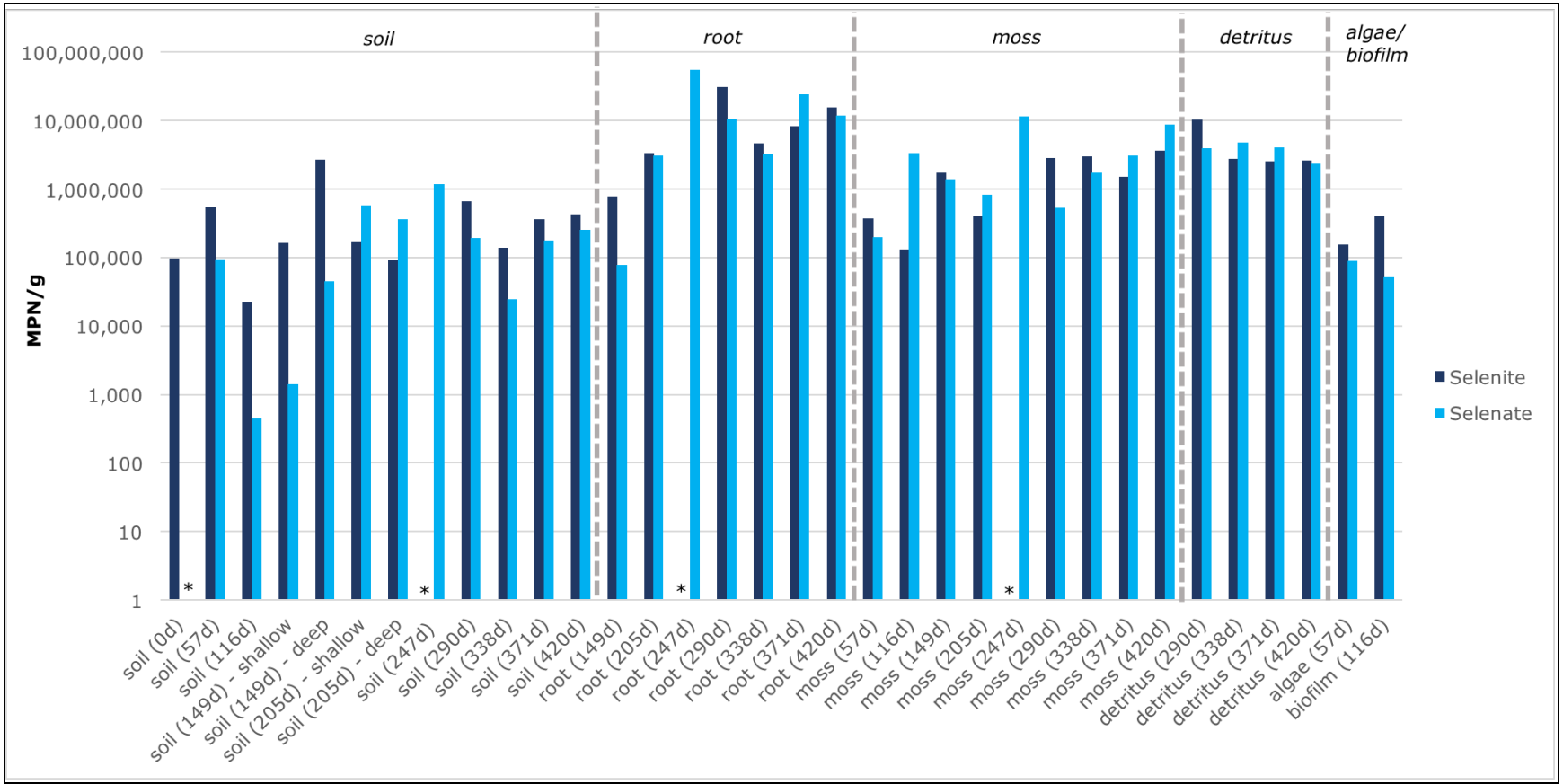



**Figure B30 – Abundance of selenite- and selenate-reducing organisms in various CWTS sample types over time.**
Shallow soil (0-5 cm); deep soil (10-20 cm); soil at 0d was that used for construction of CWTS. Organics material was added to the CWTS after day 236.

# Appendix C

**Table C1 - Schedule of work and activities for demonstration-scale CWTS**

| Item | Date | Activities | Actual |
|---|---|---|---|
| Construction | June 1-14 2014 | Identify potential location for demonstration scale CWTS (Contango site visit – 1 scientist) | Completed |
| | June - July 2014 | Engineering and geotechnical (Minto) | Completed |
| | July 2014 | Construction (Minto) | Completed |
| | August 2014 | Planting and bringing system online (Contango site visit – 1 scientist, 1 technologist), coordinate for local students to assist | Completed (no students available, brought 2 technologists) |
| Commissioning | 2014 | Acclimation and maturation at constant flow rate, ~20 hr HRT | Completed |
| | | September - Contango site visit/checkup (1 technologist, 1 scientist) | Did not occur because construction was last week of August |
| | 2015 | Continued commissioning. Operation at constant flow rate, ~20 hr HRT | Completed (at shorter HRT) |
| | | Spring – Contango site visit/checkup (1 technologist, 1 scientist), includes micro sampling | Completed |
| | | Summer - Increase depth from 10 cm to 20 cm (1 technologist), includes micro sampling | Completed (scientist) |
| | | Fall – Contango site visit/checkup (1 technologist), includes micro sampling | Completed (scientist) |
| | 2016 | Minto to add sandbags prior to first site visit and begin W15 creek monitoring | Completed May/June 2016 |
| | | Spring – Contango site visit (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Table 5 of report. HRT tracer study completed, outlined in section 7 of report. | Completed June 2016 |
| | | Summer - Contango site visit/checkup (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Table 5 of report. Evapotranspiration study completed as outlined in section 9 of report. Organics were added to the CWTS as outlined in section 5.1 of report. | Completed July 2016 |
| | | Fall - Contango site visit/checkup (1 technologist), includes microbial sampling and tasks outlined in Table 5 of report | Completed September 2016 |

| | | | |
|---|---|---|---|
| | 2017 | Continued commissioning operations at constant flow rate. | Completed May 2017 |
| | | Two evapotranspiration studies were completed | May/June 2017 |
| | | Spring – Contango site visit (1 scientist, 1 technologist), includes microbial sampling and tasks outlined in Appendix A of report. Completed HRT tracer study. Sample for AVS to assess if the added organics are having the desired effect. | Completed June 2017 |
| | | Summer - Contango site visit/checkup (1 scientist), includes microbial sampling and tasks outlined in Appendix A of report. | Completed July 2017. Seasonal water sampling was not completed due to flow interruptions. Seasonal water sampling was completed by Minto in August. |
| Commissioning | | Minto added sandbags to outflows of CWTS cells to increase water depth | August 2017 |
| | | Commissioning completed and beginning of operational period | Completed August 2017 |
| Operations | | Fall – Contango site visit/checkup (1 scientist), includes microbial sampling and tasks outlined in Table 5 of report. | Completed by Minto, after being taught microbial sampling by Contango. No site visit needed by Contango. |
| | | Monitor soil redox. Determine when it consistently reaches targeted range. | Completed throughout 2017 |
| Performance monitoring | 2018 | Fluctuate flow rates, based on expected amount of water for full-scale wetland (scaled to size). Evaluate performance of wetland at different key periods. | Throughout 2018, |
| Operations | | Develop a flow rate schedule, sampling plan, and aphid control and monitoring plan for 2018 | March, 2018 |
| | | Start water flow to CWTS; add sand bags on top of existing sandbags and to edges and end of CWTS to increase water depth to ~20 cm; aphid control using more powerful Insecticide on a routine schedule | April/May 2018 |

| | | | |
|---|---|---|---|
| | | Spring – Contango site visit; monitor for presence of aphids, collect one bag of *C. aquatilis* and one bag of polyester filter foam from each CWTS cell | May/June 2018 |
| | | Summer – Contango site visit; conduct a vegetation plot harvest and assessment of biomass produced | July/August 2018 |
| | | Conduct evapotranspiration study for warmer months | July/August 2018 |
| | | Fall – Contango site visit (if necessary), replanting if needed. | September 12, 2018 |
| | | 2018 Update Report | December 2018 |
| Reporting | 2014-2018 | Reporting will be performed annually, with verbal and/or emailed interim updates | On Schedule |

[1] The commissioning-B period will continue in 2017 until the demonstration-scale CWTS performance is consistently achieving performance expectations.

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# Technical Memo

**To:** Ryan Herbert, Environmental and Permitting Manager, Capstone Mining Corp. Minto Mine

**From:** Monique Simair & Rachel Martz, Contango Strategies Ltd.

**Date:** December 2017

**Project:** Minto Explorations Ltd. - Future Terraced Wetland (FTW) area near W15

**Client:** Capstone Mining Corp.

**Subject:** 2017 Future Terraced Wetland Area Monitoring Program

**Document #:** 011_1217_09B

## 1. Introduction

Minto Mine's Reclamation and Closure Plan (2017-01) includes consideration for a future terraced wetland (FTW) with in the upper south-west reach of the Minto Creek watershed to treat water that is impacted by the Southwest Waste Rock Dump (SWD) seepage. Therefore, Contango was contracted in 2016 to complete an assessment of the FTW area to determine if a terraced wetland was practicable for improving water quality at the W15 pond (collection point for the watershed). Contango completed an initial study of the FTW area in 2013 during a site assessment (Contango, 2014). In 2016 Contango implemented a monitoring program to define the seepage inflow path to the FTW area, and assess water quality over time (Contango, 2017a). This current memo is an update to the FTW monitoring program, with 2017 data incorporated. These findings are guiding an options assessment of the FTW area.

### 1.1 2013 Study Findings

In 2013, a site assessment was completed by Contango Strategies Ltd. (Contango, 2014) to inform the design of site-specific passive treatment technologies for the Minto site post closure. One of the primary efforts of the 2013 site assessment was to identify natural water treatment processes that are currently occurring at the Minto site. As such, the focus of the 2013 assessment was on the SWD drainage, which consists of SWD seepage, the upper reaches of Minto Creek and a seepage collection pond area known as "W15".

One of the primary findings of the 2013 assessment was that there were elevated concentrations of constituents at the W15 sampling location, and in the SWD seeps but concentrations were lower in the seepage fed creek upstream of W15. This suggested that natural water treatment was occurring between seeps along the toe of the SWD and the creek. The initial field investigation in 2013 suggested that the source of contaminants at W15 was from road runoff from a culvert entering the W15 area (Contango, 2014), which was later found to also include water from the W38 SWD seep. However, there was only one set of data from 2013 on which to make this inference so further studies were warranted.

### 1.2 2016 Study Findings

In June 2016, a monitoring program was developed and initiated on the components of the SWD drainage area. The monitoring program was intended to further investigate the findings of the 2013 site assessment and determine the source of impacted water to the W15 seepage

collection pond. The monitoring program selected five additional sampling sites (FTW-A, -B, -B1, -C, and –D) that intercepted locations where water was entering the W15 pond. FTW-A, -B, and -B1 were branches of the main creek that feed the W15 pond from the southwest, and FTW-C and -D were receiving seepage water from W38 (FTW-D had higher flows than FTW-C, and corresponded to the area identified in 2013 that also had culvert runoff). Based on 2016 findings it was concluded that FTW-B was representative of the water entering W15 from the creek to the southwest, and was low in copper concentrations. Meanwhile, high copper concentrations were found at FTW-D entering W15 from the west, and suggests that seepage from W38 is the major load contribution, rather than the creek coming from W10 to W15, which was originally the target for treatment by the FTW. Based on the results of the 2016 monitoring program (Contango, 2017), water quality monitoring was recommended to continue in 2017 to further assess these findings.

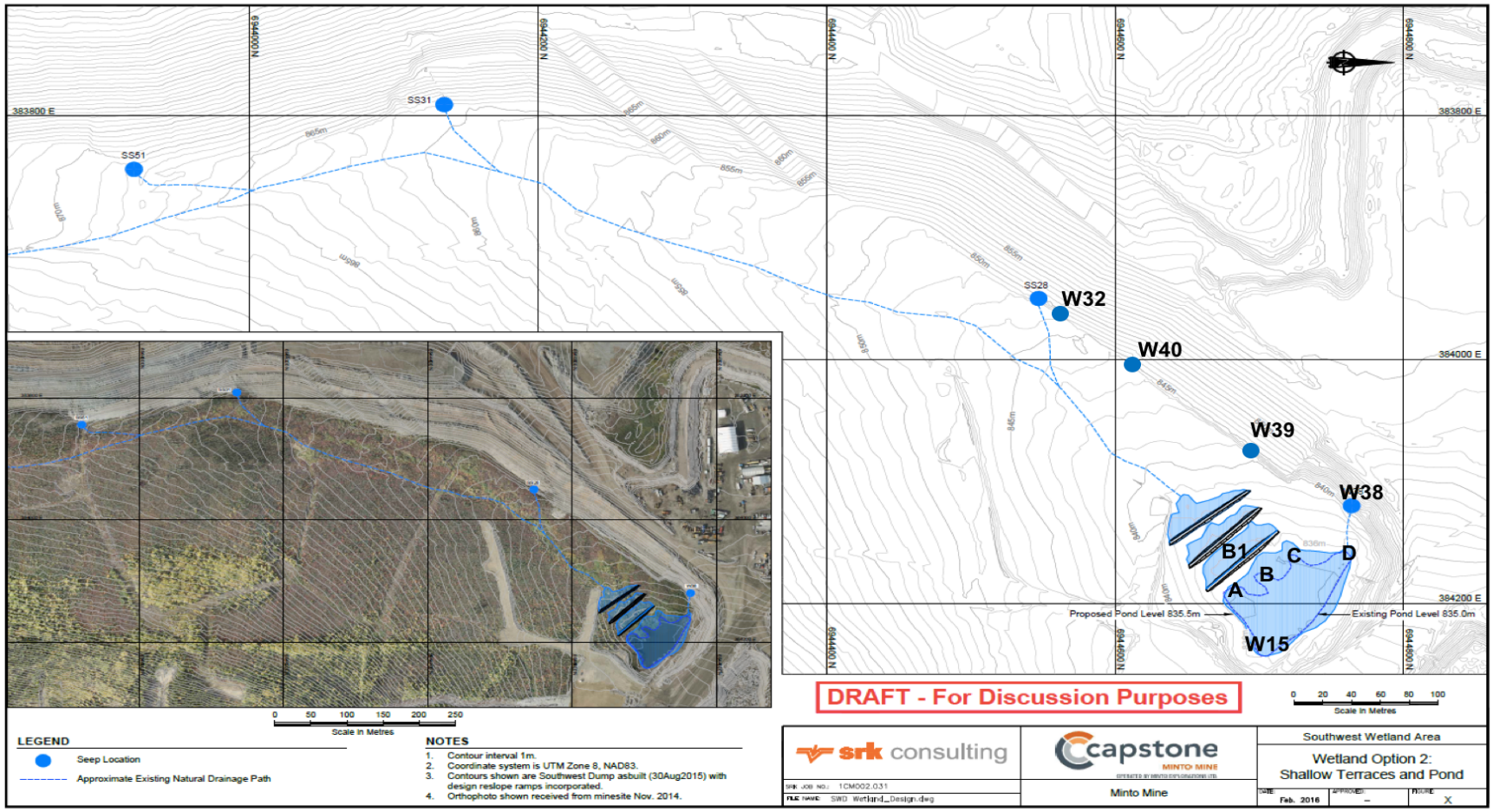



**Figure 1 - Proposed terraced wetlands and sampling locations.**
Estimated location of W32, W39, and W40 seeps shown on map. W39 is approximately 80 m southwest of W38 on the same toe of the SWD. Sites A, B, B1, C and D are equivalent to sites FTW-A, FTW-B, FTW-B1, FTW-C, FTW-D discussed in this report. W10 sampling location is approximately 1.5 km Southwest of W15.

### 1.3 2017 Study Objectives

The objective of the 2017 program was to continue monitoring and gathering additional data to more accurately determine the source and quality of impacted water to the W15 pond area, such that a terraced wetland or other treatment options could be properly selected, designed, and situated. Sampling sites were refined in 2017 to include FTW-B, FTW-D, W15, and surrounding seeps (i.e., removing FTW-A, -B1, and -C).

## 2. Methods

The 2017 FTW monitoring program consisted of water sampling at FTW-B, FTW-D (downstream of Seep W38), and W15 on a biweekly basis. Seeps W32, W38, W39, and W40 in the W15 area were also monitored on a biweekly basis in 2017, as part of the Minto Mine's routine monitoring program. Data from these seeps was also incorporated into the FTW monitoring program. The 2017 sampling program collected limited data from the seep locations as most of the seeps were dry (Table 1). FTW-D was also dry for most of 2017 which is expected as the flow at FTW-D generally appears to originate from seep W38 which was also dry.

Land reclamation on the SWD has been ongoing through this monitoring program and is intended to decrease seepage in the area, and therefore may be contributing to changing seepage patterns and diminishing the quantity of water that reaches the seeps. Additionally, 2017 had 24% less precipitation than 2016 with total rainfall between April and September in 2016 amounting to 223 mm and in 2017 amounting to 169 mm (weather data obtained from Minto).

Water samples for the FTW monitoring program have been analyzed for parameters in Table 2. Samples were collected by grab method, field filtered, and/or preserved as appropriate to the analysis. Following each sampling event, in situ measurements were taken using a handheld YSI unit at each sample location. *In situ* parameters measured include temperature, dissolved oxygen (DO), specific conductance (SPC), pH, and oxidation-reduction potential (ORP).

Dissolved metals concentrations were used in this report rather than total metals concentrations, as total values were variable. The variability of the total metals concentrations is likely owing to particulate material containing metals being part of the grab sample collection method (influenced by TSS) and are likely not representative of the dissolved bioavailable metals concentrations at the sampling locations.

**Table 1 – Sample location monitoring.**

| Date | Sample Locations | | | | | | |
|---|---|---|---|---|---|---|---|
| | W15 | W32[1] | W38[1] | W39[1] | W40[1] | FTW-B | FTW-D[2] |
| 26-May-17 | Sampled | Sampled | Not Sampled[3] | Not Sampled[3] | Not Sampled[3] | Sampled | Sampled |
| 09-Jun-17 | Sampled | Sampled | Frozen | Dry | Dry | Sampled | Sampled |
| 21-Jun-17 | Sampled | Dry | Dry | Dry | Dry | Sampled | Dry |
| 07-Jul-17 | Sampled | Dry | Dry | Dry | Dry | Sampled | Dry |
| 22-Jul-17 | Sampled | Dry | Dry | Dry | Dry | Sampled | Dry |
| 04-Aug-17 | Sampled | Dry[4] | Dry | Dry | Dry[4] | Sampled | Dry |
| 11-Aug-17 | Not Sampled[3] | Dry | Dry[5] | Dry[5] | Dry | Not Sampled[3] | Dry[5] |
| 01-Sep-17 | Sampled | Dry | Dry | Dry | Dry | Sampled | Dry |
| 11-Sep-17 | Sampled | Dry | Dry | Dry | Dry | Sampled | Dry |
| 29-Sep-17 | Sampled | Dry | Dry | Dry | Dry | Sampled | Dry |

[1] Seeps were often dry in 2017 due to land reclamation in the area and low precipitation.
[2] FTW-D is fed by W38 (which was often dry), resulting in limited samples from FTW-D.
[3] Sampling events missed.
[4] Site not visited due to high risk bear activity in the area. It was assumed these sites were dry due to the proximity of the seep to other seep locations that were dry.
[5] Gaps in record keeping were due to human error. It was assumed these sites were dry due to the proximity of the seep to other seep locations that were dry.

**Table 2 – 2017 water sampling and analysis program.**

| Sample location | Frequency | Water Sample Parameters |
|---|---|---|
| **W15** | Biweekly | Total metals<br>Dissolved metals<br>Routine (Ca, Mg, Na, K, Cl, $SO_4$, $NO_3$, $NO_2$, hardness, Alkalinity, pH, EC, TDS)<br>TSS<br>COD<br>TKN<br>Ammonia<br>TOC<br>Total Nitrogen |
| **W32** | | |
| **W38** | | |
| **W39** | | |
| **W40** | | |
| **FTW-B** | | |
| **FTW-D** | | |

## 3. Results

Seepage from W32 appears to flow towards the creek before sampling site FTW-B, but was not observed to reach the creek by surface flow. That is, the seepage water daylights at the toe of the SWD, but infiltrates to the ground and did not appear to surface before the creek. There appears to be natural attenuation (e.g., treatment or dilution) occurring between these seeps and the creek (as measured at FTW-B). This is suggested with the lower concentrations of all constituents of concern (cadmium, copper, molybdenum, selenium, nitrate, nitrite) at FTW-B compared the seeps (Table 3, Figure 2 to Figure 7). Additionally, SPC was higher at W32, but lower at FTW-B, reaffirming that natural treatment or dilution is occurring between W32 and FTW-B (Table 4). Moreover, FTW-B had lower concentrations of copper, molybdenum, and nitrate (with the exception of the first sampling event in 2017 for nitrate) and similar concentrations of cadmium and selenium compared to W15 throughout 2016 and 2017 (Table 3, Figure 2 to Figure 7).

The lower concentrations observed at FTW-B compared to W15 confirms that FTW-B and contributing seeps are not the source of elevated constituents in the W15 pond (Table 3, Figure 2 to Figure 7). The constituents of concern must therefore enter the W15 pond from another source. Following the 2016 monitoring program, seeps feeding FTW-D (e.g., seep W38) were hypothesized to be the source of elevated concentrations of constituents at W15 (Contango, 2017a). The 2016 findings showed high copper concentrations at FTW-D (fed by W38) compared to W15 (Table 3, Figure 2). The 2017 sampling also indicated elevated concentrations of all constituents of concern (except nitrate) at FTW-D compared to W15, further suggesting that W38 (which feeds FTW-D) is the source of elevated metals and metalloids at W15 (Table 3, Figure 2 to Figure 7).

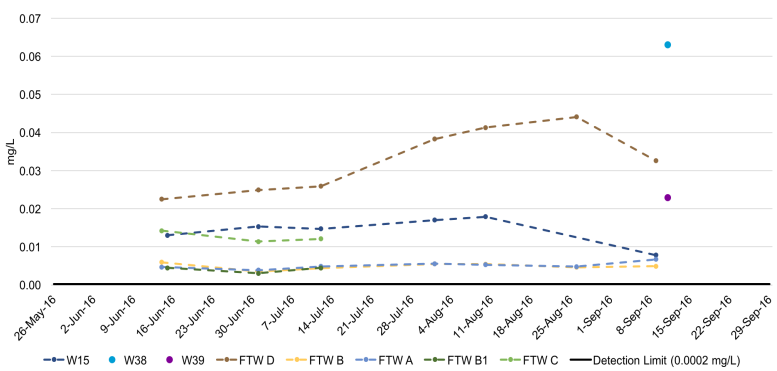
Annual trends at W15 water chemistry for copper have remained consistent since 2014. This is notable because in 2016 W38 flowed year-round while in 2017 W38 was mostly dry. Although there was no surface water flow at FTW-D in 2017, it may contribute constituents to W15 through subsurface flow. This is supported by the similar copper concentrations observed throughout the monitoring program, as well as the seasonal trends occurring each year (Figure 8). Alternatively, it is possible that there might be elevated constituents in the soils and sediments of W15 pond, releasing metals and metalloids into the water as has been seen with the copper and aluminum bearing soils that were used in construction of the CWTS on site (Contango, 2015; 2016; 2017b).

Reclamation activities and lower precipitation appear to be the major contributing factors in decreased visible seepage water flows along the toe of the SWD. Reclamation activities over the past two years include re-contouring and overburden placement in the SWD. Annual precipitation in 2017 decreased compared to 2016. Planned reclamation activities for the SWD, such as covers and vegetation, are expected to improve water quality and decrease volumes of water reporting from the seepage locations.

**Table 3 – FTW 2017 sampling program average, minimum, and maximum concentrations for constituents of concern.**

| Parameter (mg/L) | | W15 | | W32 | | FTW-B | | FTW-D | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| **Cd** | Min | 0.000005 | 0.000005 | N/A | 0.000019 | 0.000005 | 0.000005 | 0.000008 | 0.000021 |
| | Avg | 0.000007 | 0.000006 | N/A | 0.000039 | 0.000010 | 0.000006 | 0.000020 | 0.000033 |
| | Max | 0.000011 | 0.000009 | N/A | 0.000059 | 0.000024 | 0.000012 | 0.000038 | 0.000046 |
| **Cu** | Min | 0.0078 | 0.0088 | N/A | 0.0208 | 0.0036 | 0.0037 | 0.0225 | 0.0368 |
| | Avg | 0.0143 | 0.0192 | N/A | 0.0293 | 0.0049 | 0.0082 | 0.0328 | 0.0449 |
| | Max | 0.0179 | 0.0286 | N/A | 0.0377 | 0.0060 | 0.0230 | 0.0441 | 0.0529 |
| **Mo** | Min | 0.00248 | 0.00194 | N/A | 0.00647 | 0.00216 | 0.00193 | 0.00243 | 0.00490 |
| | Avg | 0.00340 | 0.00257 | N/A | 0.01214 | 0.00264 | 0.00235 | 0.00509 | 0.00696 |
| | Max | 0.00395 | 0.00319 | N/A | 0.01780 | 0.00319 | 0.00289 | 0.00723 | 0.00902 |
| **Se** | Min | 0.0023 | 0.0013 | N/A | 0.0125 | 0.0026 | 0.0014 | 0.0020 | 0.0007 |
| | Avg | 0.0038 | 0.0018 | N/A | 0.0159 | 0.0033 | 0.0019 | 0.0064 | 0.0018 |
| | Max | 0.0047 | 0.0028 | N/A | 0.0193 | 0.0041 | 0.0023 | 0.0082 | 0.0029 |
| **$NO_3$** | Min | 8.8 | 4.9 | N/A | 33.8 | 9.0 | 7.2 | 14.0 | 0.5 |
| | Avg | 14.8 | 7.3 | N/A | 40.9 | 12.7 | 9.3 | 24.2 | 4.4 |
| | Max | 19.1 | 9.8 | N/A | 47.9 | 17.4 | 11.5 | 29.0 | 8.2 |
| **$NO_2$** | Min | 0.0093 | 0.0062 | N/A | 0.2220 | 0.0056 | 0.0036 | 0.0020 | 0.0950 |
| | Avg | 0.0261 | 0.0382 | N/A | 0.3785 | 0.0155 | 0.0607 | 0.0095 | 0.2135 |
| | Max | 0.0375 | 0.1580 | N/A | 0.5350 | 0.0239 | 0.4430 | 0.0264 | 0.3320 |

N/A = location was not sampled in 2016 as the seep was dry. W32 and FTW-D have recorded values from 26-May-17 and 09-Jun-17. W15 and FTW-B have recorded values from 26-May-17 to 29-Sep-17.



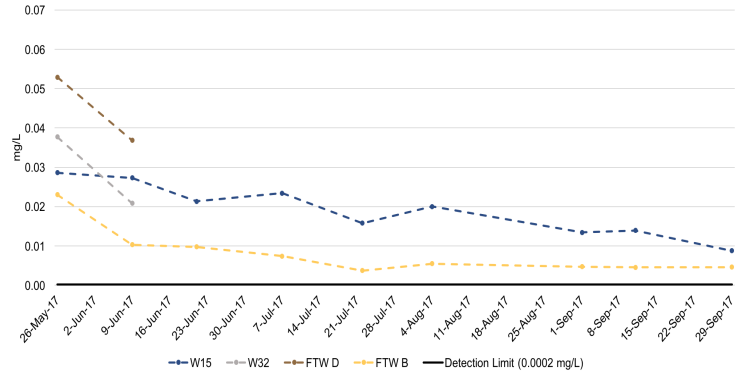
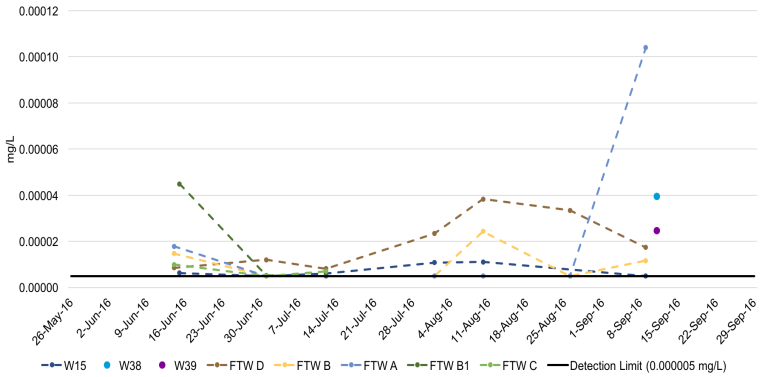




**Figure 2 - Concentrations of dissolved copper at the W15 pond area.**
The left graph shows 2016 data and the right graph shows 2017 data. W38 and W39 were sampled once in 2016 and are represented by the single points.



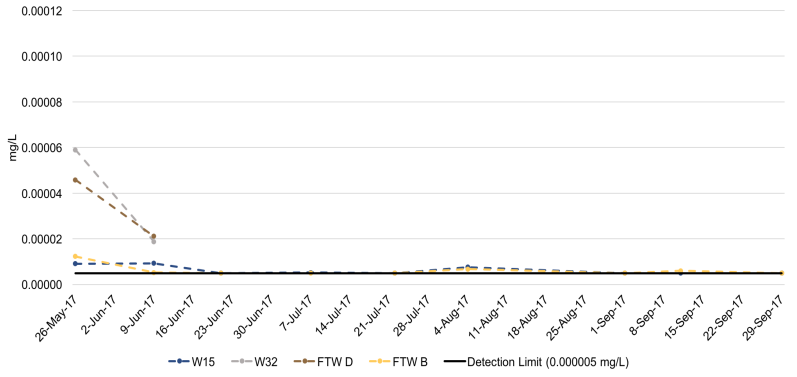
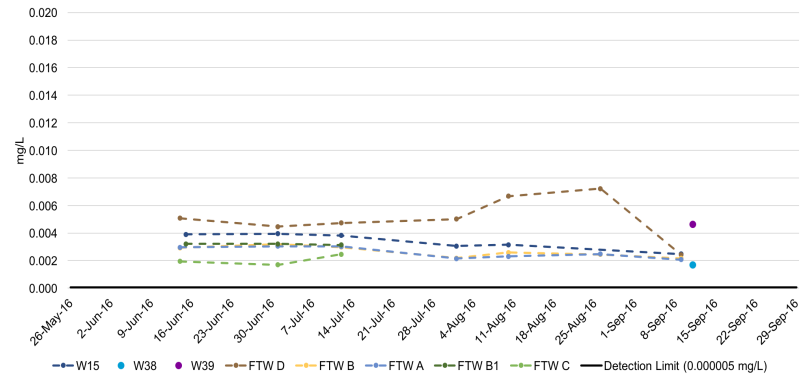




**Figure 3 – Concentrations of dissolved cadmium at the W15 pond area.**
The left graph shows 2016 data and the right graph shows 2017 data. W38 and W39 were sampled once in 2016 and are represented by single points.



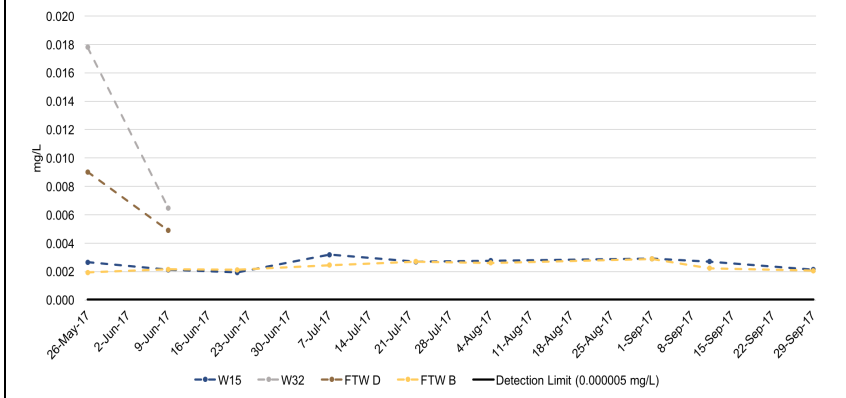
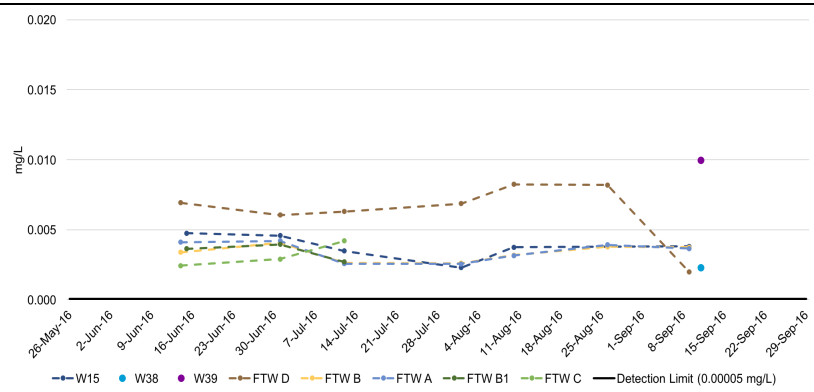




**Figure 4 – Concentrations of dissolved molybdenum at the W15 pond area.**
The left graph shows 2016 data and the right graph shows 2017 data. W38 and W39 were sampled once in 2016 and are represented by single points.



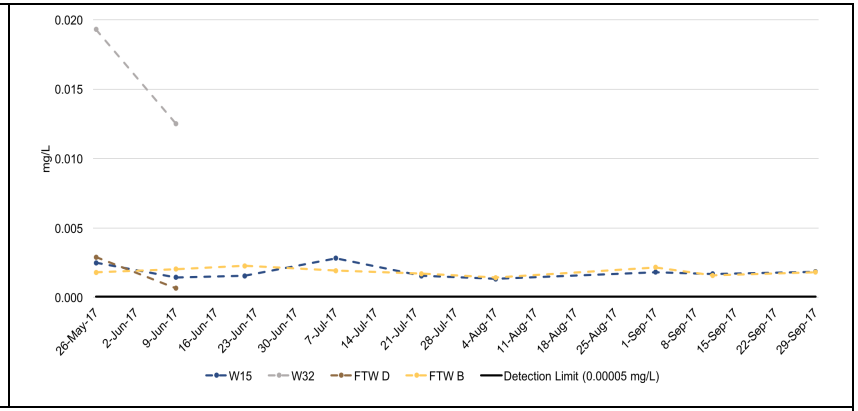




**Figure 5 – Concentrations of dissolved selenium at the W15 pond area.**
The left graph shows 2016 data and the right graph shows 2017 data. W38 and W39 were sampled once in 2016 and are represented by single points.

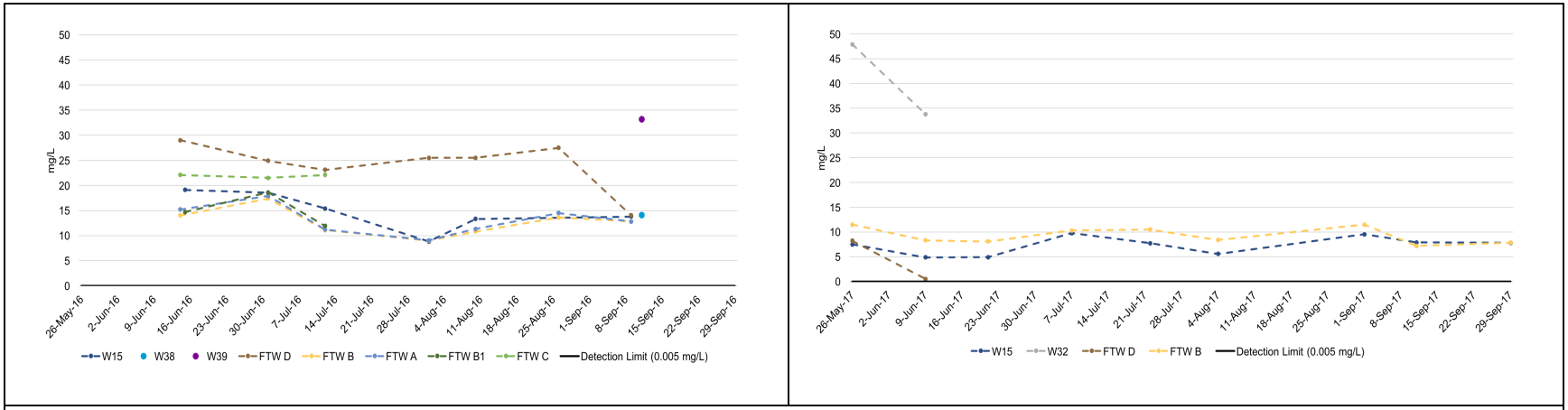



**Figure 6 - Concentrations of nitrate at the W15 pond area.**
The left graph shows 2016 data and the right graph shows 2017 data. W38 and W39 were sampled once in 2016 and are represented by single points.

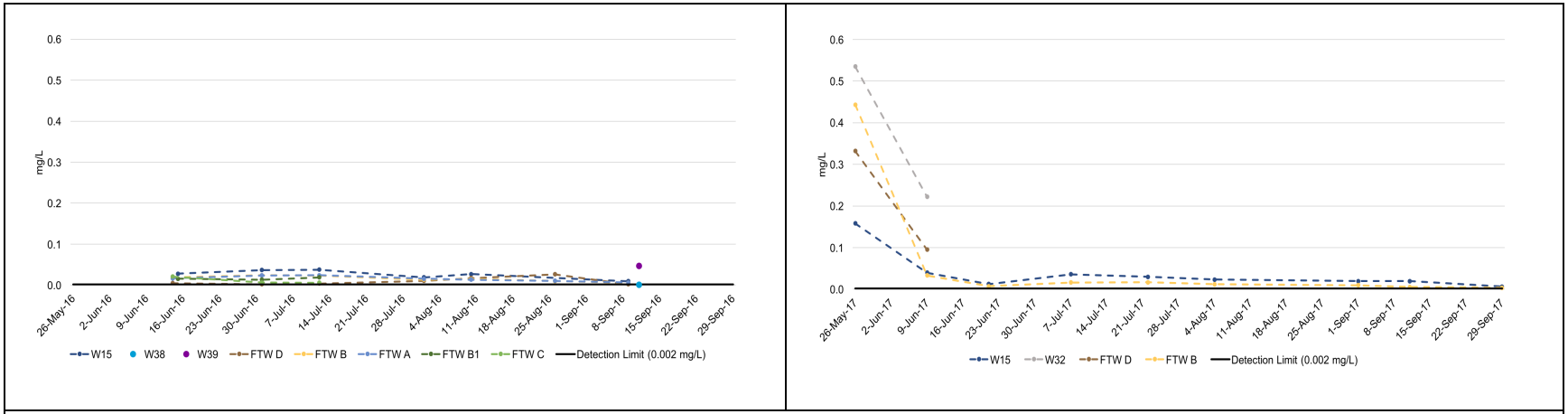



**Figure 7 - Concentrations of nitrite at the W15 pond area.**
The left graph shows 2016 data and the right graph shows 2017 data. W38 and W39 were sampled once in 2016 and are represented by single points.

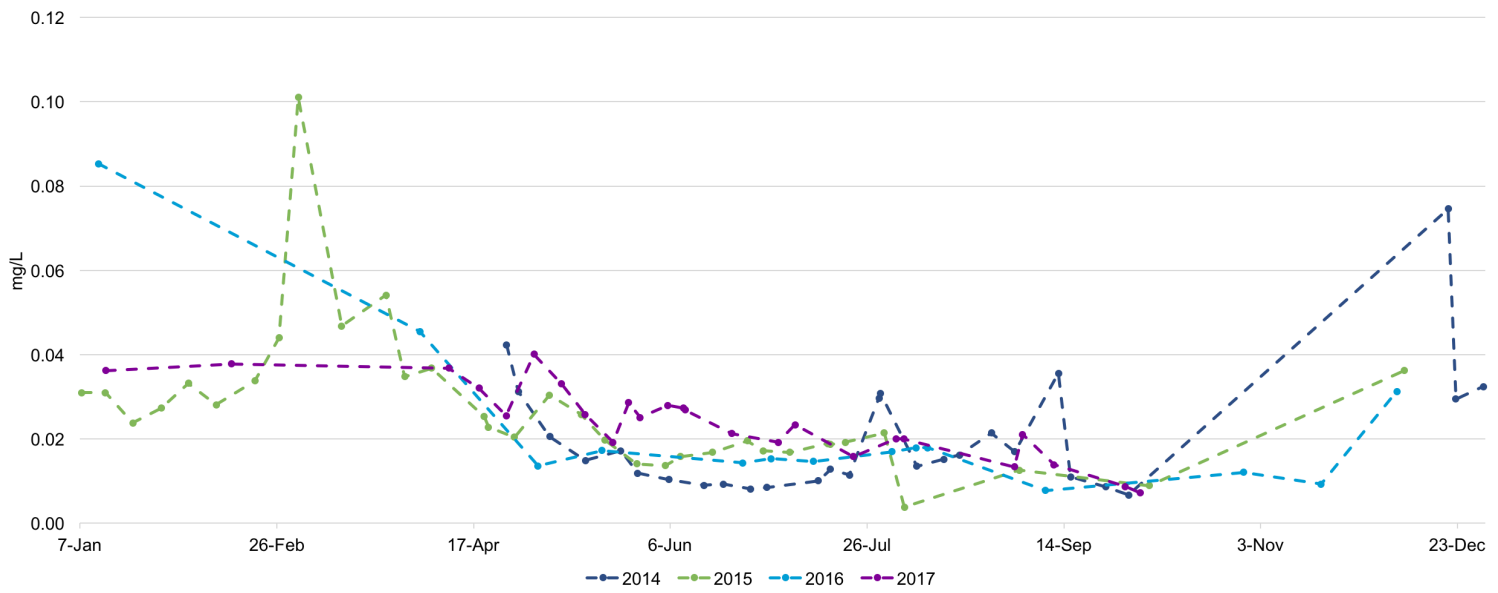



**Figure 8 – Comparison of seasonal variation of dissolved copper at W15 pond for 2014 through 2017.**
Dissolved copper concentrations from 2014 to 2017 at W15.

**Table 4 – 2017 average, minimum, and maximum *in situ* water measurements.**

| Parameter | | W15 | W32 | FTW-B | FTW-D |
|---|---|---|---|---|---|
| Temp (°C) | Min | 2.4 | 0.9 | 0.5 | 1.9 |
| | Avg | 12.7 | 1.5 | 5.4 | 6.7 |
| | Max | 20.2 | 2.1 | 9.2 | 11.5 |
| | SD | 6.6 | N/A | 3.1 | N/A |
| DO (mg/L) | Min | 6.75 | 6.34 | 7.58 | 8.97 |
| | Avg | 9.36 | 9.72 | 10.12 | 10.75 |
| | Max | 13.66 | 13.09 | 12.91 | 12.53 |
| | SD | 2.16 | N/A | 1.60 | N/A |
| SPC (µS/cm) | Min | 456.2 | 886 | 529.3 | 529.3 |
| | Avg | 657.8 | 1107 | 712.7 | 555.8 |
| | Max | 852 | 1328 | 910 | 582.3 |
| | SD | 150.1 | N/A | 103.8 | N/A |
| pH | Min | 7.54 | 7.49 | 7.43 | 7.56 |
| | Avg | 7.72 | 7.57 | 7.60 | 7.66 |
| | Max | 7.87 | 7.65 | 7.77 | 7.75 |
| | SD | 0.11 | N/A | 0.13 | N/A |
| ORP (mV) | Min | 83.1 | 126.6 | 5.9 | 192.2 |
| | Avg | 132.0 | 195.6 | 94.3 | 210.6 |
| | Max | 206.1 | 264.5 | 205 | 229 |
| | SD | 46.5 | N/A | 73.7 | N/A |
| # of samples | n | 9 | 2 | 9 | 2 |

W32 and FTW-D have recorded values from 26-May-17 and 09-Jun-17.
W15 and FTW-B have recorded values from 26-May-17 to 29-Sep-17.
SD = standard deviation, N/A = SD was not calculated as there were not enough samples; DO = dissolved oxygen; SPC = specific conductance; ORP = oxidation-reduction potential.

## 4. Recommendations

The location of the conceptual FTW layout design proposed in 2015 should be reconsidered as the seeps contributing impacted water to the W15 area would not be intercepted by the current layout (since they are downstream). Therefore, treatment by terraced wetland is not recommended between W10 and FTW-B. The monitoring program in 2016 and 2017 has indicated that the creek is not the source of elevated metals. Rather, the source of constituents appears to be seeps reporting directly from the SWD to the west side of the W15 pond (i.e., W38 seep, via FTW-D monitoring point or subsurface flow). Additionally, since water from the creek (FTW-B) does not contribute to elevated constituents at W15, it will not require treatment.

Due to the construction of the ridgetop waste rock dump to the southeast of W15, the area should continue to be monitored and re-evaluated to determine if it is suitable for a treatment wetland or other passive treatment. It is recommended that the monitoring program continue in 2018. The 2018 spring and fall seepage monitoring program will identify if seep locations have migrated or if new seeps have emerged.

During the 2018 monitoring program, it is also recommended that the soil from the W15 pond be analyzed for leachable and total metals to determine if the elevated metal concentrations are being re-released from the soils and contributing to elevated concentrations in the W15 pond.

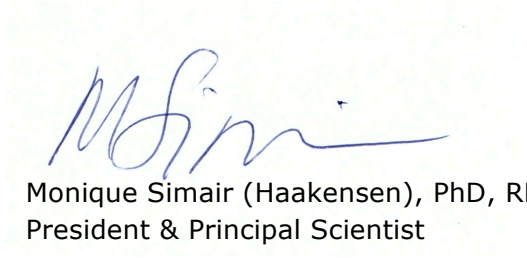
Once the chemistry and location of the seeps along the toe are delineated, flows should be assessed to determine potential load contributions to the W15 area and if treatment is feasible.

## 5. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Regards,

Contango Strategies Ltd.



Monique Simair (Haakensen), PhD, RPBio, PBiol, EP
President & Principal Scientist



Rachel Martz, BSc
Environmental Scientist



## 6. References

Contango Strategies Ltd. (2014). Minto Mine Constructed Wetland Treatment Research Program - Site Assessment. YESAB Registry documents number 2013-0100-256 and 2013-0100-257. March 24, 2014. Available at http://www.yesabregistry.ca/wfm/lamps/yesab/lowspeed/projectdetails.jsp;time=1510008082247.

Contango Strategies Ltd. (2015). Minto Mine Constructed Wetland Treatment Research Program – Demonstration Scale. March 22, 2015. Document #011_0315_01B.

Contango Strategies Ltd. (2016). Minto Mine Constructed Wetland Treatment Research Program – Demonstration Scale 2015 Update. March 2016. Document #011_0316_03B.

Contango Strategies Ltd. (2017a). Minto Mine Constructed Wetland Treatment Research Program – Demonstration Scale 2016 Update. February, 2017. Document #011_0217_05B.

Contango Strategies Ltd. (2017b). Future Terraced Wetland (FTW) Area Near W15 – Baseline Monitoring Program. Document #011_0217_06B.

**Table A1 – FTW 2017 sampling program average, min, max concentrations for constituents of concern in mg/L.**

| Parameter | Results | Surface Water Monitoring Site | Seep Monitoring Sites | FTW Monitoring Site | |
|---|---|---|---|---|---|
| | | W15 | W32 | FTW-B | FTW-D |
| Al-D | Min | 0.0060 | 0.0020 | 0.0096 | 0.0035 |
| | Avg | 0.0167 | 0.0051 | 0.0191 | 0.0050 |
| | Max | 0.0364 | 0.0082 | 0.0363 | 0.0064 |
| Al-T | Min | 0.0553 | 0.0295 | 0.0237 | 0.2970 |
| | Avg | 0.3887 | 0.5148 | 0.1092 | 0.3135 |
| | Max | 1.6200 | 1.0000 | 0.3050 | 0.3300 |
| Ag-D | Min | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| | Avg | 0.00001 | 0.00001 | 0.00001 | 0.000012 |
| | Max | 0.00001 | 0.00001 | 0.00001 | 0.000013 |
| Ag-T | Min | 0.00001 | 0.00001 | 0.00001 | 0.00003 |
| | Avg | 0.00002 | 0.00002 | 0.00001 | 0.00003 |
| | Max | 0.00008 | 0.00004 | 0.00002 | 0.00004 |
| Cd-D | Min | 0.000005 | 0.000019 | 0.000005 | 0.000021 |
| | Avg | 0.000006 | 0.000039 | 0.000006 | 0.000033 |
| | Max | 0.000009 | 0.000059 | 0.000012 | 0.000046 |
| Cd-T | Min | 0.000005 | 0.000022 | 0.000005 | 0.000032 |
| | Avg | 0.000010 | 0.000053 | 0.000009 | 0.000039 |
| | Max | 0.000027 | 0.000084 | 0.000024 | 0.000047 |
| Cr-D | Min | 0.00010 | 0.00010 | 0.00016 | 0.00010 |
| | Avg | 0.00020 | 0.00010 | 0.00022 | 0.00010 |
| | Max | 0.00030 | 0.00010 | 0.00031 | 0.00010 |
| Cr-T | Min | 0.00020 | 0.00026 | 0.00022 | 0.00020 |
| | Avg | 0.00044 | 0.00833 | 0.00038 | 0.00039 |
| | Max | 0.00084 | 0.01640 | 0.00053 | 0.00058 |
| Cu-D | Min | 0.0088 | 0.0208 | 0.0037 | 0.0368 |
| | Avg | 0.0192 | 0.0293 | 0.0082 | 0.0449 |
| | Max | 0.0286 | 0.0377 | 0.0230 | 0.0529 |
| Cu-T | Min | 0.0194 | 0.0252 | 0.0046 | 0.0536 |
| | Avg | 0.0444 | 0.0617 | 0.0132 | 0.0695 |
| | Max | 0.1190 | 0.0982 | 0.0497 | 0.0853 |
| Fe-D | Min | 0.086 | 0.010 | 0.056 | 0.011 |
| | Avg | 0.132 | 0.013 | 0.098 | 0.014 |
| | Max | 0.202 | 0.016 | 0.159 | 0.016 |
| Fe-T | Min | 0.277 | 0.153 | 0.091 | 0.368 |
| | Avg | 0.809 | 0.662 | 0.353 | 0.420 |
| | Max | 3.180 | 1.170 | 1.340 | 0.472 |
| Mo-D | Min | 0.00194 | 0.00647 | 0.00193 | 0.00490 |
| | Avg | 0.00257 | 0.01214 | 0.00235 | 0.00696 |
| | Max | 0.00319 | 0.01780 | 0.00289 | 0.00902 |
| Mo-T | Min | 0.0022 | 0.0070 | 0.0023 | 0.0051 |
| | Avg | 0.0029 | 0.0122 | 0.0027 | 0.0070 |
| | Max | 0.0034 | 0.0173 | 0.0031 | 0.0088 |
| Ni-D | Min | 0.00059 | 0.00050 | 0.00054 | 0.00119 |
| | Avg | 0.00097 | 0.00050 | 0.00095 | 0.00119 |
| | Max | 0.00120 | 0.00050 | 0.00112 | 0.00119 |

| Parameter | Results | Surface Water Monitoring Site | Seep Monitoring Sites | FTW Monitoring Site | |
|---|---|---|---|---|---|
| | | W15 | W32 | FTW-B | FTW-D |
| Ni-T | Min | 0.00094 | 0.00050 | 0.00090 | 0.00138 |
| | Avg | 0.00114 | 0.00059 | 0.00108 | 0.00152 |
| | Max | 0.00142 | 0.00067 | 0.00129 | 0.00166 |
| Pb-D | Min | 0.000050 | 0.000050 | 0.000050 | 0.000050 |
| | Avg | 0.000056 | 0.000050 | 0.000050 | 0.000050 |
| | Max | 0.000100 | 0.000050 | 0.000050 | 0.000050 |
| Pb-T | Min | 0.000050 | 0.000050 | 0.000050 | 0.000112 |
| | Avg | 0.000138 | 0.000243 | 0.000069 | 0.000134 |
| | Max | 0.000473 | 0.000436 | 0.000124 | 0.000155 |
| Se-D | Min | 0.0013 | 0.0125 | 0.0014 | 0.0007 |
| | Avg | 0.0018 | 0.0159 | 0.0019 | 0.0018 |
| | Max | 0.0028 | 0.0193 | 0.0023 | 0.0029 |
| Se-T | Min | 0.0012 | 0.0119 | 0.0015 | 0.0007 |
| | Avg | 0.0018 | 0.0153 | 0.0021 | 0.0017 |
| | Max | 0.0026 | 0.0186 | 0.0039 | 0.0027 |
| Zn-D | Min | 0.0010 | 0.0012 | 0.0010 | 0.0012 |
| | Avg | 0.0010 | 0.0016 | 0.0011 | 0.0026 |
| | Max | 0.0010 | 0.0020 | 0.0016 | 0.0039 |
| Zn-T | Min | 0.0030 | 0.0067 | 0.0030 | 0.0030 |
| | Avg | 0.0047 | 0.0073 | 0.0030 | 0.0046 |
| | Max | 0.0123 | 0.0078 | 0.0031 | 0.0062 |
| Ammonia | Min | 0.0155 | 0.0526 | 0.007 | 0.133 |
| | Avg | 0.0451 | 0.0656 | 0.026 | 0.245 |
| | Max | 0.0956 | 0.0786 | 0.054 | 0.356 |
| Nitrate | Min | 4.9 | 33.8 | 7.2 | 0.5 |
| | Avg | 7.3 | 40.9 | 9.3 | 4.4 |
| | Max | 9.8 | 47.9 | 11.5 | 8.2 |
| Nitrite | Min | 0.0062 | 0.2220 | 0.0036 | 0.0950 |
| | Avg | 0.0382 | 0.3785 | 0.0607 | 0.2135 |
| | Max | 0.1580 | 0.5350 | 0.4430 | 0.3320 |

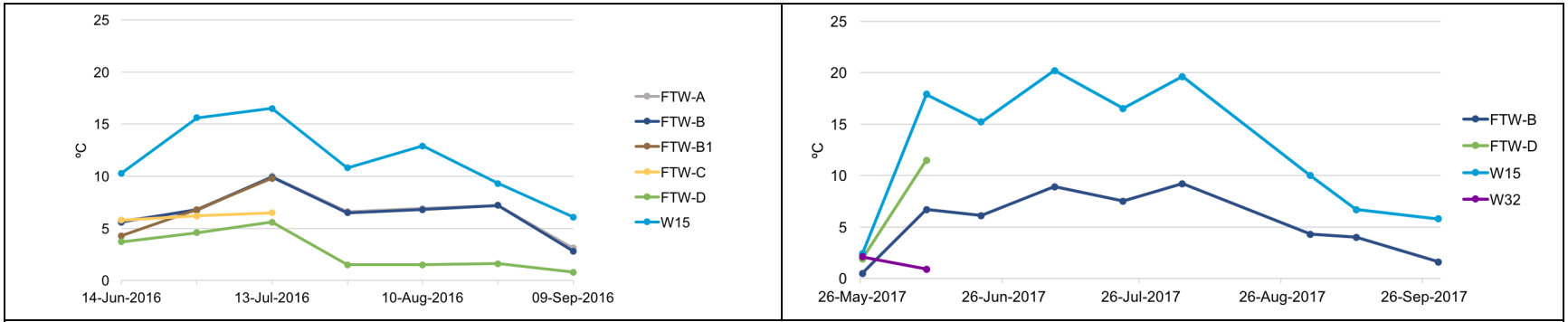



**Figure A1 – Field temperature measurements.**

The left graph shows 2016 data and the right graph shows 2017 data. Field measurements were not available for W32 in 2016. In 2016, FTW-C and FTW-B1 were only sampled three times as they were dry the for the remaining sampling dates. In 2017, FTW-D and W32 were only sampled twice as they were dry for the remaining sampling dates.

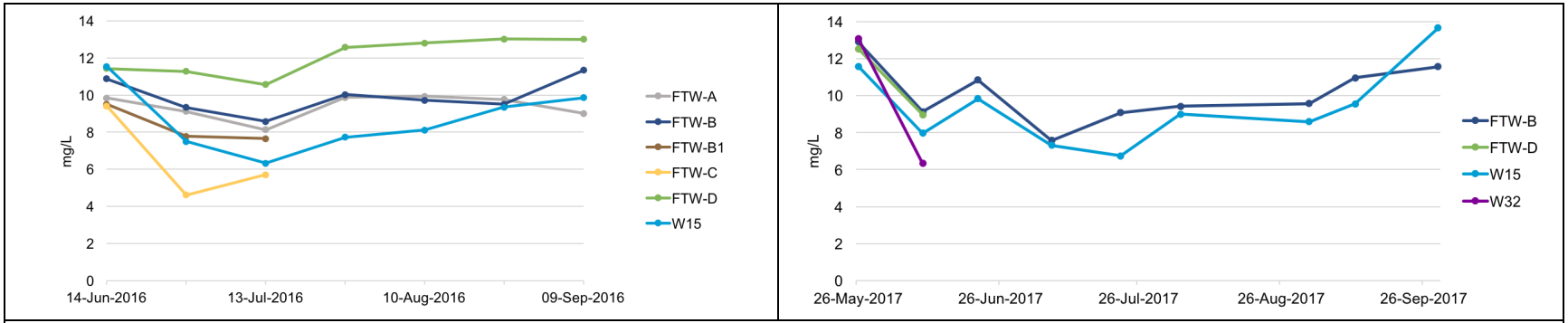
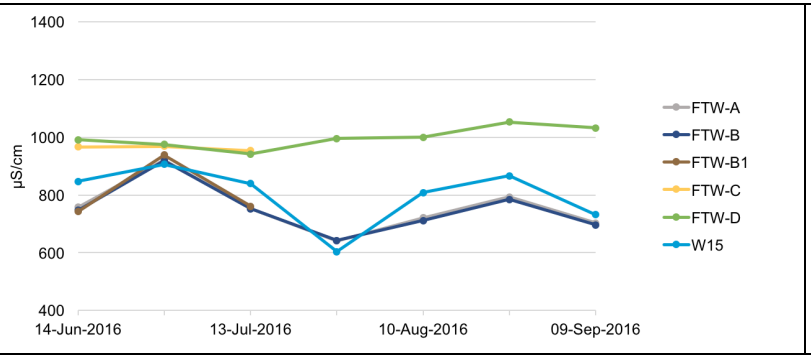



**Figure A2 – Field dissolved oxygen (DO) measurements.**

The left graph shows 2016 data and the right graph shows 2017 data. Field measurements were not available for W32 in 2016. In 2016, FTW-C and FTW-B1 were only sampled three times as they were dry the for the remaining sampling dates. In 2017, FTW-D and W32 were only sampled twice as they were dry for the remaining sampling dates.



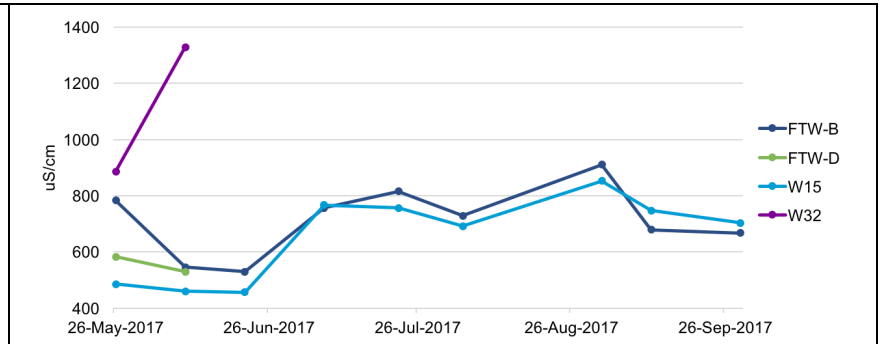
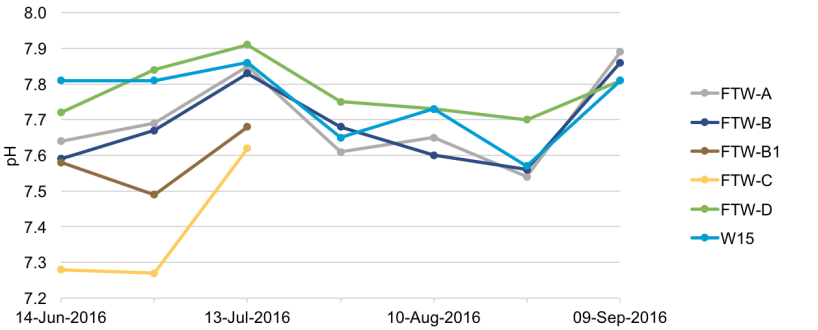




**Figure A3 – Field specific conductance (SPC) measurements.**

The left graph shows 2016 data and the right graph shows 2017 data. Field measurements were not available for W32 in 2016. In 2016, FTW-C and FTW-B1 were only sampled three times as they were dry the for the remaining sampling dates. In 2017, FTW-D and W32 were only sampled twice as they were dry for the remaining sampling dates.



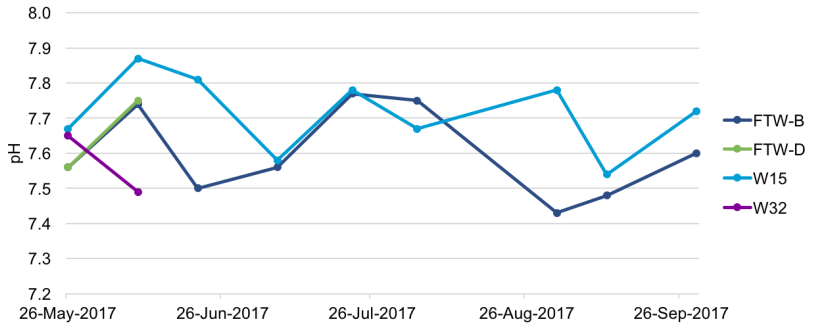
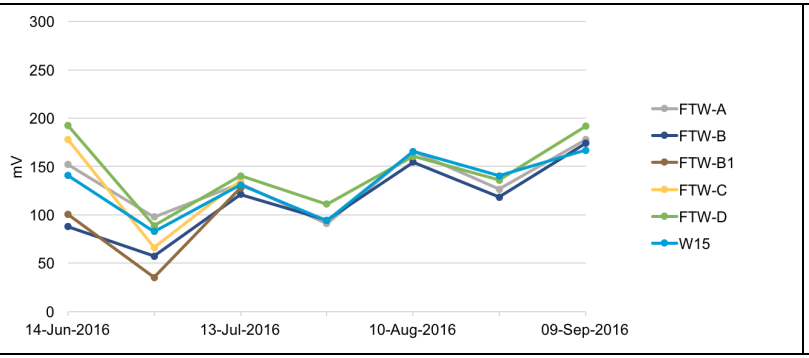




**Figure A4 – Field pH measurements.**

The left graph shows 2016 data and the right graph shows 2017 data. Field measurements were not available for W32 in 2016. In 2016, FTW-C and FTW-B1 were only sampled three times as they were dry the for the remaining sampling dates. In 2017, FTW-D and W32 were only sampled twice as they were dry for the remaining sampling dates.



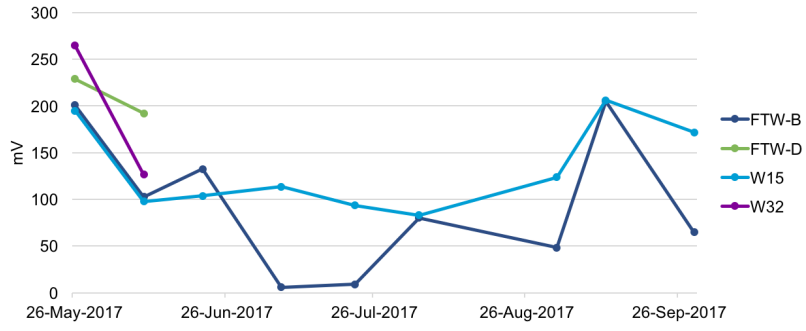




**Figure A5 – Field oxidation reduction potential (ORP) measurements.**

The left graph shows 2016 data and the right graph shows 2017 data. Field measurements were not available for W32 in 2016. In 2016, FTW-C and FTW-B1 were only sampled three times as they were dry the for the remaining sampling dates. In 2017, FTW-D and W32 were only sampled twice as they were dry for the remaining sampling dates.

| 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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| (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 | | | | |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| (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 | | | |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| (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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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 | | |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| (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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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 |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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 |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| meeting)<br>Pelly Crossing | | Minto Mine, including permitting and closure planning | objectives at closure. | |
| 25/11/2013<br>(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<br>(meeting)<br>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<br>(meeting)<br>Whitehorse | YWB | Clarification on guidance document | Discussion to obtain clarity on information requirements under YWB's various guidance documents. | |
| 2014/02/07 (call)<br>Whitehorse/<br>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<br>(meeting)<br>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<br>(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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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 | |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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 | |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| (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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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. |

| Date, Event, Location | Stakeholder/Group | Issue | Engagement Details | Outcome/Purpose |
|---|---|---|---|---|
| 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. |

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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.<br><br>(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.<br><br>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.<br><br>Does not play a role in the evaluation of "reasonable and practical" passive treatment. |
| Aeration Treatment Systems | Treatment of anoxic or high BOD waters.<br><br>(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.<br><br>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.<br><br>(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.<br><br>(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.<br><br>(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.<br><br>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.<br><br>(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.<br><br>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.<br><br>(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.<br><br>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.<br><br>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.<br><br>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.<br><br>(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.<br><br>(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.<br><br>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.<br><br>(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. |

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 |
|---|---|---|---|---|---|
| Excavation and Disposal of Solid Mine Waste | Prevention.<br><br>(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.<br><br>(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.<br><br>(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.<br><br>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.<br><br>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.<br><br>Currently considered a contingency treatment technology.<br><br>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.<br><br>(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.<br><br>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.<br><br>(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. |

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 |
|---|---|---|---|---|---|
| Phytotechnologies | Prevention.<br><br>(Not relevant in WQO context) | Phytotechnologies use plants to remediate various media impacted with different types of contaminants.<br>Phytotechnologies can be applied to address certain issues associated with mining solid wastes and mining-impacted waters.<br>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.<br><br>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.<br><br>(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.<br>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).<br><br>The WUL specifically prohibits mine waste from being transported off-site. | Optimal reprocessing of marginal waste rock is incorporated in the MWROMP.<br><br>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.<br><br>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).<br><br>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.<br><br>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.<br><br>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) |

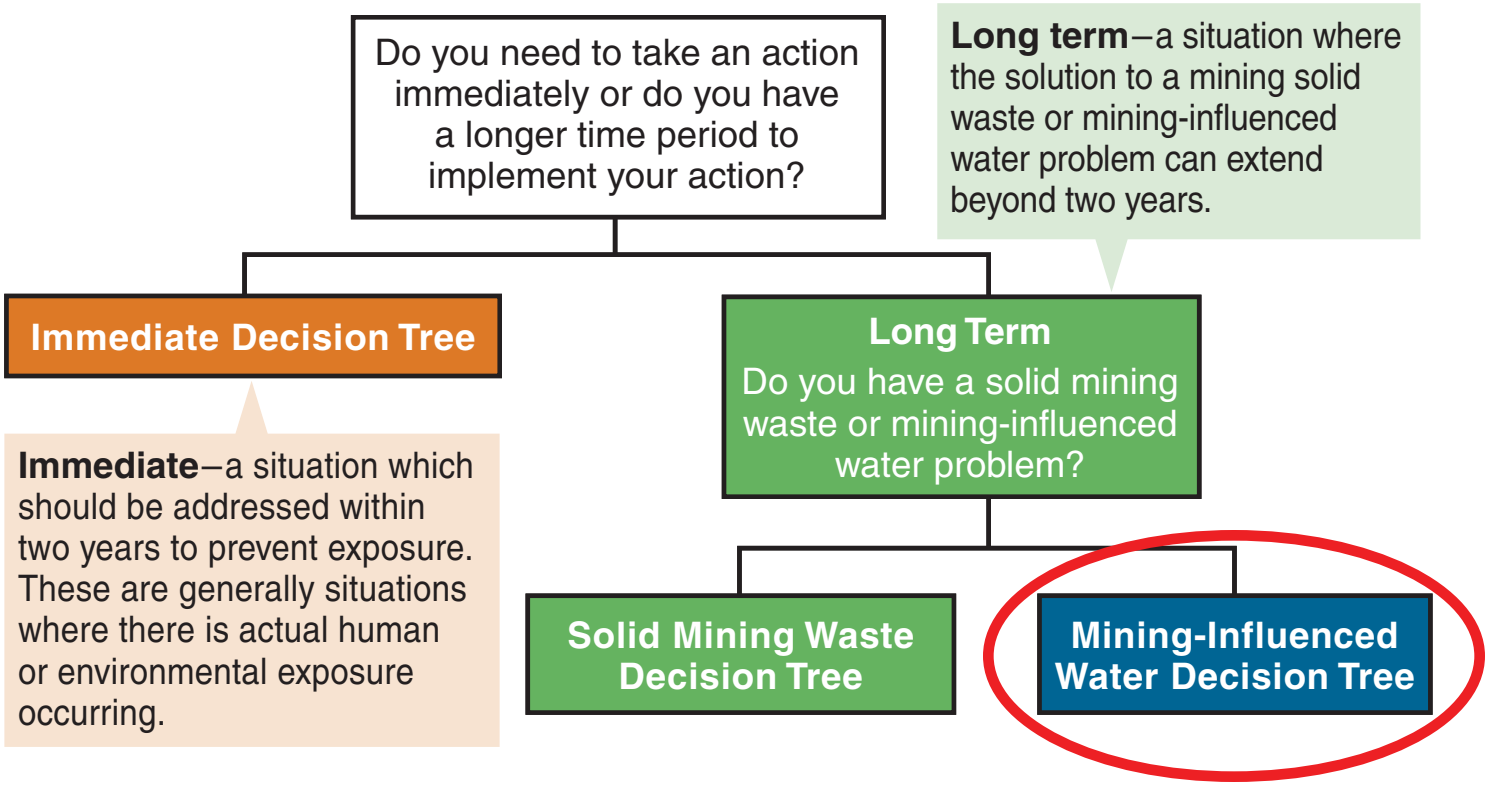
Notes:
1 This technology is considered the most appropriate for evaluation under "Steps 2 and 3" of the Framework for Developing Minto Closure WQO.
2 These technologies are considered "Contingency" passive treatment technologies.

# 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.

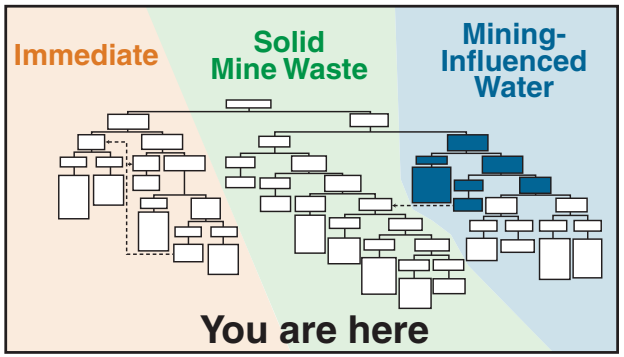
At the end of each string of questions in the decision tree is a list of treatment technologies. Clicking on that list will take users to Technology Overviews where they will learn more about the applicability of specific technologies and supporting case studies.

## Mining Waste Team Decision Tree—Initial Questions



# Mining-Influenced Water Decision Tree

*Part One*




**Mining-Influenced Water**

Do you need to control water quality at the human receptor or at the source?

**Receptor**

**Administrative/ Engineering Controls**

**Pressure-Driven Membrane Separation**

**Ion Exchange**

**Source**

Can you eliminate the mining-influenced water by addressing the solid mining waste source?

**Yes**

See Solid Mining Waste Decision Tree

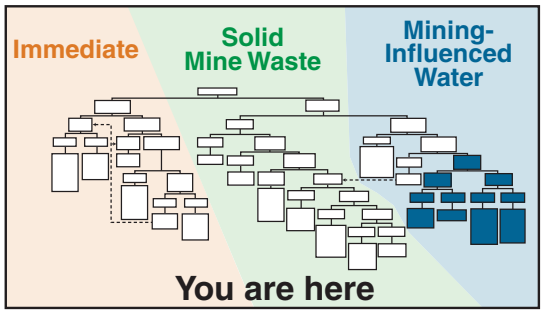
**No**

**See Solid Mining Waste Decision Tree**

*Part Two*

# Mining-Influenced Water Decision Tree

*Part Two*




**No**

Do you need to control water quality in groundwater or surface water?

**Groundwater**

Do you want to pump water and treat it at the surface?

**No**

- ☑ Permeable Reactive Barriers
- ☑ In Situ Treatment
- Electrokinetics
- ☑ In Situ Biological Treatment

**Yes**

See Surface Water

**Surface Water**

Do you need a treatment technology that is more passive or can you use a more active technology?

**Passive**

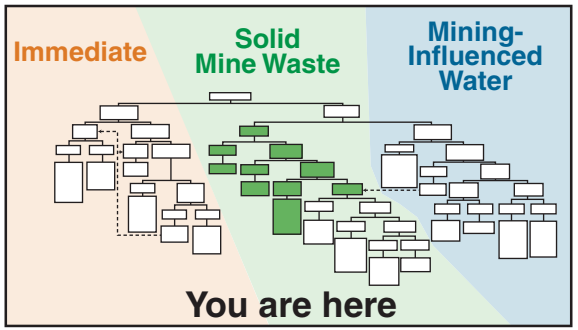
- ☑ Biochemical Reactors
- ☒ Microbial Mats
- ☑ Constructed Treatment Wetland
- ☒ Anoxic Limestone Drains
- ☑ Aeration
- ☑ In Situ Biological Treatment

**Active**

- ☑ Chemical Precipitation
- Ion Exchange
- Pressure-Driven Membrane Separation
- Aeration
- Electrocoagulation

# Solid Mining Waste Decision Tree

*Part One*




**Solid Mining Waste**

Do you have saturated sediments affected by mine waste?

**Yes**

**ITRC Contaminated Sediments Public Page**

**No**

Do you need to control exposure to mining wastes which have been transported indoors?

**Yes**

**Administrative/ Engineering Controls**

**No**

Do you need to control exposure in a residential yard?

**Yes**

**Administrative/Engineering Controls**

**Excavation and Disposal**

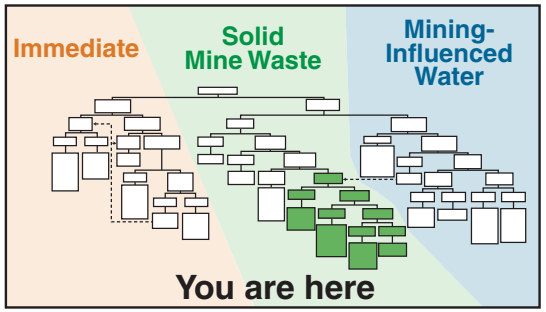
**Capping, Covers and Grading**

**Chemical Stabilization**

**No**

# Solid Mining Waste Decision Tree

*Part Two*




From Mining-Influenced Water Decision Tree

**No**
Is it feasible to remove the mine waste?

**Yes**

- ☑ Excavation and Disposal
- ☑ Subaqueous Disposal
- ☑ Re-Use and Reprocess

**No**
Can you control exposure by treating the mining waste?

**Yes**

- ☑ Passivation
- Chemical Stabilization
- ☑ In Situ Biological Treatment
- Electrokinetics
- Phytotechnologies

**No**
Can you control exposure with physical barriers?

**Yes**

- ☑ Capping, Covers and Grading
- ☑ Diversionary Structures
- ☑ Phytotechnologies

**No**

- ☑ Administrative/ Engineering Controls

| | Closure Scenario 1: Source Control Focus | Consequence | | Likelihood | Risk Rating | NOTES |
|---|---|---|---|---|---|---|
| | | Type | Severity | Probability | Descriptive | |
| **1** | **Source Terms** | | | | | |
| A | Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site** | Env. Imp. | Critical | Possible | High | assuming no AMP in place |
| B | Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site** | Env. Imp. | Moderate | Possible | Moderately High | assumed AMP in place so Severity moderate, critical to understand chemistry as fully as possible - reflected in likelihood designation, concern about reliance on AMP |
| C | | Conseq. Costs | Major | Possible | High | |
| D | | Spec. Cons. | Moderate | Possible | Moderately High | |
| E | Source water quality (source term) worse than expected and causes unacceptable water quality conditions **on site** | Env. Imp. | Moderate | Unlikely | Moderate | |
| F | | Legal Obl. | Major | Possible | High | This could apply to the preceding mode if there were W2 standards in place |
| G | | Conseq. Costs | Moderate | Possible | Moderately High | |
| H | Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned | Conseq. Costs | Moderate | Possible | Moderately High | assuming 200 yr flood design, note - sensitivity analysis for precip on water quality, |
| I | Localized precip > regional => less dilution in downstream in downstream environment resulting in unacceptable water quality conditions downstream of site | Env. Imp. | Minor | Likely | Moderate | |
| **2** | **Cover Performance** | | | | | |
| A | Covers don't perform as designed re: infiltration resulting in unacceptable water quality conditions **downstream of site** | Env. Imp. | Moderate | Unlikely | Moderate | Assuming AMP and monitoring will respond to any defects |
| B | | Conseq. Costs | Major | Unlikely | Moderately High | |
| **3** | **Geotechnical Stability** | | | | | |
| A | Geotechnical failure of any waste facility (slope stability) resulting in waste material exposure to water leading to unacceptable water quality conditions downstream of site | Env. Imp. | Moderate | Possible | Moderately High | this is a result of there being permafrost considerations under some facilities, and uncertainty associated. Could result from differential settlement of pockets of more moist materials |
| B | | Conseq. Costs | Moderate | Possible | Moderately High | |
| C | Geotechnical failure of any waste facility (differential settlement) resulting in rupture of cover and waste material exposure to water leading to unacceptable water quality conditions downstream of site | Env. Imp. | Moderate | Likely | Moderately High | Could result from differential settlement of pockets of high moisture materials. Could be moderated by waste mgmt practices limiting wet waste in waste dumps |
| D | Geotechnical failure of any waste facility (slope stability) resulting in debris dam, breaching, mobilizing materials and pulse of water into Main Pit, and sediments/tailings leaving pit, leading to unacceptable water quality conditions downstream of site | Env. Imp. | Minor | Possible | Moderate | |
| **4** | **Conveyance Structures** | | | | | |
| A | Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs | Conseq. Costs | Moderate | Unlikely | Moderate | Need to do landscape design carefully to avoid this failure mode |
| B | Undiverted runoff upstream of waste mgmt facilities leads to excessive infiltration into upgradient base of dump, resulting in higher flows of poor quality water and unacceptable water quality conditions downstream | Env. Imp. | Moderate | Unlikely | Moderate | |
| **5** | **Administrative** | | | | | |
| A | Failure to implement AMP, resulting in unacceptable water quality conditions downstream | Env. Imp. | Critical | Possible | High | |
| B | Failure to design an appropriate AMP, resulting in unacceptable water quality conditions downstream | Env. Imp. | Major | Unlikely | Moderately High | Important to recognize that AMP is more than just monitoring - but careful identification of potential issues, thresholds and appropriate responses. AMP not just an add-on. Needs to be critical component of closure plan at same detail as rest of plan |
| C | Departure from design of engineered structures, resulting in unacceptable water quality conditions downstream | Env. Imp. | Major | Possible | High | |

| | Scenario 2: Hybrid Source Control/Passive Treatment Focus | Consequence | | Likelihood | Risk Rating | NOTES |
|---|---|---|---|---|---|---|
| | | Type | Severity | Probability | Descriptive | |
| **1** | **Bioreactors** | | | | | |
| A | Bioreactors don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream | Env. Imp. | Moderate | Almost Certain | High | Assumption: effective AMP in place<br>Notes: cryo-concentration in seeps, ice cleaner, residual seeps higher concentration<br>Leslie: make sure that any supporting work here has data - not just stories that they work -i.e. Andre Sobolewski's work at G900 didn't work, but MPERG report still says it does. |
| **2** | **Wetlands** | | | | | |
| A | Wetlands don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream | Env. Imp. | Moderate | Almost Certain | High | |
| B | High flow blow out wetland, causing damage and maintenance requirements, assuming high flows designed to bypass | Env. Imp. | Moderate | Unlikely | Moderate | Assumption: peak flows not treated by wetlands - need to understand the implications of this during freshet and also during peak flow events. Wetlands are not designed nor capable of treating peak flows, so this is a significant red-flag for planning - needs very careful consideration. |
| C | | Conseq. Costs | Moderate | Unlikely | Moderate | Need to understand the implications of this during freshet and also during peak flow events. |
| **3** | **Pit Lake Treatment** | | | | | |
| **A** | Non-Flow through Pit: | | | | | |
| i | Non-flow through Area 2 Pit treatment compromised because of diversion ditch failure, resulting in flow through condition | Env. Imp. | Minor | Possible | Moderate | Assuming pit water quality has moderate initial contamination level - make sure this is covered in AMP. What if WQ in Area 2 pit were higher than anticipated? |
| ii | Non-flow through pit treatment does not perform | Env. Imp. | Minor | Possible | Moderate | |
| iii | Pit Wall Failure in Area 2 results in wave of water released from pit causing damage to downstream facilities and tailings mobilization from bottom of Area 2 pit | Conseq. Costs | Major | Unlikely | Moderately High | Resolution would be difficult - would mean appropriate sizing of the spillway, locating of facilities downgradient |
| **B** | Flow through Pit: | | | | | |
| | Flow through Pit treatment does not perform as expected | Env. Imp. | Minor | Unlikely | Low | Assume treatment expectations consider flow through condition and limitations |
| | Flow through Pit source term underestimated, resulting in higher than expected loading from pit and unacceptable water quality results downstream | Env. Imp. | Moderate | Unlikely | Moderate | |
| | Pit Wall Failure in Area 2 results in wave of water released from pit causing damage to downstream facilities and tailings mobilization from bottom of Area 2 pit | Conseq. Costs | Major | Very Unlikely | Moderate | In the flow through pit condition, the downstream channels and facilities would be designed for hitgher flows, so likelihood lower than in the non-flow through condition. |
| **4** | **Cover Performance** | | | | | |
| A | Does not achieved expected infiltration reduction, leads to increased loading and unacceptable downstream WQ effects | Env. Imp. | Moderate | Possible | Moderately High | |
| B | Erosion leads to increased infiltration and unacceptable downstream WQ effects | Env. Imp. | Moderate | Unlikely | Moderate | Risks different for DSTSF than for other facilities, potential effects of erosion still need to be considered in design, maintenance costing, etc. |
| **5** | **Conveyance Structures** | | | | | |
| A | Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs | Conseq. Costs | Minor | Unlikely | Low | Need to do landscape design carefully to avoid this failure mode |
| B | Undiverted runoff upstream of waste mgmt facilities leads to excessive infiltration into upgradient base of dump, resulting in higher flows of poor quality water and unacceptable water quality conditions downstream | Env. Imp. | Moderate | Possible | Moderately High | |
| **6** | **Administrative** | | | | | |
| A | General failure to maintain site requirements as required - passive treatment, cover maintenance, etc. | Env. Imp. | Major | Possible | High | |

| | Scenario 3: Treatment Focus | Consequence | | Likelihood | Risk Rating | NOTES |
|---|---|---|---|---|---|---|
| | | Type | Severity | Probability | Descriptive | |
| | Assumption is that this option needs redesign compared with existing collection/treatment system in place - many risks could be addressed through this redesign, or batch treatment, etc. | | | | | |
| **1** | **Collection Systems** | | | | | |
| A | Tailings seepage collection systems inadequate, leading to unacceptable WQ downstream | Env. Imp. | Moderate | Possible | Moderately High | design, size, location, construction, operation - all contributors to the potential issue, these need to be thought through more for the mitigation |
| B | | Conseq. Costs | Major | Possible | High | |
| C | SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream | Env. Imp. | Minor | Likely | Moderate | minor because pit is downstream |
| D | | Conseq. Costs | Moderate | Likely | Moderately High | Feasiblilty of this collection system questionable - due to ice-rich area and deformations, and no clear segregation from valley flows. Mitigation might be to avoid collection system altogher and focus on treatment of full W15 flow in pit. |
| E | Collection of cleaner runoff in inadequate, leading to mixing with water requiring treatment and increased treatment costs | Conseq. Costs | Minor | Likely | Moderate | |
| **2** | **Cover Performance** | | | | | |
| A | Does not achieved expected infiltration reduction, leads to increased loading and unacceptable downstream WQ effects | Env. Imp. | Moderate | Possible | Moderately High | Assumption that these Option 3 covers are thinner than Option 2 |
| B | Erosion leads to increased infiltration and unacceptable downstream WQ effects | Env. Imp. | Moderate | Possible | Moderately High | risks different for DSTSF than for other facilities, potential effects of erosion still need to be considered in design, maintenance costing, etc. |
| C | Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs | Conseq. Costs | Moderate | Unlikely | Moderate | Need to do landscape design carefully to avoid this failure mode |
| D | Undiverted runoff upstream of waste mgmt facilities leads to excessive infiltration into upgradient base of dump, resulting in higher flows of poor quality water and unacceptable water quality conditions downstream | Env. Imp. | Moderate | Possible | Moderately High | |
| **3** | **Dam - assume reduced height** | | | | | **may want to consider removing top level at least - man/made materials** |
| A | Seismic or extreme flood event larger than design leads to dam failure, resulting in surge of water and solids into Minto Creek | Env. Imp. | Moderate | Very Unlikely | Low | |
| B | Dam maintenance requirements not met, resulting in failure and surge of water and solids into Minto Creek | Env. Imp. | Moderate | Very Unlikely | Low | assumes design with maintenance requirements |
| **4** | **Treatment Plant (plant, any byproduct, and storage capacity)** | **Env. Imp.** | **Very Low** | **Very Unlikely** | **Low** | |
| A | Flow rates exceed plant/surge capacity, resulting in unnacceptable water quality downstream | Env. Imp. | Moderate | Possible | Moderately High | Mitigation : increase surge capacity and/or operate surge volumes better - depending on why surge capacity was overwhelmed |
| B | | Conseq. Costs | Major | Unlikely | Moderately High | assume worst case - plant/surge exceeded because not sufficient |
| C | Contaminant loading exceeds treatment capacity, resulting in unnacceptable water quality downstream | Env. Imp. | Moderate | Unlikely | Moderate | Function of geochemical source term identification |
| D | | Conseq. Costs | Major | Unlikely | Moderately High | |
| E | Treatment technology ineffective for contaminants of concern, resulting in unnacceptable water quality downstream | Env. Imp. | Moderate | Very Unlikely | Low | |
| F | | Conseq. Costs | Major | Very Unlikely | Moderate | |
| G | Inadequate capacity for storage of byproducts, leads to costs for removal off site | Conseq. Costs | Moderate | Very Unlikely | Low | |
| **5** | **Administrative** | **Env. Imp.** | **Very Low** | **Very Unlikely** | **Low** | |
| A | General failure to maintain site requirements as required - collection/conveyance, active treatment, cover maintenance, etc. | Env. Imp. | Major | Possible | High | |

# MINTO MINE CLOSURE – FAILURE MODES AND EFFECTS ASSESSMENT

## 2014 WORKSHOP REPORT

# FINAL REPORT

December 2014

Prepared for:

**MINTO EXPLORATIONS LTD.**

ACCESS

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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.

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## 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

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  - 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.

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# 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.

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# 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).

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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.

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**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;

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- 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.

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# 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**

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

**Table 2. Likelihood Terminology**

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

**Table 3. Risk Matrix**

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

# APPENDIX B

## MINTO MINE FMEA METHODOLOGY AND AGENDA

**Minto Explorations Ltd.**

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

# 1 Introduction

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

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

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

# 2 Workshop Objectives

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

# 3 Scope and Approach

The FMEA will cover RCP v5.1 and related design elements for the proposed closure measures. Familiarity with the RCP v5.1 document for all participants will be critical to a meaningful

contribution to the FMEA workshop. Familiarity with facility design reports referenced in the RCP will also be necessary. Access to all of these reports will be provided via FTP site.

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

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

**Facilities:**

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

**Site-Wide Topics:**

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

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

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

# 4 Risk Rating Tools

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

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

**Table 1. Consequence-Severity Matrix**

| | Severity Descriptors | | | | |
|---|---|---|---|---|---|
| **Consequence Categories** | **Very Low** | **Minor** | **Moderate** | **Major** | **Critical** |
| **1. Environmental Impact** | No impact. | Minor localized or short-term impacts. | Significant impact on valued ecosystem component. | Significant impact on valued ecosystem component and medium-term impairment of ecosystem function. | Serious long-term impairment of ecosystem function. |
| **2. Traditional Use** | Some disturbance but no impact to traditional land use. | Minor or perceived impact to traditional land use. | Some mitigable impact to traditional land use. | Significant temporary impact to traditional land use. | Significant permanent impact on traditional land use. |
| **3. Regulatory and Legal** | Informal advice from a regulatory agency. | Technical/Administrative non-compliance with permit, approval or regulatory requirement.<br>Warning letter issued. | Breach of regulations, permits, or approvals (e.g. 1 day violation of discharge limits).<br>Order or direction issued. | Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits).<br>Prosecution. | Major breach of regulation – wilful violation.<br>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.<br>Assuming annual inspections (1st 5 years? - Scott to check)<br>Lower Minto Creek is a relatively small and relatively unproductive ecosystem |
| | A | Tailings seepage collection systems inadequate, leading to unacceptable WQ downstream | 2W, 6W, 7W,12 | Env. Imp. | Moderate | Possible | Moderately High | design, size, location, construction, operation - all contributors to the potential issue, these need to be thought through more for the mitigation |
| | B | | | Conseq. Costs | Major | Possible | High | |
| | C | | 3W, 12 | Env. Imp. | Minor | Likely | Moderate | minor because pit is downstream |
| | D | SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream | | Conseq. Costs | Moderate | Likely | Moderately High | Feasiblilty of this collection system questionable - due to ice-rich area and deformations, and no clear segregation from valley flows.<br>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 unnacceptable 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 unnacceptable water quality | 11 | Env. Imp. | Moderate | Unlikely | Moderate | Function of geochemical source term identification |
| | D | downstream | | Conseq. Costs | Major | Unlikely | Moderately High | |
| | E | Treatment technology ineffective for contaminants of concern, resulting in unnacceptable | 11 | Env. Imp. | Moderate | Very Unlikely | Low | |
| | F | water quality downstream | | Conseq. Costs | Major | Very Unlikely | Moderate | |
| | G | Inadequate capacity for storage of byproducts, leads to costs for removal off site | | Conseq. Costs | Moderate | Very Unlikely | Low | |
| | A | Extreme event leads to failure of conveyance structure upgradient of DSTSF, flow onto DSTSF leading to cover damage and tailings mobilization across top of DSTSF leading to unacceptable water quality conditions downstream | 7W, 10, 12, 15 | Env. Imp. | Major | Possible | High | upslope key of cover? Pitwall failure should be considered elsewhere in planning. Reducing dependance on manmade structures is desirable-i.e. wingwalls at pit outlets |
| | B | Leakage from conveyance structure upgradient of DSTSF increases flow subsurface and contaminant loading from tailings leading to unacceptable downstream water quality | 7W, 12, 15 | Env. Imp. | Moderate | Unlikely | Moderate | these should be designed to reduce leakage/seepage to DSTSF |
| | **2** | **Chemical Stability** | | | | | | |
| | A | Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site** | 3,7,10 | Env. Imp. | Critical | Possible | High | assuming no AMP in place |
| | B | Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site** | | Env. Imp. | Moderate | Possible | Moderately High | assumed AMP in place so Severity moderate, critical to understand chemistry as fully as possible - reflected in likelihood designation, concern about reliance on AMP |
| | C | | | Conseq. Costs | Major | Possible | High | |
| | D | | | Spec. Cons. | Moderate | Possible | Moderately High | |
| | E | Source water quality (source term) worse than expected and causes unacceptable water quality conditions **on site** | | Env. Imp. | Moderate | Unlikely | Moderate | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | F | | 2,3,7,10 | Legal Obl. | Major | Possible | High | This could apply to the preceding mode if there were W2 standards in place |
| | G | | | Conseq. Costs | Moderate | Possible | Moderately High | |
| | A | Covers don't perform as designed re: infiltration resulting in unacceptable water quality conditions **downstream of site** | 10 | Env. Imp. | Moderate | Unlikely | Moderate | Assuming AMP and monitoring will respond to any defects |
| | B | | | Conseq. Costs | Major | Unlikely | Moderately High | |
| | B | Erosion leads to increased infiltration and unacceptable downstream WQ effects | 10, 12,15 | Env. Imp. | Moderate | Unlikely | Moderate | Risks different for DSTSF than for other facilities, potential effects of erosion still need to be considered in design, maintenance costing, etc. |
| | A | Bioreactors don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream | 11 | Env. Imp. | Moderate | Almost Certain | High | Assumption: effective AMP in place<br>Notes: cryo-concentration in seeps, ice cleaner, residual seeps higher concentration<br>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 (yellow highlighted notes are conditional risk ratings) |
|---|---|---|---|---|---|---|
| | | Type | Severity | Probability | Descriptive | |
| **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.<br>-Large degree of uncertainty regarding the likelyhood of failure.<br>-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;<br>-Ranking preliminary; Failure has not been evaluated.<br>-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<br>-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<br>-Could be mitigated by adding material to dam to account for settlement and/or reevaluation of spillway<br>-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.<br>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<br>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.<br>-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.<br>-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.

# 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.

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| | | | |
| | | | |

## ALEXCO ENVIRONMENTAL GROUP INC. SIGNATURES

Report prepared by:



13/12/2017

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1/23/2018

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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.**

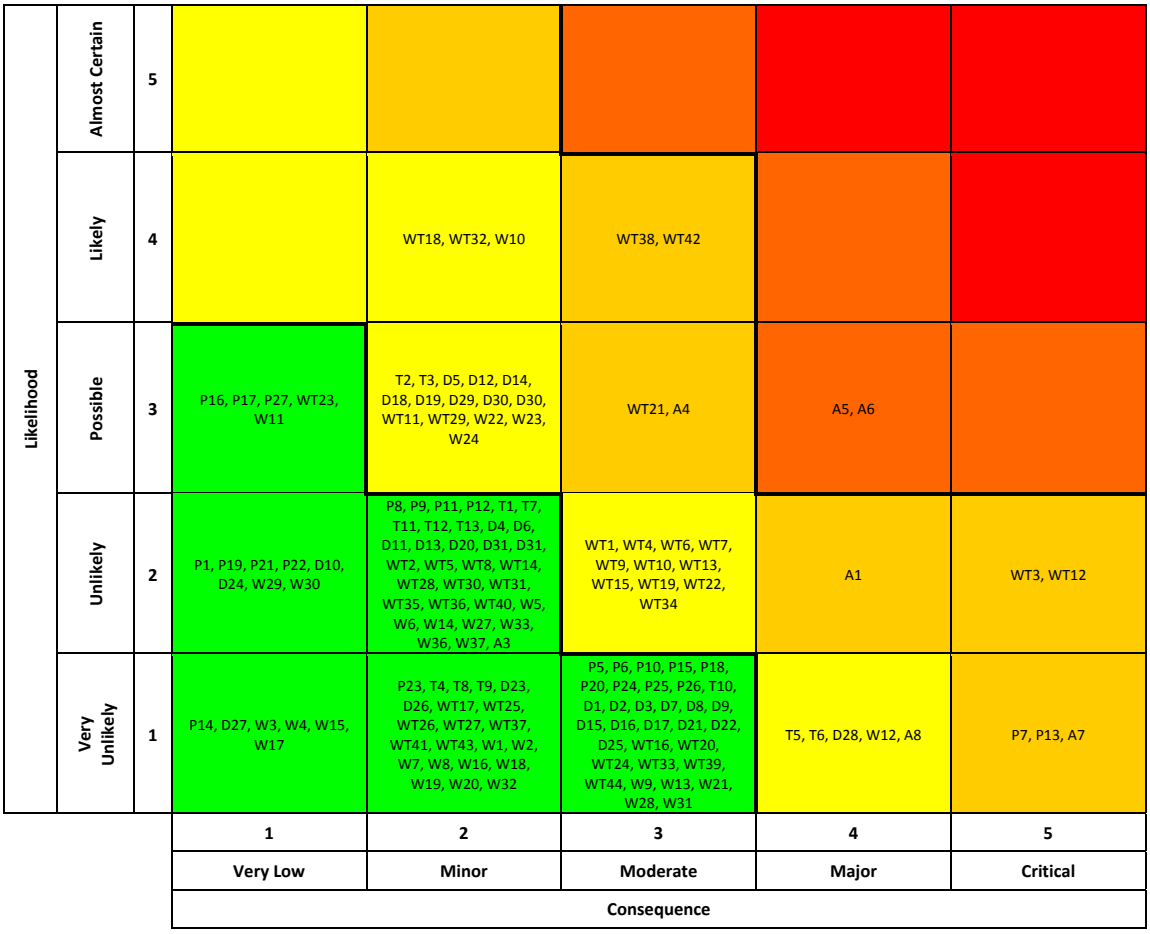



**Figure 3: Overall summary risk matrix from 2017 FMEA for RCP v2017-01 with inclusion of additional proposed mitigation measures being planned for inclusion in RCP v2018-01.**

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

| | Severity Descriptors | | | | |
|---|---|---|---|---|---|
| **Consequence Categories** | **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 L | RISK RATING C | CLASSIFICATION | changed? | COMMENTS | Potential Mitigations | RISK RATING L | RISK RATING C | CLASSIFICATION |
| 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<br>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'<br>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;<br>-Ranking preliminary; Failure has not been evaluated.<br>-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<br>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 L | RISK RATING C | CLASSIFICATION | changed? | COMMENTS | Potential Mitigations | RISK RATING L | RISK RATING C | CLASSIFICATION |
| 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 wildilife | 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 L | RISK RATING C | CLASSIFICATION | changed? | COMMENTS | Additional Potential Mitigations | RISK RATING L | RISK RATING C | CLASSIFICATION |
| 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 | | | | |

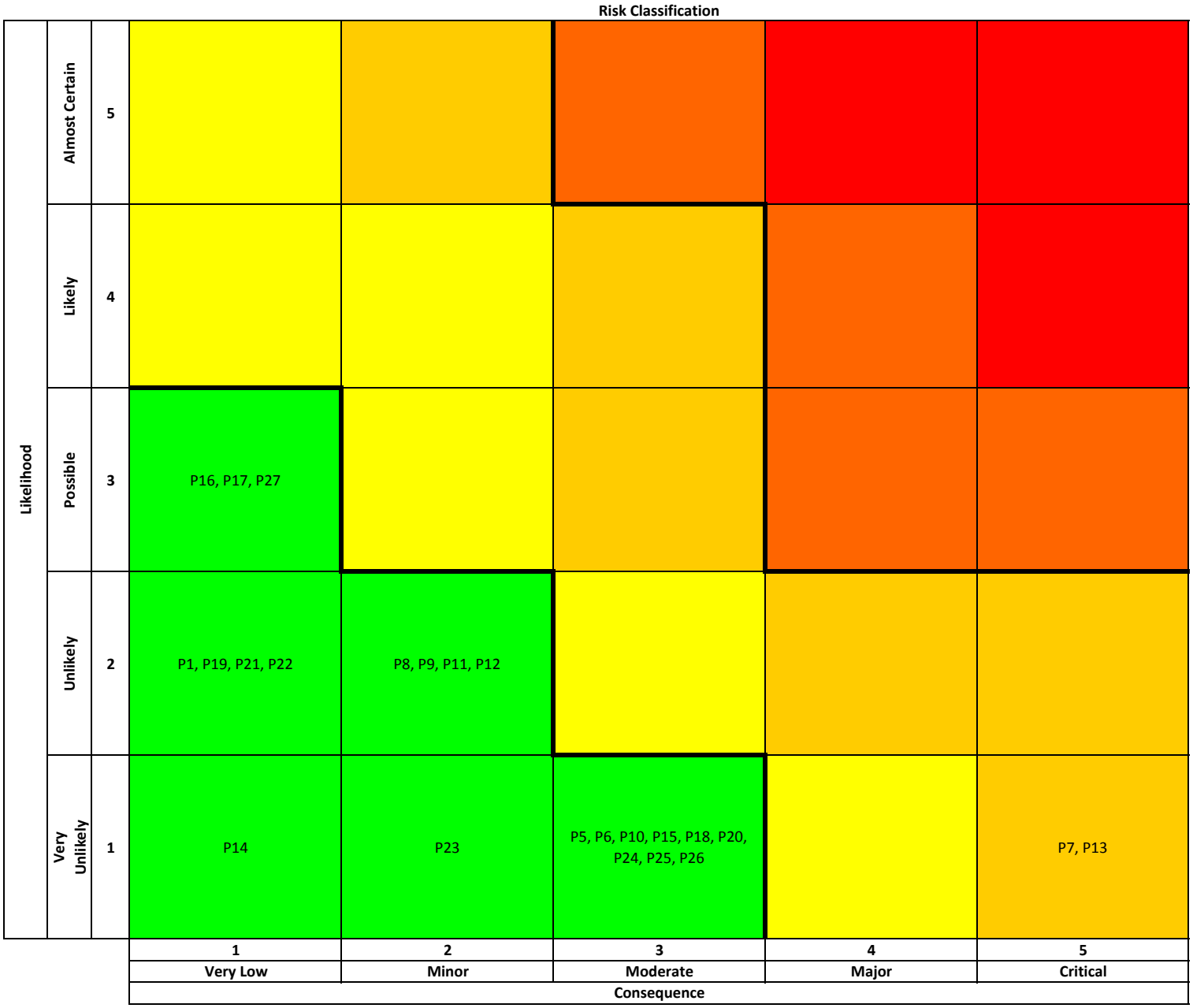
APPENDIX C.

# 2017 FMEA Risk Matrices

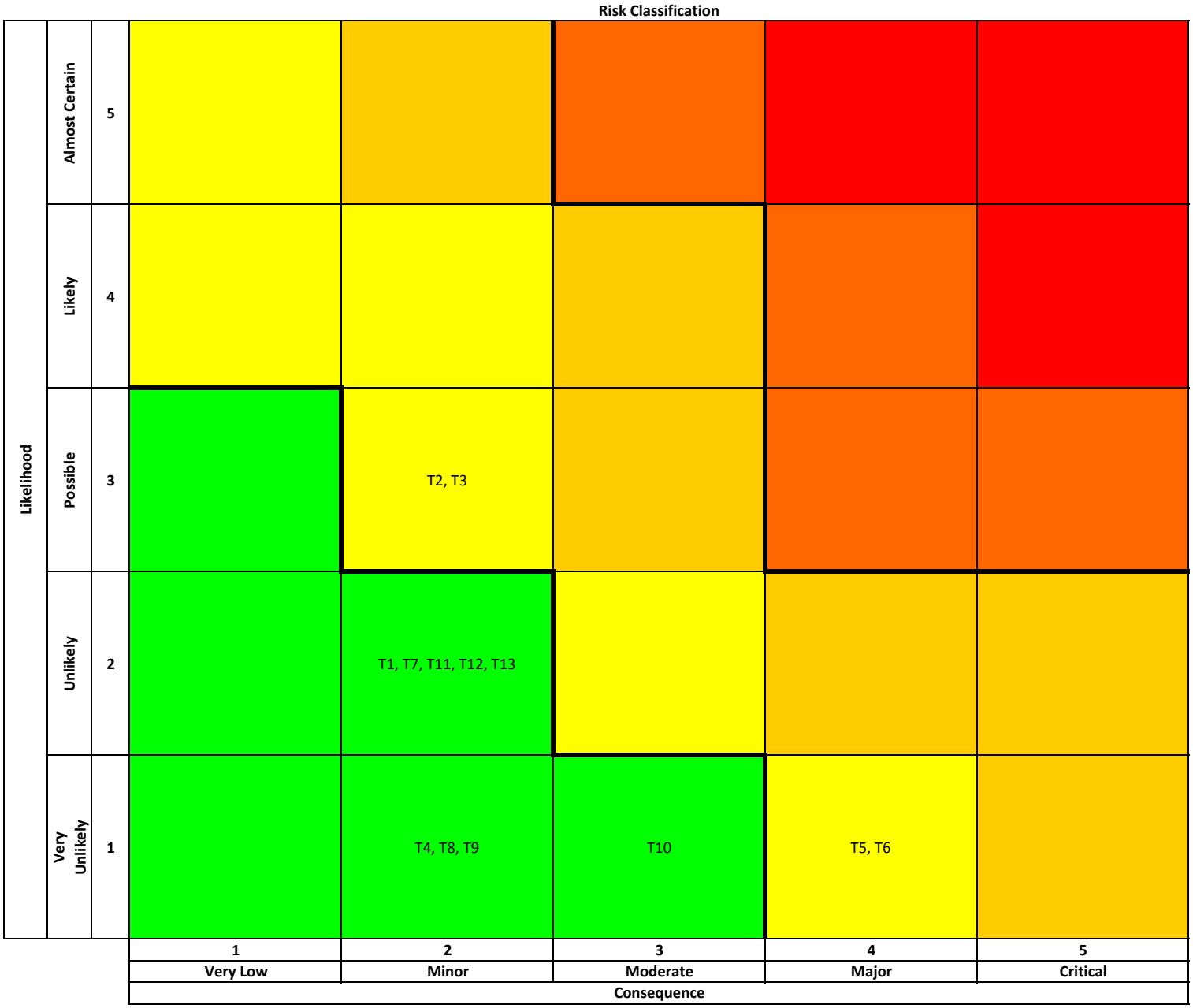
## Risk Matrix - Overall Summary (2018-01)

| | | | Risk Classification | | | | |
|---|---|---|---|---|---|---|---|
| | 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 | | | | |

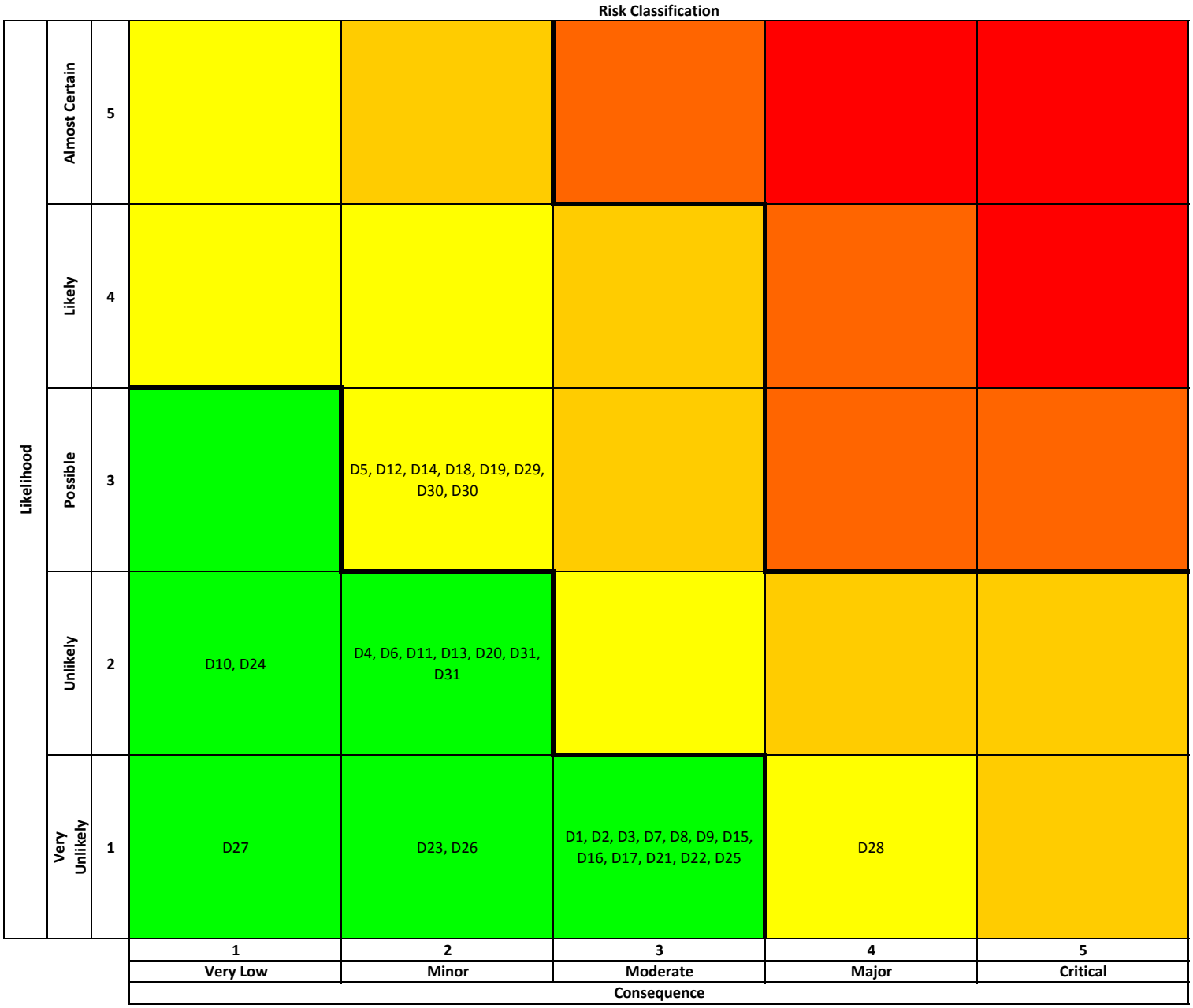
## Risk Matrix - Open Pits (P) (2018-01)



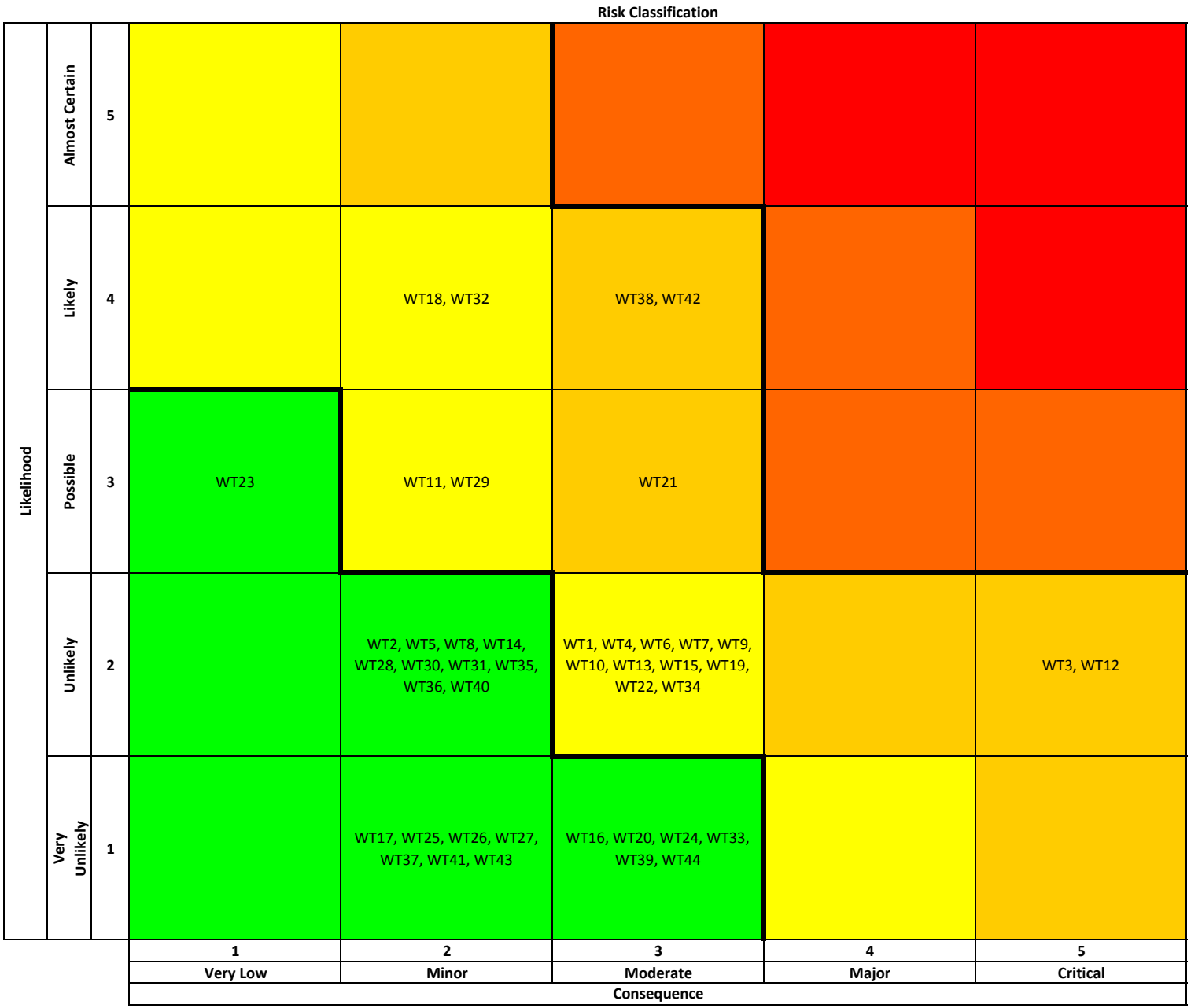
## Risk Matrix - Dry Stack Tailings Storage Facility (T) (2018-01)



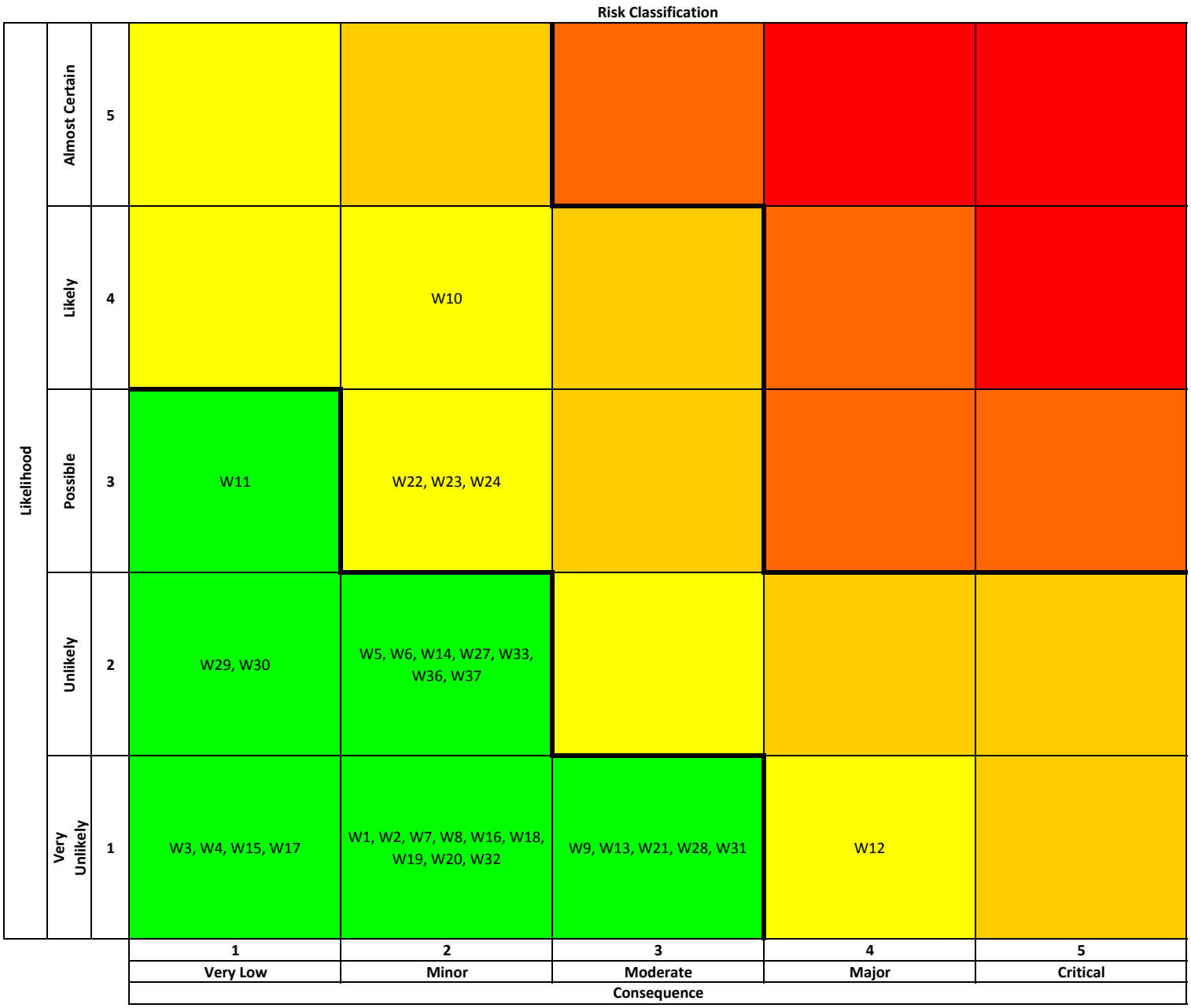
## Risk Matrix - Waste Rock Dumps (D) (2018-01)



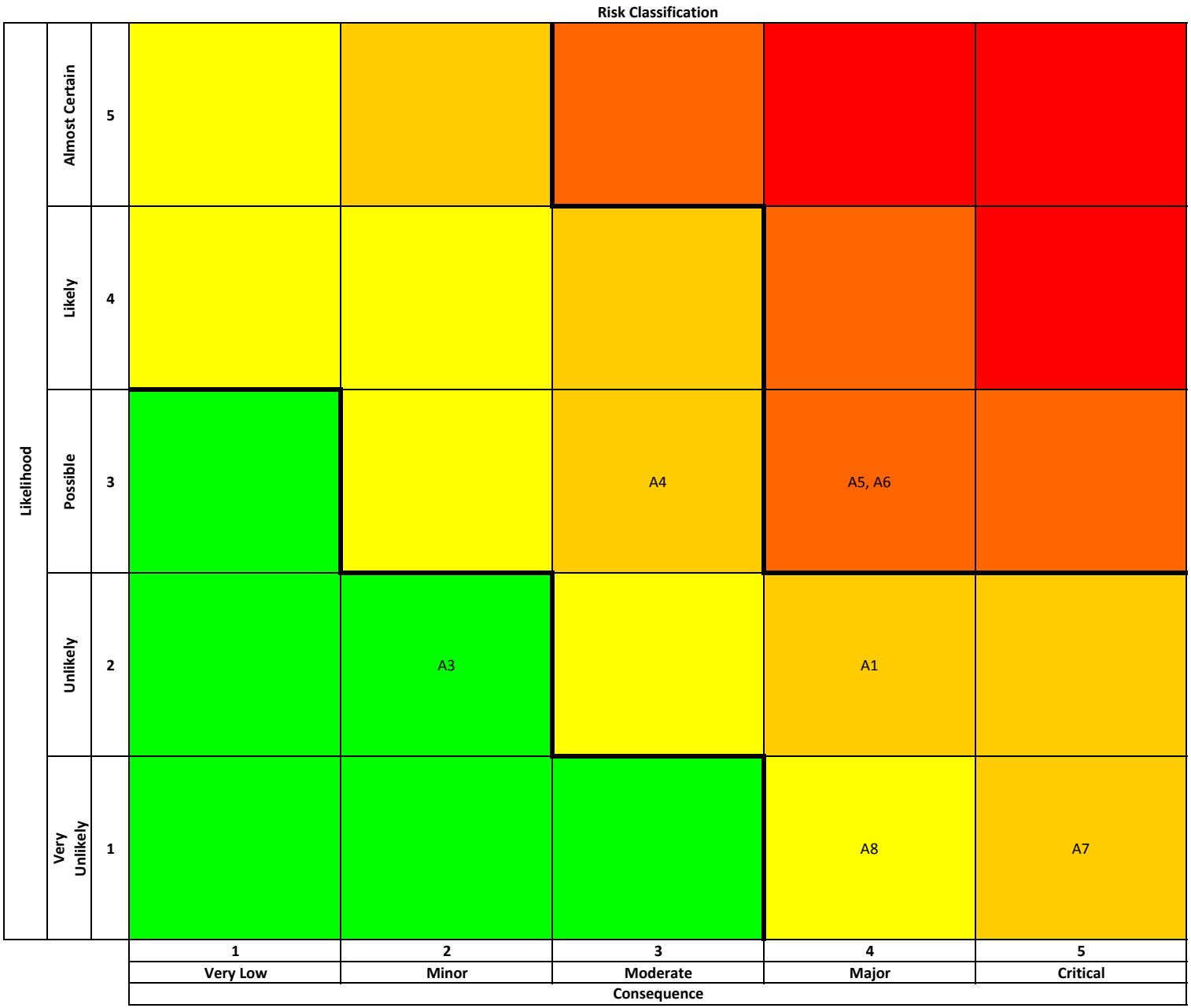
## Risk Matrix - Water Treatment (WT) (2018-01)



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



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



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 | | CLASSIFICATION | 2014 COMMENTS | Rationale for Not Re-evaluating Risk |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | L | C | | | |
| 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 | | CLASSIFICATION | 2014 COMMENTS | Rationale for Not Re-evaluating Risk |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | L | C | | | |
| 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.<br>-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 |

# 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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# 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 $1 \times 10^{-7}$ 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., $1 \times 10^{-8}$ m/sec or 315 mm/year). Data for the waste rock is not available but it is likely to be about $1 \times 10^{-4}$ 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 $1.06 \times 10^{-8}$ 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 $2.12 \times 10^{-9}$ 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 $1.99 \times 10^{-7}$ to $1.12 \times 10^{-7}$ 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;<br>Low Infiltration Cover: no more than 10% of mean annual precipitation with no significant breakthrough events, and;<br>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;<br>Main Pit Tailings: up to 30 cm on beach areas and up to 100 cm on slimes areas<br>(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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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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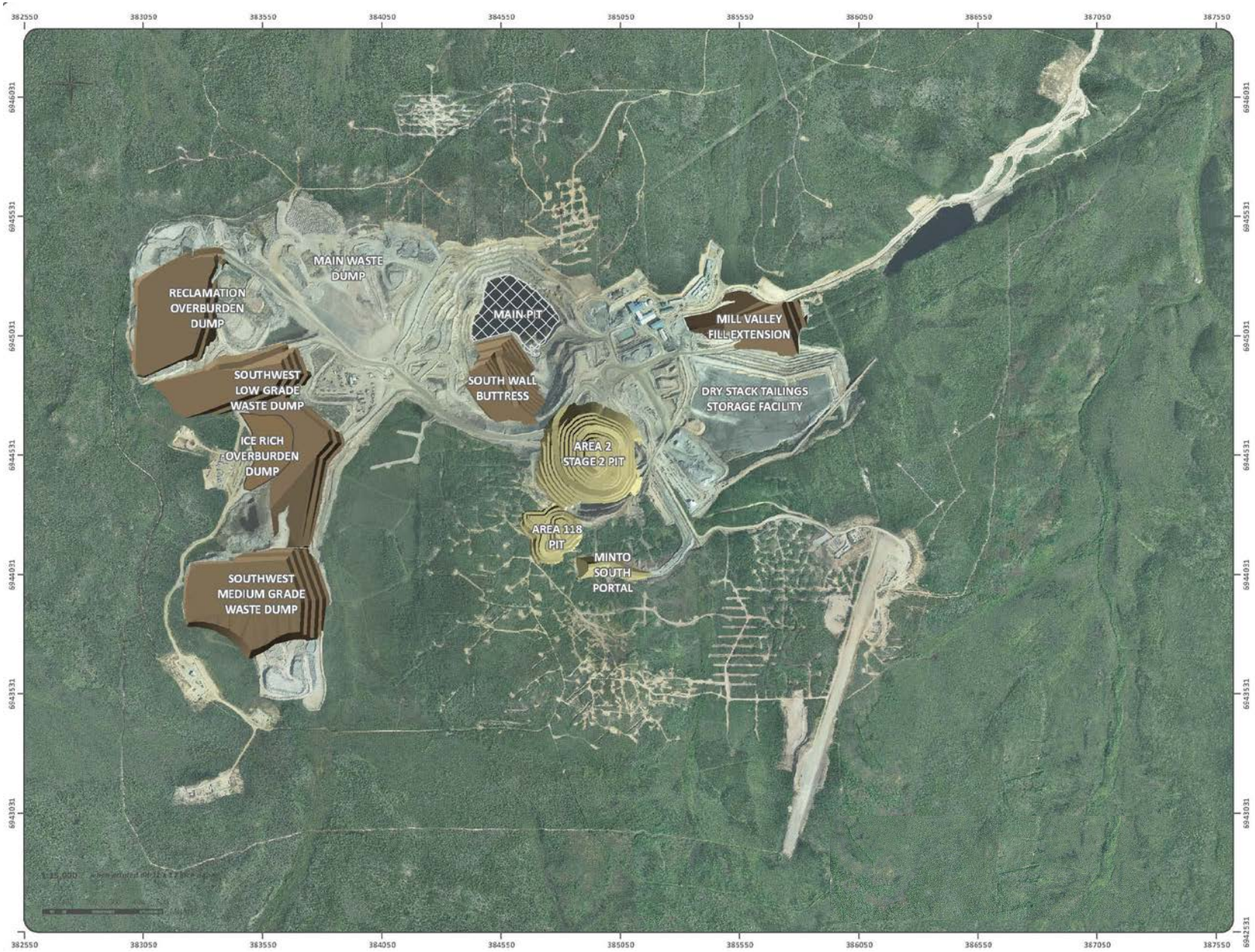
Figures




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

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Scoping Level Cover Assessment

**General Site Layout**

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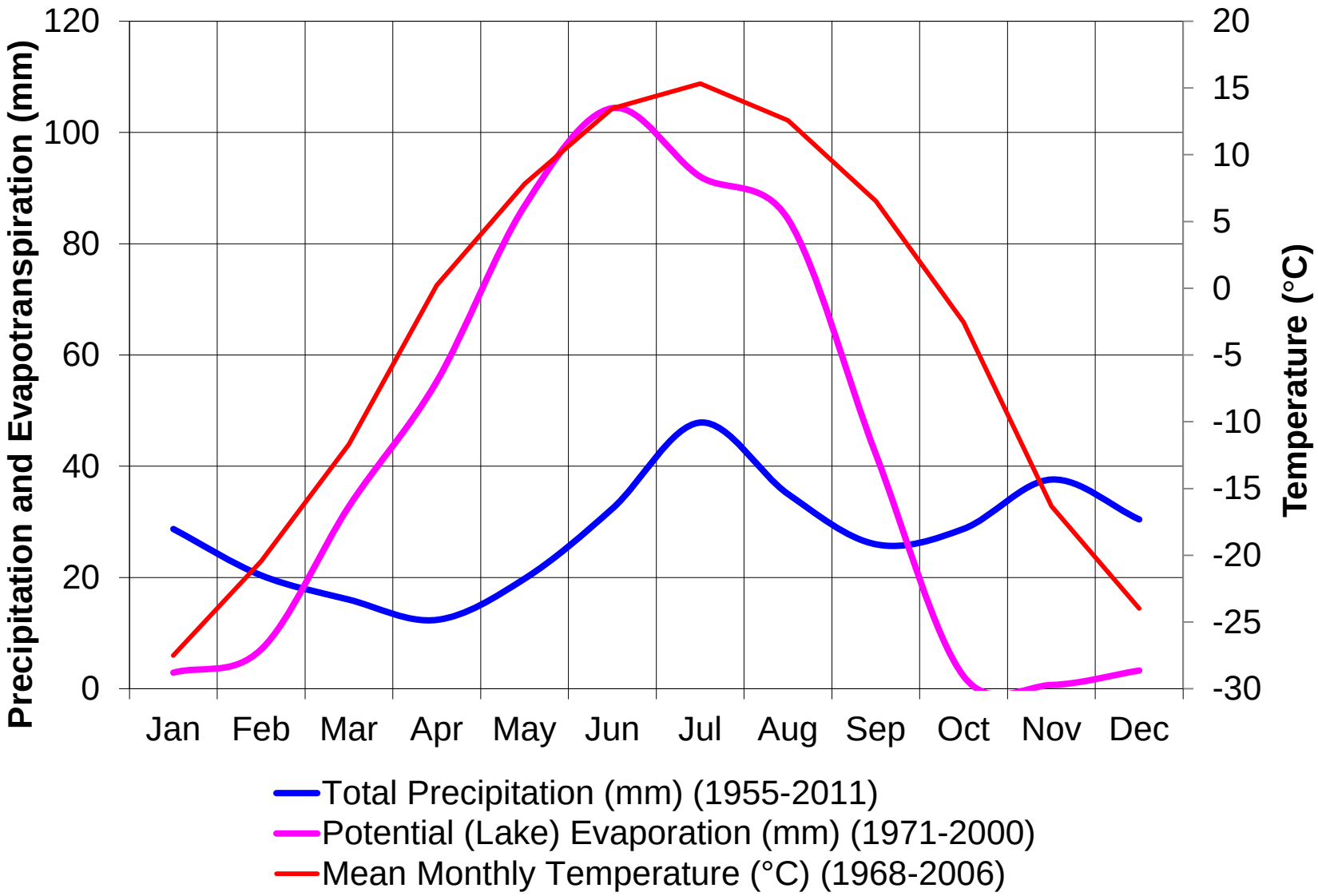


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Scoping Level Cover Assessment

**Climatic Water Balance**

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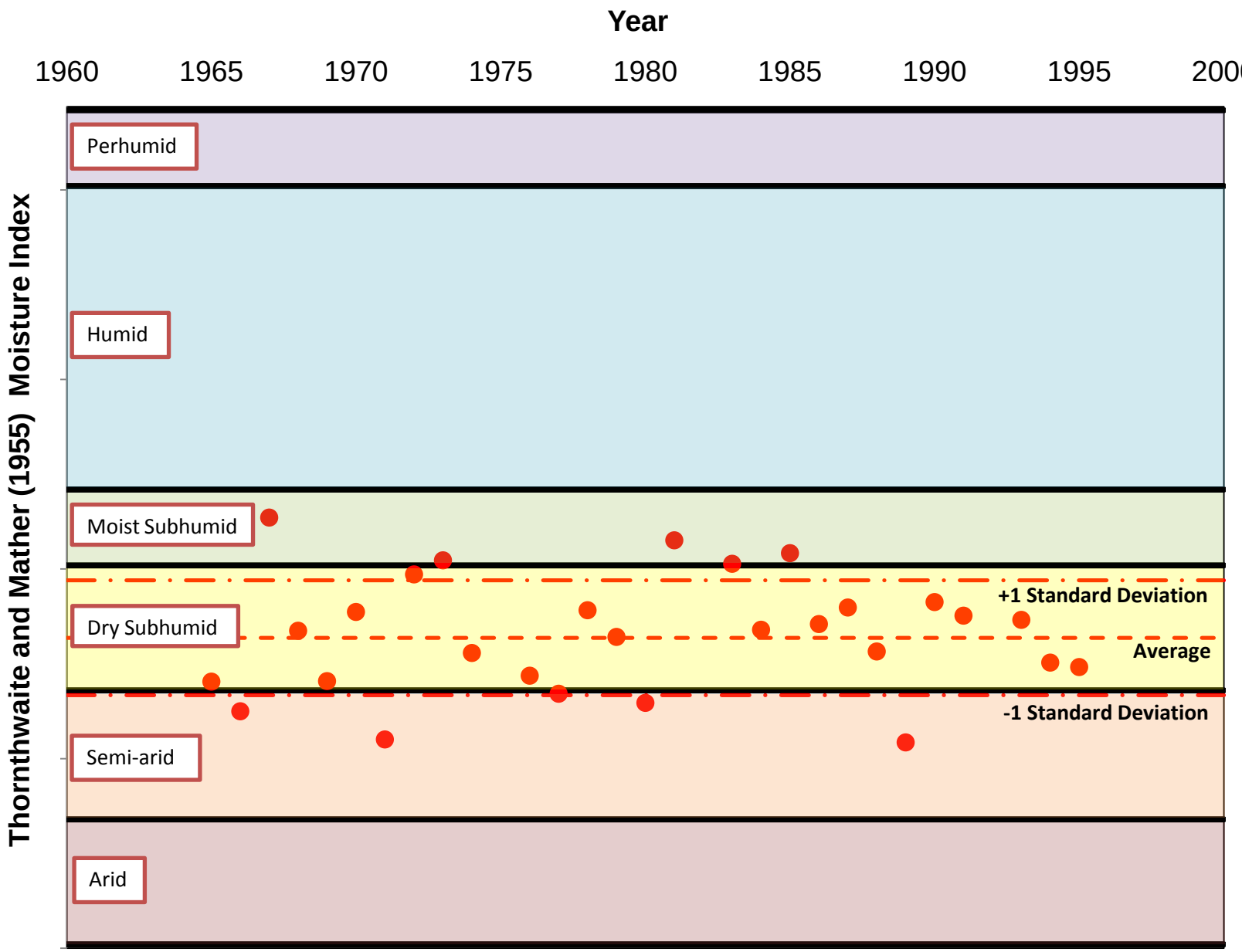


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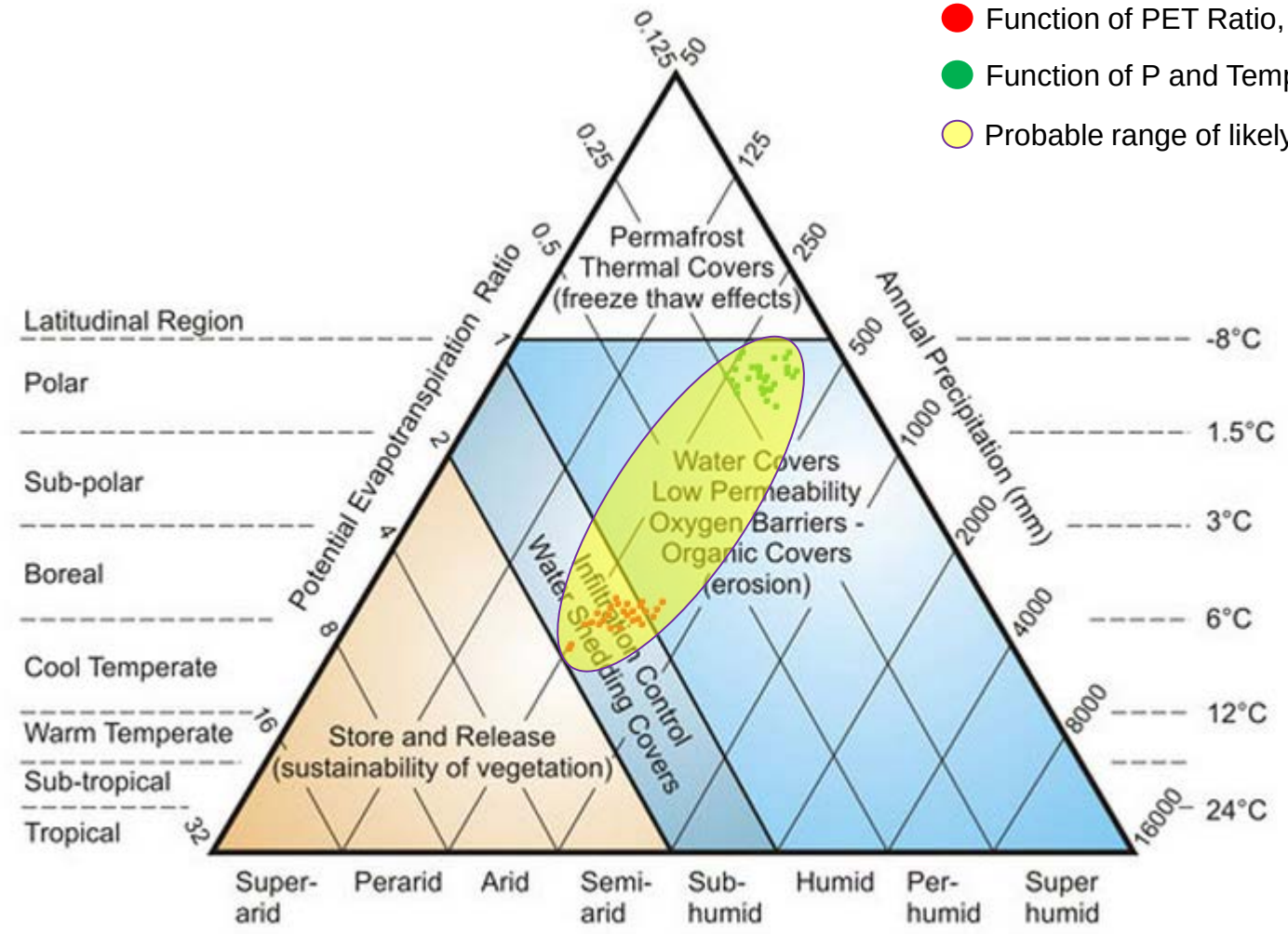


Chart obtained from:
Chapter 6 - GARDGuide. 2013. *Chapter 6 - GARDGuide*. [ONLINE] Available at: http://www.gardguide.com/index.php/Chapter_6. [Accessed 04 April 2013]. (Wickland and Wilson, 2006)

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| | | **Typical Cover Types** |
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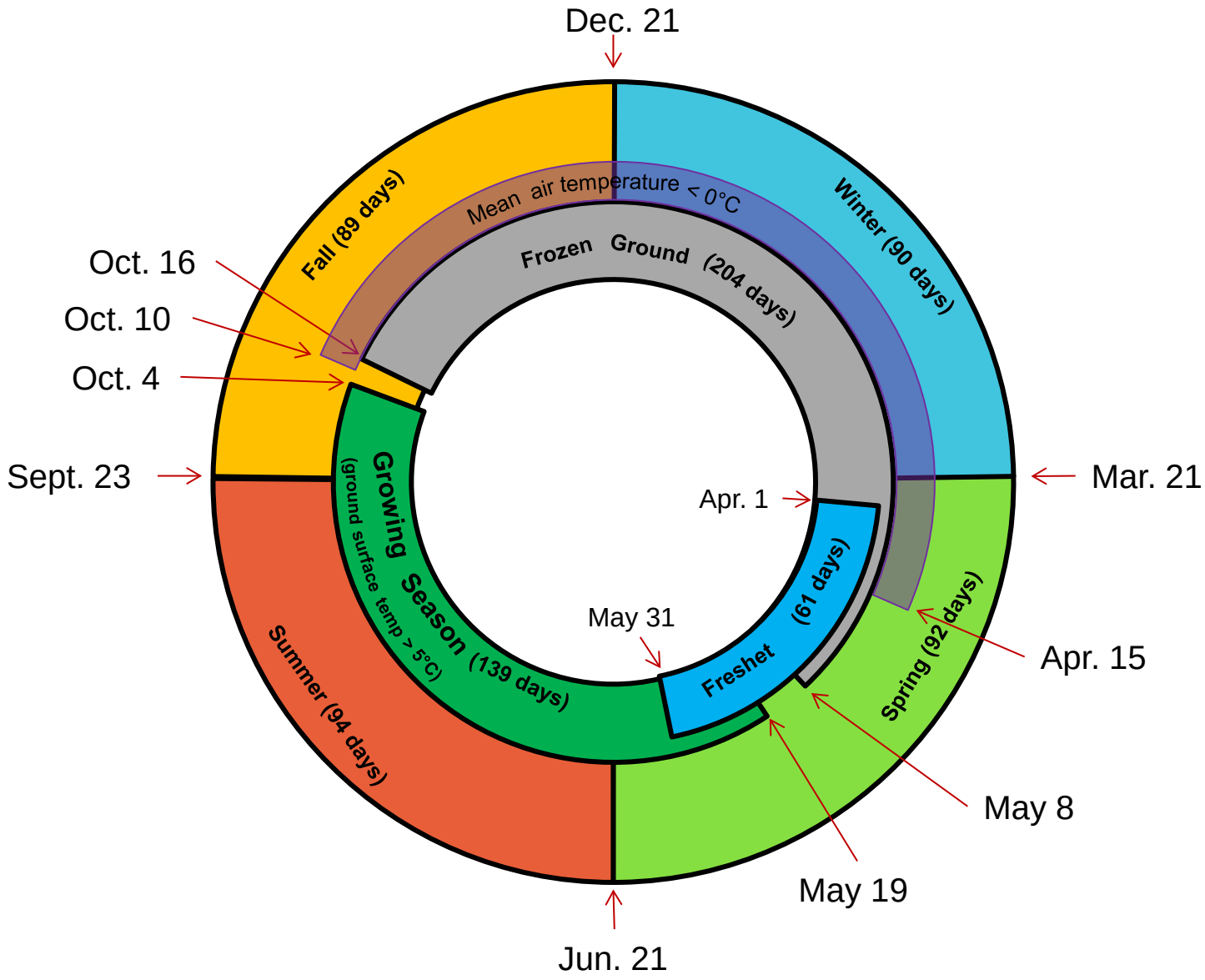


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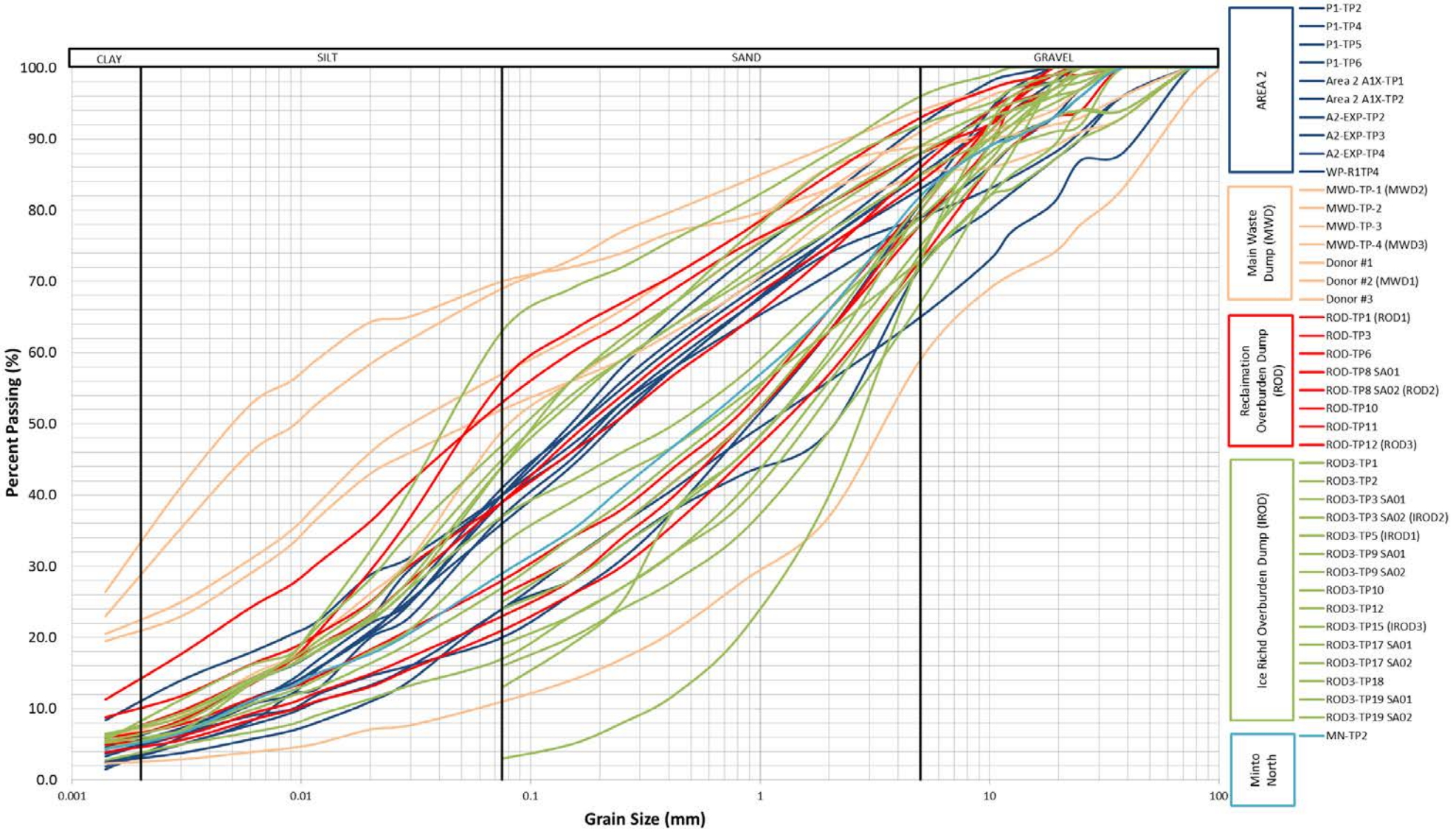


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Scoping Level Cover Assessment

**Grain Size Distribution Curves for All Candidate Cover Materials**

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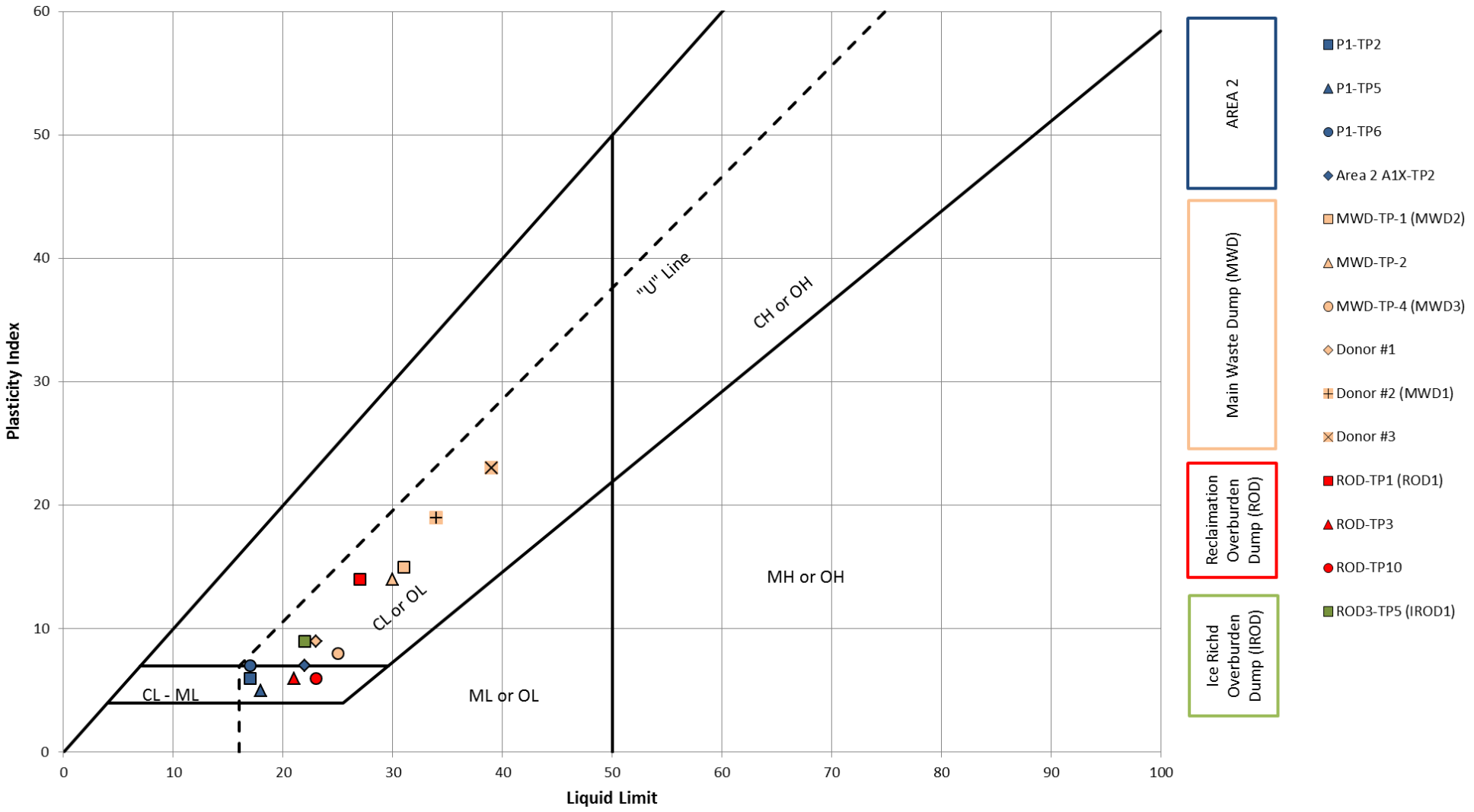


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Scoping Level Cover Assessment

**Atterberg Limits for All Candidate Cover Materials**

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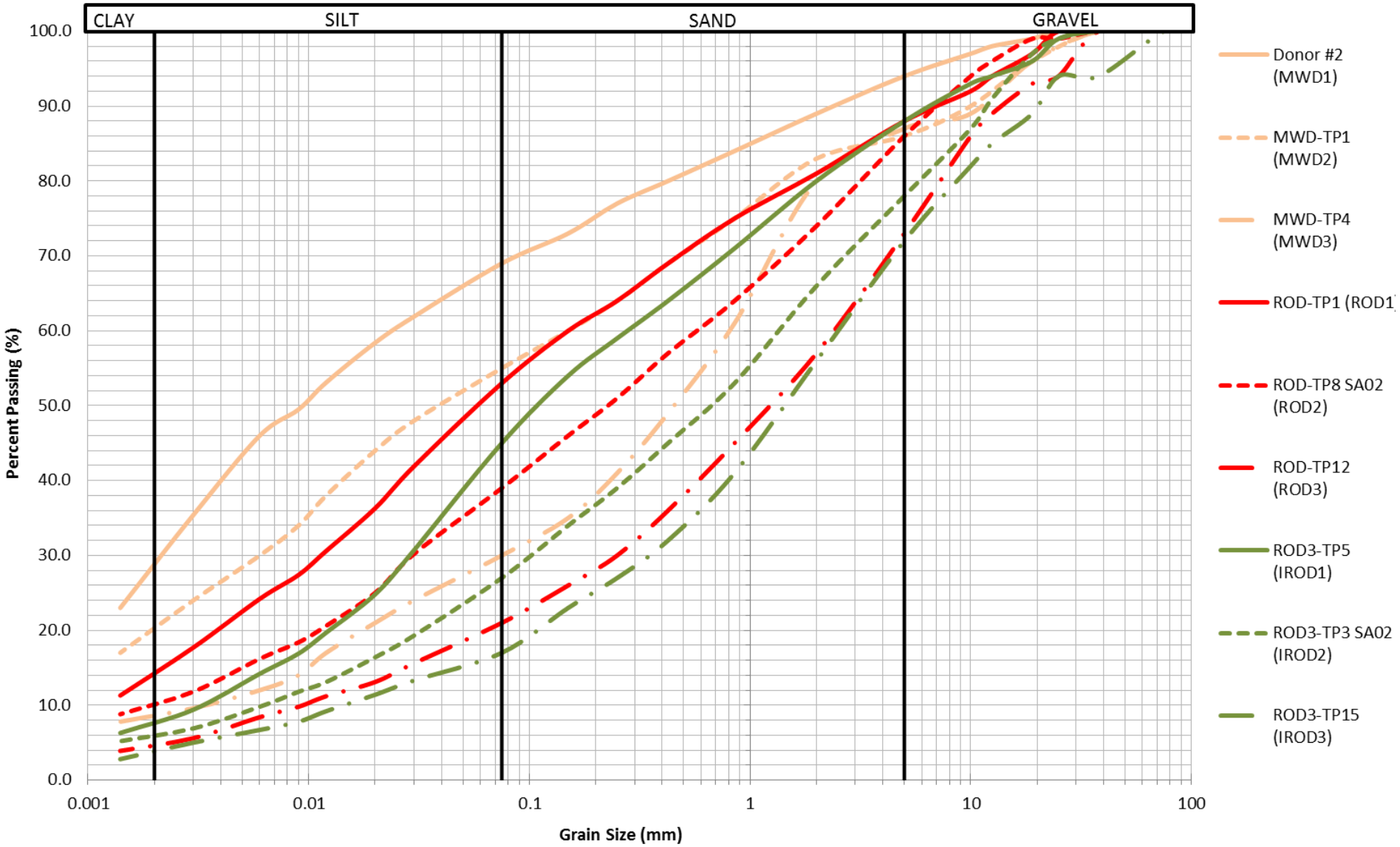


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**Representative Cover Materials**

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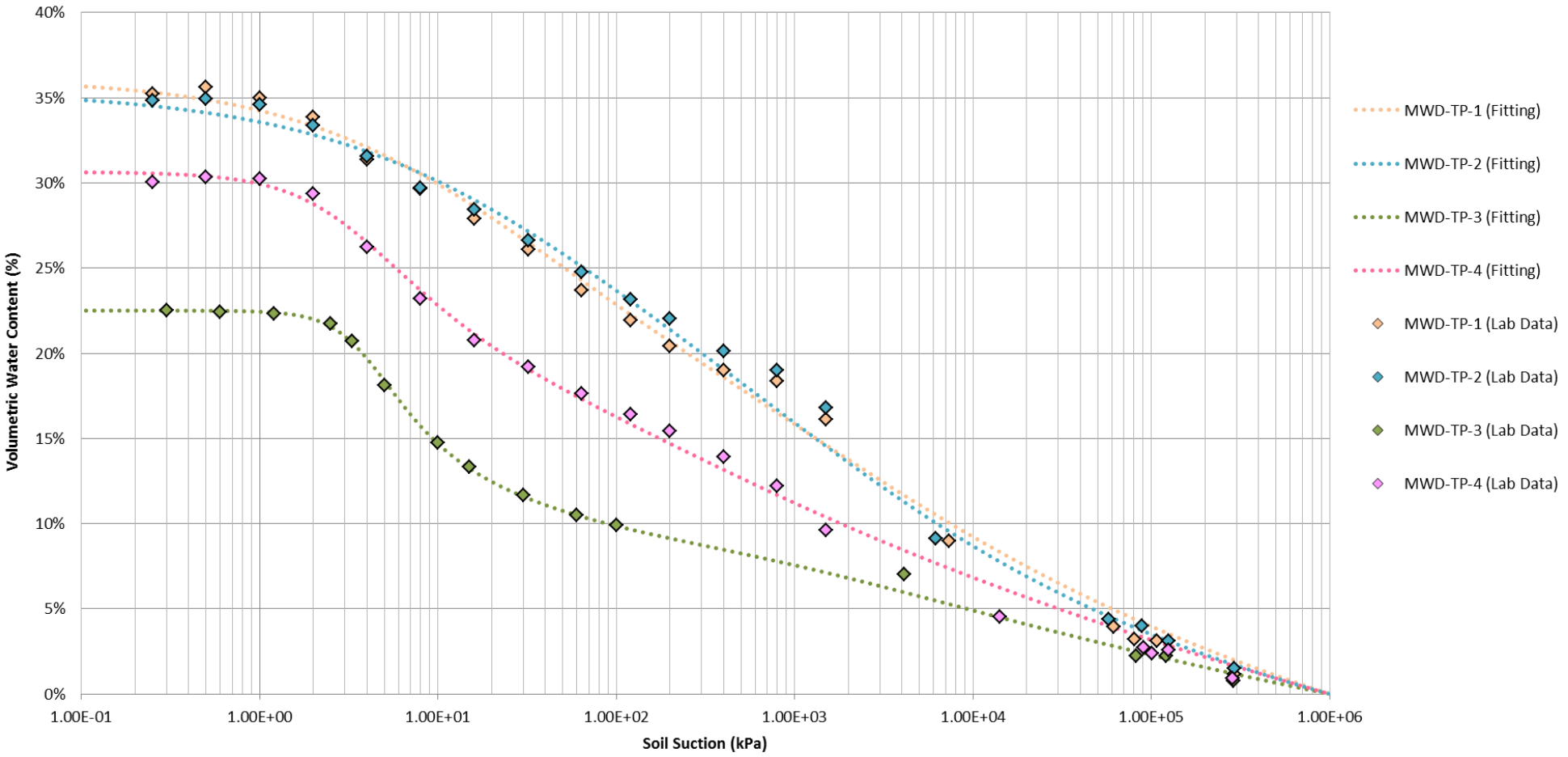


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Scoping Level Cover Assessment

**Measured Soil Water Characteristic Curves**

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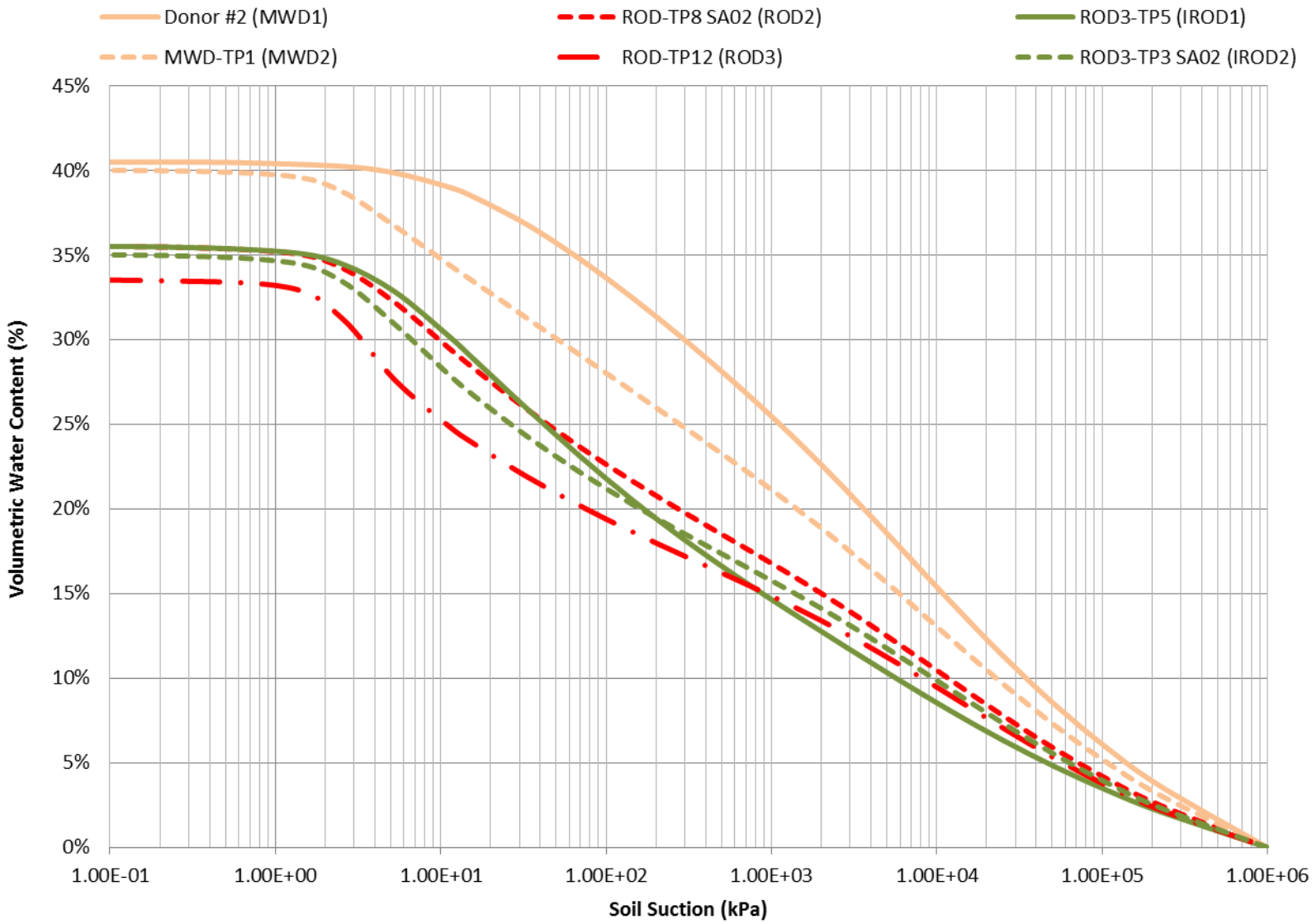


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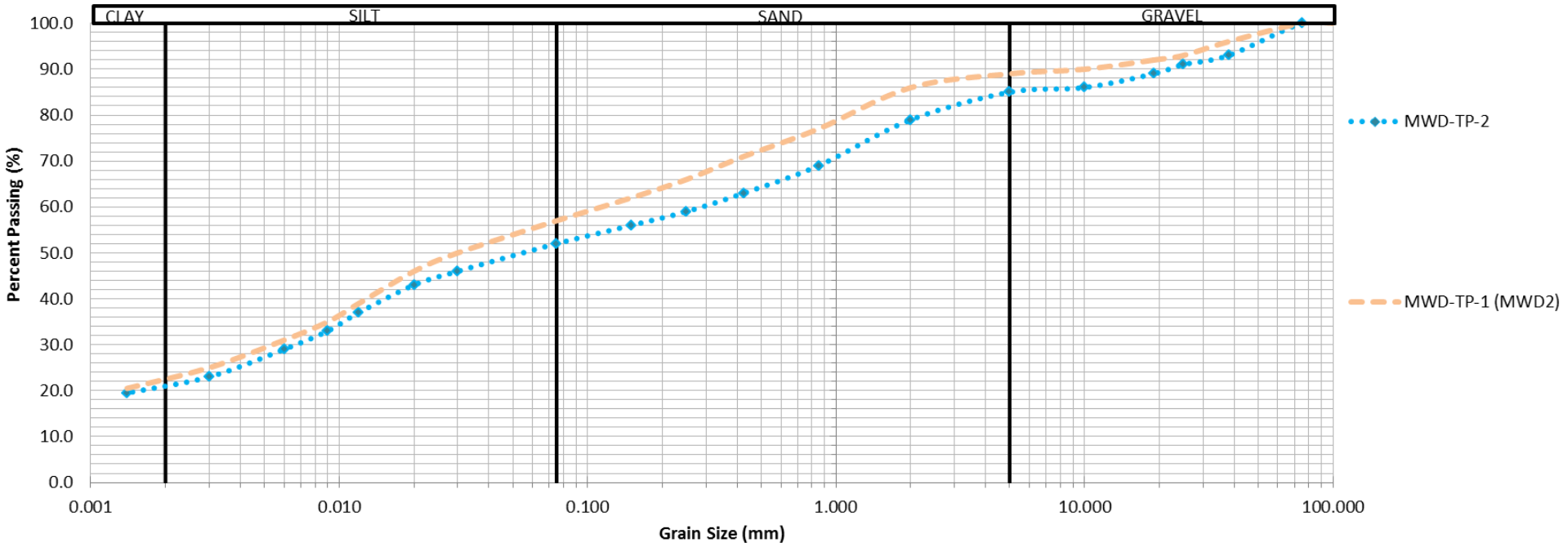


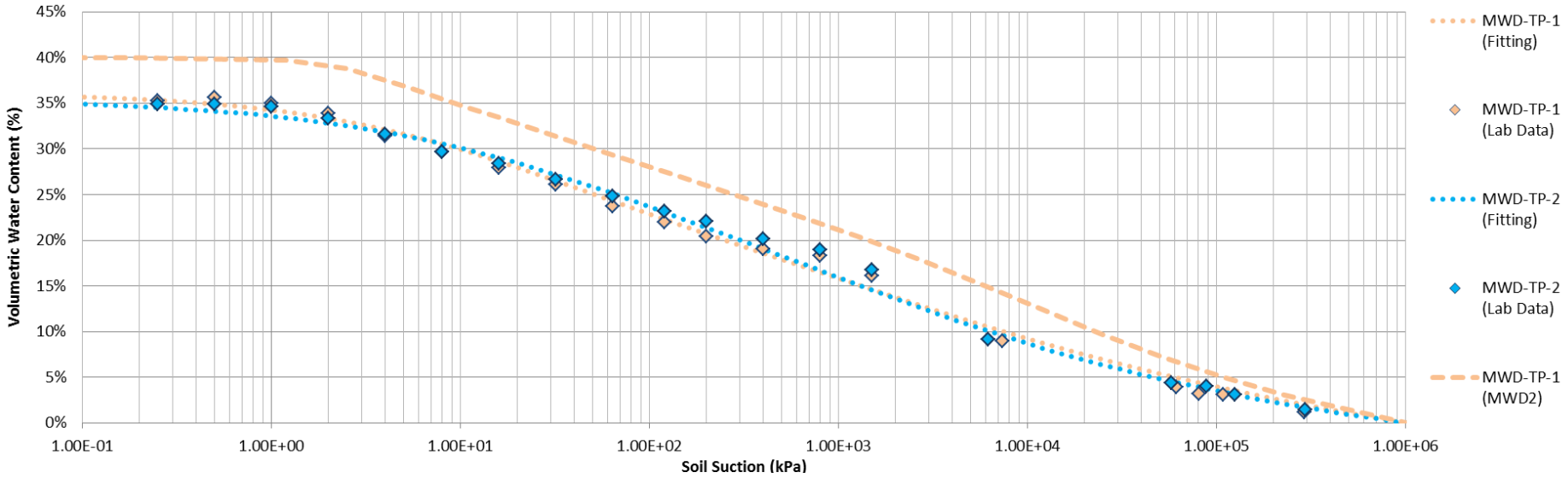


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Scoping Level Cover Assessment

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

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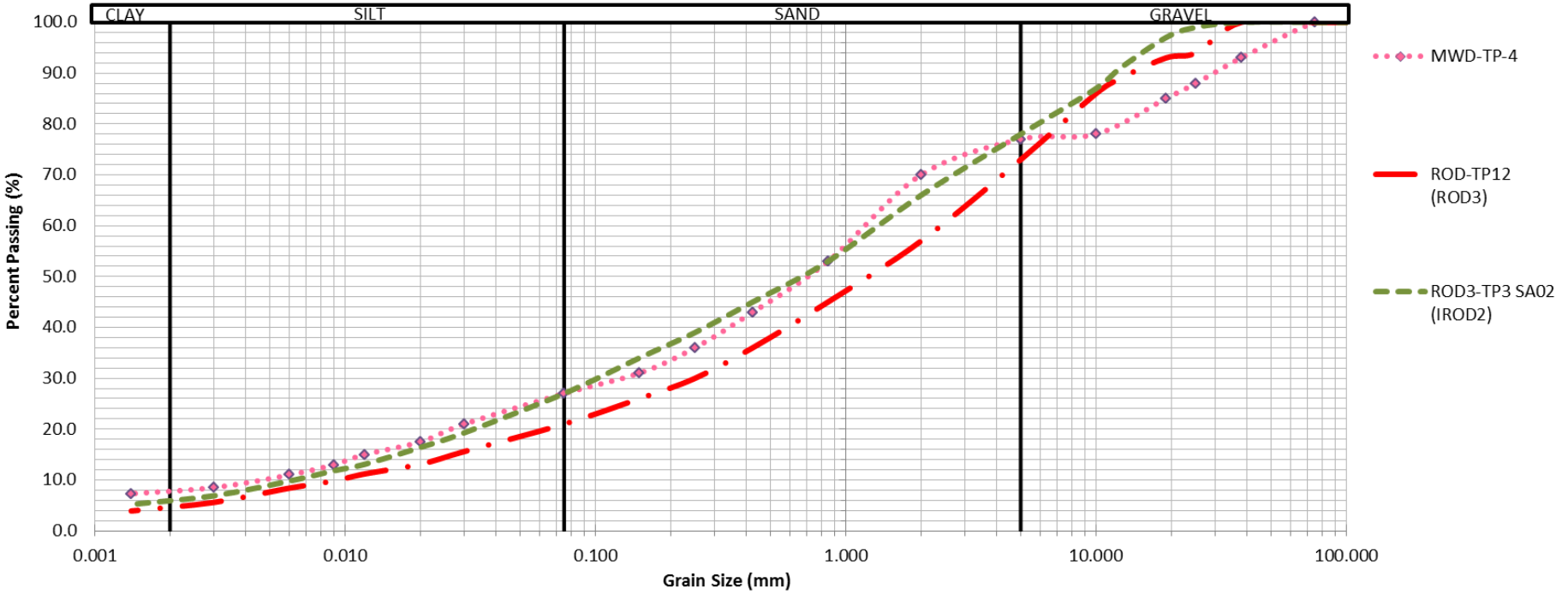


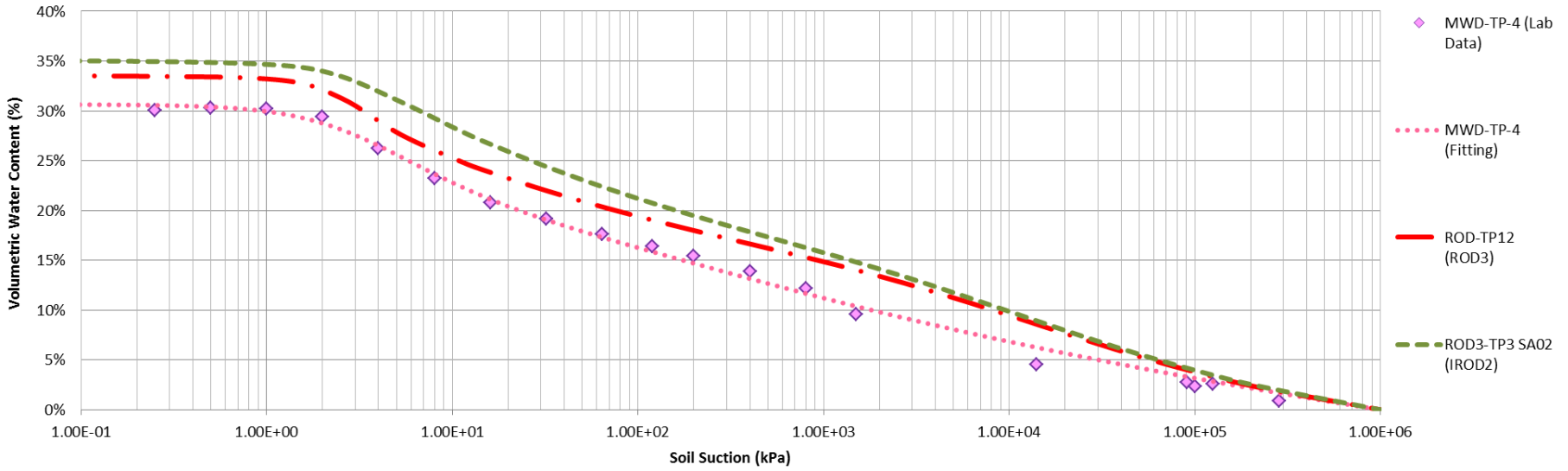


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Scoping Level Cover Assessment

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

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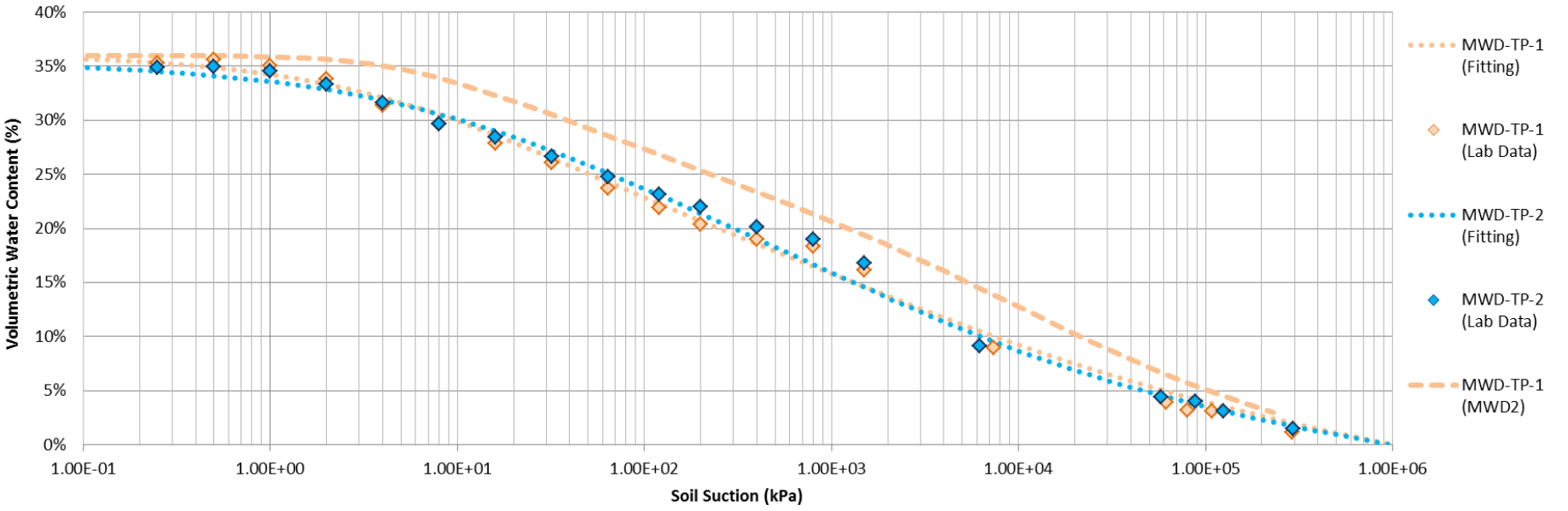


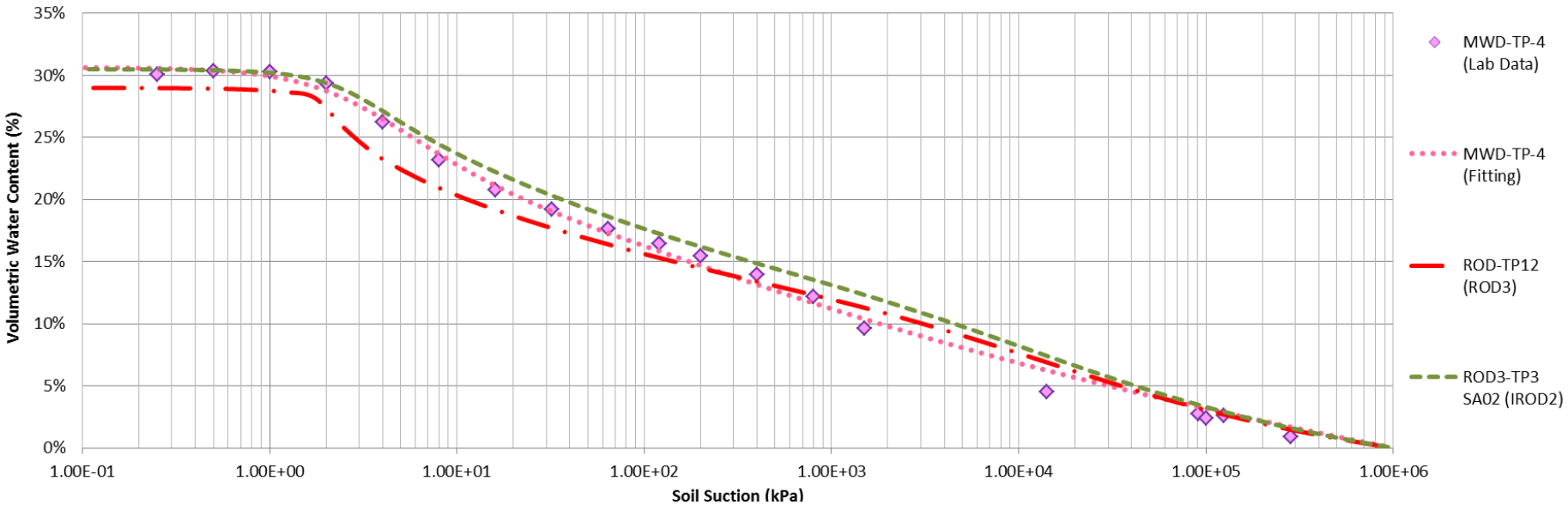


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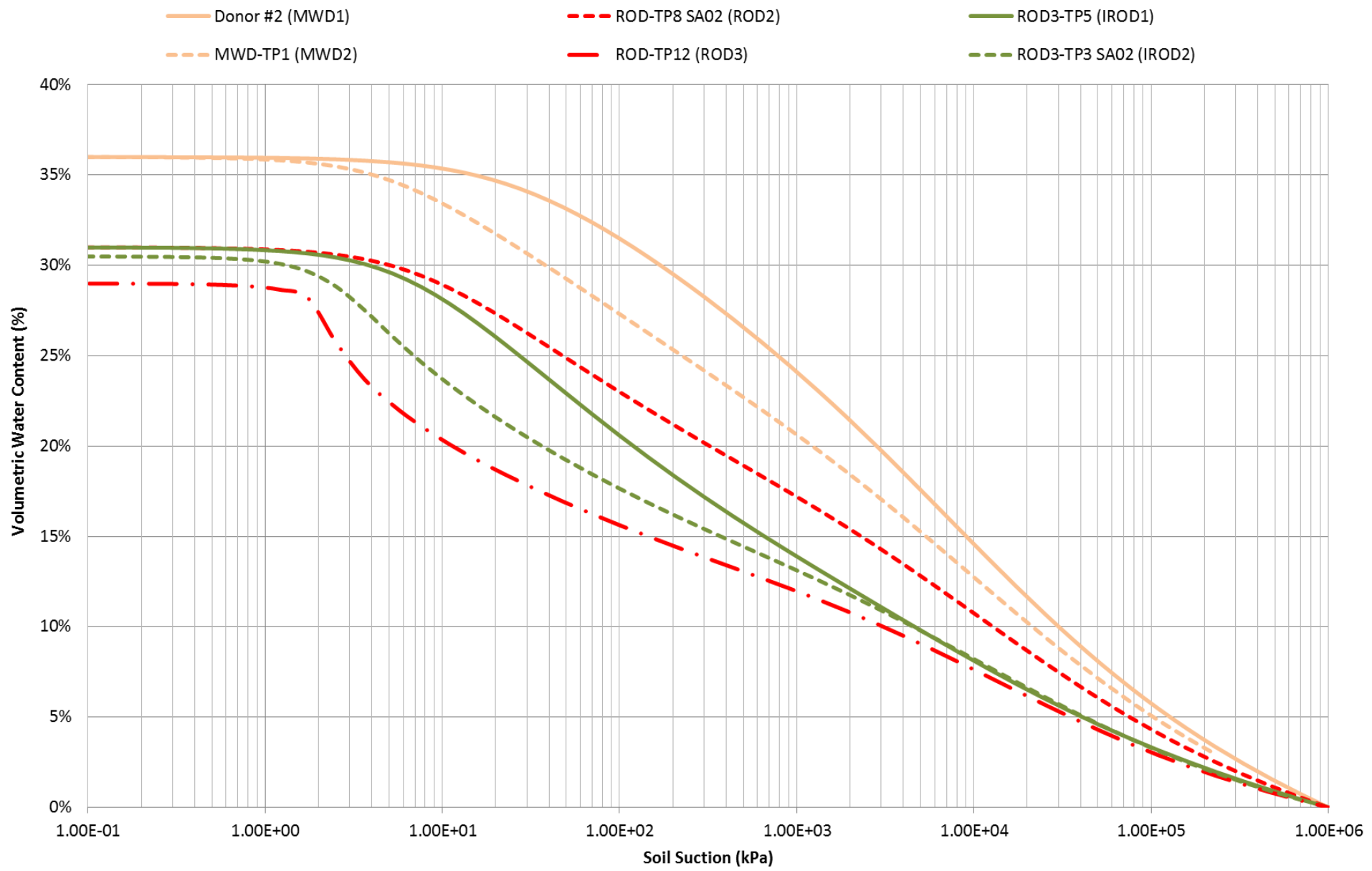


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Scoping Level Cover Assessment

**Calibrated Soil Water Characteristic Curves**

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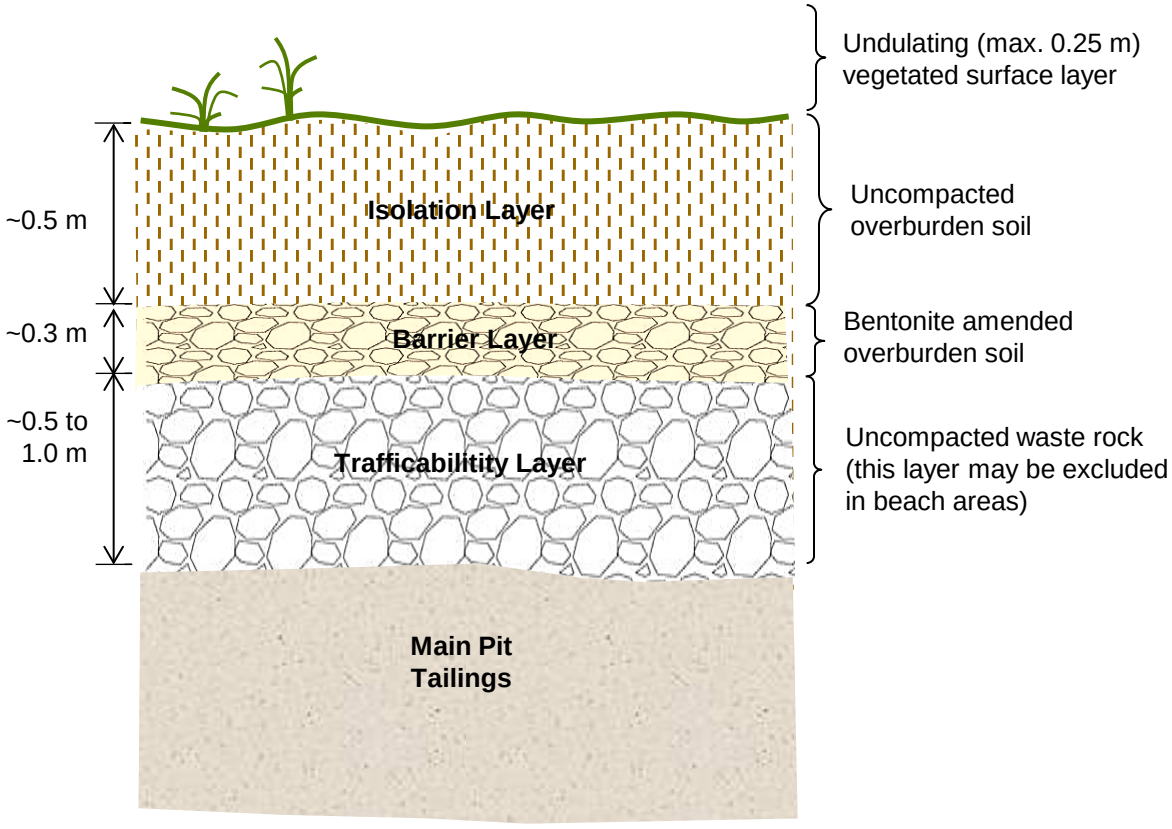


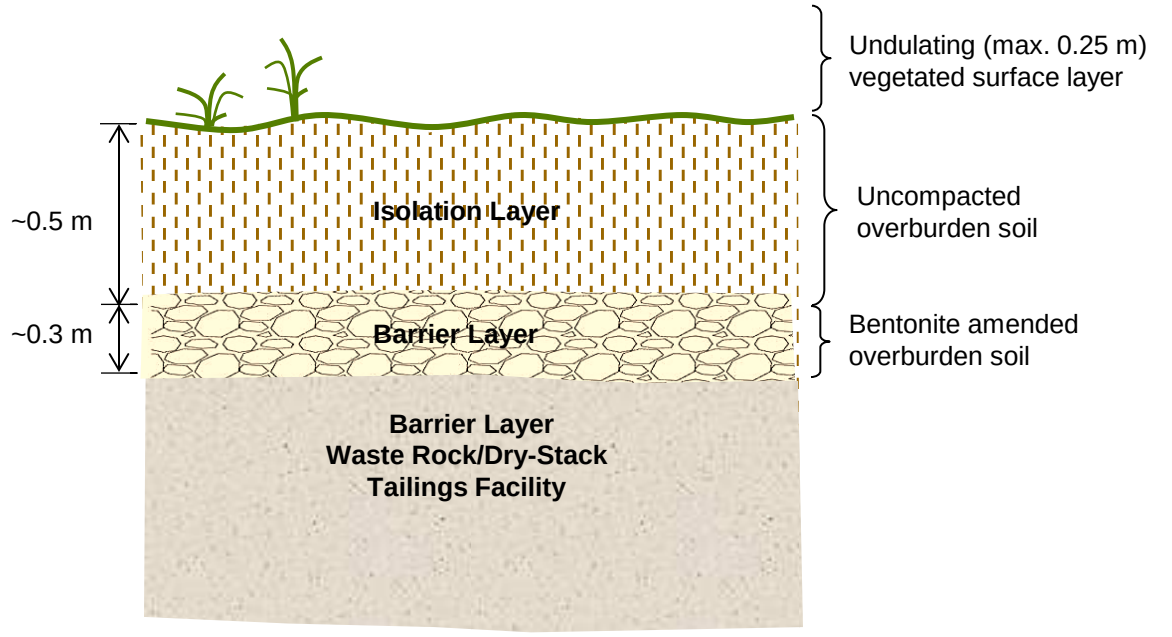


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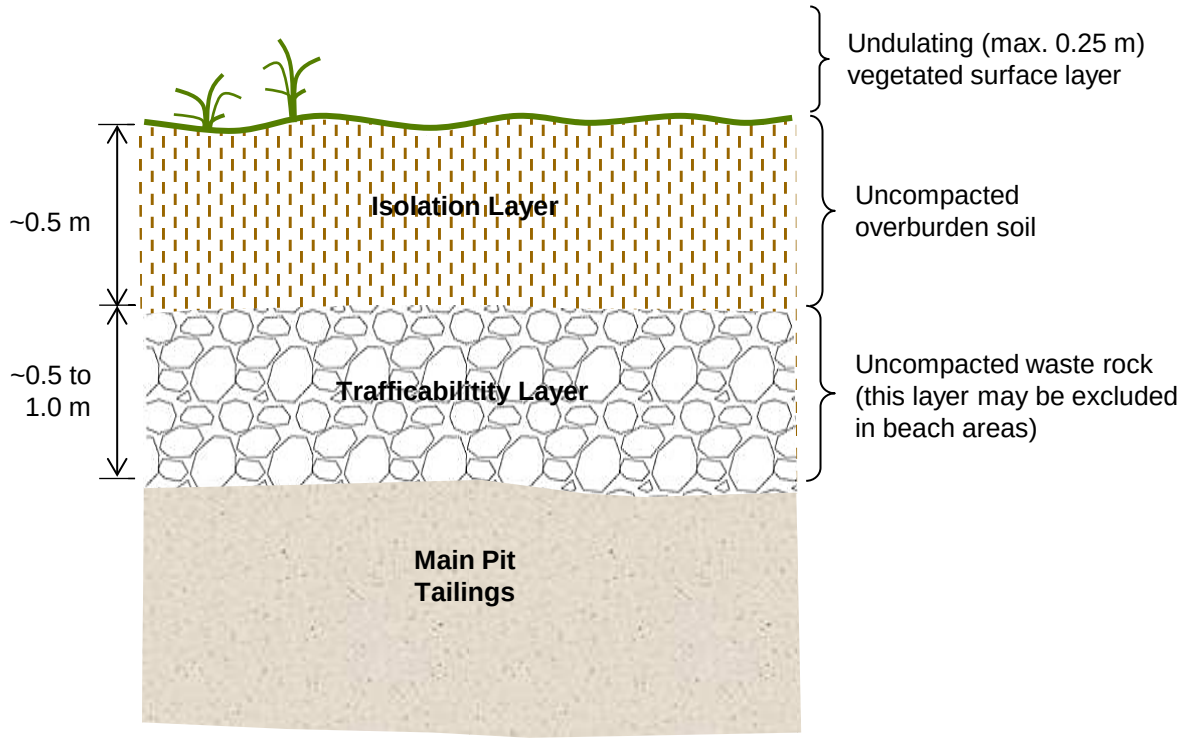


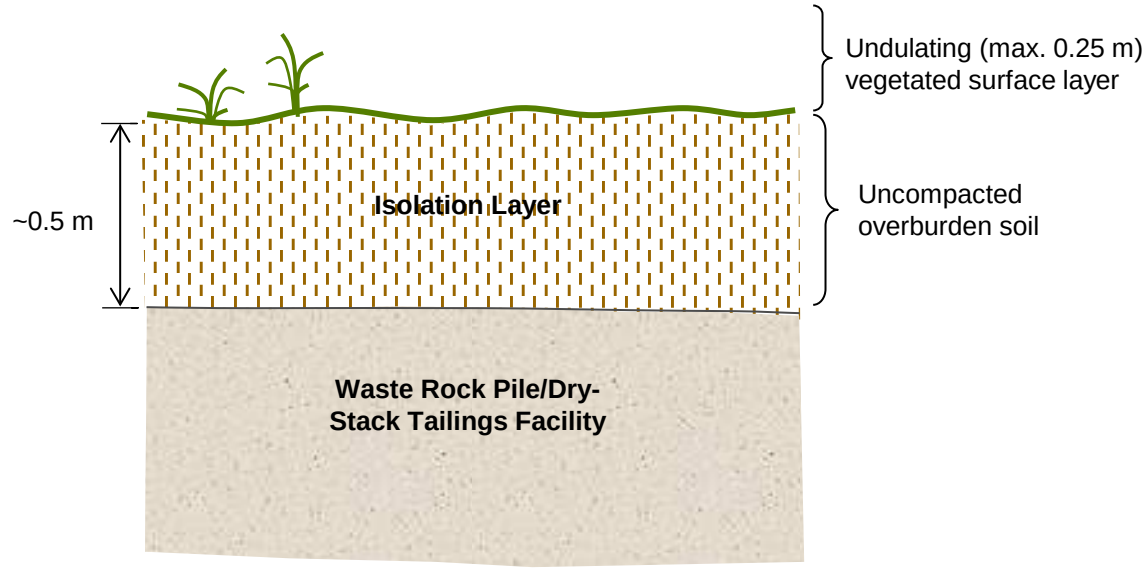


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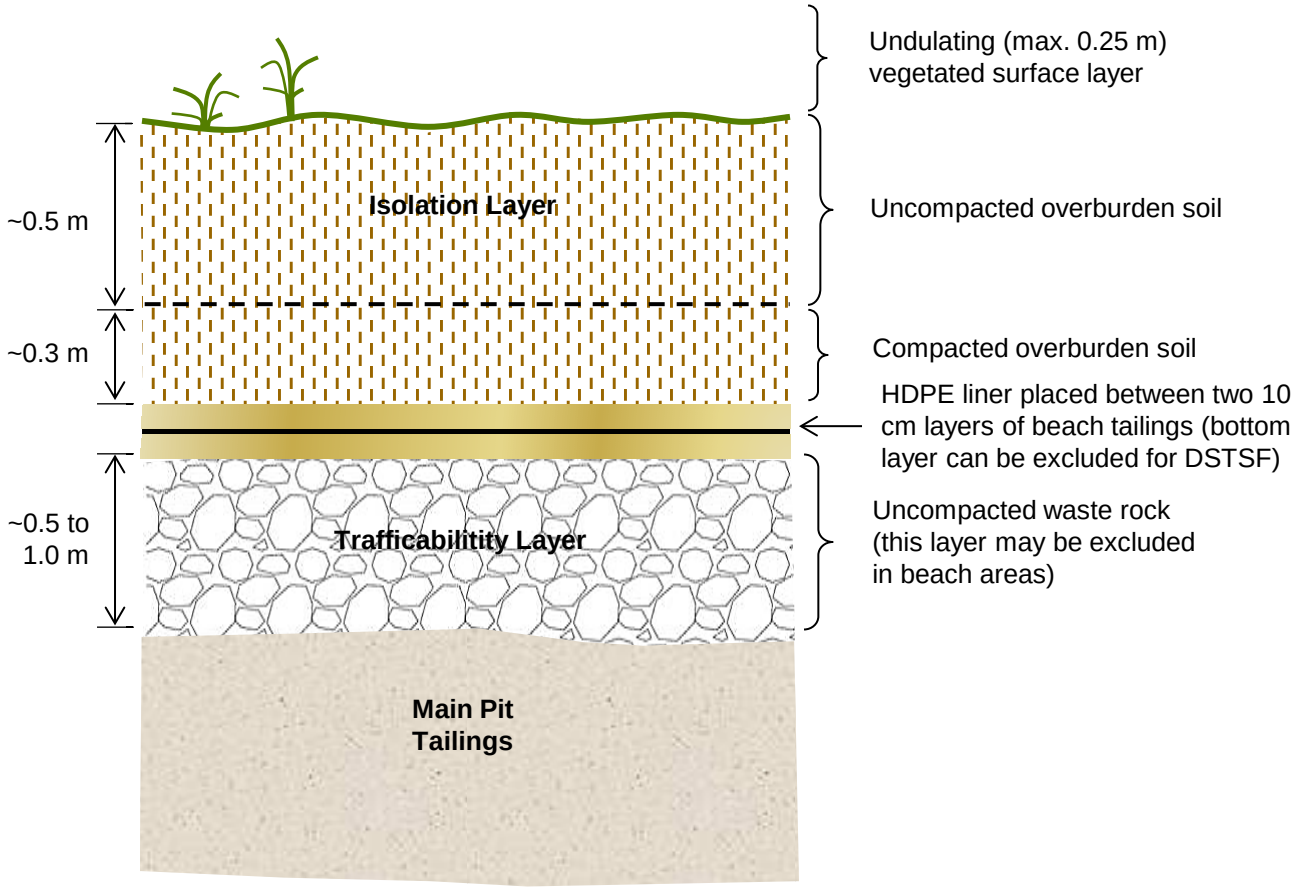
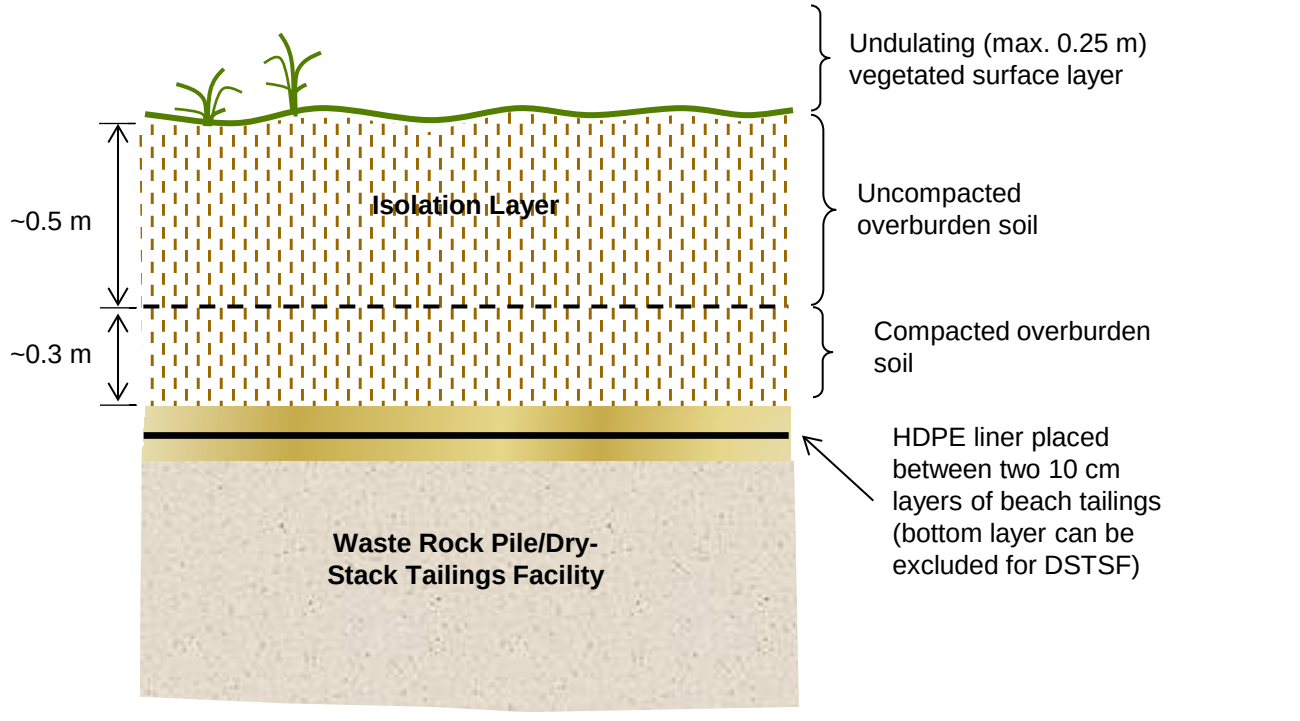
| | | **Conceptual Isolation Cover** | | |
| Job No: 1CM002.007<br>Filename: Figure 15-17_1CM002.0007_Conceptual Covers | Minto Mine | Date: July 2013 | Approved: EMR | Figure: **15** |

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|---|---|---|---|---|
| srk consulting | CAPSTONE MINING CORP. MINTO MINE | Scoping Level Cover Assessment | | |
| | | **Conceptual Very Low Infiltration Cover** | | |
| Job No: 1CM002.007<br>Filename: Figure 15-17_1CM002.0007_Conceptual Covers | Minto Mine | Date: July 2013 | Approved: EMR | Figure: **17** |

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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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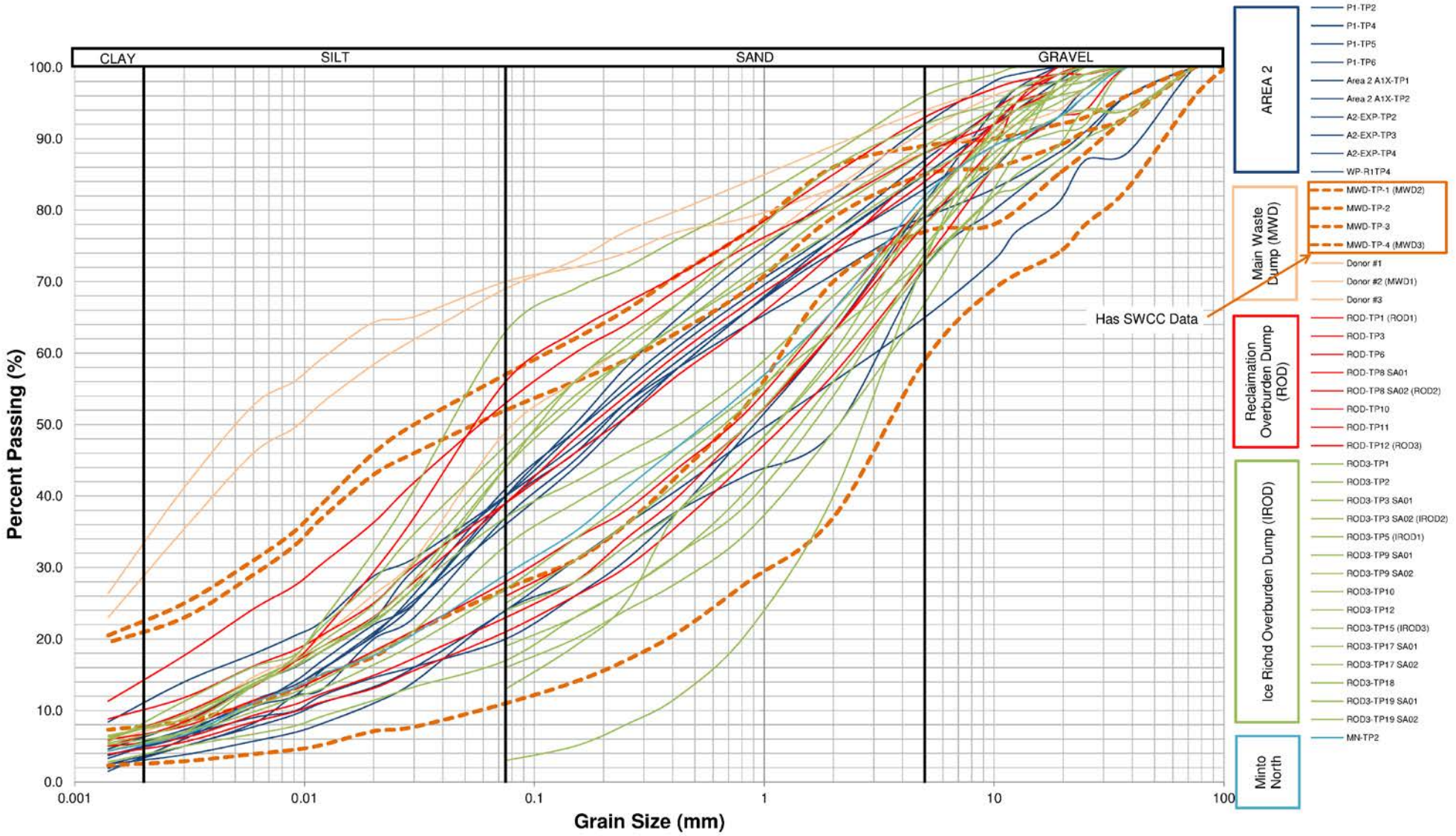


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# Closure Covers Model

## Particle Size Distribution of all Candidate Cover Material on Site

Job No: 1CM002.030

Filename: CoverModel_Figures_1CM002.030_Rev01_IM.pptx

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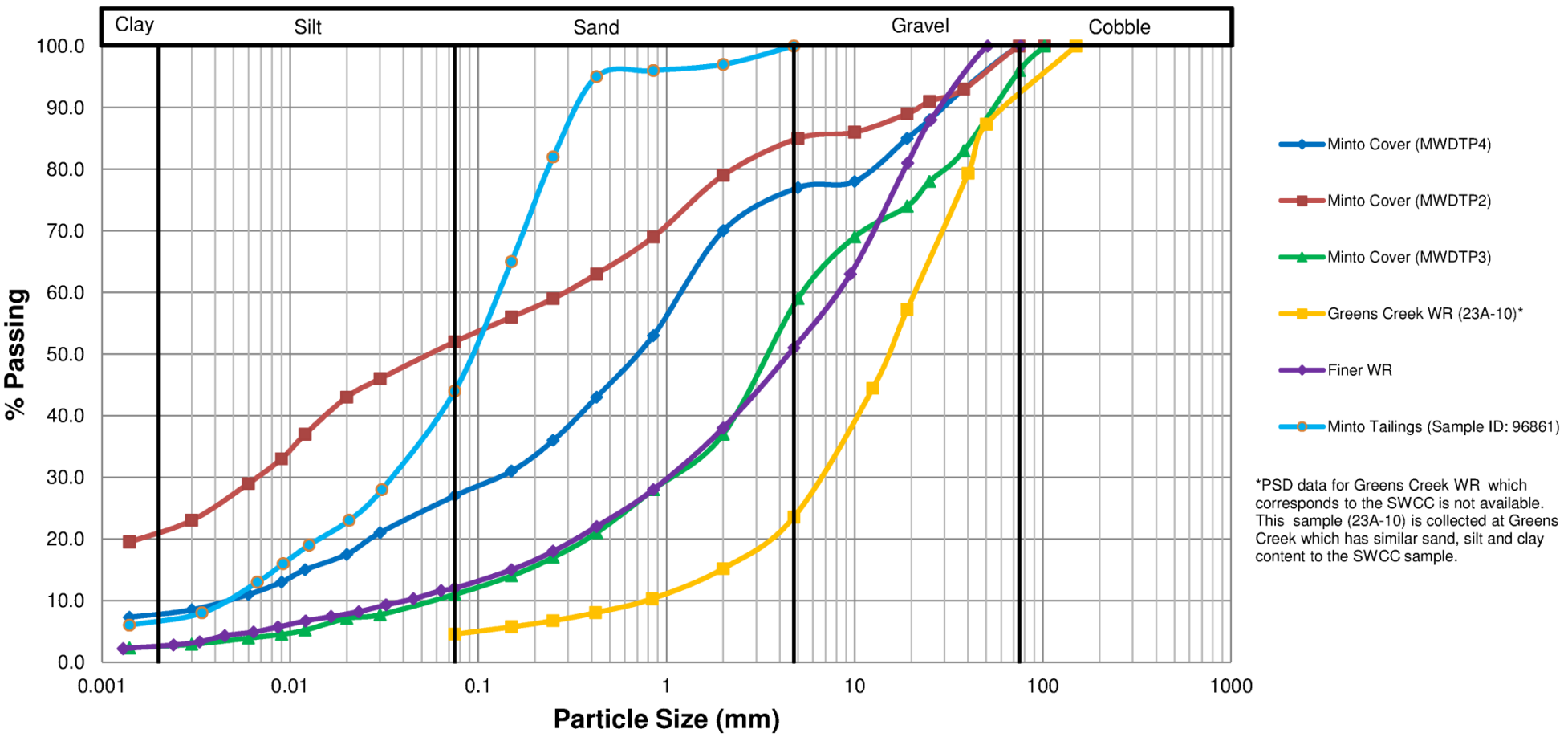


*PSD data for Greens Creek WR which corresponds to the SWCC is not available. This sample (23A-10) is collected at Greens Creek which has similar sand, silt and clay content to the SWCC sample.

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# Closure Covers Model

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

Job No: 1CM002.030

Filename: CoverModel_Figures_1CM002.030_Rev01_IM.pptx

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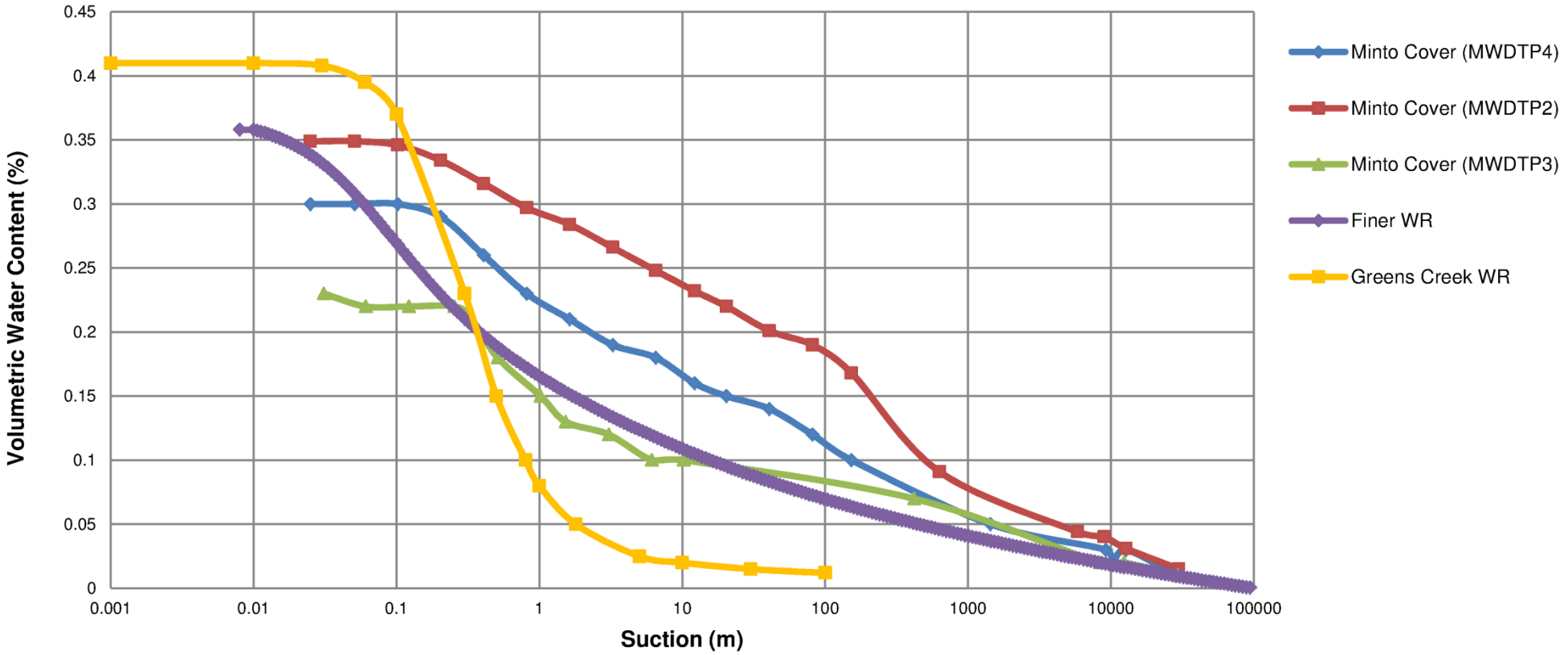


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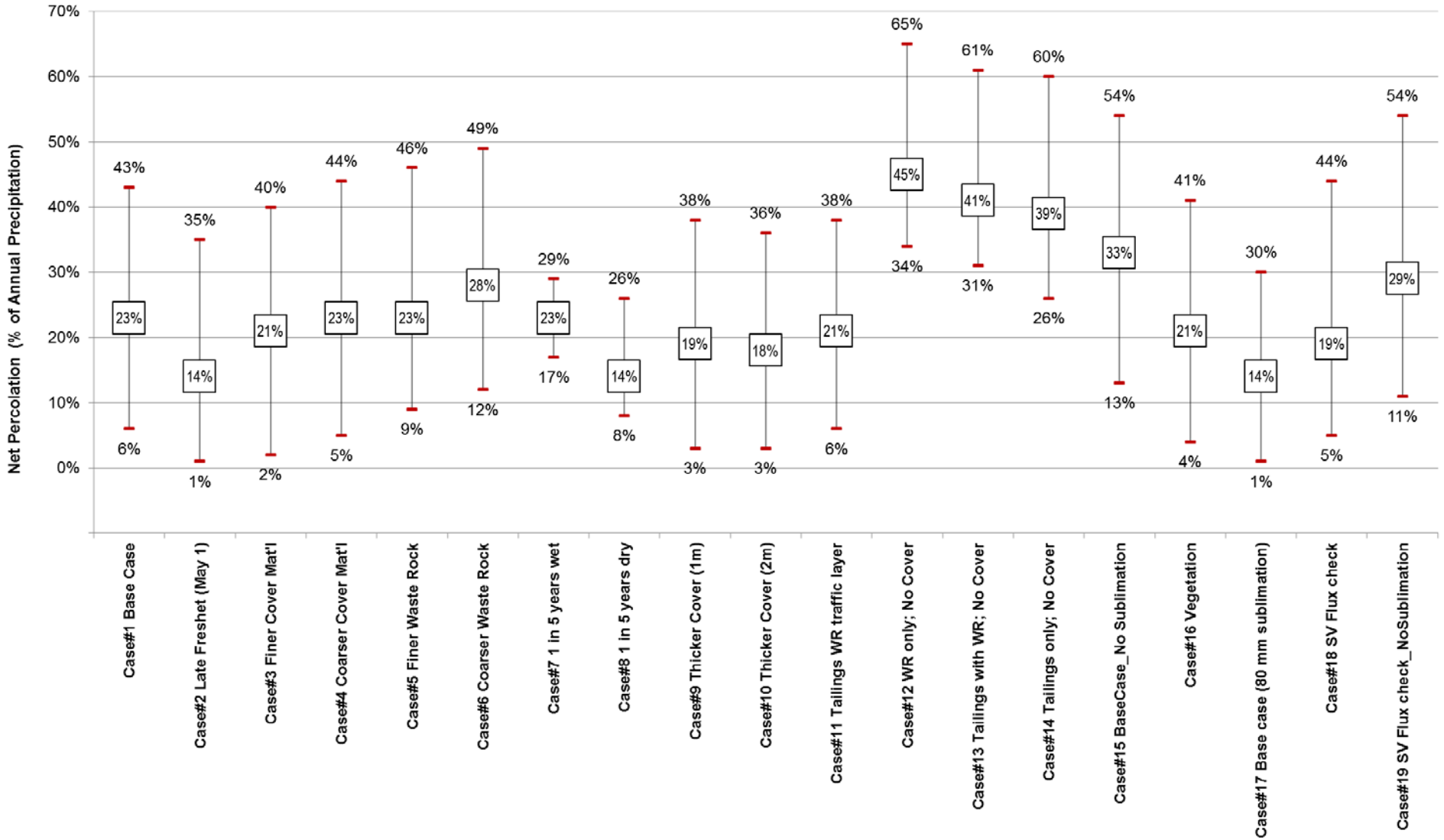


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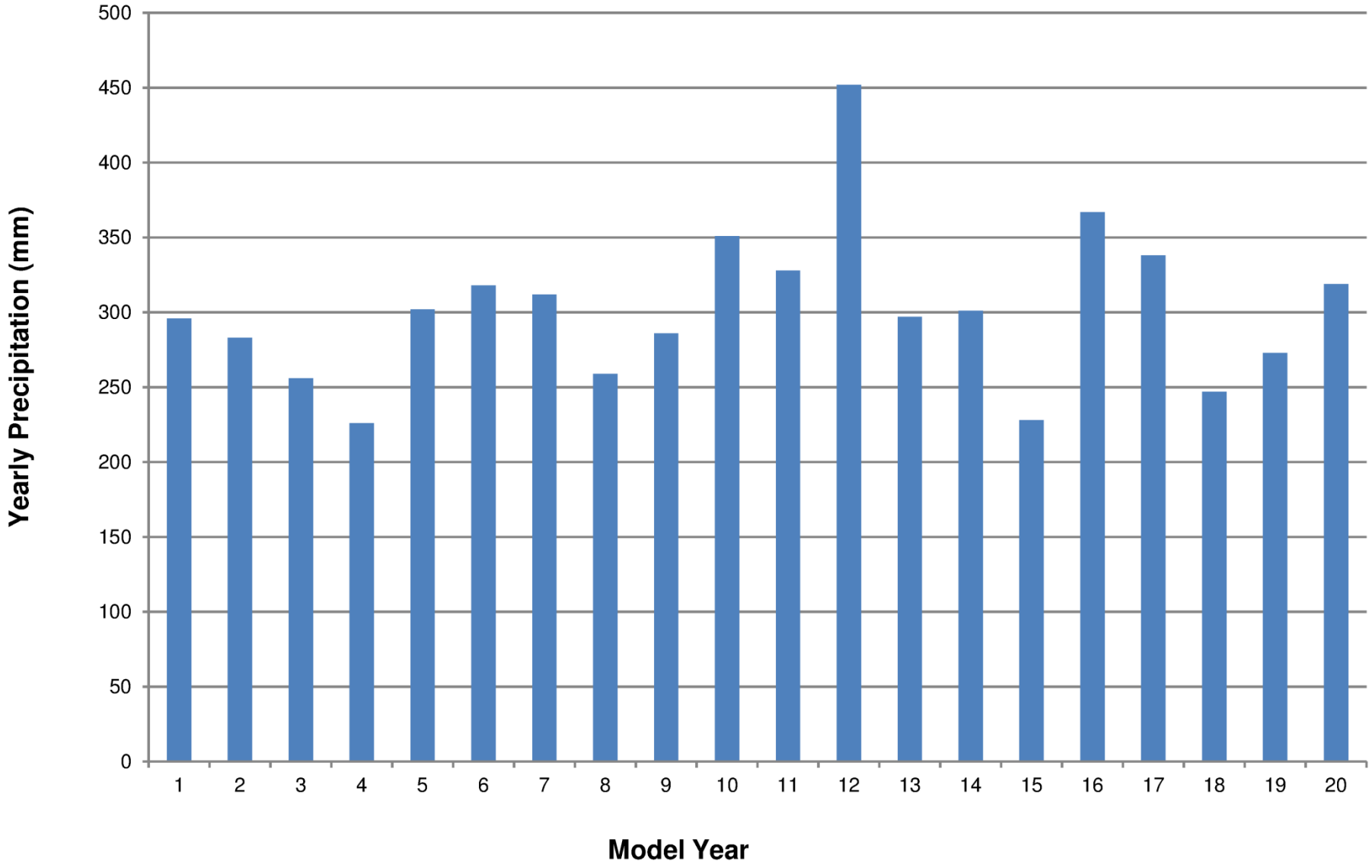


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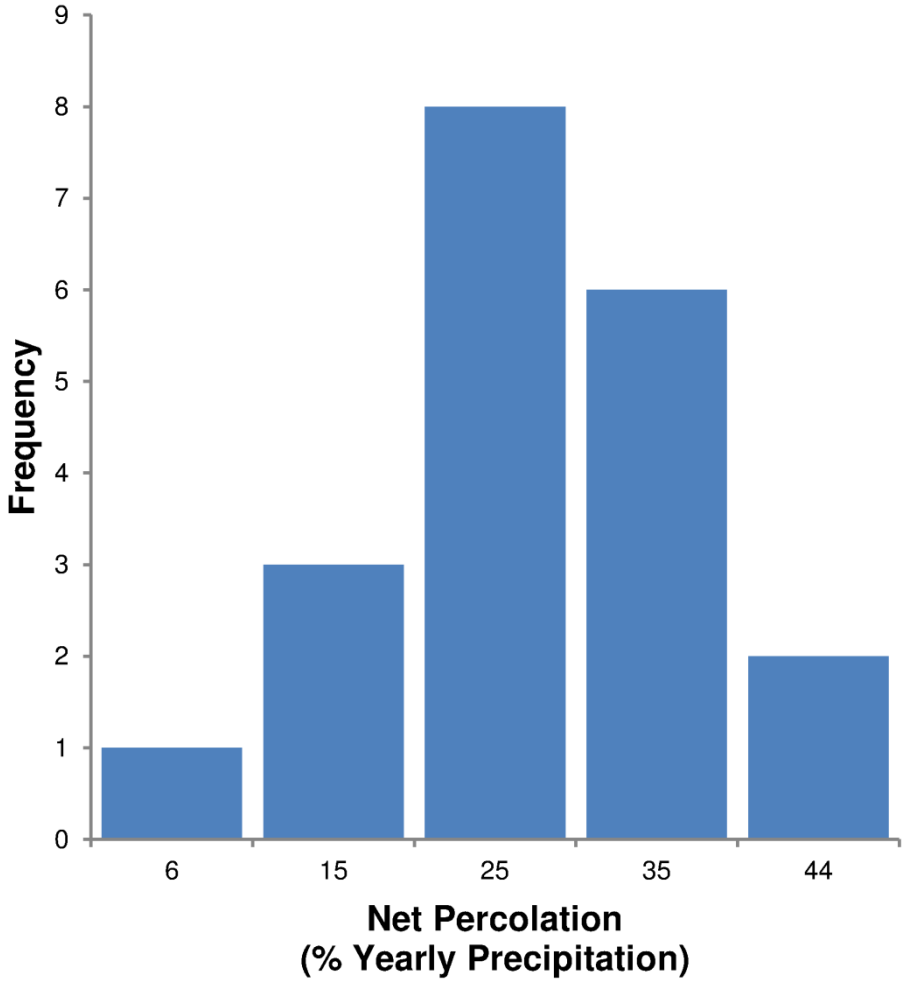


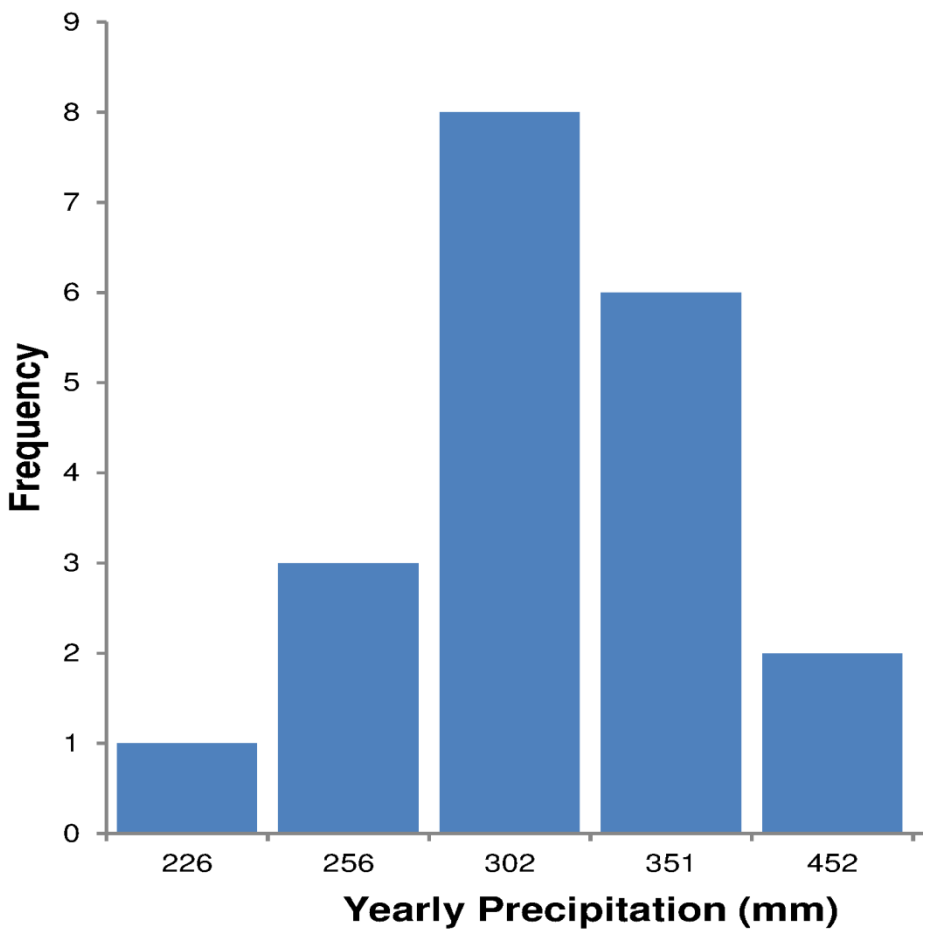


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| | | Comparison of Statistical Distribution of Net Percolation and Precipitation |
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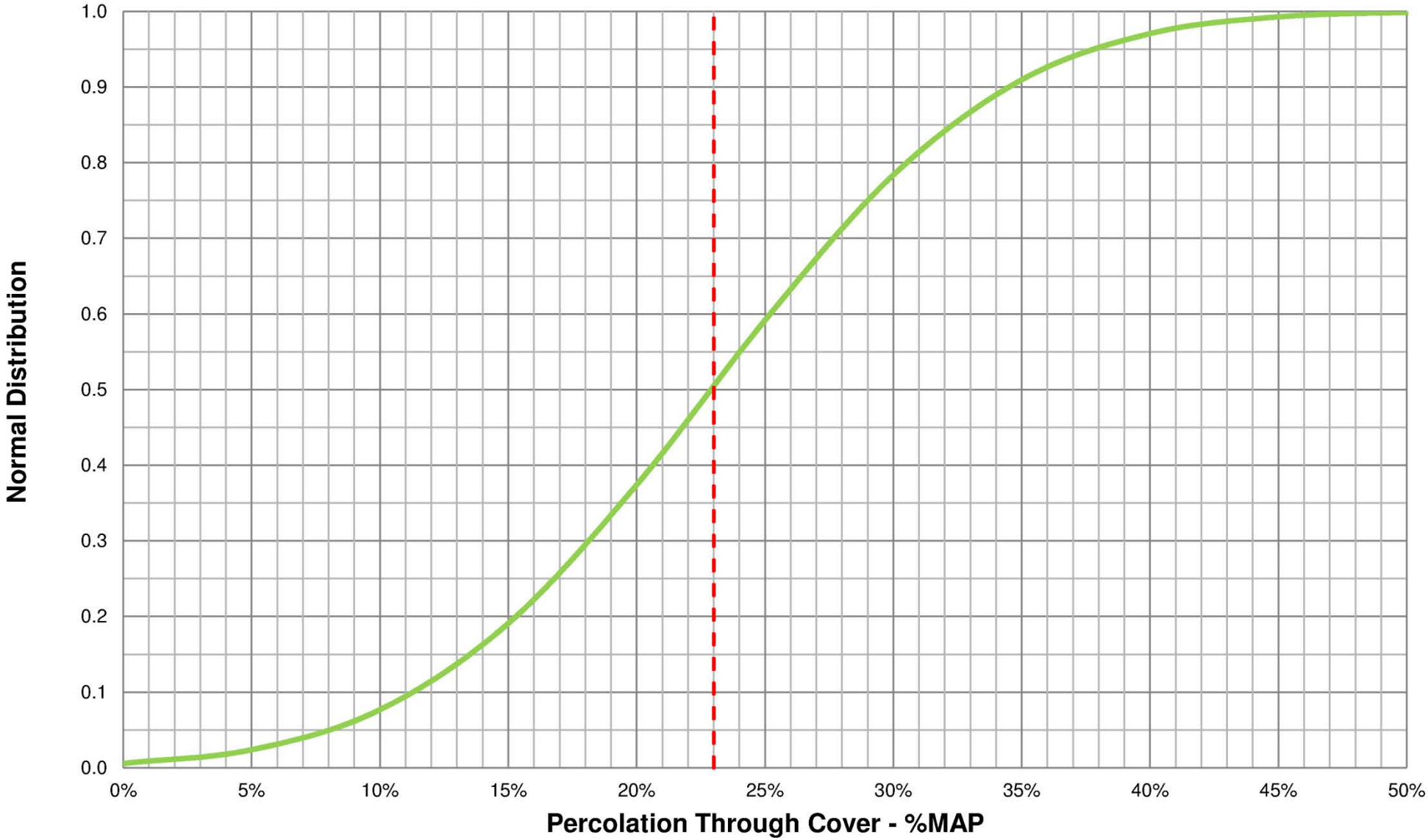


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# Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan

**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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# 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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Appendix E – Minto Mine Preliminary Closure Cover Revegetation Plan

Appendix F – Minto Closure Cover Design – Hydrotechnical Designs for Engineered Landforms

# 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.<br><br>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.<br><br>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. |

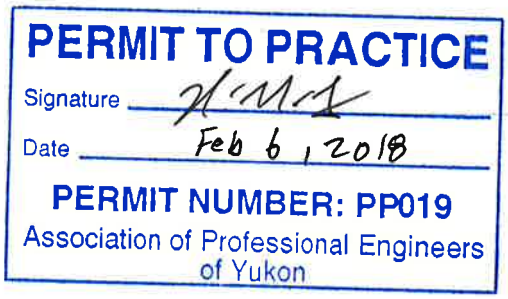
Other primary conclusions of this document include:

- 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




Erik Ketilson, MEng, PEng
Senior Consultant




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.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

# 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 consulting

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# 2018 Updated Closure Cover Design

## Existing Site Conditions

| DATE: | APPROVED: | FIGURE: |
|---|---|---|
| January 2018 | EPK | 01 |

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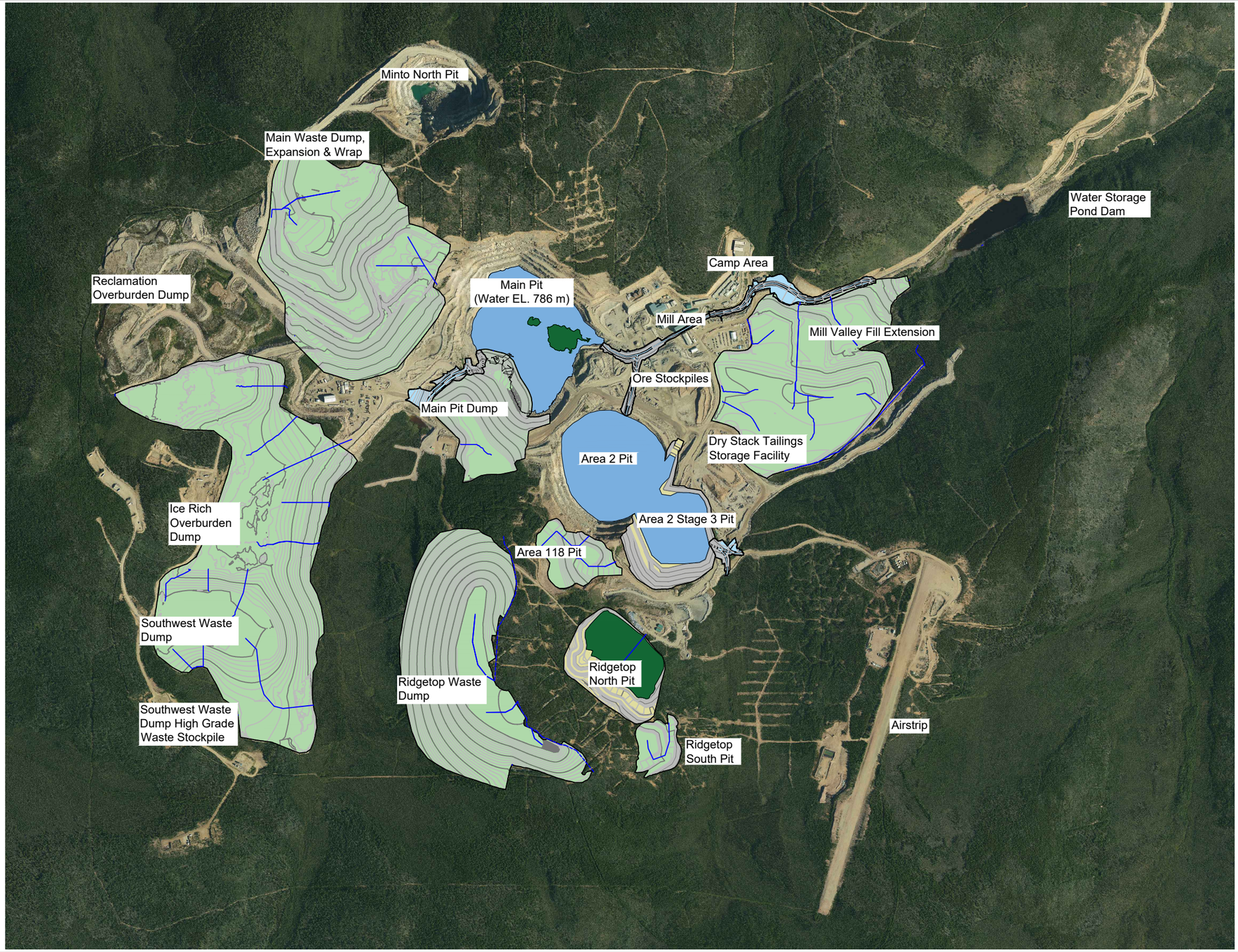


## LEGEND

- 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

DATE: January 2018 | APPROVED: EPK | FIGURE: 02

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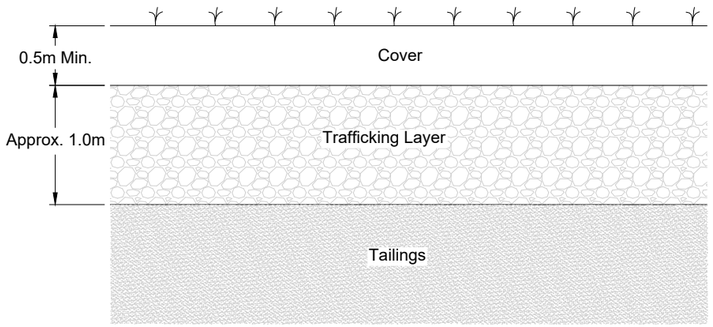


1 Subaerial Tailings Cover

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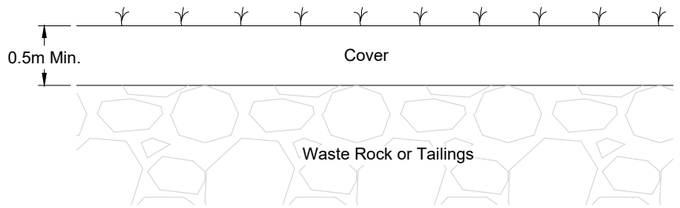
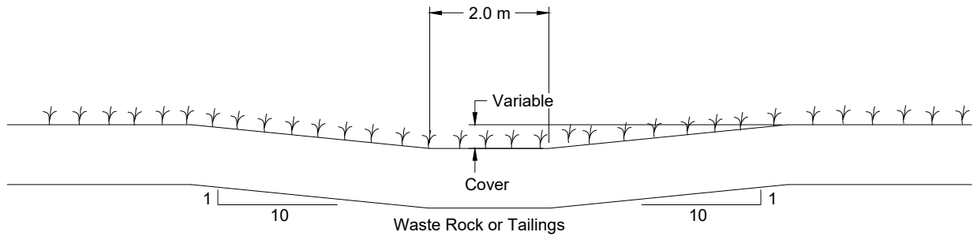



2 Cover Detail

Not To Scale




3 Swale Detail

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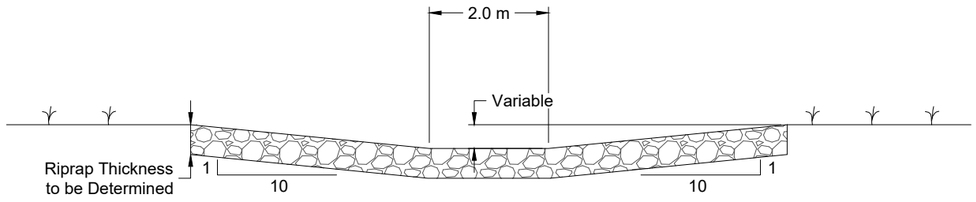


4 Slope Swale Detail

Not To Scale

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2018 Updated Closure Cover Design

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.

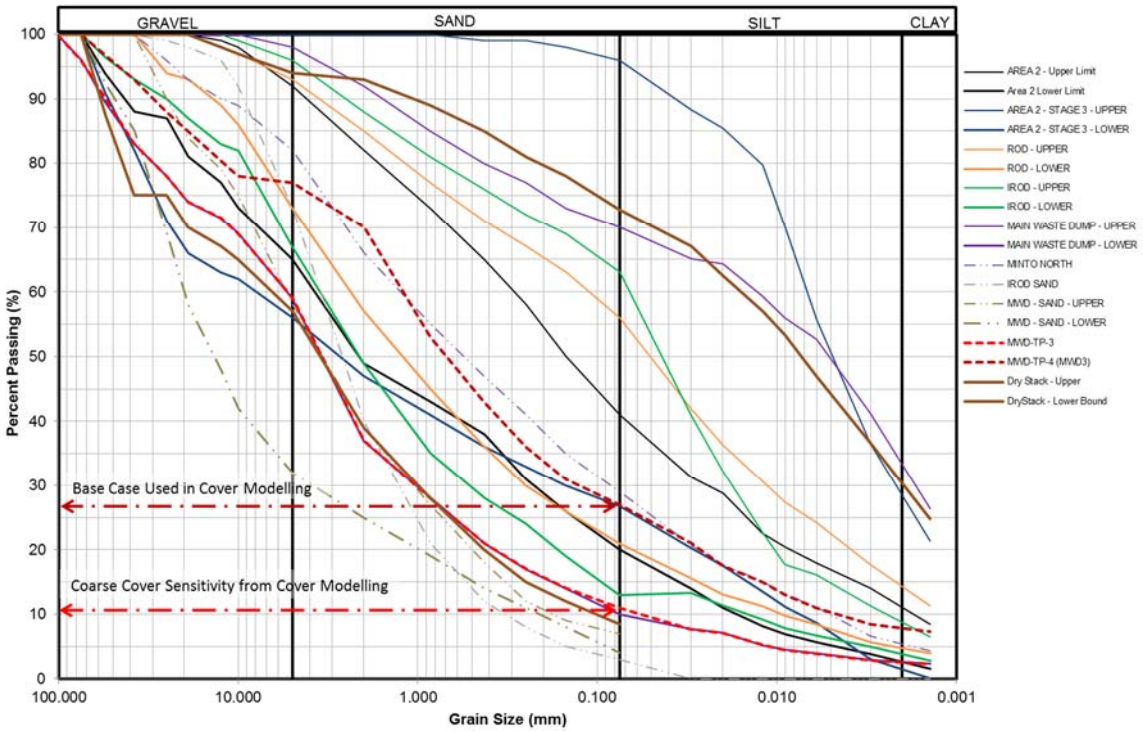


**Figure 1: Particle Size Distribution**

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).

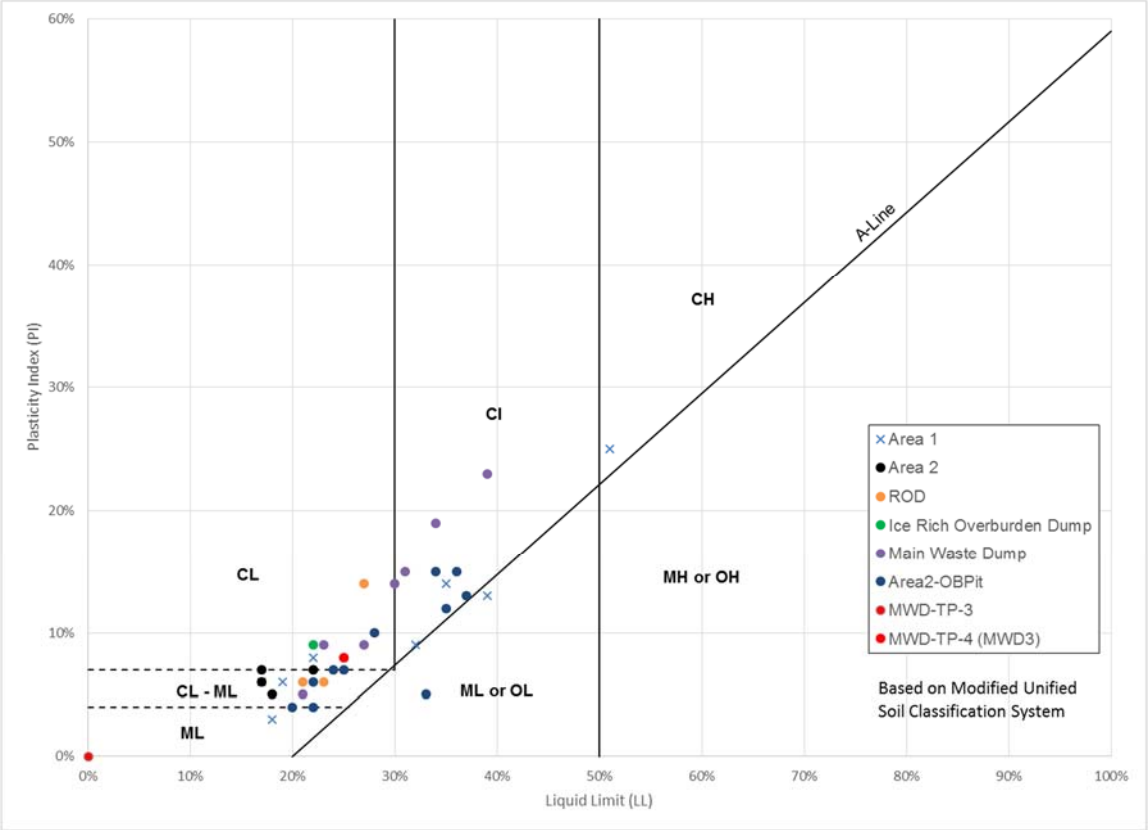


**Figure 2: Atterberg Limits**

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.

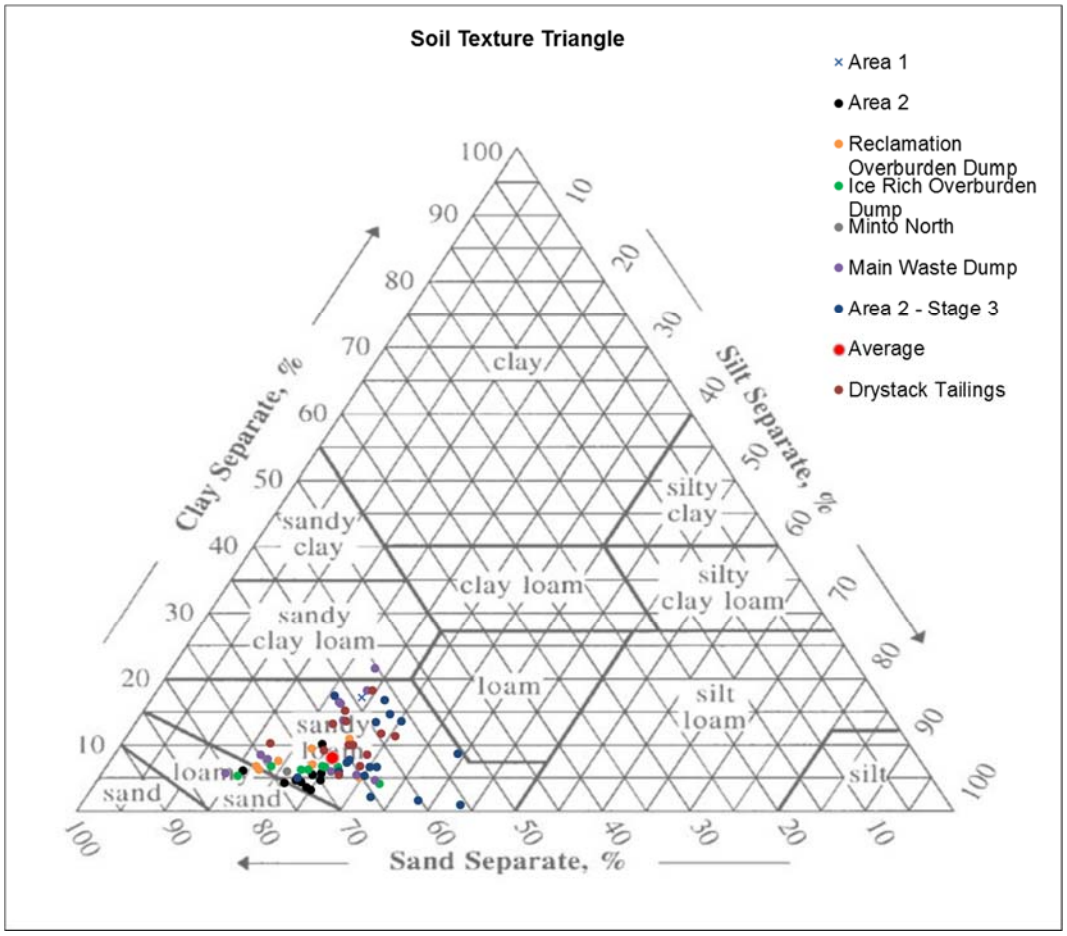


**Figure 3: Soil Classification Based on Soil Texture Triangle**

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**

| 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 |

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(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

srk consulting

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vancouver@srk.com
www.srk.com

# 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 27$^{th}$ through November 5$^{th}$ 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% |

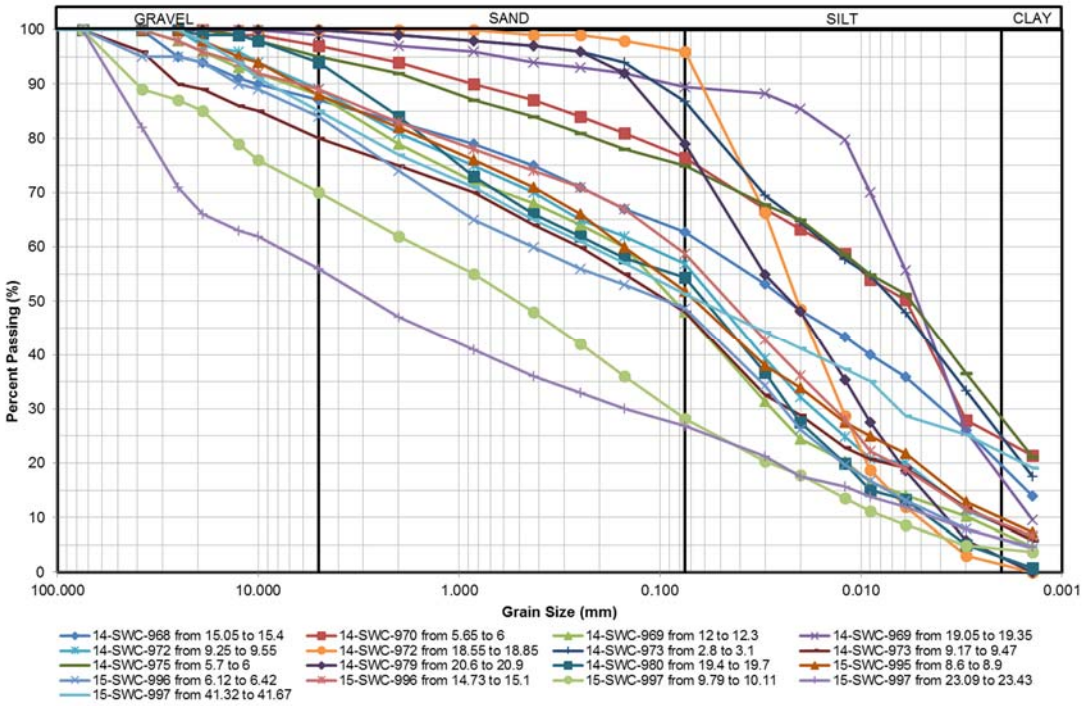


**Figure 1: Particle Size Distribution Analysis Results**

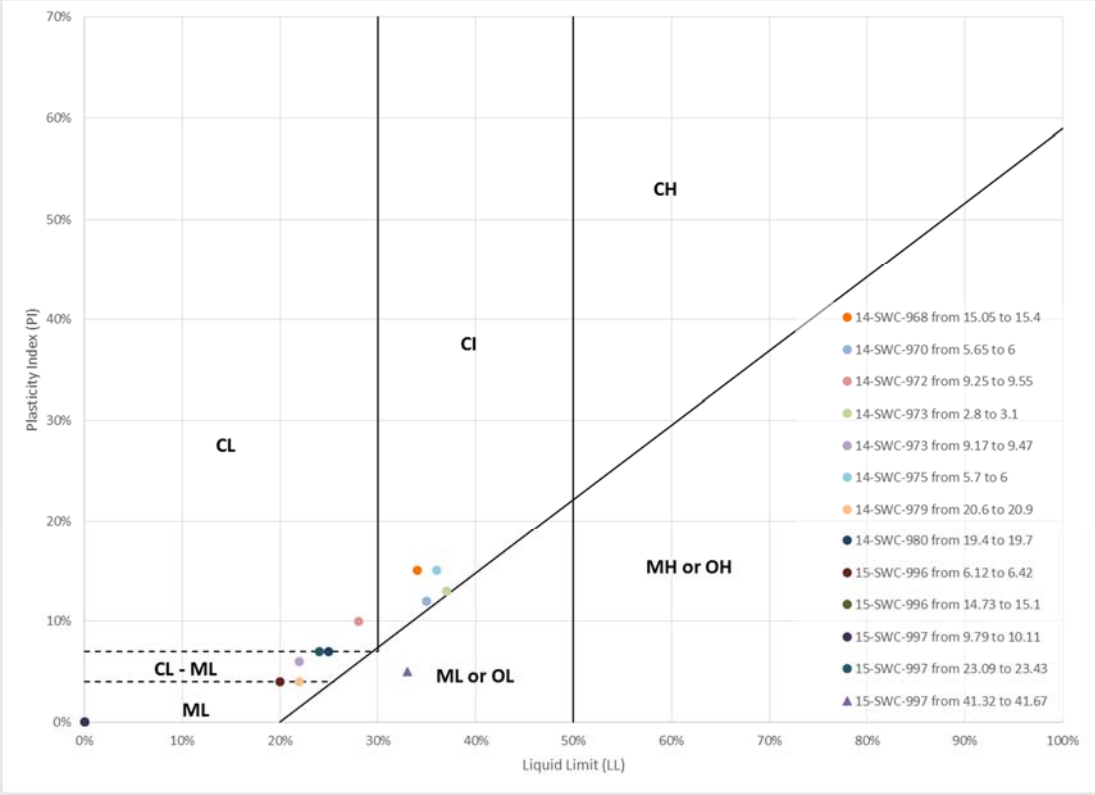


**Figure 2: Atterberg Limit Analysis Results**

# 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.

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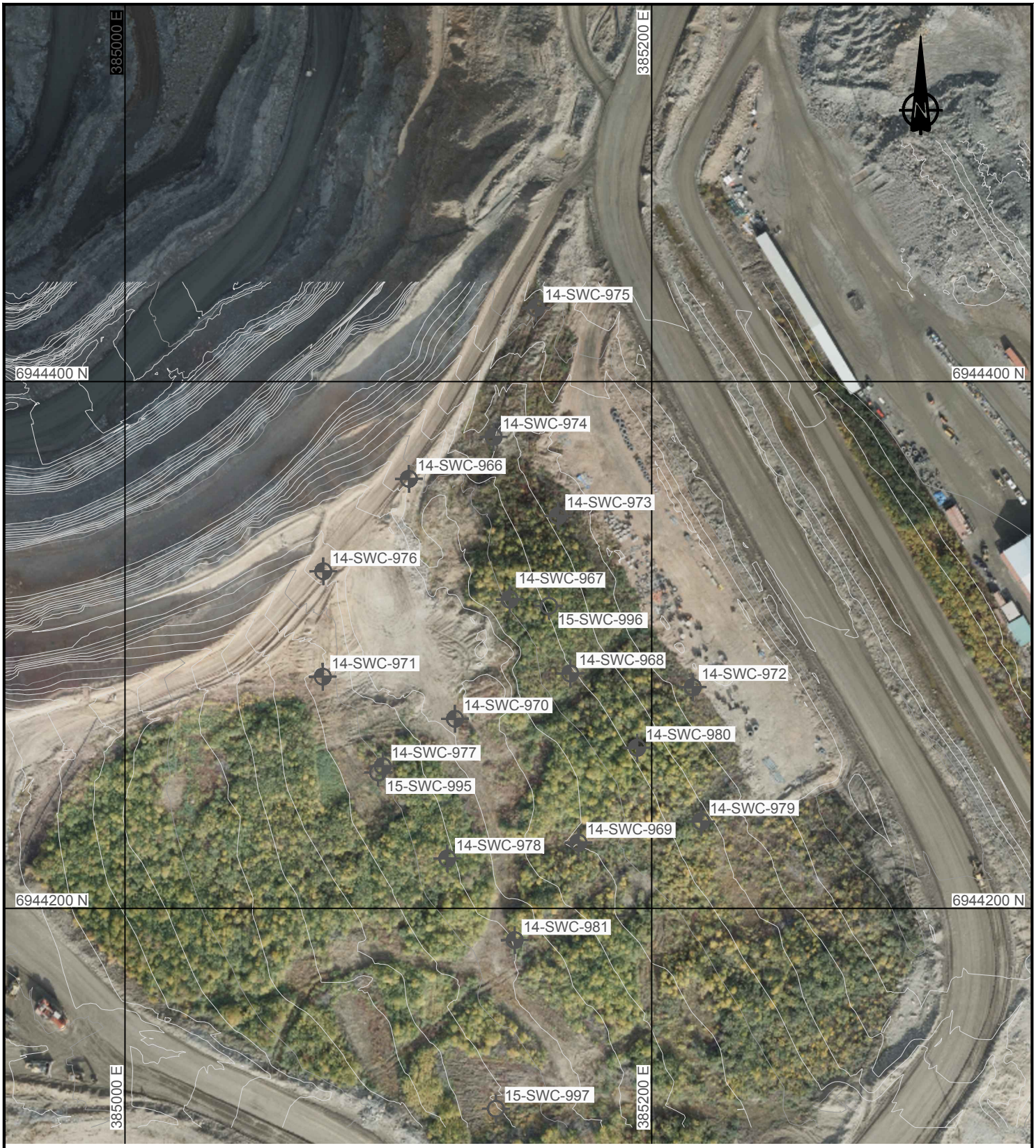
The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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

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

Z:\01_SITES\Minto\040_AutoCAD\OVB Drilling 2014-15\OVB_Drilling_Borehole_Plan_1CM002_037.dwg

# Attachment 1: Borehole Logs

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-966** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385107.8 E 6944363.1 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 830.7 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 827.05 |
| TOTAL DEPTH (m): | 3.65 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 | 830.6 | | | | SAND, few gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive | |
| | | | MM-101251 | | BOULDER | Granoriorite |
| | | | | | SAND, few gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive | |
| 2 | 828.6 | | MM-101252 | | GRAVEL, some sand , well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive | Minor fines near bedrock transition |
| | | | | | BEDROCK | Weathered granodiorite |
| 4 | | | | | | |

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-967** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385146.1 E 6944317.3 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 828.4 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 814.4 |
| 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(%)

| Depth (m) | Elev (m) | Recovery % (0 20 40 60 80 100) | Sample Type (Grab, SPT) | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|---|---|
| 0 | 828 | | | | SILT, some sand , little gravel, well graded, black, sub-angular, moist, non-plastic, cohesive, massive | Unclear how much organics exist due to poor recovery |
| | | | | | CLAY, some silt, few sand , few gravel, well graded, grey-brown, sub-rounded, moist, low-plasticity, cohesive, massive | Matrix supported |
| 2 | 826 | | MM-1012 53 | | | |
| | | | | | | Decreased gravel content |
| 4 | 824 | | | | SAND, some silt, trace gravel, poorly graded, grey-brown, sub-rounded, moist, low-plasticity, cohesive, laminated | Sand fraction is primarily fine |
| 6 | 822 | | MM-1012 54 | | | |
| 8 | 820 | | 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 | 818 | | | | SAND, little gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive | Primarily medium to coarse sand |
| | | | MM-1012 56 | | | |
| 12 | 816 | | | | | |

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-967** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385146.1 E 6944317.3 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 828.4 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 814.4 |
| 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(%)

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

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

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-968** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385169.1 E 6944289.2 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 827.7 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 807.7 |
| TOTAL DEPTH (m): | 20 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

Moisture Content, Liquid Limit, Plastic Limit (%)

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

Depth (m) | Elev (m) | Recovery % | Sample Type (Grab, SPT)

| USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|
| | 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 |
| | SAND, some silt, trace gravel, poorly graded, brown, wet, cohesive, massive | |

Sample: MM-1012 57

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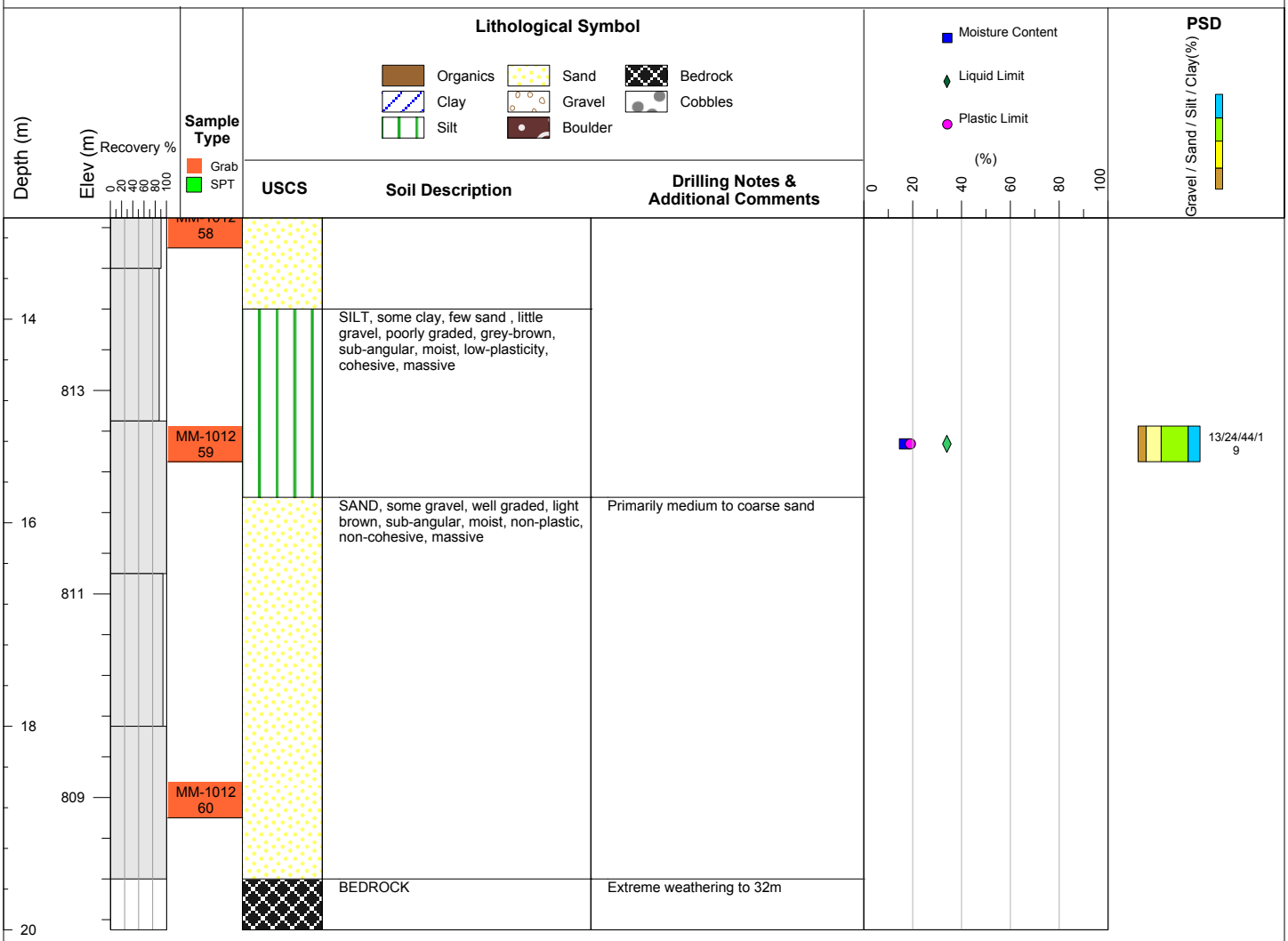
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-968** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385169.1 E 6944289.2 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 827.7 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 807.7 |
| TOTAL DEPTH (m): | 20 |

DEPOSIT AREA: Area 2



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capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-969** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385172.2 E 6944225 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 831.1 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 808.1 |
| TOTAL DEPTH (m): | 23 |

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 |
|---|---|---|
| | SAND, few gravel, little silt, well graded, light brown, sub-rounded, moist, non-plastic, non-cohesive, massive | Majority of matrix material (sand) washed out |
| | SAND, some clay and silt, little gravel, poorly graded, dark brown, sub-angular, moist, low-plasticity, cohesive, massive | |
| | SILT, some clay, little gravel, poorly graded, dark grey, sub-angular, moist, mid-plasticity, cohesive, laminated | Trace sand |
| | SAND, some gravel, little clay and silt, well graded, grey brown, sub-angular, moist, non-plastic, cohesive, massive | Occasional cobbles |
| | 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 |
| | SAND, some clay, few silt, poorly graded, dark grey, sub-angular, moist, mid-plasticity, cohesive, massive | Minor organic intervals of <3cm |

Depth 0, 2, 4, 6, 8, 10, 12 m — Elev 830, 828, 826, 824, 822, 820 m

MM-1012 68

MM-1012 69

MM-1012 70

12/40/41/7

srk consulting

capstone MINTO MINE

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

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 (%)

**PSD** — Gravel / Sand / Silt / Clay(%)

| Depth (m) | Elev (m) | Recovery % | Sample Type | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|---|---|
| 0 | 818 | | MM-1012 71 | | | |
| 14 | | | | | SAND, few gravel, few clay and silt, well graded, grey, sub-angular, moist, low-plasticity, cohesive, massive | Occasional cobbles |
| | 816 | | | | SAND, few gravel, few silt, well graded, brown grey and reddish grey, sub-angular, moist, non-plastic, cohesive, massive | Minor low-plasticity intervals |
| 16 | | | MM-1012 72 | | | |
| | 814 | | | | | |
| 18 | | | | | | |
| | 812 | | MM-1012 73 | | SILT, some sand , little gravel, poorly graded, grey brown, sub-angular, moist, non-plastic, cohesive, massive | |
| 20 | | | | | SAND, few silt, little gravel, well graded, reddish grey brown, sub-angular, moist, non-plastic, cohesive, massive | Contact with bedrock |
| | 810 | | | | | |
| 22 | | | MM-1012 74 | | | |
| | 808 | | | | BEDROCK | Extremely weathered to 23.0m, heavily weathered to 29.50 m |
| 24 | | | | | | |
| | 806 | | | | | |

1/10/74/15

srk consulting

capstone MINTO MINE

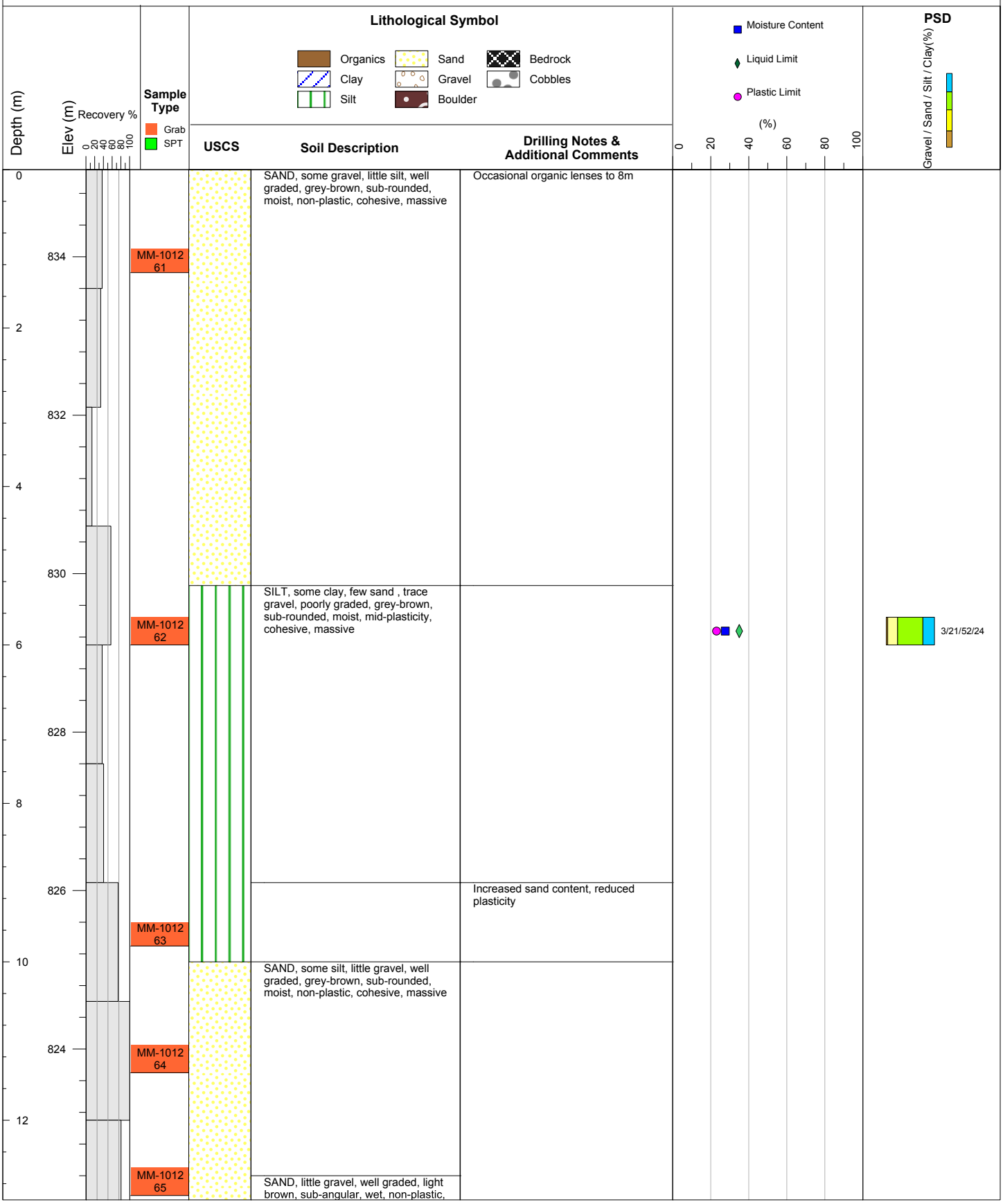
PROJECT: Minto

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



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capstone MINTO MINE

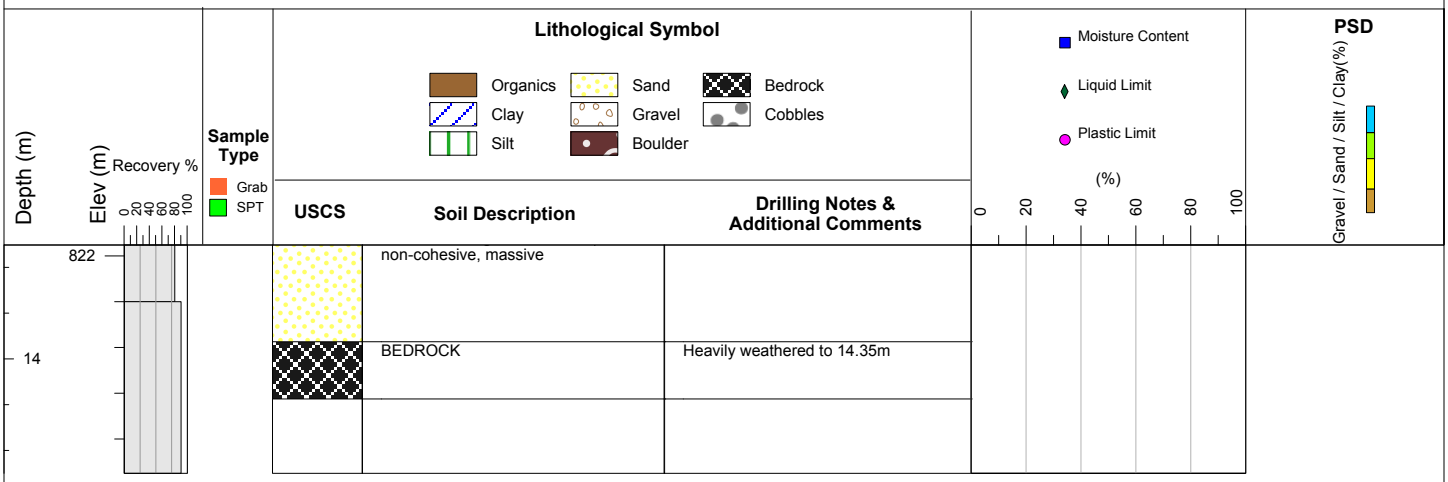
PROJECT: Minto

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



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capstone MINTO MINE

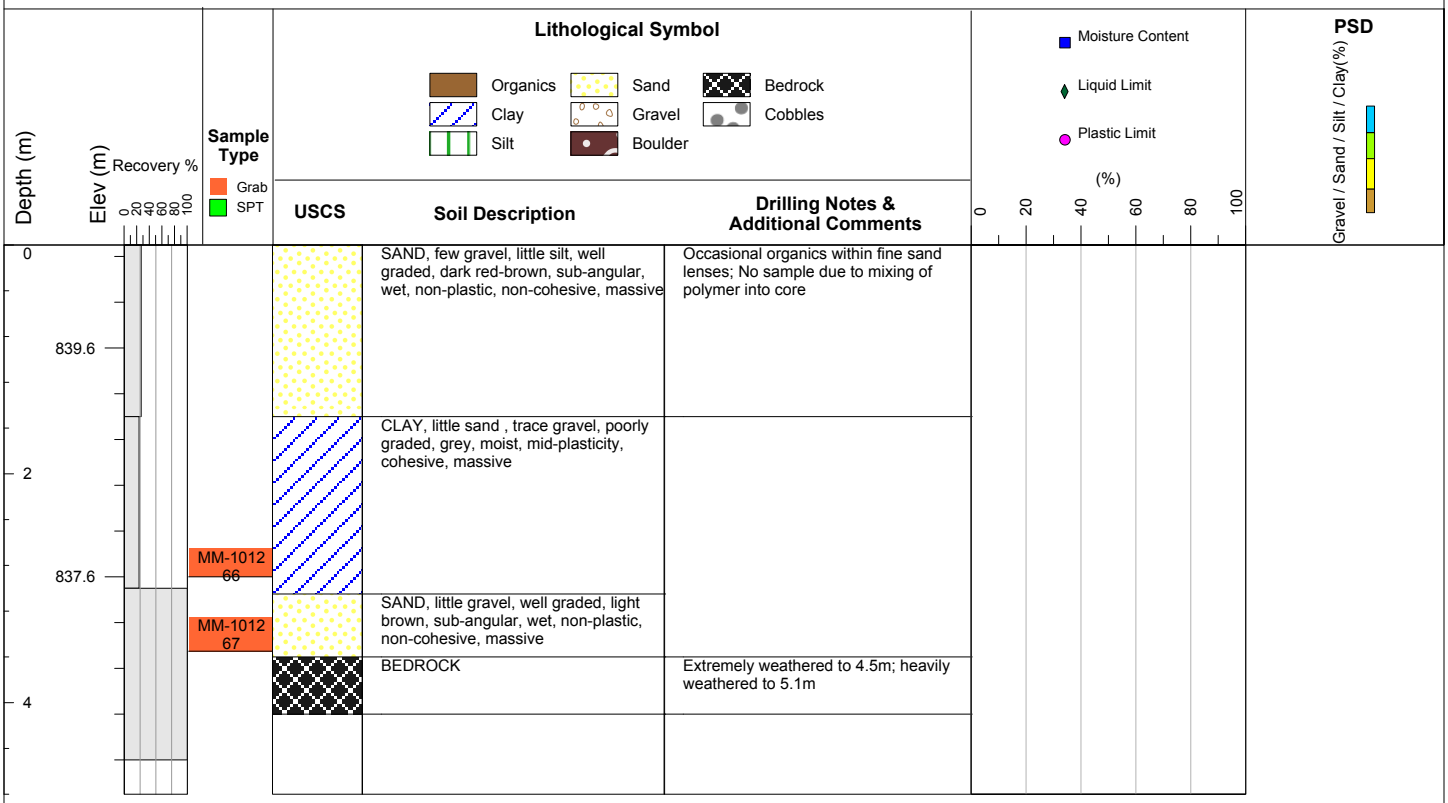
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-971** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385075.1 E 6944288 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 840.5 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 836.4 |
| TOTAL DEPTH (m): | 4.1 |

DEPOSIT AREA: Area 2



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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-972** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385215.6 E 6944284 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 822.4 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 797.1 |
| TOTAL DEPTH (m): | 25.3 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 | | | | SAND , few gravel, some silt, well graded, Brownish Grey, sub-angular, moist, non-plastic, cohesive, massive | |
| 2 | 820 | | | | | |
| 4 | 818 | | MM-1012 75 | | | |
| 6 | 816 | | | | SILT, some clay, few gravel, little sand , well graded, Grey, angular, moist, low-plasticity, cohesive, massive | |
| 8 | 814 | | MM-1012 76 | | SILT, some clay, little gravel, some sand , well graded, Grey, sub-angular, moist, low-plasticity, cohesive, massive | |
| | | | MM-1012 77 | | SILT, some sand , trace gravel, well graded, Brown grey, sub-angular, wet, non-plastic, non-cohesive, massive | |
| 10 | 812 | | | | | |
| 12 | | | MM-1012 78 | | | 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 | |

11/32/49/8

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capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-972** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385215.6 E 6944284 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 822.4 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 797.1 |
| TOTAL DEPTH (m): | 25.3 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 |
|---|---|---|---|---|---|---|
| 14 | 808 | | MM-101279 | | | |
| 16 | 806 | | | | | |
| 18 | 804 | | MM-101280 | | SILT, few sand , poorly graded, brown, wet, non-plastic, cohesive, massive | |
| 20 | 802 | | MM-101281 | | SAND, little silt, poorly graded, brown, wet, non-plastic, non-cohesive, massive | Primarily fine sand |
| 22 | 800 | | MM-101282 | | SAND, few silt, few gravel, well graded, brown, wet, non-plastic, cohesive, massive | Increased gravel content in bottom of this material unit |
| 24 | 798 | | MM-101283 | | SAND, some gravel, well graded, light brown, wet, non-plastic, non-cohesive, massive | |
| 26 | | | | | BEDROCK | Heavily weathered to 28m |

PSD: 0/4/95/1

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 | 824 | | MM-101284 | | 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-101285 | | CLAY, trace silt, trace gravel, poorly graded, Grey, sub-angular, moist, high-plasticity, cohesive, massive | Actual length of core 1.34m |
| 4 | 820 | | MM-101286 | | 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-101287 | | 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-101288 | | SILT, some clay, few gravel, trace sand , well graded, grey/brown, sub-angular, moist, mid-plasticity, cohesive, blocky | Actual length same as run block |
| 10 | 814 | | | | | |
| 12 | 812 | | MM-101289 | | GRAVEL, few sand , trace clay and silt, poorly graded, reddisg brown, sub-angular, moist, non-plastic, non-cohesive | |

PSD: 0/13/63/24

PSD: 20/32/40/8

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

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 | 810 | | | | GRAVEL, little sand , poorly graded, grey/black brown, angular, moist, non-plastic, non-cohesive | No sample |
| 16 | 808 | | | | GRAVEL, some sand , trace silt, well graded, brown, angular, moist, non-plastic, non-cohesive, massive | One sample from box |
| 18 | 806 | | | | | |
| 20 | 804 | | | | | |
| 22 | 802 | | MM-101290 | | | |
| 24 | 800 | | MM-101291 | | GRAVEL, few sand , trace silt, poorly graded, brown, angular, moist, non-plastic, non-cohesive, massive | |
| 26 | 798 | | | | | |

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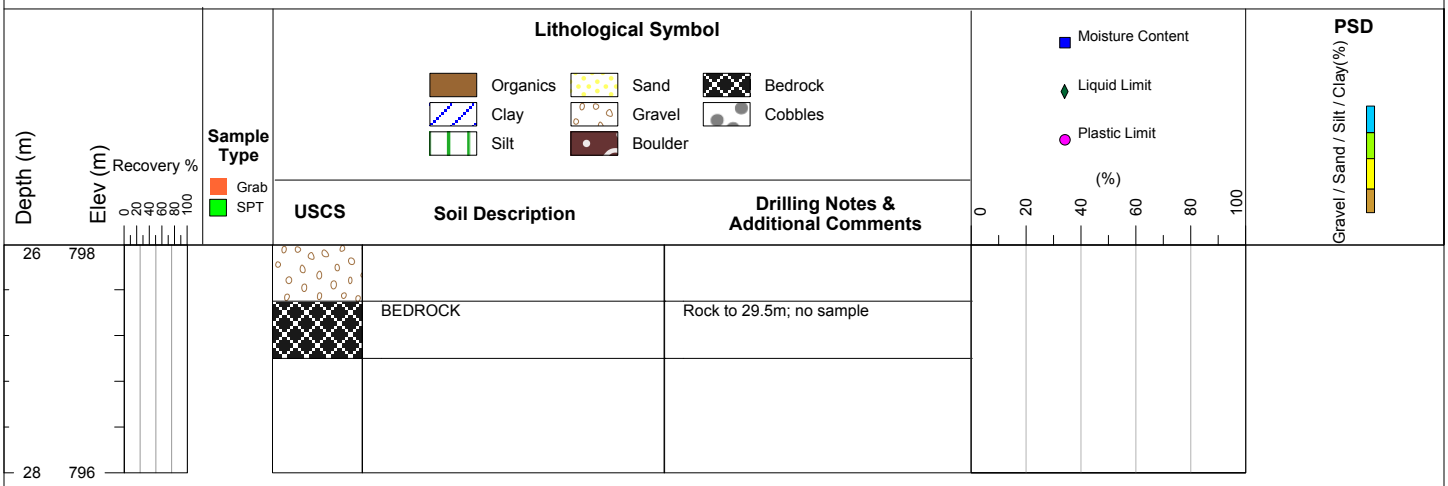
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

DEPOSIT AREA: Area 2



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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-974** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385140 E 6944379 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 824.8 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 811.3 |
| TOTAL DEPTH (m): | 13.5 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 | 824 | | MM-101292 (Grab) | | SILT, little organics, little sand , poorly graded, grey, sub-rounded, wet, low-plasticity, cohesive, massive | Actual length of core 1.5m |
| 2 | 822 | | MM-101293 (Grab) | | CLAY, few silt, trace sand , poorly graded, grey, sub-rounded, wet, low-plasticity, cohesive, massive | |
| 4 | 820 | | MM-101294 (Grab) | | CLAY, little silt, trace sand , poorly graded, grey/brown, angular, moist, mid-plasticity, cohesive, massive | Actual length of core 2.5m |
| 6 | 818 | | MM-101295 (Grab) | | CLAY AND SILT, trace sand , little gravel, poorly graded, grey, sub-rounded, moist, mid-plasticity, cohesive, massive | Actual length of core 2.1m |
| 8 | 816 | | MM-101296 (Grab) | | BEDROCK, few gravel, little sand , poorly graded, red/brown, angular, moist, non-plastic, non-cohesive, massive | Actual length of core 4.5m |
| 10 | 814 | | | | | |
| 12 | 812 | | | | 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 |

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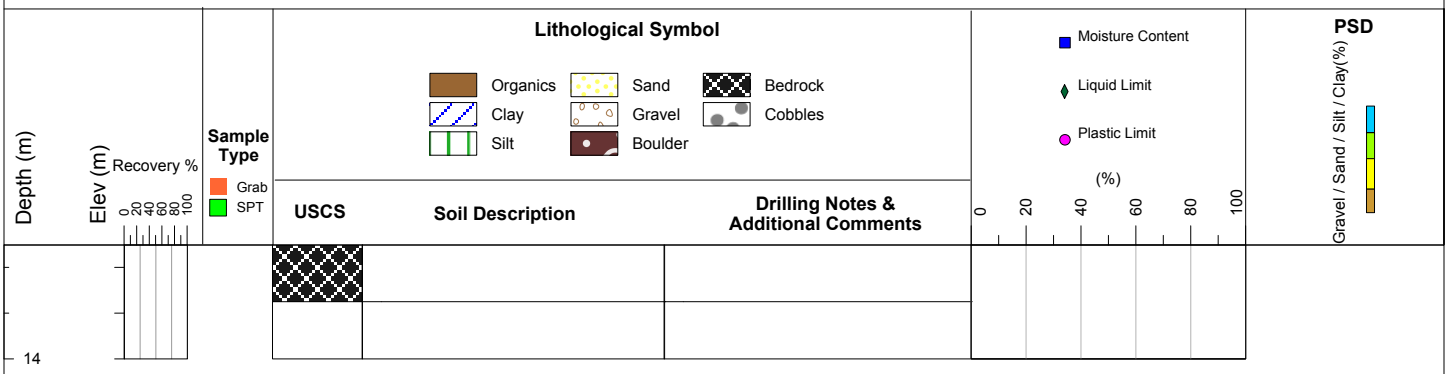
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-974** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385140 E 6944379 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 824.8 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 811.3 |
| TOTAL DEPTH (m): | 13.5 |

DEPOSIT AREA: Area 2



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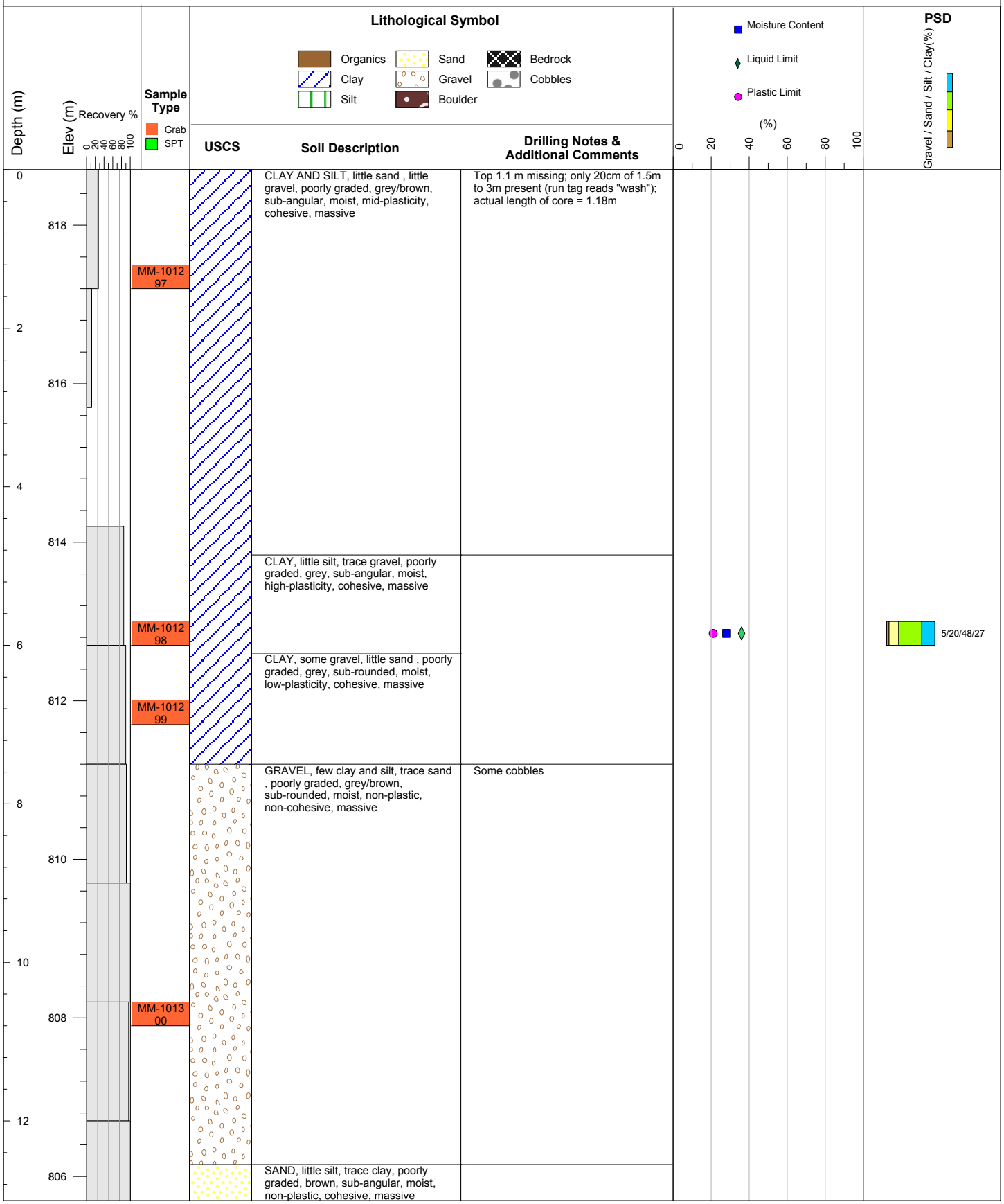
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-975** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385156.1 E 6944428 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 818.7 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 796.3 |
| TOTAL DEPTH (m): | 22.4 |

DEPOSIT AREA: Area 2




| USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|
| | 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 |
| | CLAY, little silt, trace gravel, poorly graded, grey, sub-angular, moist, high-plasticity, cohesive, massive | |
| | CLAY, some gravel, little sand , poorly graded, grey, sub-rounded, moist, low-plasticity, cohesive, massive | |
| | GRAVEL, few clay and silt, trace sand , poorly graded, grey/brown, sub-rounded, moist, non-plastic, non-cohesive, massive | Some cobbles |
| | SAND, little silt, trace clay, poorly graded, brown, sub-angular, moist, non-plastic, cohesive, massive | |

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| | |
|---|---|
| HOLE ID: | **14-SWC-975** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385156.1 E 6944428 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 818.7 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 796.3 |
| TOTAL DEPTH (m): | 22.4 |

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

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

| Depth (m) | Elev (m) | Recovery % | Sample Type | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|---|---|
| 14 | 804 | | MM-1013 01 | | | |
| | | | MM-1013 02 | | | |
| 16 | 802 | | | | GRAVEL, some sand , trace silt, poorly graded, brown, angular, moist, non-plastic, non-cohesive, massive | Sections of competent and weathered rock |
| 18 | 800 | | | | | |
| 20 | 798 | | MM-1013 03 | | | |
| 22 | 796 | | | | | |
| 24 | 794 | | | | | |

(%) 0 20 40 60 80 100

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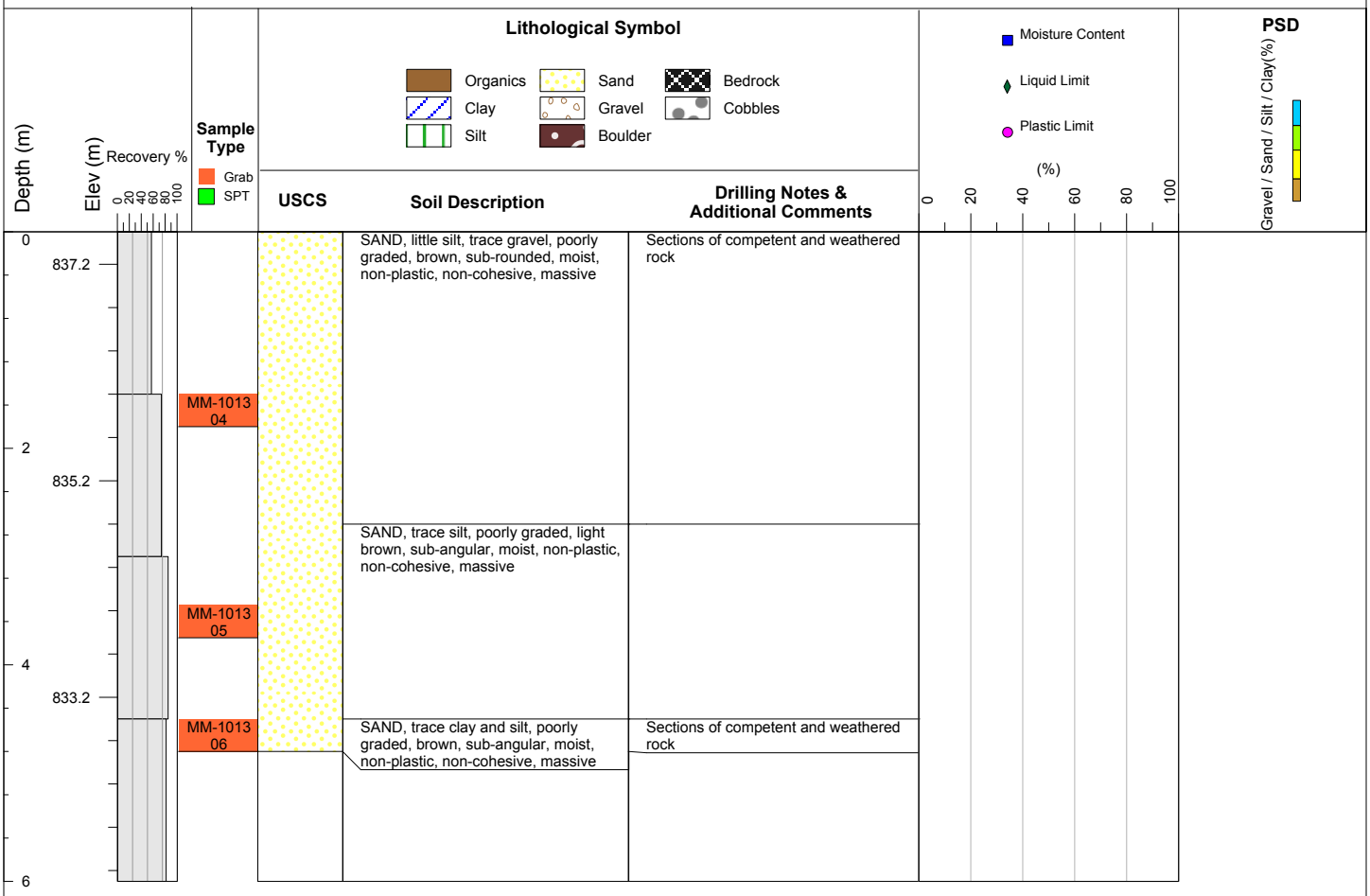
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-976** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385075.3 E 6944328 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 837.5 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 832.77 |
| TOTAL DEPTH (m): | 4.8 |

DEPOSIT AREA: Area 2



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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-977** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385097.9 E 6944254 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 839.4 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 827.3 |
| TOTAL DEPTH (m): | 12.1 |

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 |
|---|---|---|---|---|---|---|
| 0 | 839 | | | | SILT, some clay, few sand , trace gravel, poorly graded, grey brown, sub-angular, moist, mid-plasticity, cohesive, massive | Long interval of ablation till |
| 2 | 837 | | | | | |
| 4 | 835 | | MM-101307 | | | |
| 6 | 833 | | | | | |
| 8 | 831 | | MM-101308 | | | |
| 10 | 829 | | | | SAND, few clay and silt, poorly graded, reddish grey brown, sub-rounded, moist, non-plastic, non-cohesive, massive | |
| 12 | 827 | | MM-101309 | | | |

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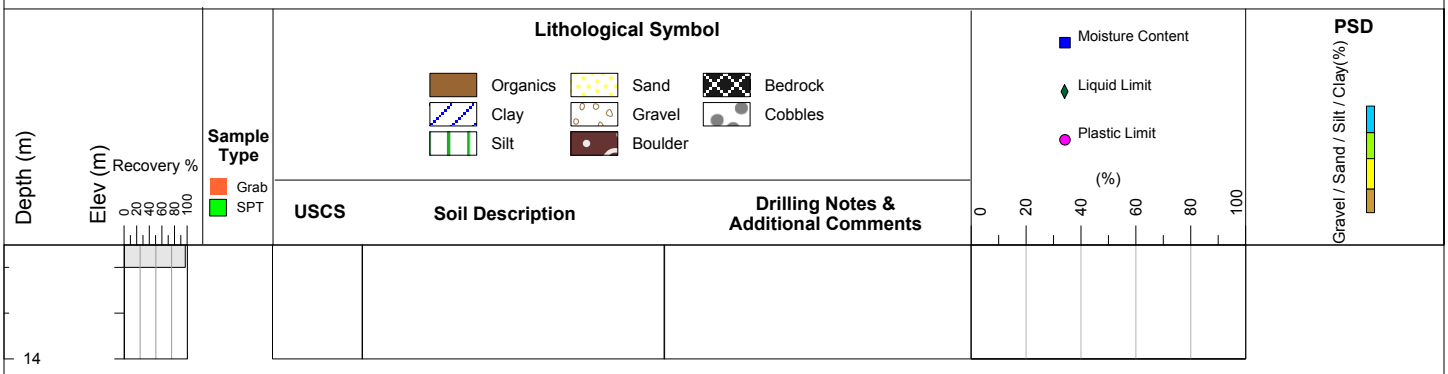
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-977** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385097.9 E 6944254 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 839.4 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 827.3 |
| TOTAL DEPTH (m): | 12.1 |

DEPOSIT AREA: Area 2



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capstone MINTO MINE

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 (%)

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

| Depth (m) | Elev (m) | Recovery % | Sample Type | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|---|---|
| 0 | 837 | | | | | |
| 2 | 835 | | | | | |
| 4 | 833 | | | | | |
| 6 | 831 | | | | | |
| 8 | 829 | | MM-101310 | | 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 |
| 10 | 827 | | MM-101311 | | CLAY AND SILT, little sand , trace gravel, poorly graded, brown matrix, sub-rounded, moist, mid-plasticity, cohesive, massive | |
| 12 | 825 | | | | | |

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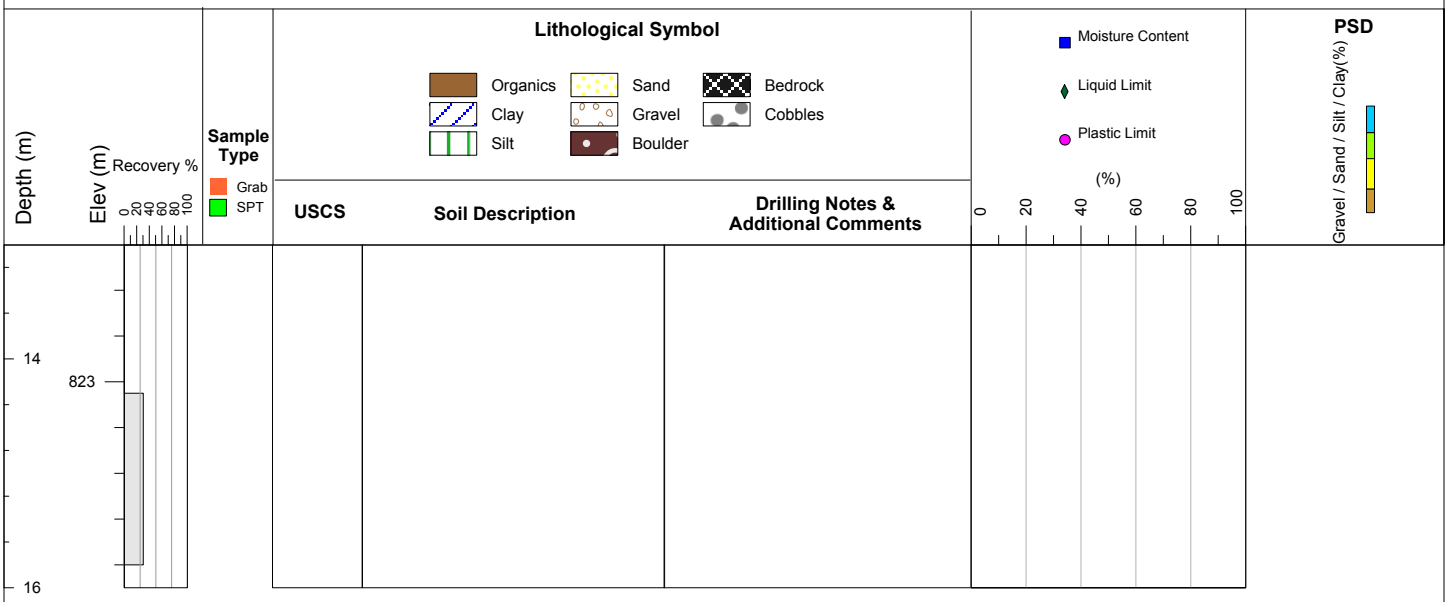
PROJECT: Minto

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



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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 |

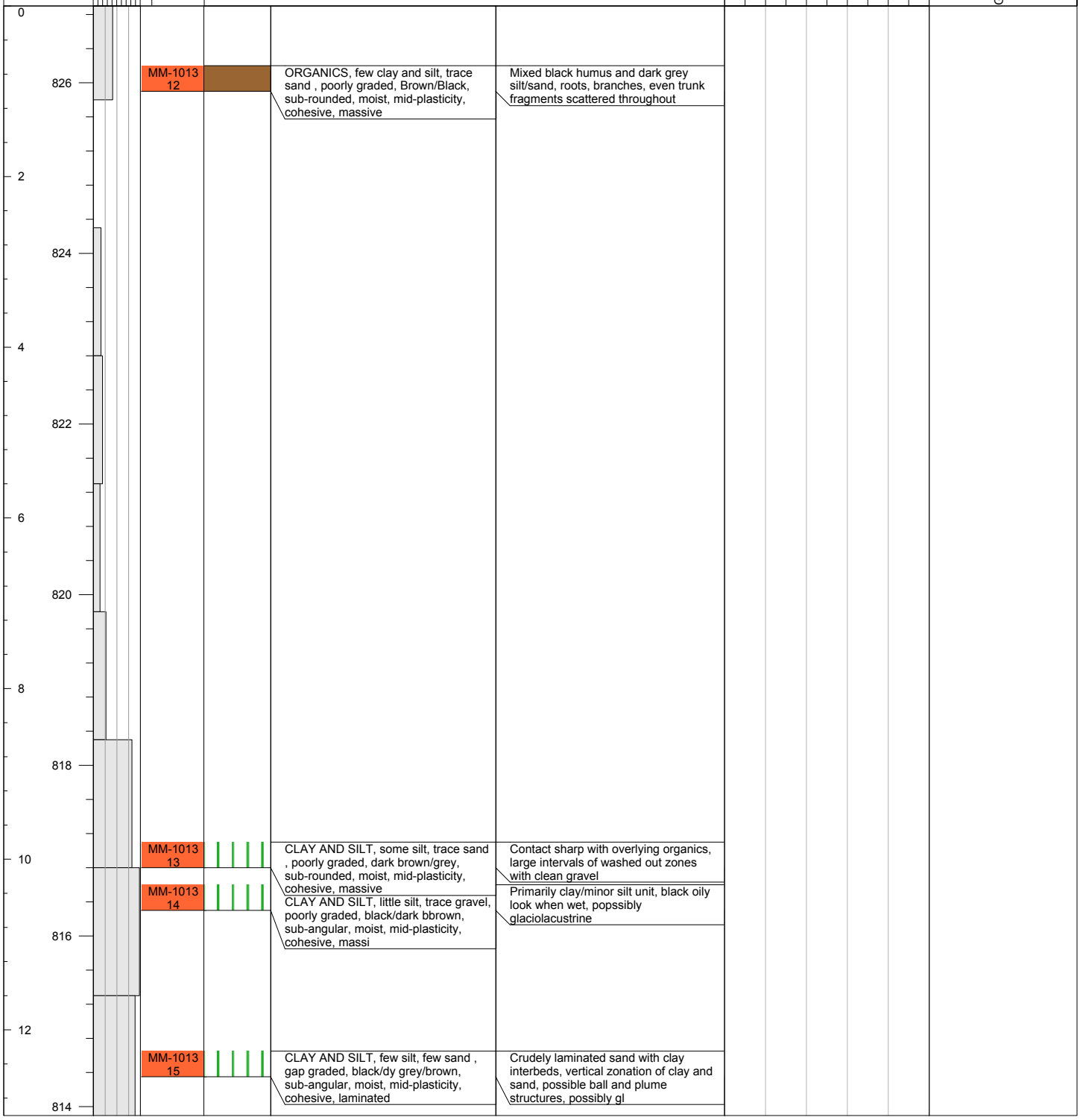
DEPOSIT AREA: Area 2

**Lithological Symbol**

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

Moisture Content, Liquid Limit, Plastic Limit (%)

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



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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, 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 | | | 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 |
| 16 | 812 | | | | | |
| 18 | 810 | | | | | |
| 20 | 808 | | | | | |
| 22 | 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 |
| 24 | 804 | | | | | |
| 26 | 802 | | MM-1013 18 | | SILT, few clay, trace sand , poorly graded, brown, rounded, moist, | Massive nondescript silt unit; possibly glaciolacustrine |

PSD: 0/21/77/2

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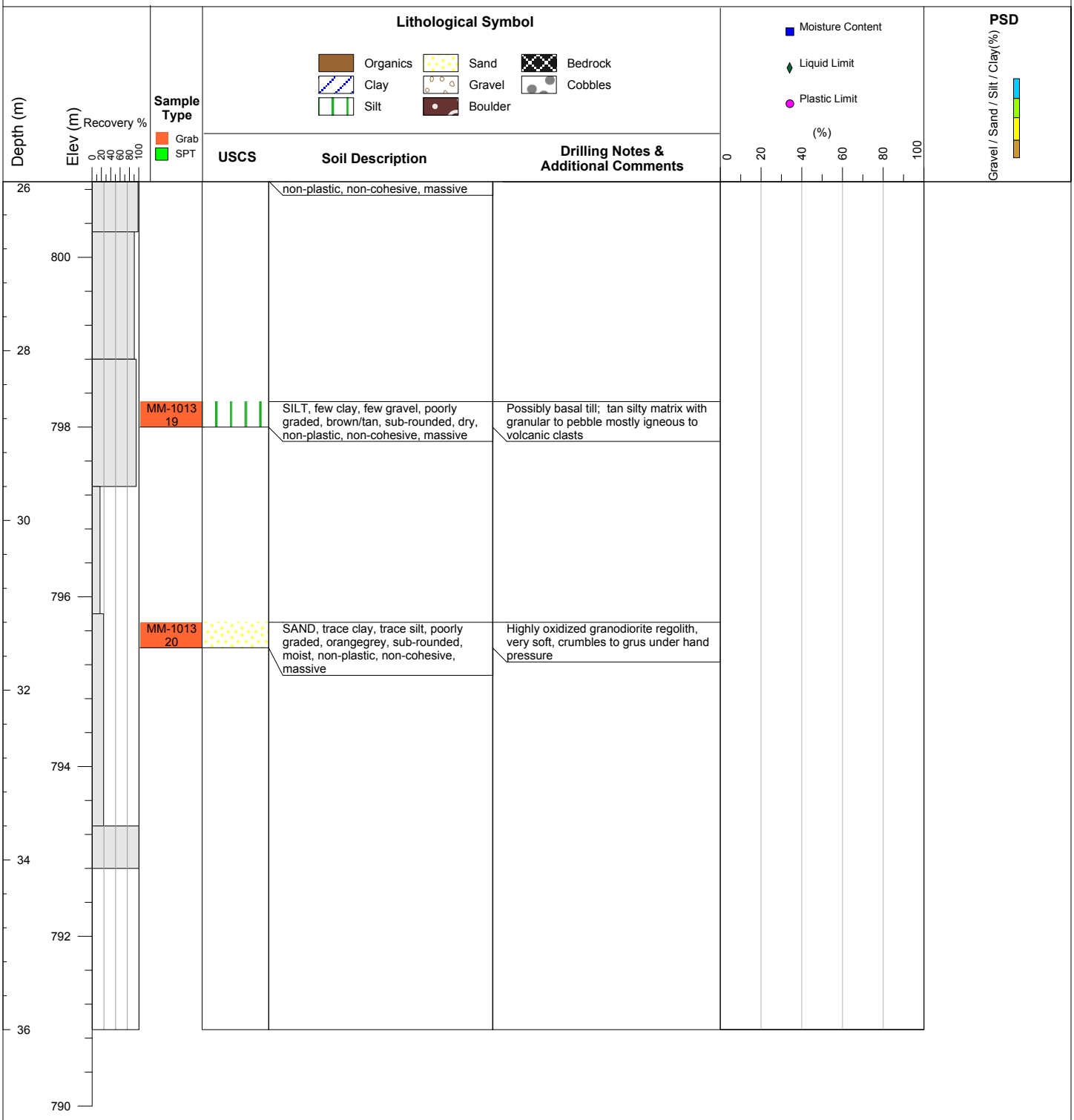
PROJECT: Minto

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



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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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

**Lithological Symbol**

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

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 | 826 | | | | | |
| 2 | 824 | | | | | |
| 4 | 822 | | MM-1013 21 | | SILT, few sand , few gravel, poorly graded, brown, sub-rounded, moist, non-plastic, cohesive, massive | Diamictic till; silty matrix |
| 6 | 820 | | MM-1013 22 | | 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 |
| 8 | 818 | | | | | |
| 10 | 816 | | MM-1013 23 | | CLAY, some silt, little gravel, poorly graded, grey/brown, sub-angular, moist, mid-plasticity, cohesive, massive | Clay with discontinous sand lenses; bedding non-apparent |
| 12 | 814 | | | | | |

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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

**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 | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|---|---|
| 14 | 812 | | MM-1013 24 (Grab) | | 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 (SPT) | | 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 (SPT) | | CLAY, little silt, trace sand , poorly graded, brown, sub-angular, moist, mid-plasticity, cohesive, massive | Massive clay; possibly glaciolacustrine |
| 22 | 804 | | MM-1013 27 (SPT) | | 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 | | | | | |

PSD: 6/40/52/2

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-981** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385148 E 6944188 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 837.838 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 807.89 |
| TOTAL DEPTH (m): | 29.95 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

Sample Type: Grab, SPT

Recovery % (0, 20, 40, 60, 80, 100)

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

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

| Depth (m) | Elev (m) | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|
| 0 | | | 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 |
| 2 | 836 | | 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 |
| 4 | 834 | | | |
| 6 | 832 | | | |
| 8 | 830 | | CLAY AND SILT, few sand , little gravel, poorly graded, grey brown, sub-rounded, moist, mid-plasticity, cohesive, massive | |
| 10 | 828 | | SAND, some gravel, trace silt, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive | |
| 12 | 826 | | 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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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-981** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385148 E 6944188 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 837.838 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 807.89 |
| TOTAL DEPTH (m): | 29.95 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

Moisture Content, Liquid Limit, Plastic Limit (%)

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 |
|---|---|---|---|---|
| 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 | |
| | | | SAND, little gravel, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive | |
| 22 | 816 | | | |
| 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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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **14-SWC-981** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM |
| BORING DATE: | Oct/Nov 2014 |

| | |
|---|---|
| COORDINATES: | 385148 E 6944188 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 837.838 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 807.89 |
| TOTAL DEPTH (m): | 29.95 |

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) | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|
| 26 | | | | |
| | | | SAND, some gravel, little clay, poorly graded, grey, sub-angular, moist, non-plastic, cohesive, massive | Local highly oxidized limoinitic fragments; some with malachite |
| | 810 | | | |
| 28 | | | GRAVEL, little sand , maroon, sub-rounded, moist, non-plastic, non-cohesive, massive | Fines almost completely washed away; only cobbles remaining |
| | | | SAND, little gravel, poorly graded, maroon, angular, moist, non-plastic, non-cohesive, massive | Probably strongly altered rock but behaving as a soil |
| | 808 | | | |
| 30 | | | | |
| | 806 | | | |

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **15-SWC-995** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM/DM |
| BORING DATE: | 5-Feb-15 To 9-Feb-15 |

| | |
|---|---|
| COORDINATES: | 385096.08 E 6944251.64 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 839.41 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 826.66 |
| TOTAL DEPTH (m): | 13.2 |

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 |
|---|---|---|---|---|---|---|
| 0 | 839 | | | | SAND, few gravel, some silt, well graded, brown, sub-angular, wet, low plasticity, cohesive, massive | Occasional cobbles |
| 2 | 838 | | | | | |
| | 837 | | 58552 | | | |
| | 836 | | | | | |
| 4 | | | | | CLAY, few silt, some sand, poorly graded, brown, , wet, med plasticity, cohesive, massive | |
| | 835 | | 58553 | | | |
| | 834 | | | | SILT, few sand, few gravel, trace clay, well graded, brown, sub-angular, wet, low plasticity, cohesive, massive | Occasional cobbles |
| 6 | 833 | | | | SILT, some sand, little gravel, little clay, well graded, brown, sub-rounded, wet, non-plastic, non-cohesive, massive | Cohesive fines; occasional cobbles |
| | 832 | | | | | |
| 8 | 831 | | 58554 | | | |
| | 830 | | | | SILT, some sand , little gravel, little clay, well graded, brown, sub-rounded, wet, non-plastic, non-cohesive, massive | |
| 10 | 829 | | 58555 | | SAND, some gravel, well graded, reddish-brown, sub-angular, wet, non-plastic, non-cohesive, massive | Extremely weathered diorite. Bedrock at 13.2m |
| | 828 | | | | | |
| 12 | 827 | | | | | |

PSD: 12/36/43/9

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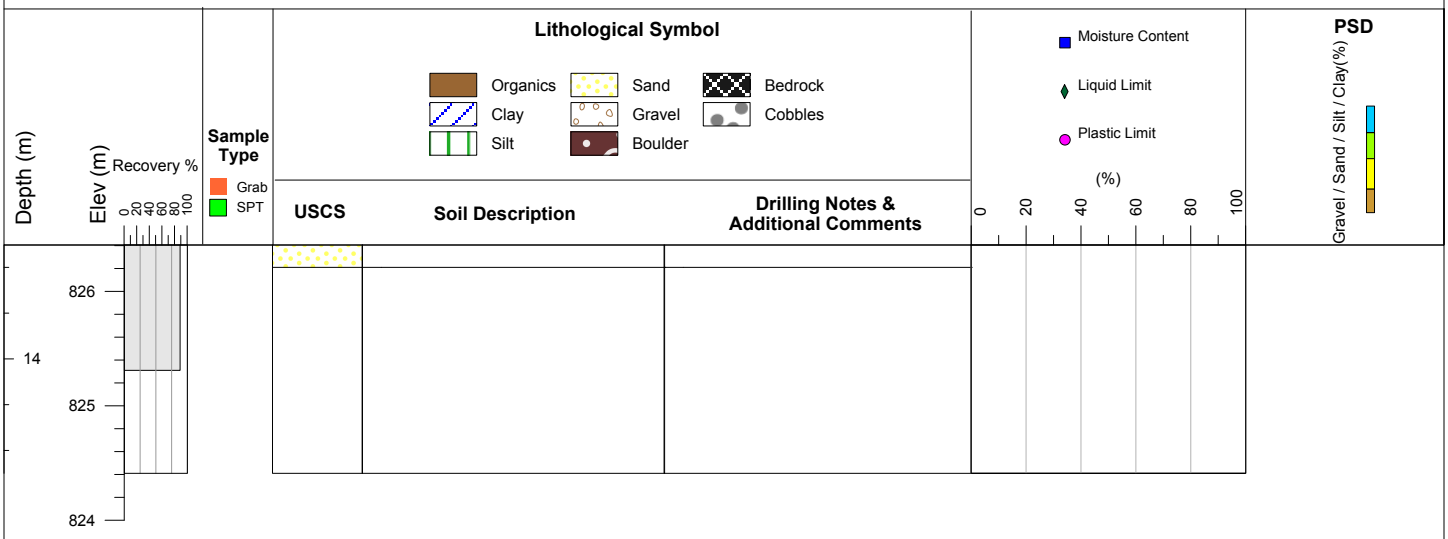
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **15-SWC-995** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM/DM |
| BORING DATE: | 5-Feb-15 To 9-Feb-15 |

| | |
|---|---|
| COORDINATES: | 385096.08 E 6944251.64 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 839.41 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 826.66 |
| TOTAL DEPTH (m): | 13.2 |

DEPOSIT AREA: Area 2



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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **15-SWC-996** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM/DM |
| BORING DATE: | 9-Feb-15 To 11-Feb-15 |

| | |
|---|---|
| COORDINATES: | 385161 E 6944314.88 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 827.87 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 803.45 |
| TOTAL DEPTH (m): | 28.2 |

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(%)

Recovery % 0 20 40 60 80 100

| Depth (m) | Elev (m) | Sample Type | USCS | Soil Description | Drilling Notes & Additional Comments |
|---|---|---|---|---|---|
| 0 | | | | SILT, few sand, few gravel, little organics, poorly graded, dark brown, sub-rounded, moist, low plasticity, cohesive, massive | |
| | | 58556 | | 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, 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, few gravel, some clay, poorly graded, mottled grey-brown, sub-rounded, , low plasticity, non-cohesive, massive | Unkown parameters due to low recovery |
| 6 | 822 | 58557 | | SILT, some sand, little gravel, well graded, light brown, sub-angular, moist, med plasticity, cohesive, bedded >3cm | Bedded at 45-55 deg tca |
| 8 | 820 | | | 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 | 58558 | | 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, few gravel, few silt, poorly graded, brown-grey, rounded, moist, | |

PSD: 16/35/43/6

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capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **15-SWC-996** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM/DM |
| BORING DATE: | 9-Feb-15 To 11-Feb-15 |

| | |
|---|---|
| COORDINATES: | 385161 E 6944314.88 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 827.87 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 803.45 |
| TOTAL DEPTH (m): | 28.2 |

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 |
|---|---|---|---|---|---|---|
| | | | | | low plasticity, cohesive, blocky | |
| 14 | 814 | | | | 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. |
| | | | 58559 | | | |
| | | | | | 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, some silt, few gravel, poorly graded, brown, sub-rounded, wet, med plasticity, cohesive, massive | |
| | | | | | SILT, some sand, little gravel, poorly graded, brown, sub-rounded, moist, low plasticity, cohesive, massive | Significant colour change at end of unit |
| 18 | 810 | | | | | |
| | | | 58560 | | | |
| 20 | 808 | | | | | |
| | | | | | SAND, few gravel, poorly graded, reddish brown, sub-angular, moist, low plasticity, cohesive, massive | Unit is composed of highly weathered bedrock material; brecciated appearance |
| 22 | 806 | | | | | |
| | | | 58561 | | | |
| | | | | | BEDROCK | |
| 24 | 804 | | | | | |
| 26 | 802 | | | | | |

PSD: 11/30/51/8

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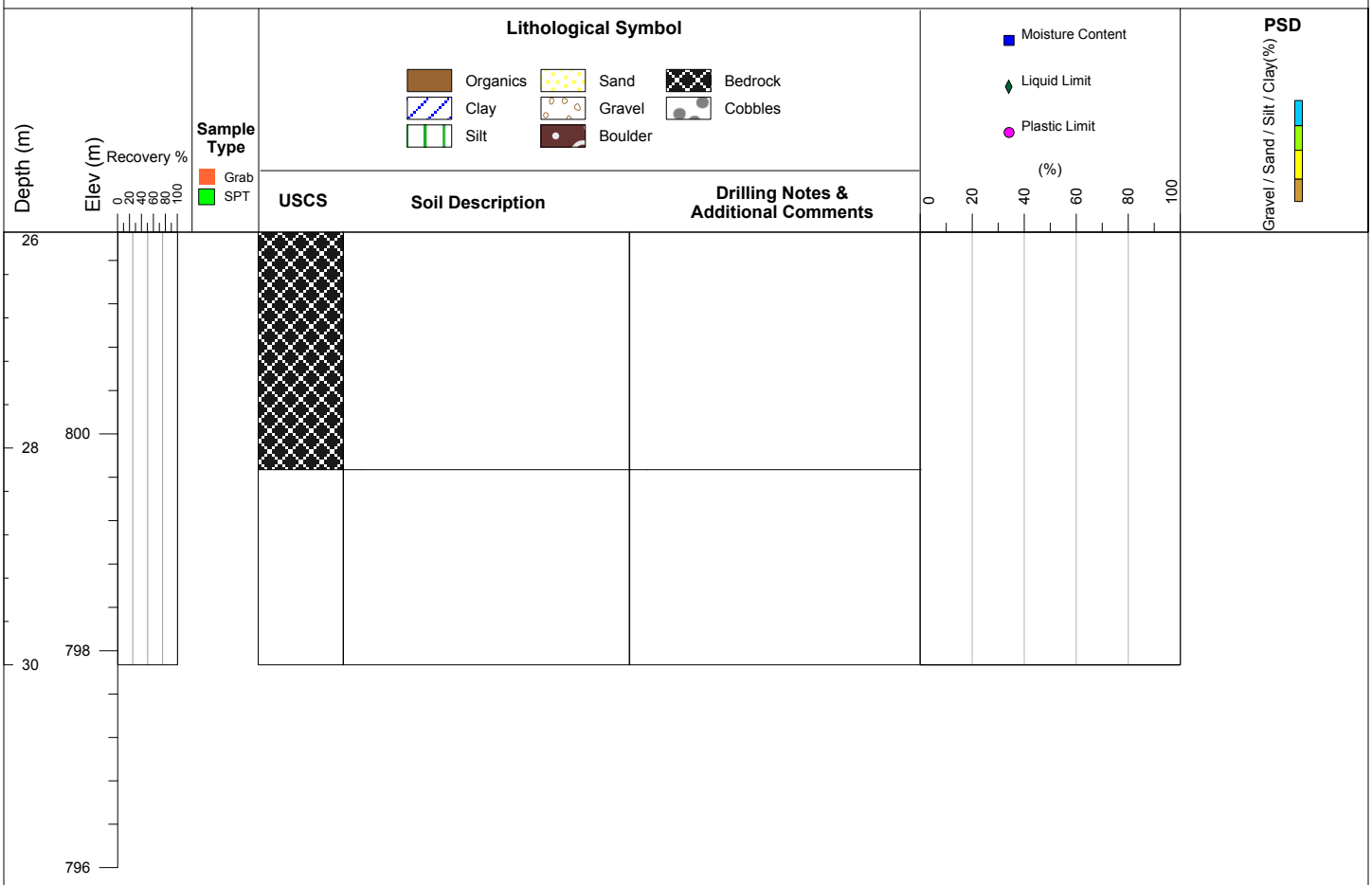
PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| HOLE ID: | **15-SWC-996** |
| LOCATION: | Yukon |
| PROJECT NO: | 1CM002.037 |
| DRILLING CONTRACTOR: | Driftwood |
| DRILLING TYPE & CORE DIA: | HQ Diamond |
| LOGGED BY: | MJM/DM |
| BORING DATE: | 9-Feb-15 To 11-Feb-15 |

| | |
|---|---|
| COORDINATES: | 385161 E 6944314.88 N |
| DATUM: | UTM Zone 8 |
| GROUND ELEV (m): | 827.87 |
| AZIMUTH: | 0 |
| COLLAR DIP: | -90 |
| EOH ELEV. (m): | 803.45 |
| TOTAL DEPTH (m): | 28.2 |

DEPOSIT AREA: Area 2



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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 | | | | | 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 |
| | | | 58562 (Grab) | | | |
| | 840 | | | | | |
| 2 | | | | | | |
| | | | | | 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 |
| 4 | | | | | | Poor recovery; indicates same a soil above; core barrel lot down hole requiring re-drill hole. |
| | 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 |
| 6 | | | | | 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. |
| | | | | | non-plastic, non-cohesive, | No recovery |
| 8 | | | | | | |
| | | | | | 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. |
| | 832 | | | | | |
| 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 |
| | | | | | | |
| 12 | | | 58563 (Grab) | | | |

PSD: 30/42/24/4

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

DEPOSIT AREA: Area 2

**Lithological Symbol**

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

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 |
|---|---|---|---|---|---|---|
| 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 | |
| 20 | | | 58567 | | 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% |
| 22 | 820 | | | | CLAY, some silt, few sand, trace organics, poorly graded, dark grey, sub-angular, moist, high plasticity, cohesive, massive | |
| | | | | | SAND, few silt, little gravel, well graded, grey, sub-angular, moist, non-plastic, cohesive, thinly bedded >0.5cm | Granite boulder |
| | | | | | BOULDER, pink-grey, sub-angular, dry, non-plastic, cohesive, blocky | |
| | | | | | CLAY, few silt, little sand, well graded, grey, sub-angular, moist, high plasticity, cohesive, massive | Trace organics present |
| 24 | | | 58568 | | GRAVEL, few sand, few silt, little clay, poorly graded, grey, sub-angular, moist, non-plastic, cohesive, thinly bedded >0.5cm | |
| 26 | 816 | | | | SAND, some silt, little gravel, trace boulder, well graded, grey-brown, sub-angular, moist, non-plastic, cohesive, thinly bedde | One 20cm boulder |

PSD: 44/29/21/6

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

DEPOSIT AREA: Area 2

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

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 |
|---|---|---|---|---|---|---|
| 26 | | | | | | |
| 28 | | | 58569 | | SILT, some sand, little clay, trace organics, well graded, light-med brown, sub-angular, moist, med plasticity, cohesive, thinl | |
| | | | | | SAND, few gravel, little silt, poorly graded, mottled brown, sub-rounded, moist, non-plastic, cohesive, massive | Locally non-cohesive |
| | 812 | | | | | |
| 30 | | | 58570 | | 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 |
| 32 | | | | | | |
| | 808 | | | | SAND, few gravel, few silt, well graded, mottled brown, sub-rounded, moist, non-plastic, cohesive, bedded >3cm | |
| 34 | | | 58571 | | | |
| | | | | | SILT, few sand, little gravel, trace boulder, well graded, med brown, sub-rounded, moist, non-plastic, cohesive, bedded >3cm | |
| 36 | | | | | | |
| | 804 | | | | | |
| 38 | | | | | SAND, few gravel, little silt, little boulder, poorly graded, mottled brown, sub-angular, moist, non-plastic, cohesive, blocky | Occasional cobble/boulder |
| | | | | | SAND, few gravel, little boulder, little | |

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capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

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 |
|---|---|---|---|---|---|
| 40 | | | | silt, poorly graded, mottled brown, sub-angular, moist, non-plastic, non-cohesive, blo | |
| | | | | SILT, few clay, some sand, few gravel, poorly graded, grey, sub-angular, moist, med plasticity, cohesive, massive | |
| | 800 | 58572 | | | |
| 42 | | | | | |
| 44 | | | | | |
| | 796 | | | | |
| 46 | | 58573 | | 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 |
| | | 58571 | | GRAVEL, some sand, little silt, well graded, grey-brown, sub-angular, moist, non-plastic, non-cohesive, massive | Poor recovery throughout this unit |
| 48 | | | | | |
| | 792 | | | | |
| 50 | | | | SAND, little silt, few gravel, well graded, red-brown, sub-rounded, moist, non-plastic, cohesive, massive | |
| 52 | | | | | |

PSD: 15/34/29/22

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capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

| | |
|---|---|
| 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 |

DEPOSIT AREA: Area 2

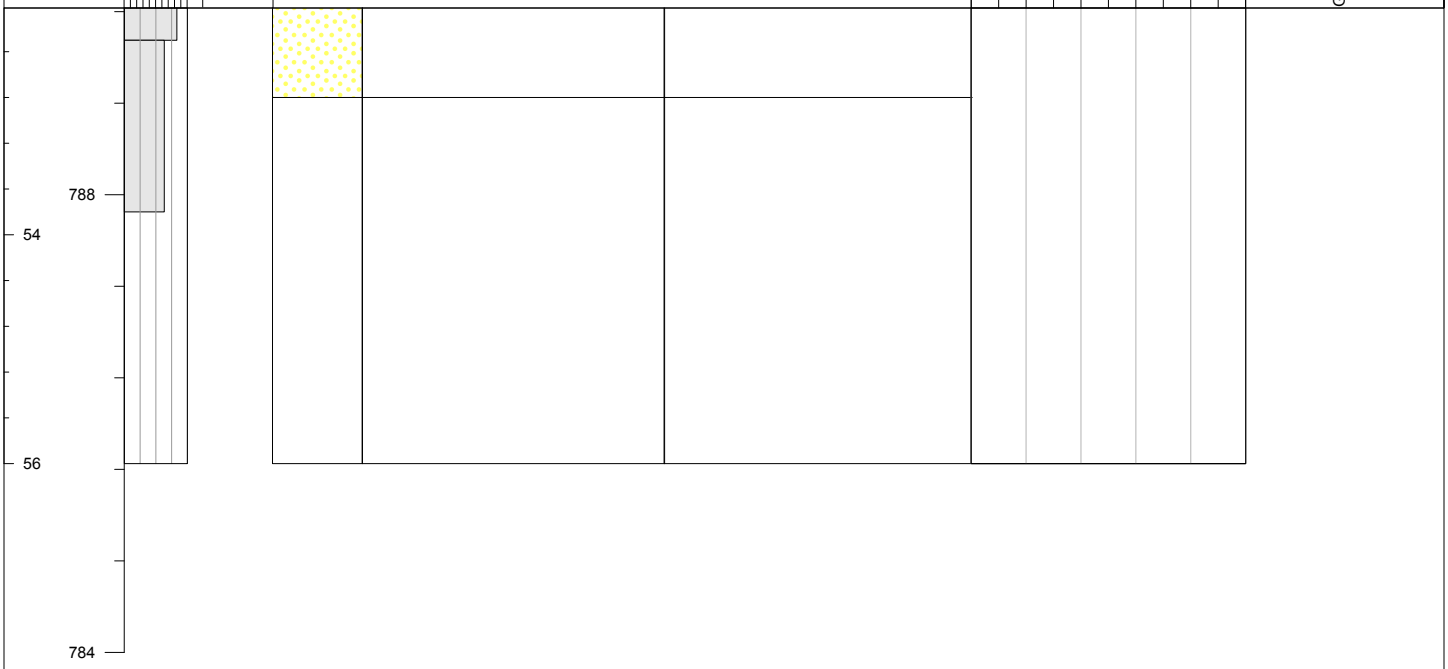
**Lithological Symbol**

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

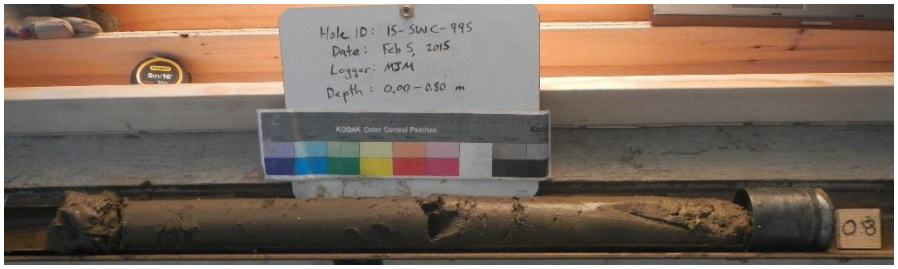
Moisture Content, Liquid Limit, Plastic Limit (%)

**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**



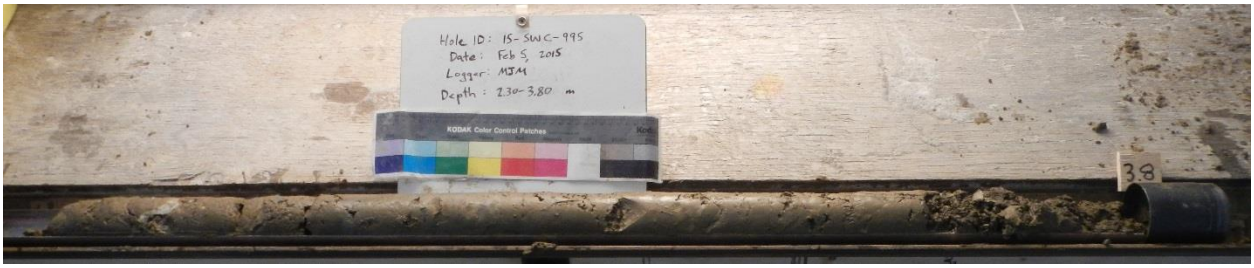
# Attachment 2: Core Photos



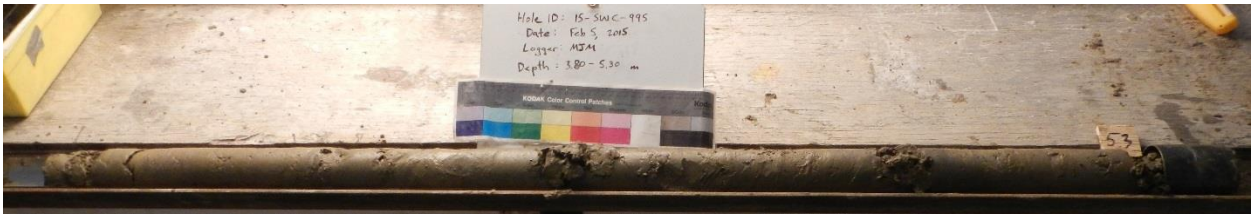

15-SWC-995: 0 m - 0.8 m




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



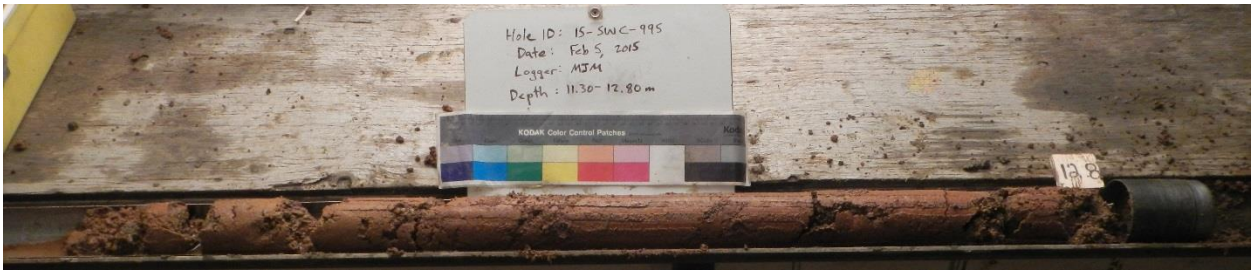

15-SWC-995: 6.8 m - 8.3 m




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



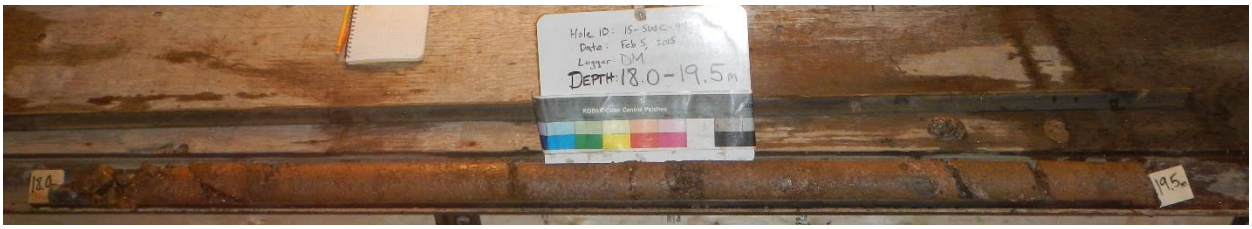

15-SWC-995: 14.1 m - 15.6 m



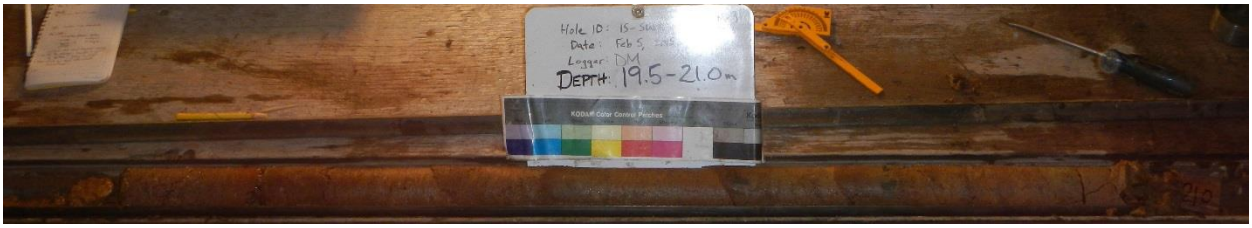
15-SWC-995: 15.6 m - 17.1 m



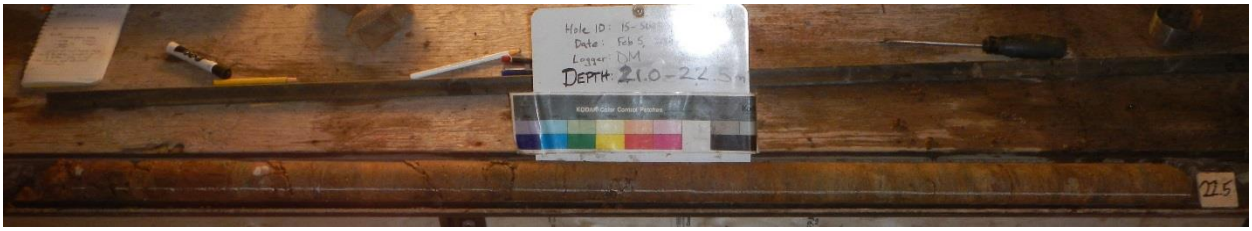

15-SWC-995: 17.1 m - 18 m




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



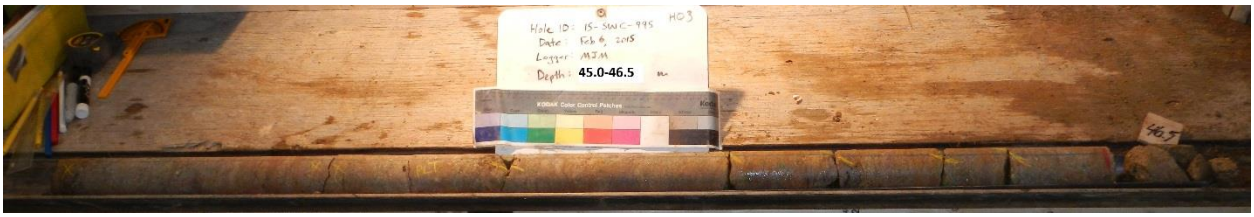

15-SWC-995: 40.5 m - 42 m




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



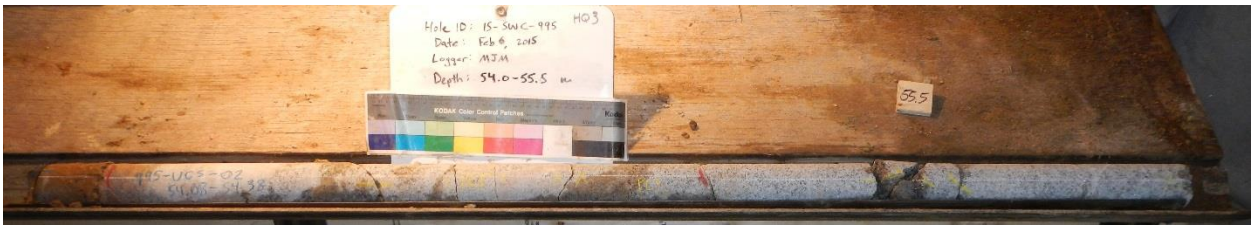

15-SWC-995: 49.5 m - 51 m




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



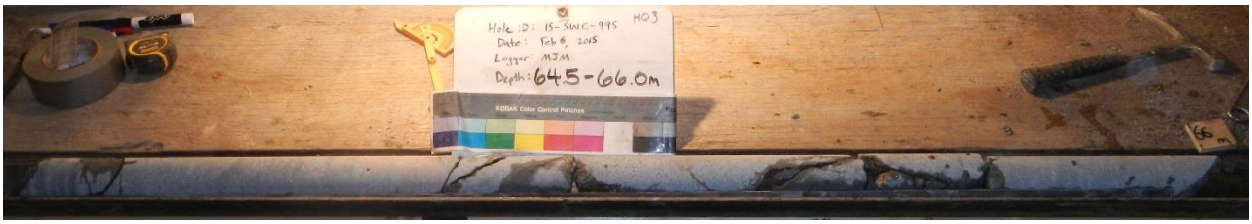

15-SWC-995: 60 m - 61.5 m




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



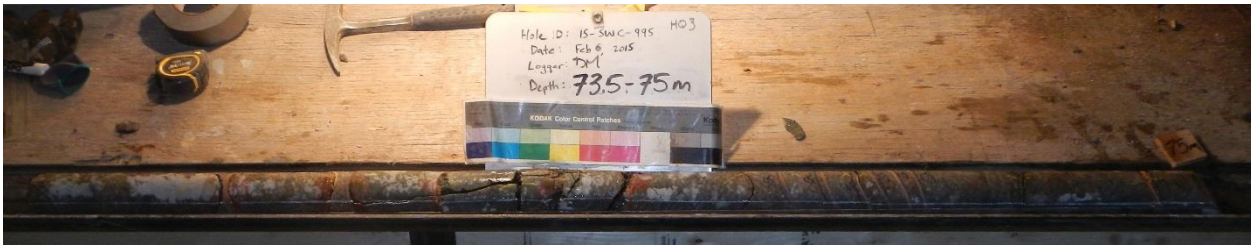

15-SWC-995: 69 m - 70.5 m




15-SWC-995: 70.5 m - 72 m



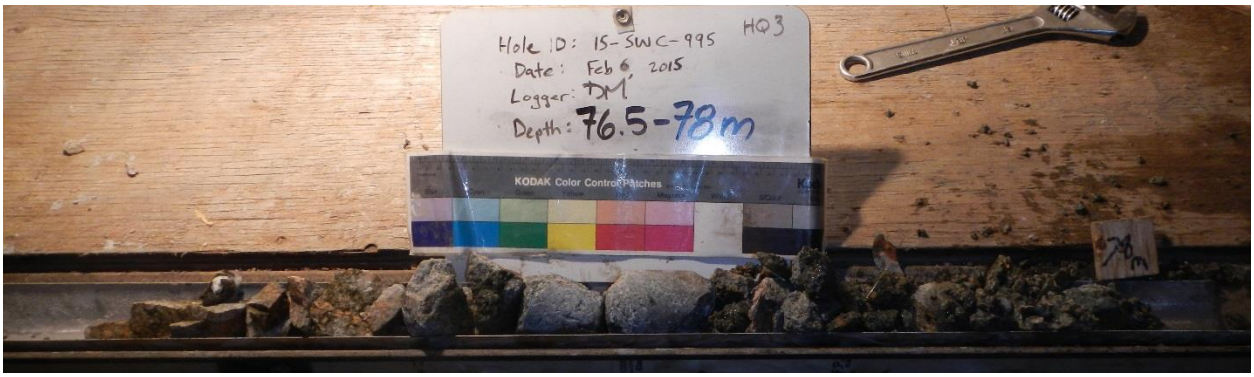

15-SWC-995: 72 m - 73.5 m




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



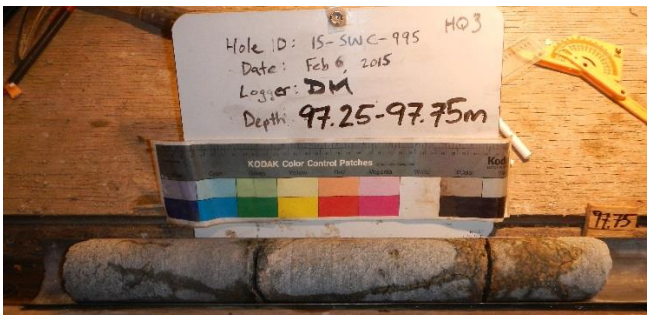

15-SWC-995: 93 m - 94.25 m




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



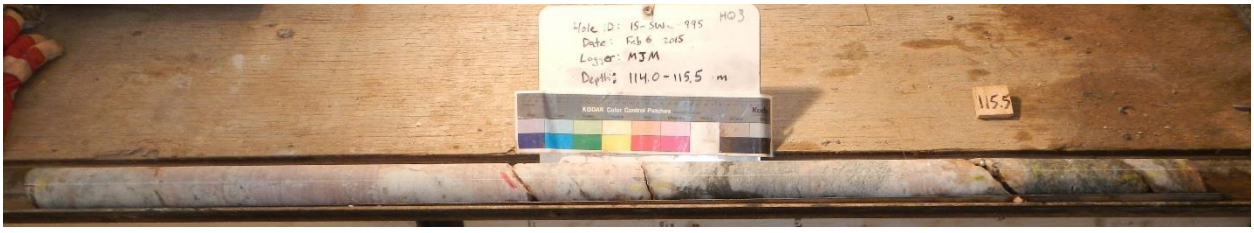

15-SWC-995: 109.5 m - 111 m




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



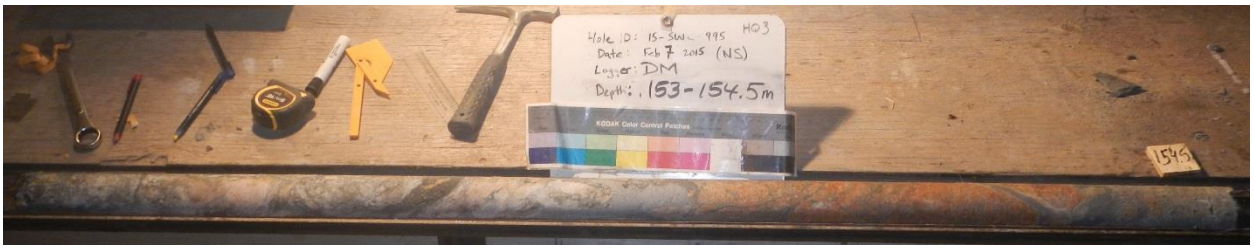

15-SWC-995: 148.5 m - 150 m




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



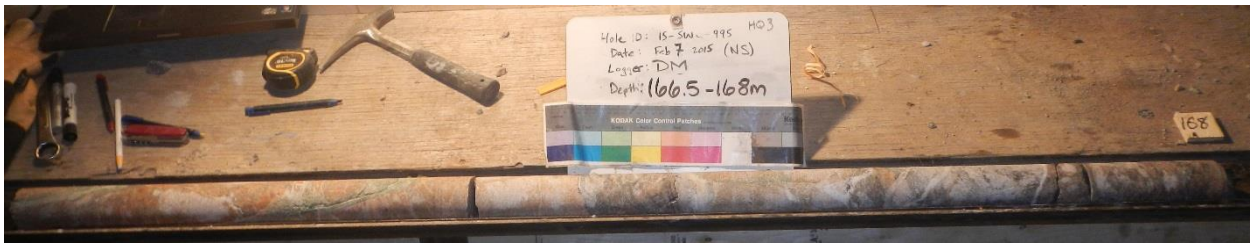

15-SWC-995: 162 m - 163.5 m




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



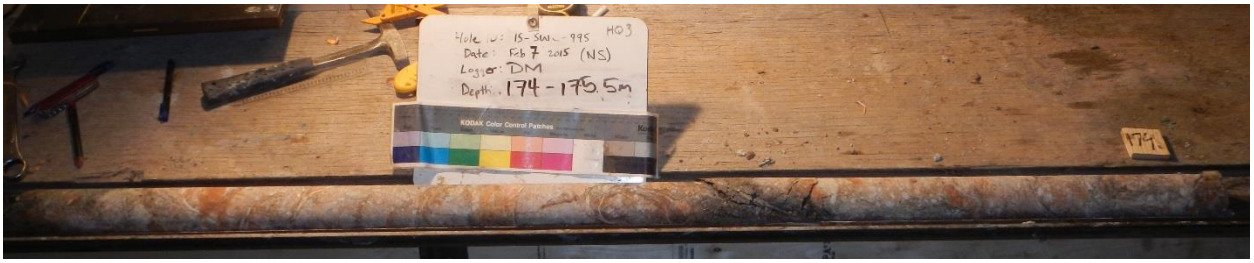

15-SWC-995: 169.5 m - 171 m




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



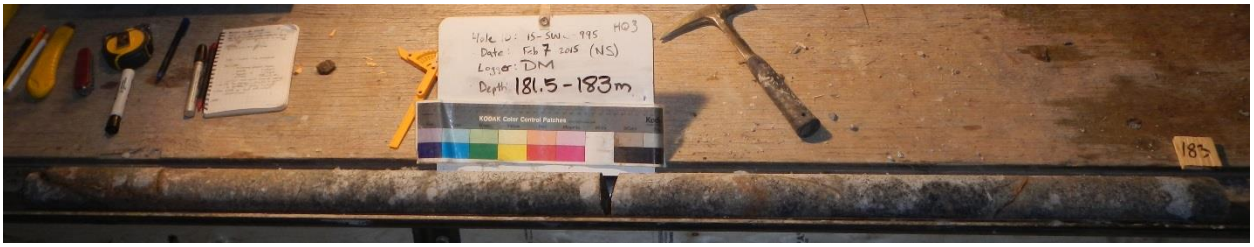

15-SWC-995: 177 m - 178.5 m




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



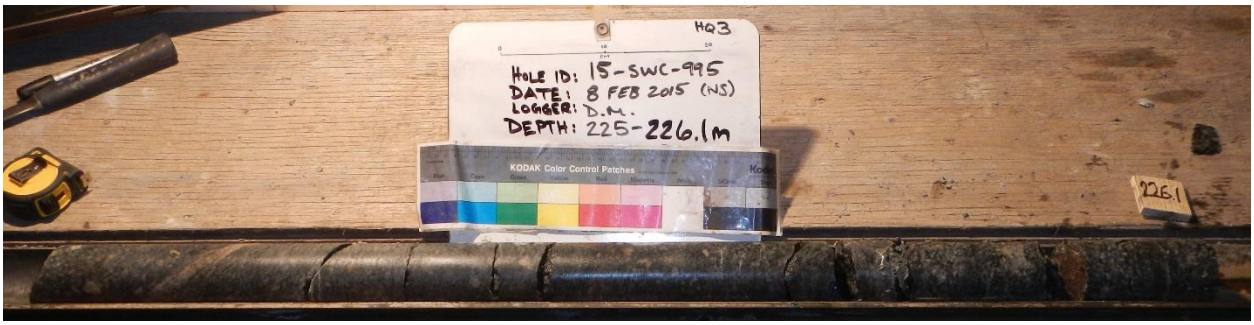

15-SWC-995: 221.8 m - 223.3 m



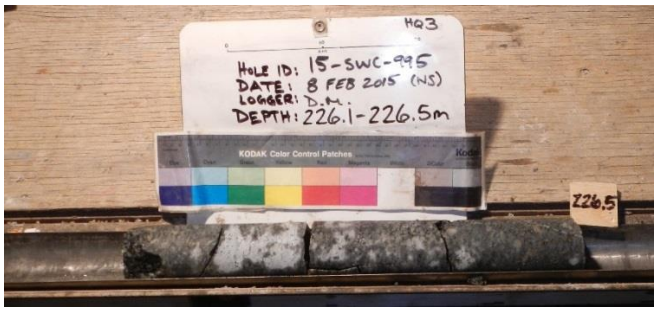

15-SWC-995: 223.3 m - 223.7 m



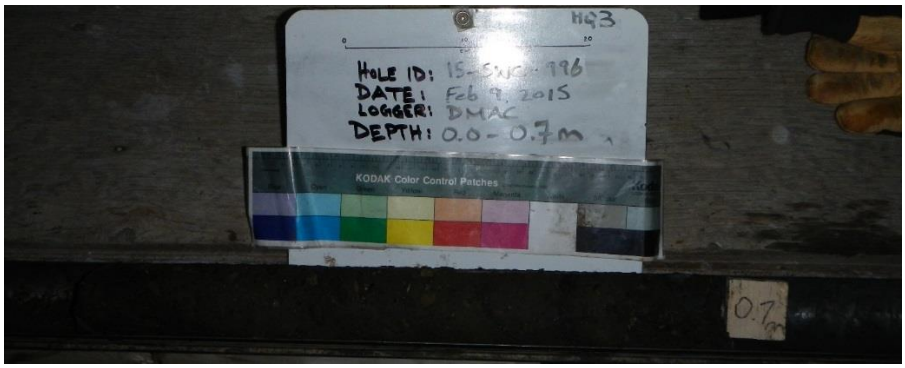

15-SWC-995: 223.7 m - 225 m



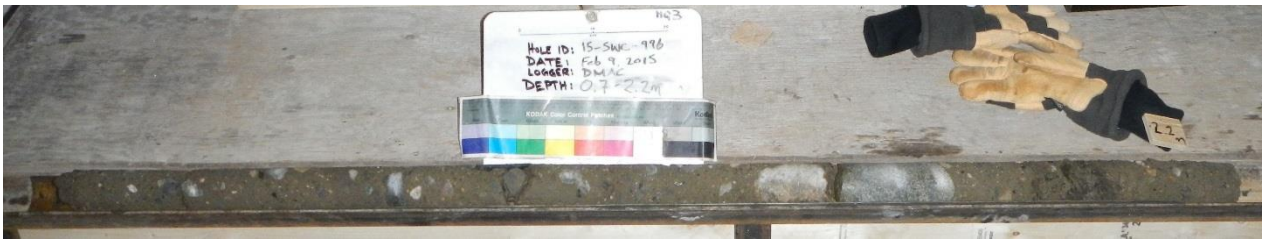

15-SWC-995: 225 m - 226.1 m



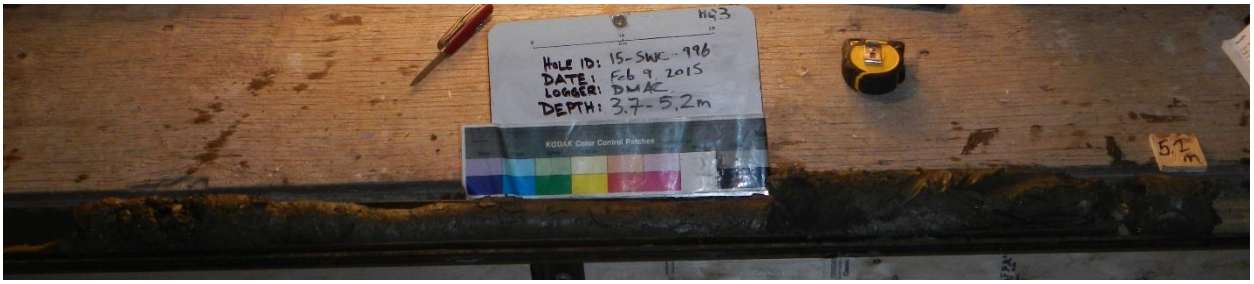

15-SWC-995: 226.1 m - 226.5 m




15-SWC-996: 0 m - 0.7 m




15-SWC-996: 0.7 m - 2.2 m



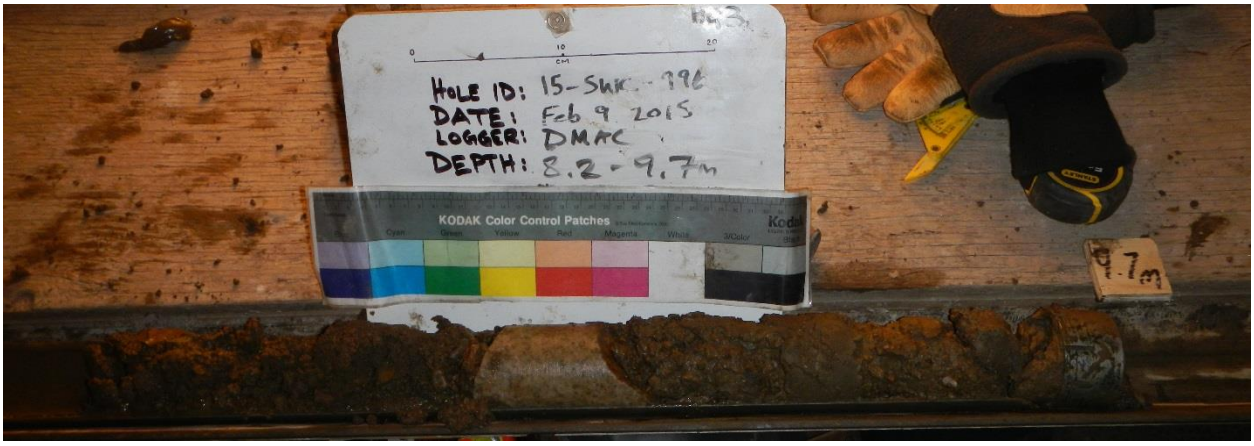

15-SWC-996: 3.7 m - 5.2 m



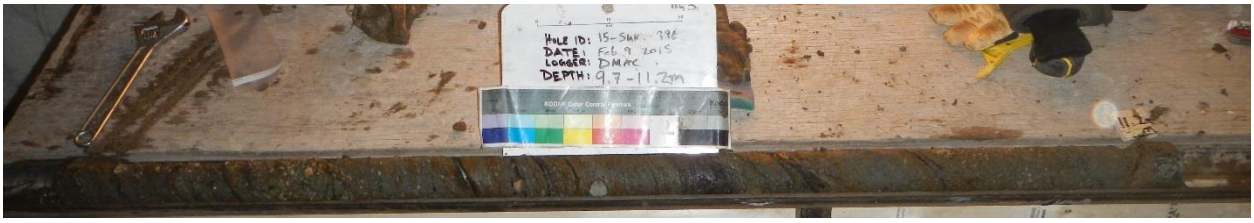

15-SWC-996: 5.2 m - 6.7 m



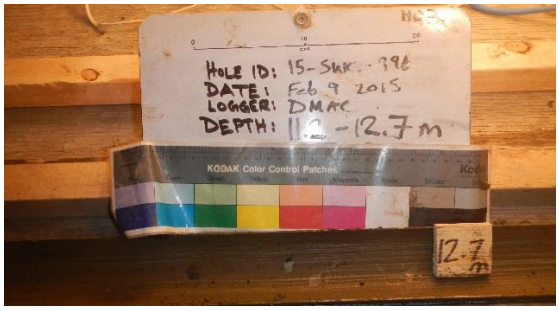

15-SWC-996: 6.7 m - 8.2 m




15-SWC-996: 8.2 m - 9.7 m




15-SWC-996: 9.7 m - 11.2 m



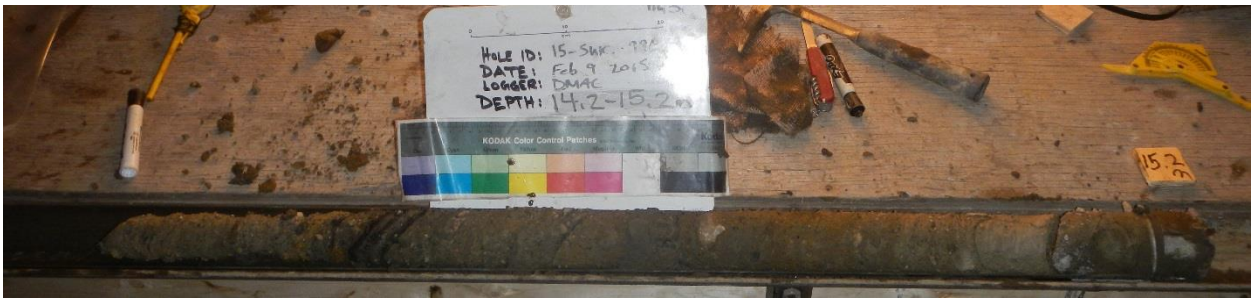

15-SWC-996: 11.2 m - 12.7 m



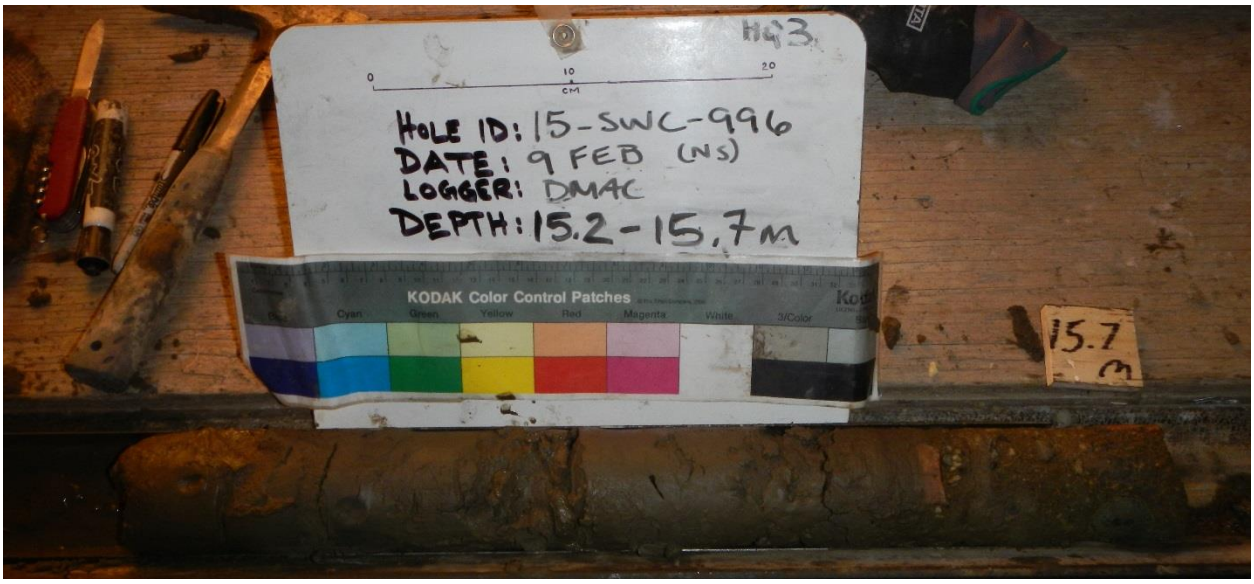

15-SWC-996: 12.7 m - 14.2 m



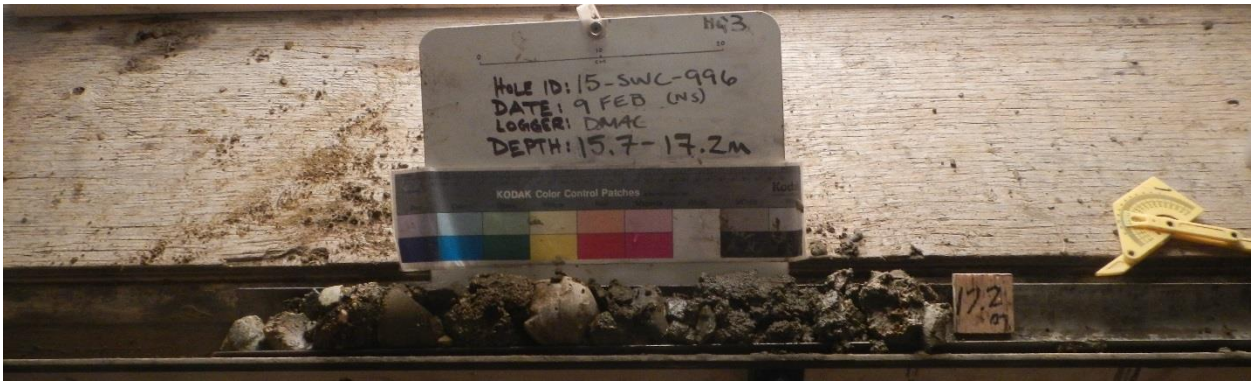
15-SWC-996: 13.6 m



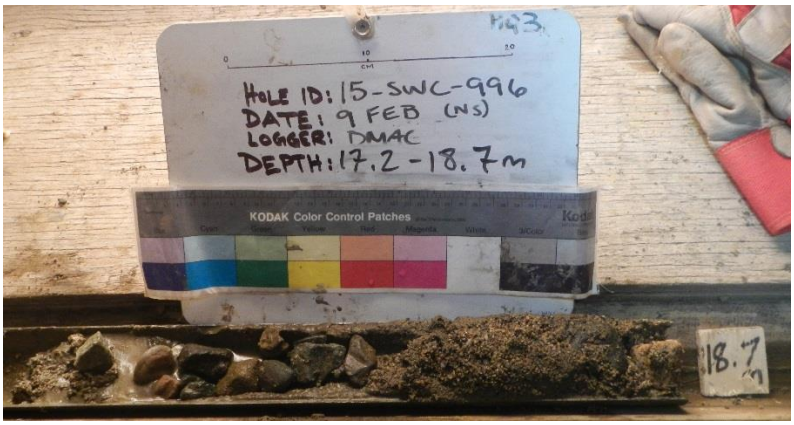

15-SWC-996: 14.2 m - 15.2 m




15-SWC-996: 15.2 m - 15.7 m




15-SWC-996: 15.7 m - 17.2 m



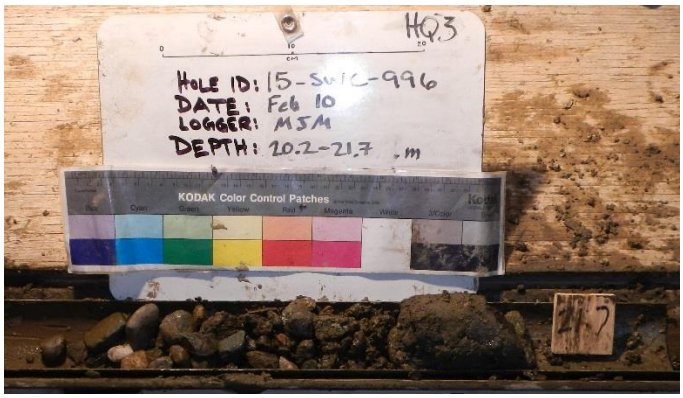

15-SWC-996: 17.2 m - 18.7 m



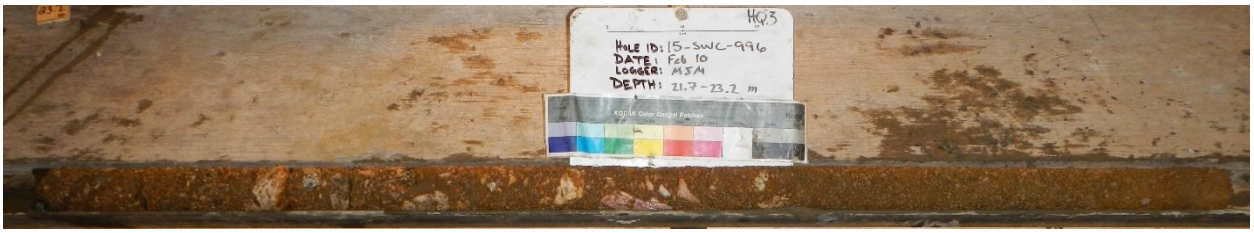

15-SWC-996: 18.7 m - 18.9 m




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



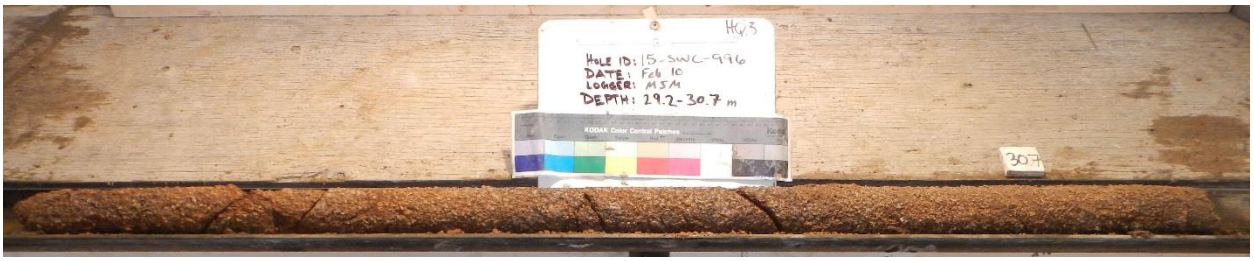

15-SWC-996: 24.7 m - 26.2 m




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



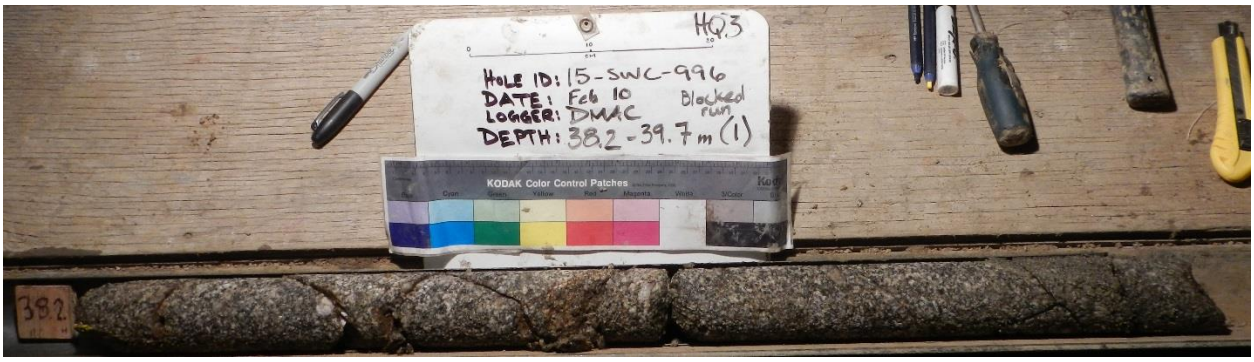

15-SWC-996: 33.7 m - 35.2 m




15-SWC-996: 35.2 m - 36.7 m



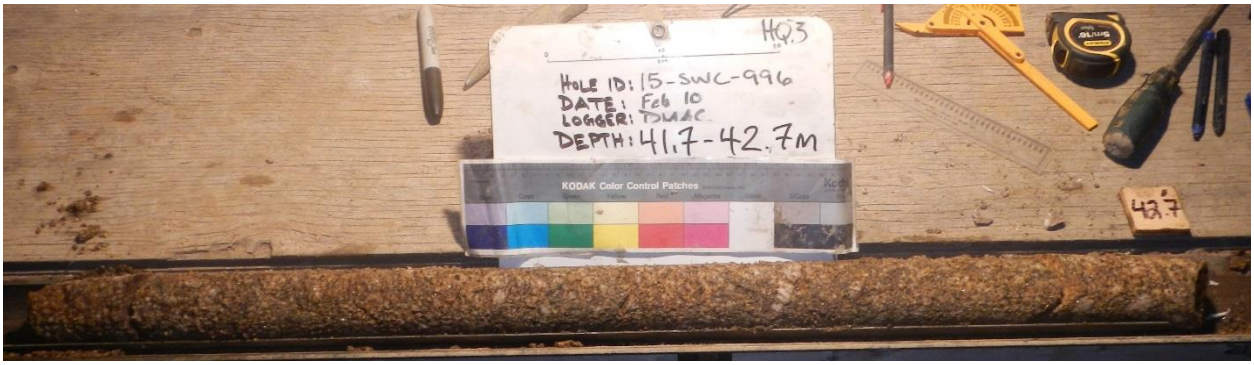

15-SWC-996: 36.7 m - 38.2 m




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



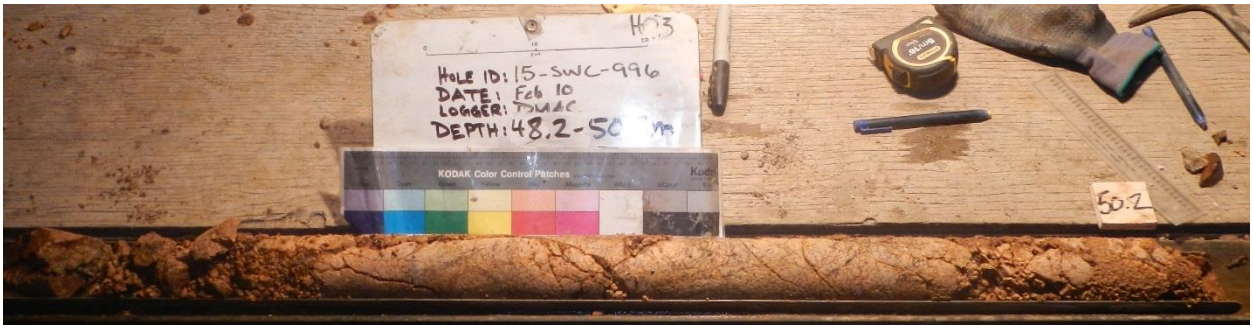

15-SWC-996: 44.2 m - 45.7 m




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



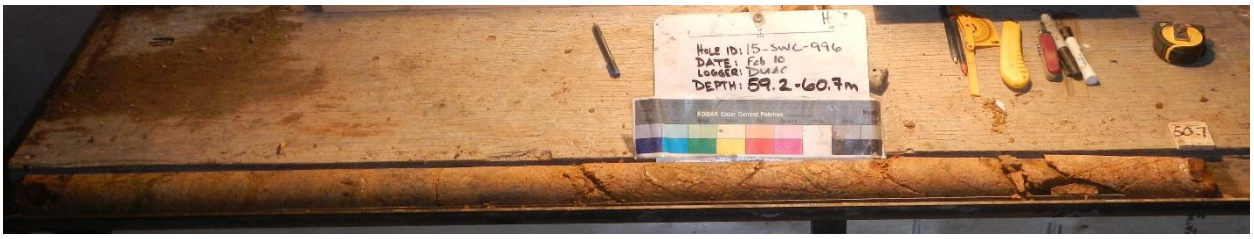

15-SWC-996: 54.7 m - 56.2 m




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



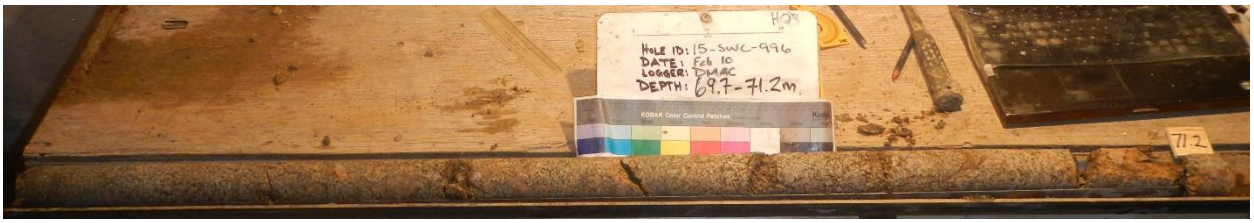

15-SWC-996: 65.2 m - 66.7 m




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



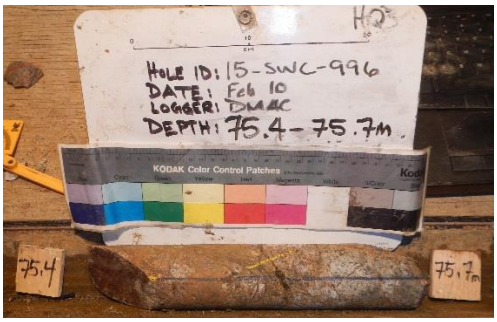

15-SWC-996: 71.2 m - 72.7 m



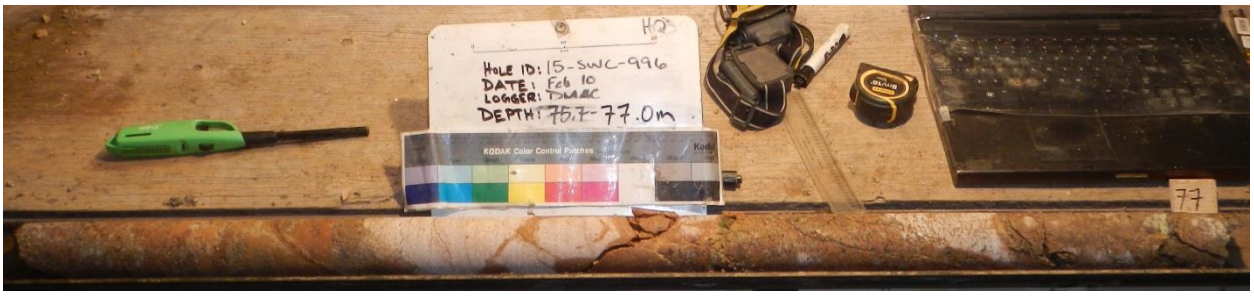

15-SWC-996: 72.7 m - 73.9 m



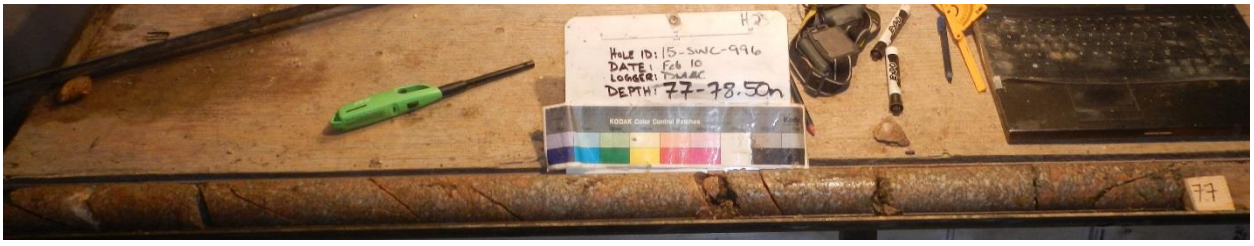

15-SWC-996: 73.9 m - 75.4 m




15-SWC-996: 75.4 m - 75.7 m




15-SWC-996: 75.7 m - 77 m



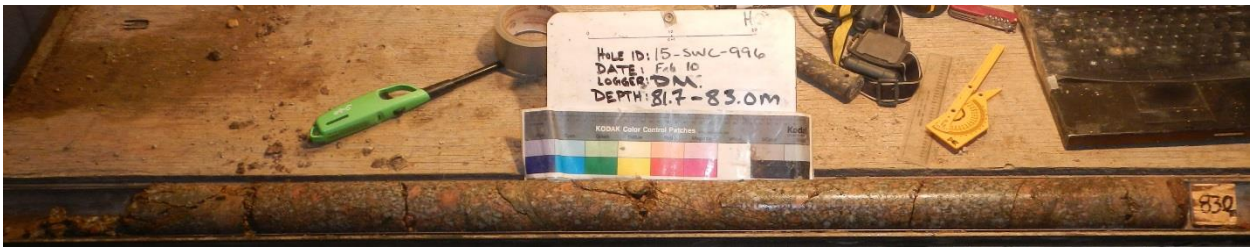

15-SWC-996: 77 m - 78.5 m




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



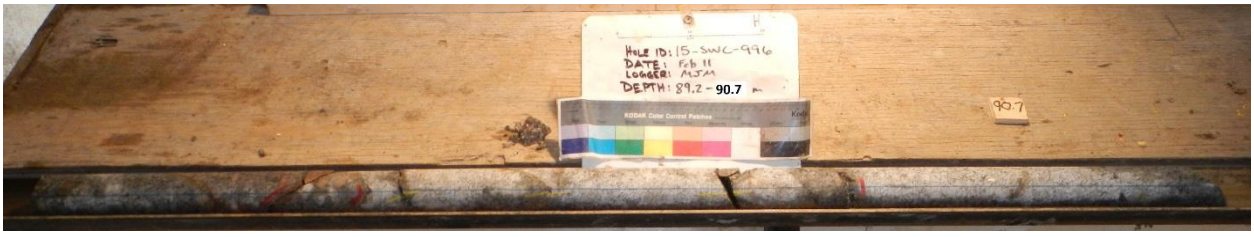

15-SWC-996: 84.7 m - 86.2 m



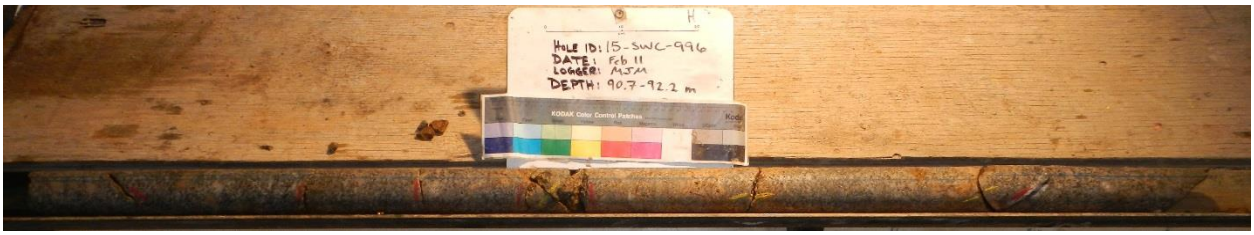

15-SWC-996: 86.2 m - 87.7 m




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



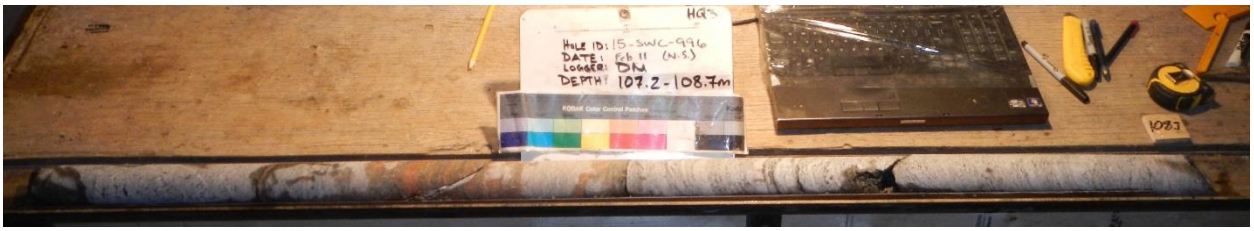

15-SWC-996: 102.7 m - 104.2 m




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



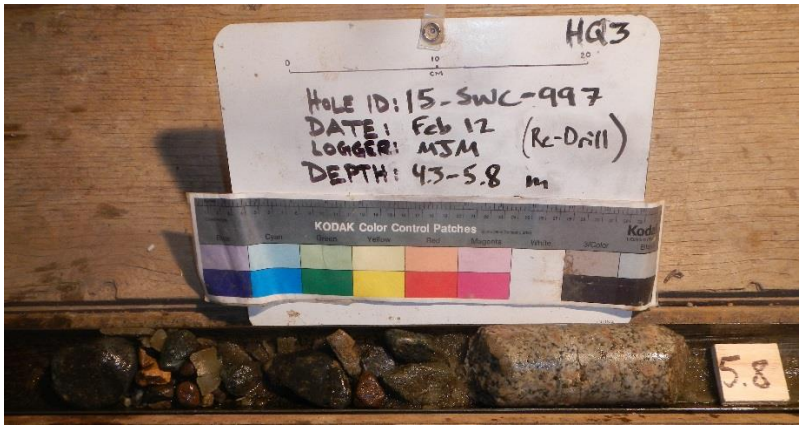

15-SWC-997: 2.8 m - 4.3 m



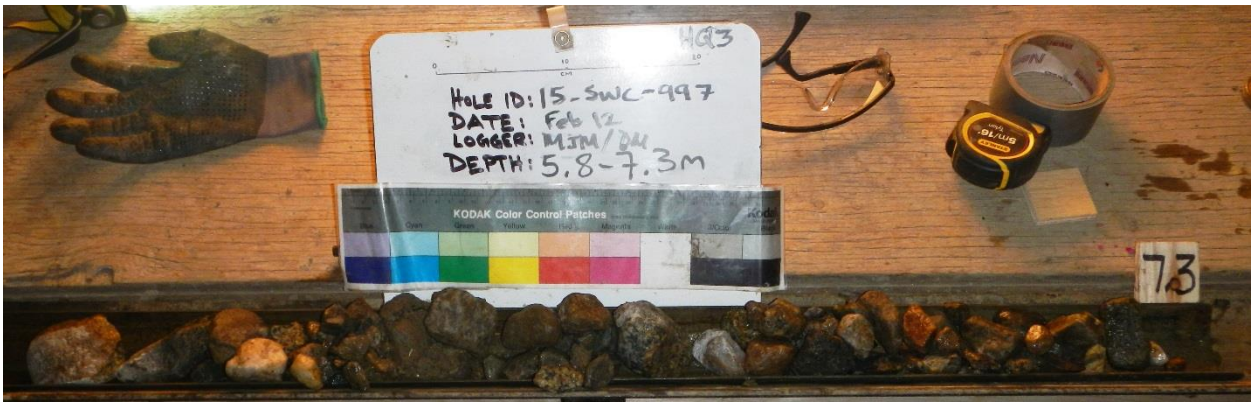

15-SWC-997: 0 m - 4.3 m re-drill



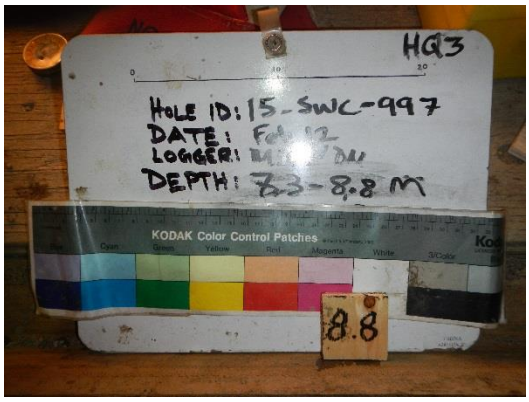

15-SWC-997: 4.3 m - 5.8 m




15-SWC-997: 4.3 m - 5.8 m re-drill




15-SWC-997: 5.8 m - 7.3 m



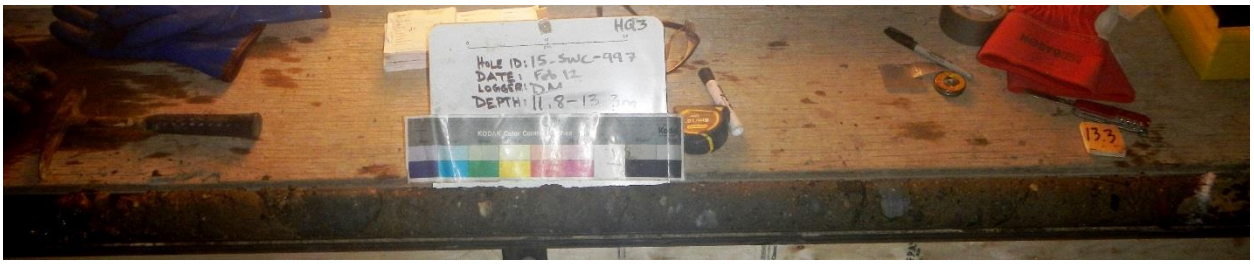

15-SWC-997: 7.3 m - 8.8 m



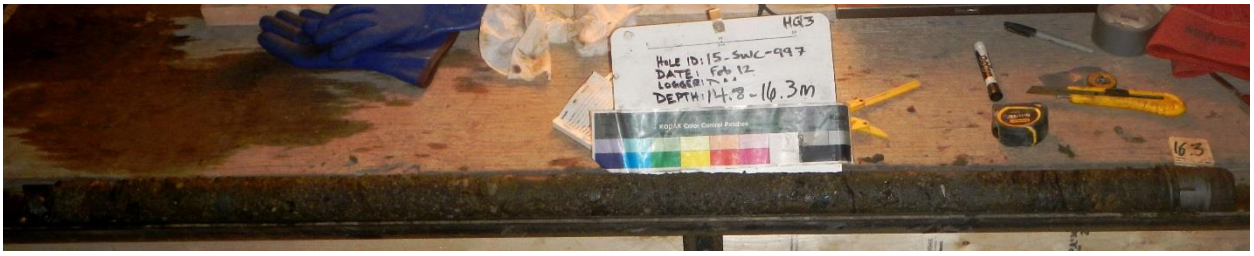

15-SWC-997: 8.8 m - 10.3 m




15-SWC-997: 10.3 m - 11.9 m



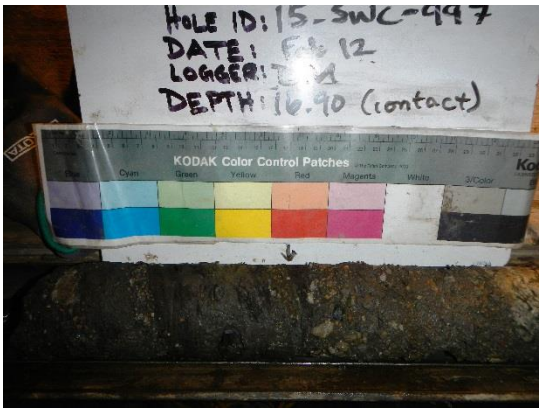

15-SWC-997: 11.8 m - 13.3 m




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



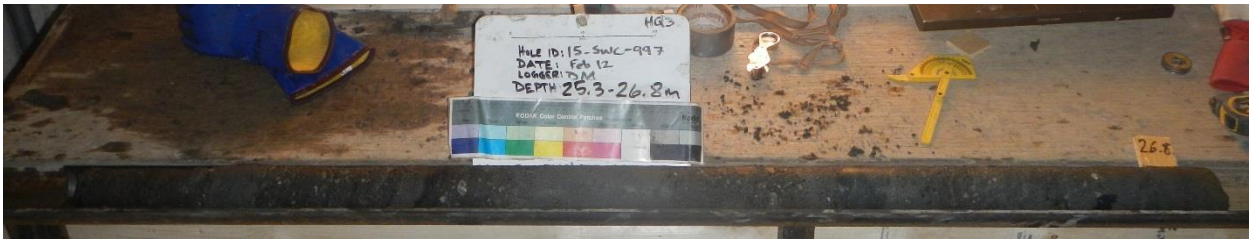

15-SWC-997: 20.8 m - 22.3 m



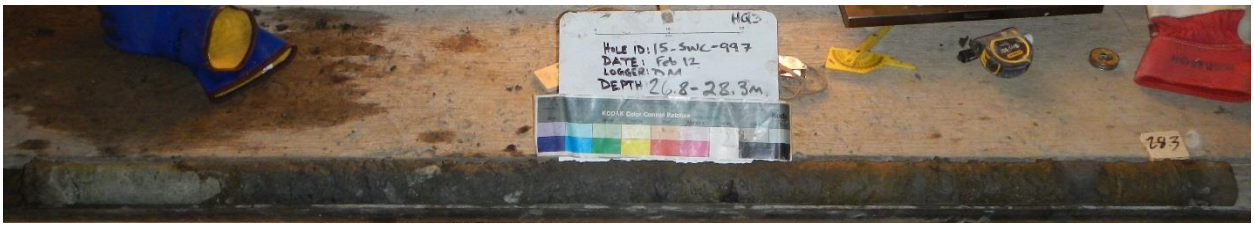

15-SWC-997: 22.3 m - 23.8 m




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



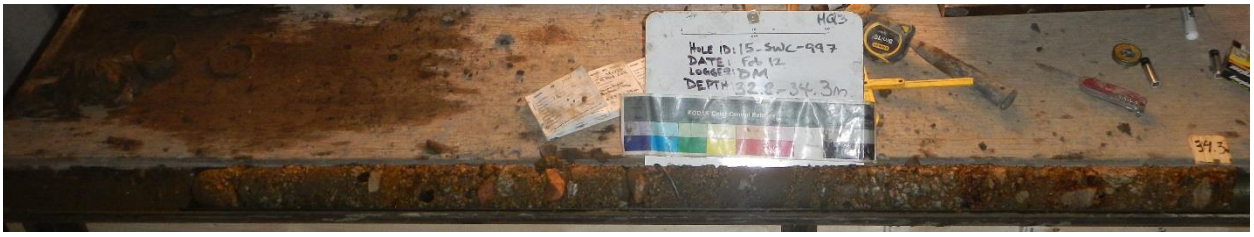

15-SWC-997: 28.3 m - 29.8 m




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



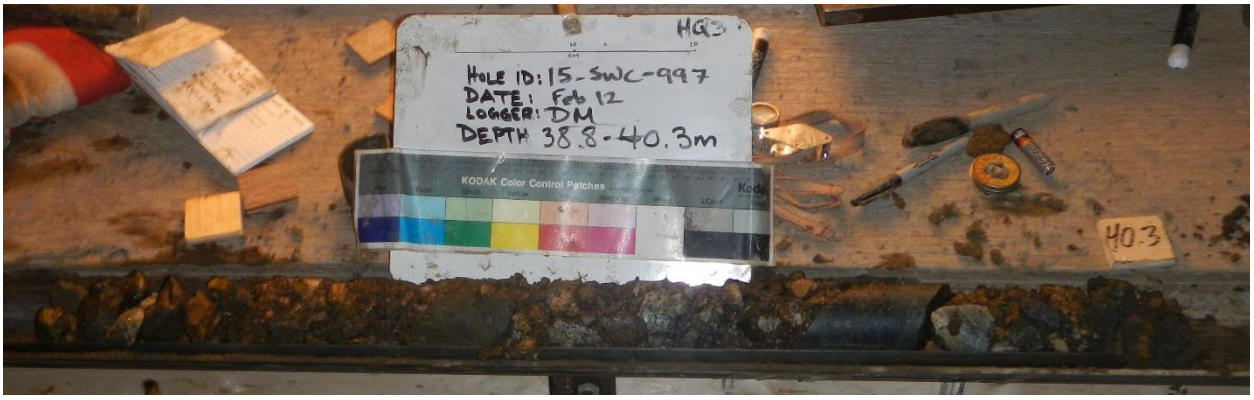

15-SWC-997: 34.3 m - 35.8 m




15-SWC-997: 35.8 m - 37.3 m



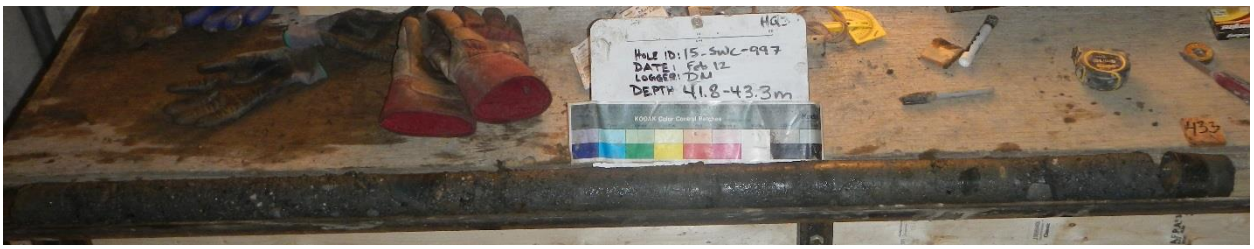

15-SWC-997: 37.3 m - 38.8 m




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.

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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 | |

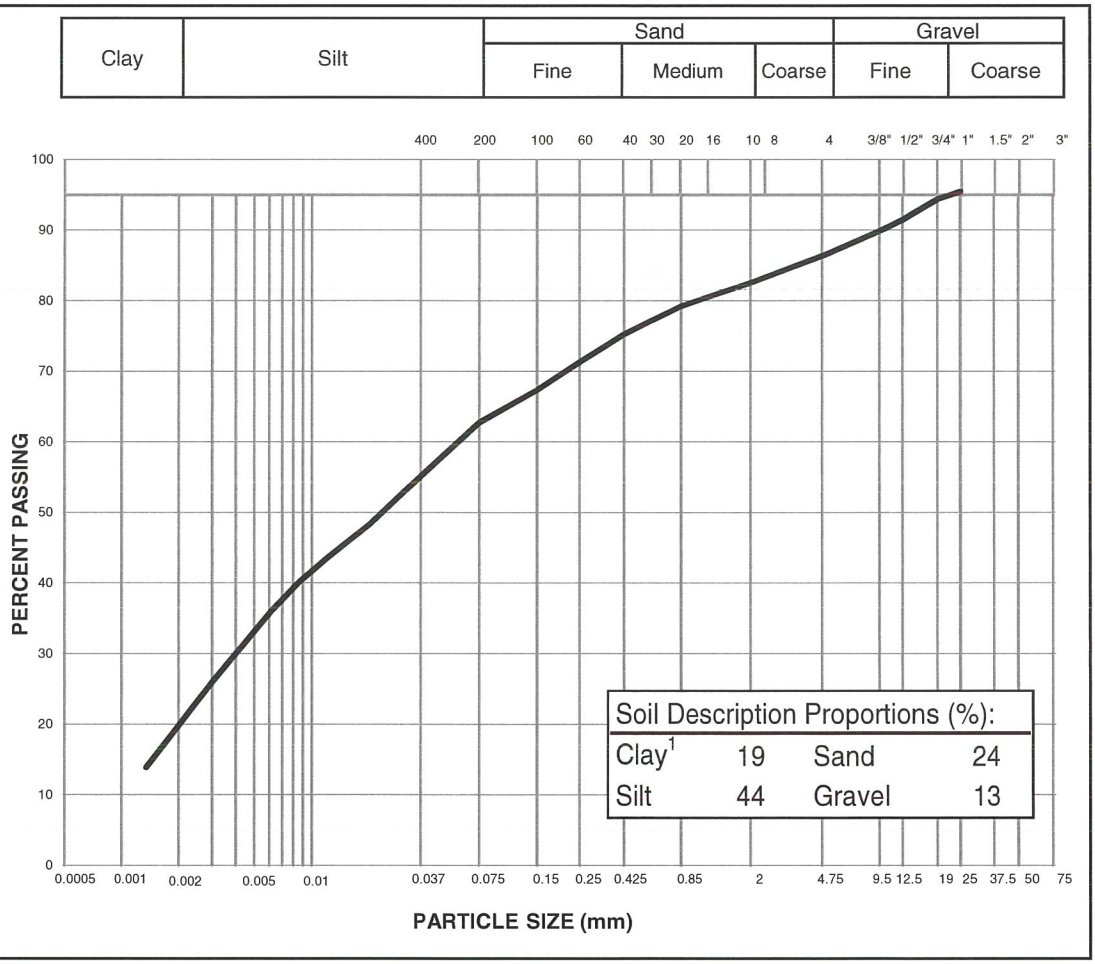
**Reviewed By:**

# 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 |




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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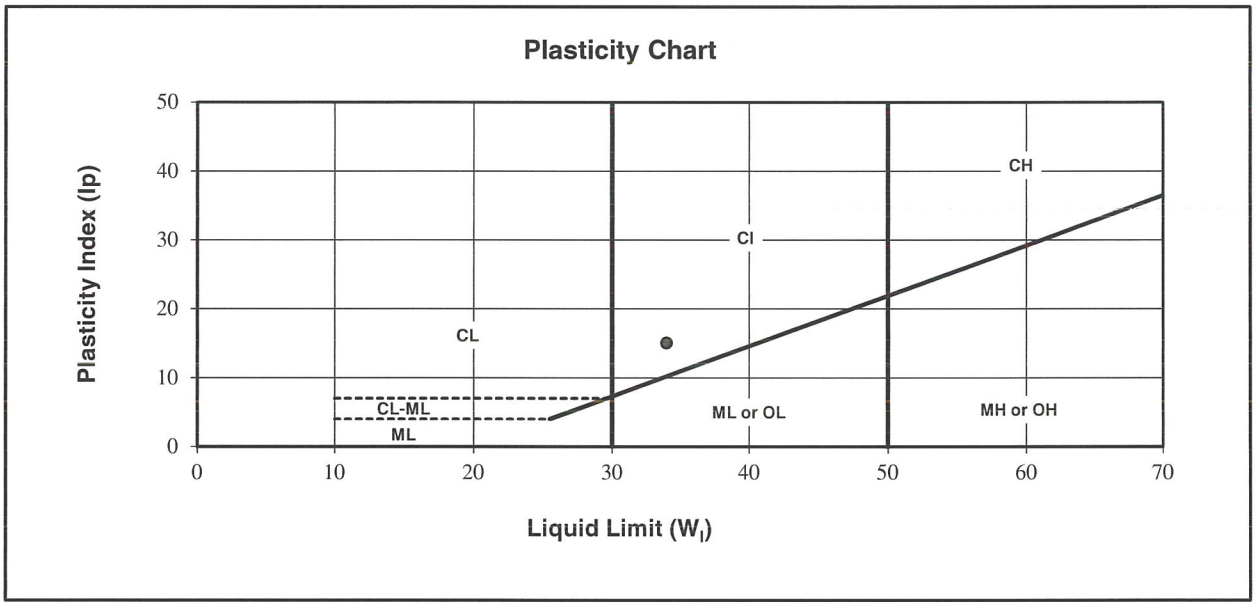
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | MM-101259 |
| | | Borehole Number: | 14-SWC-968 |
| Project No: | W14103546-01 | Depth: | 15.05 - 15.40 m |
| Client: | SRK Consulting (Canada) Inc. | Sampled By: | Client |
| Attention: | Murrary McGregor | Tested By: | AMT |
| Email: | | Date Sampled: | November 1, 2014 |
| | | 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:** C.E.T.

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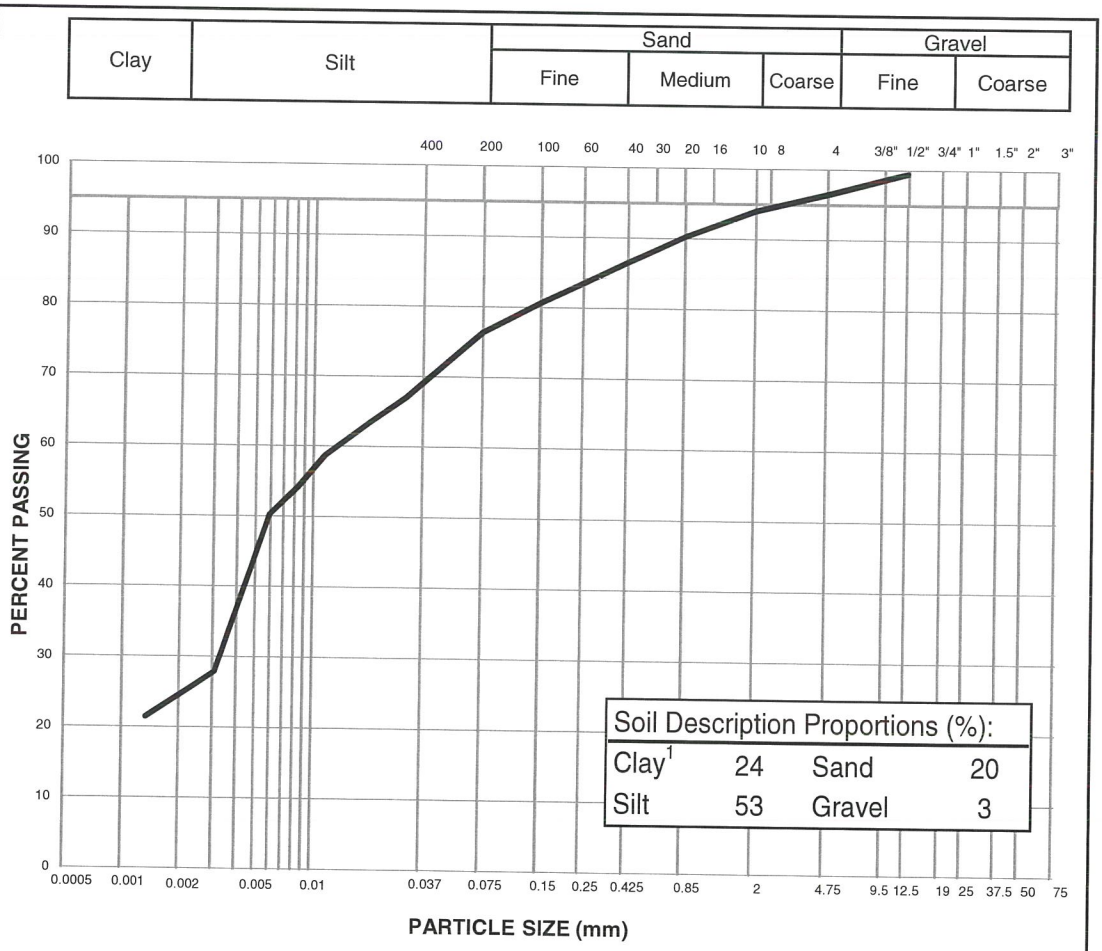
TETRA TECH

# 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 |




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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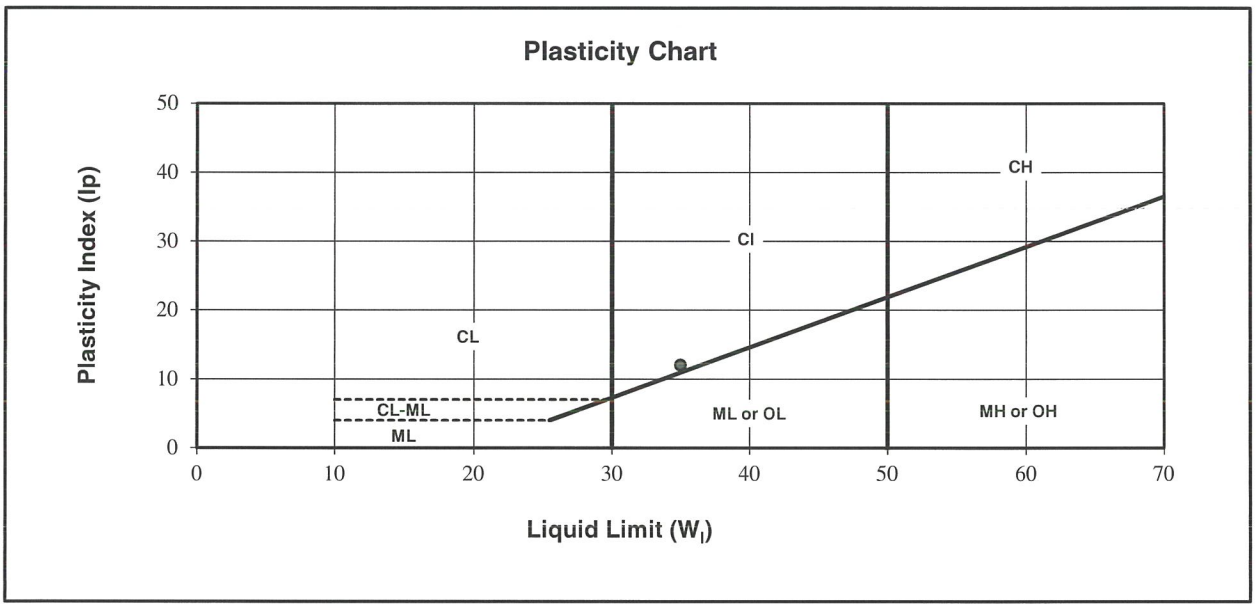
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | MM-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




| | | | |
|---|---|---|---|
| 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.

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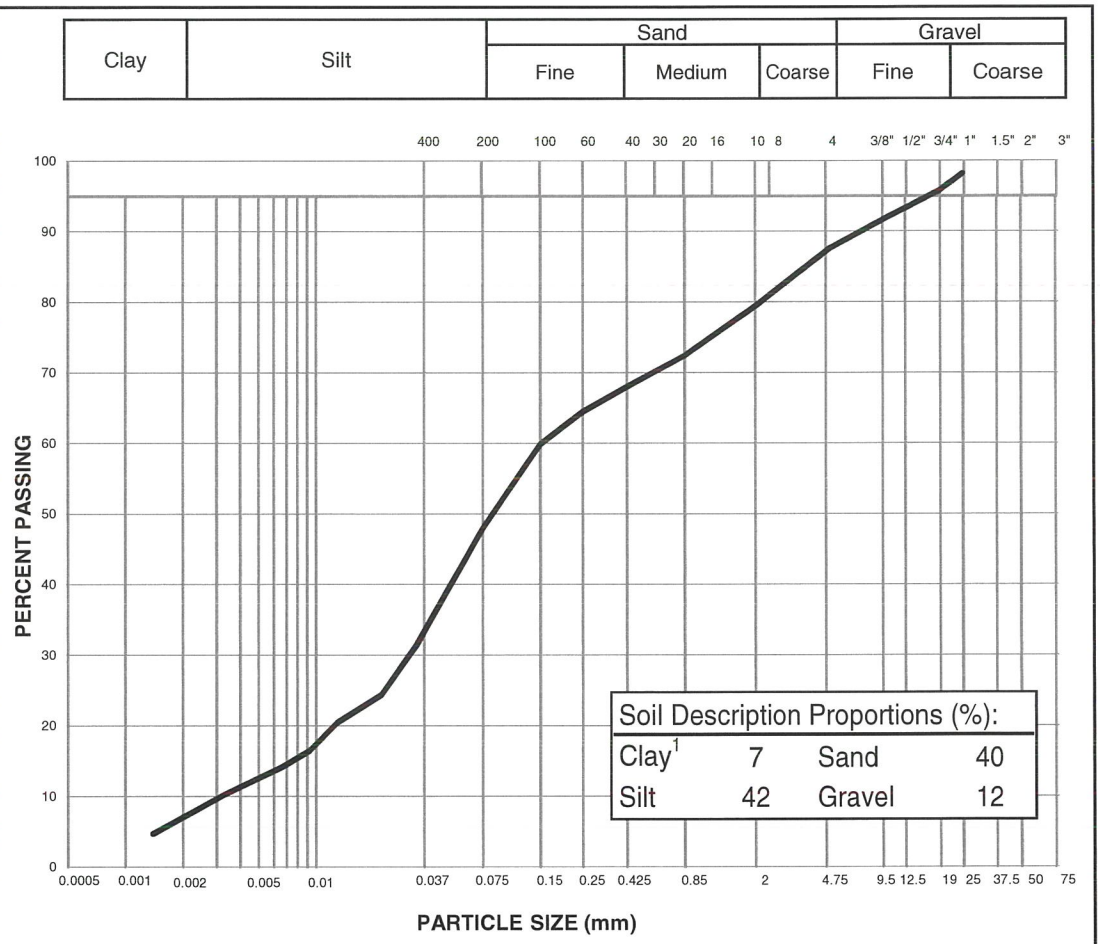
TETRA TECH

# 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 |




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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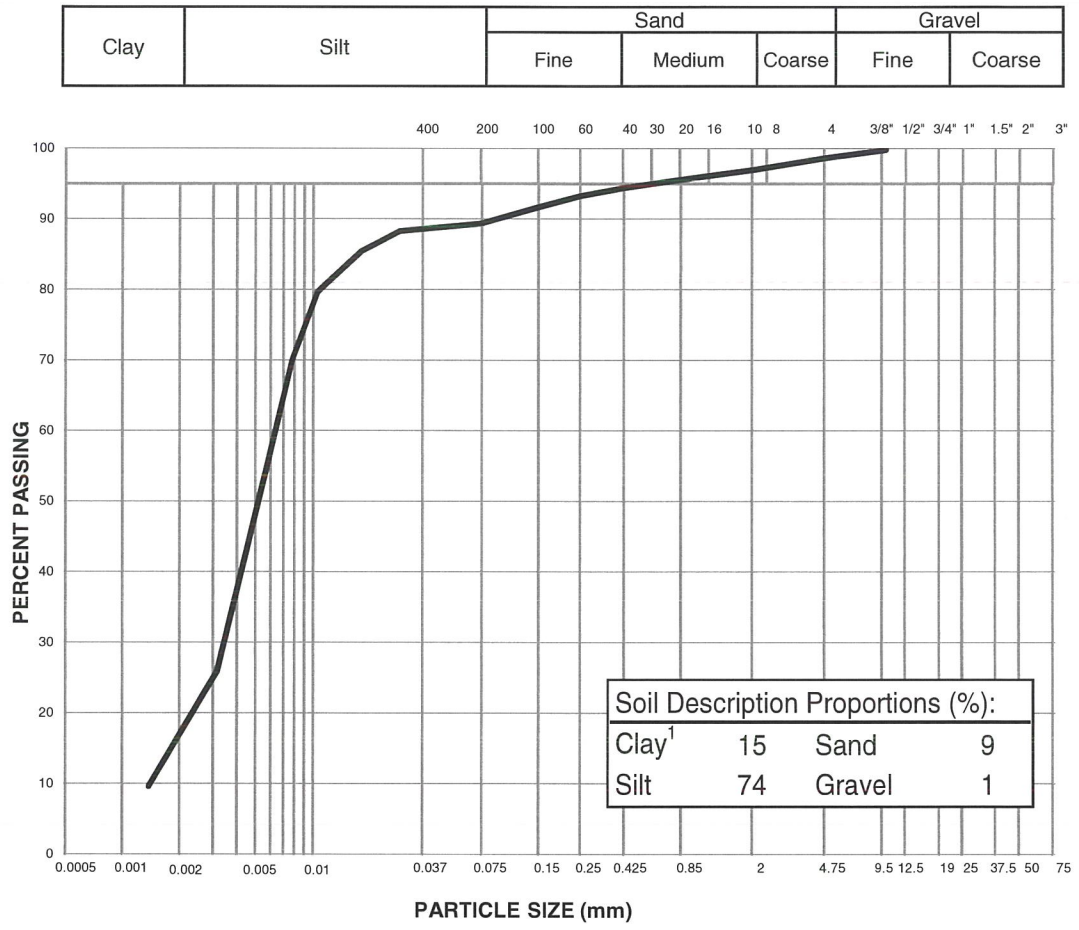
TETRA TECH

# 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 |




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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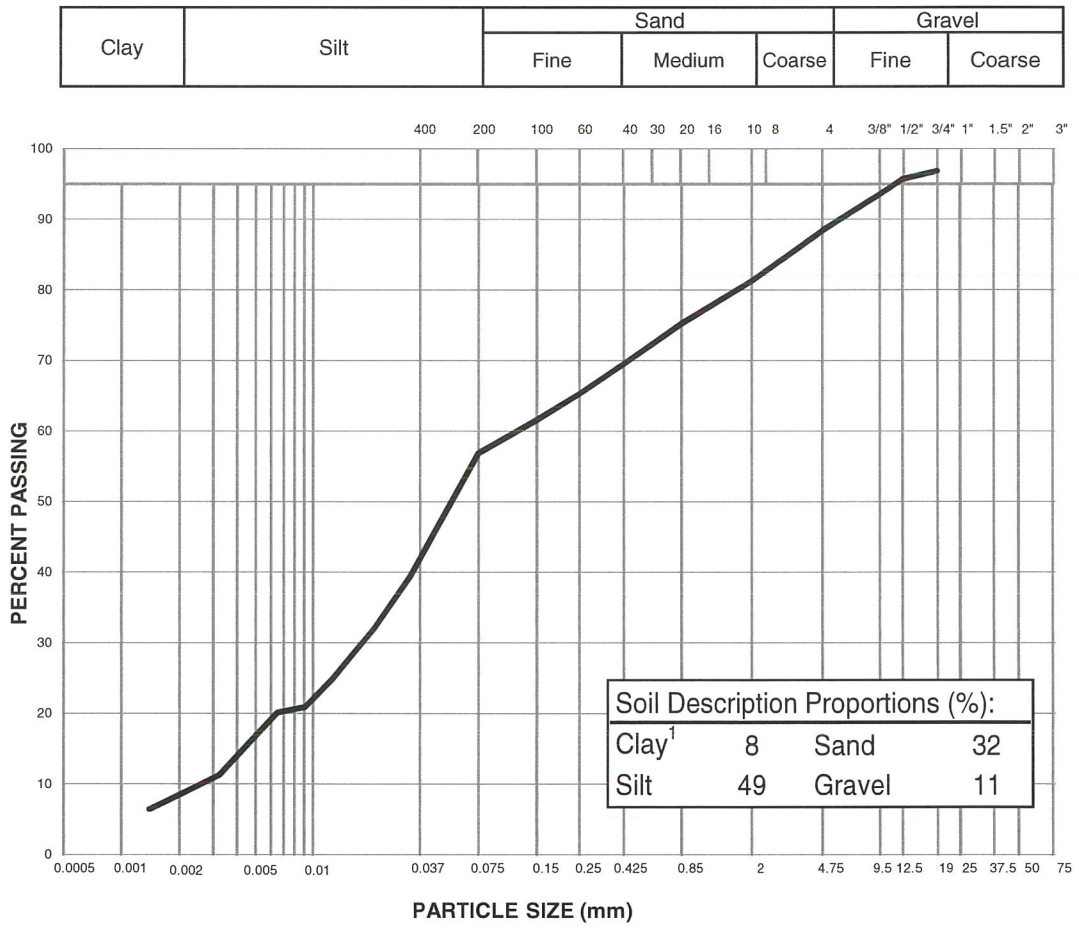
# PARTICLE SIZE ANALYSIS REPORT

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 |




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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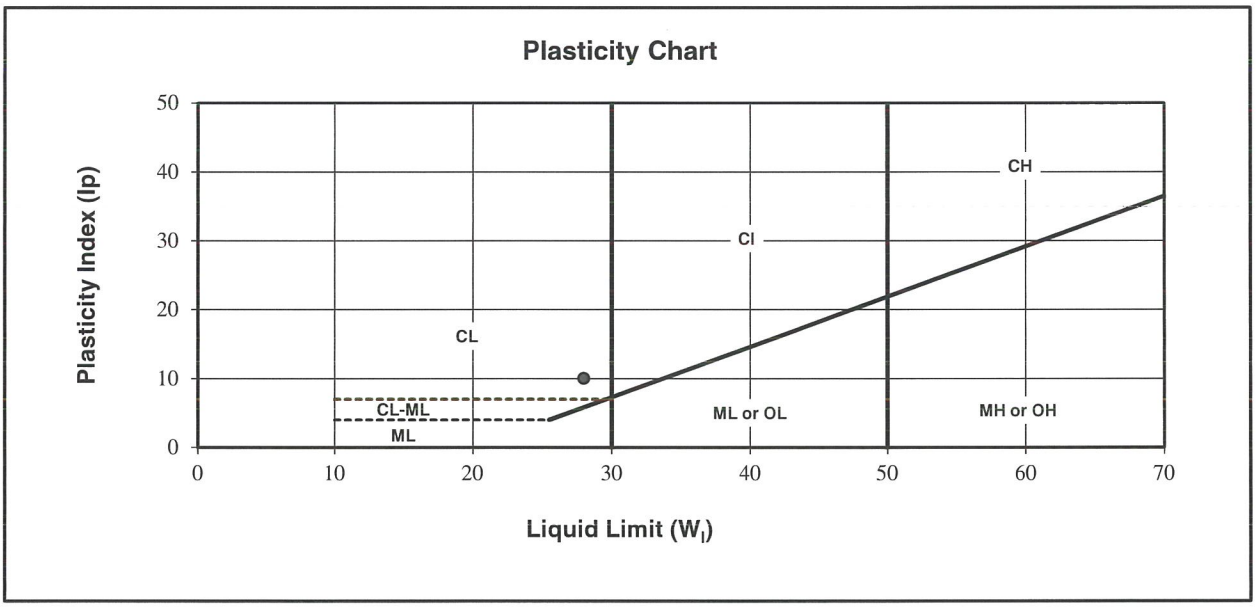
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | MM-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: | Murrary 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:** C.E.T.

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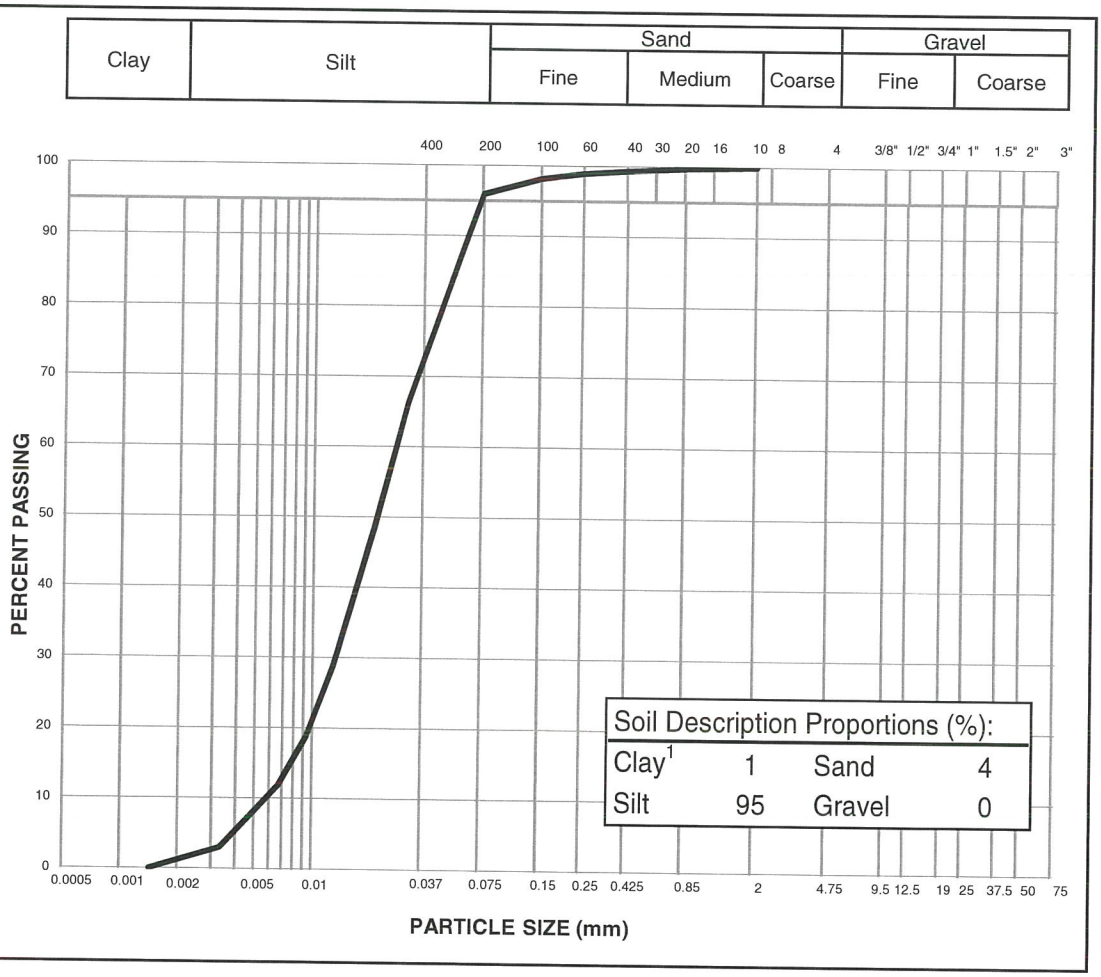
TETRA TECH

# 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 |




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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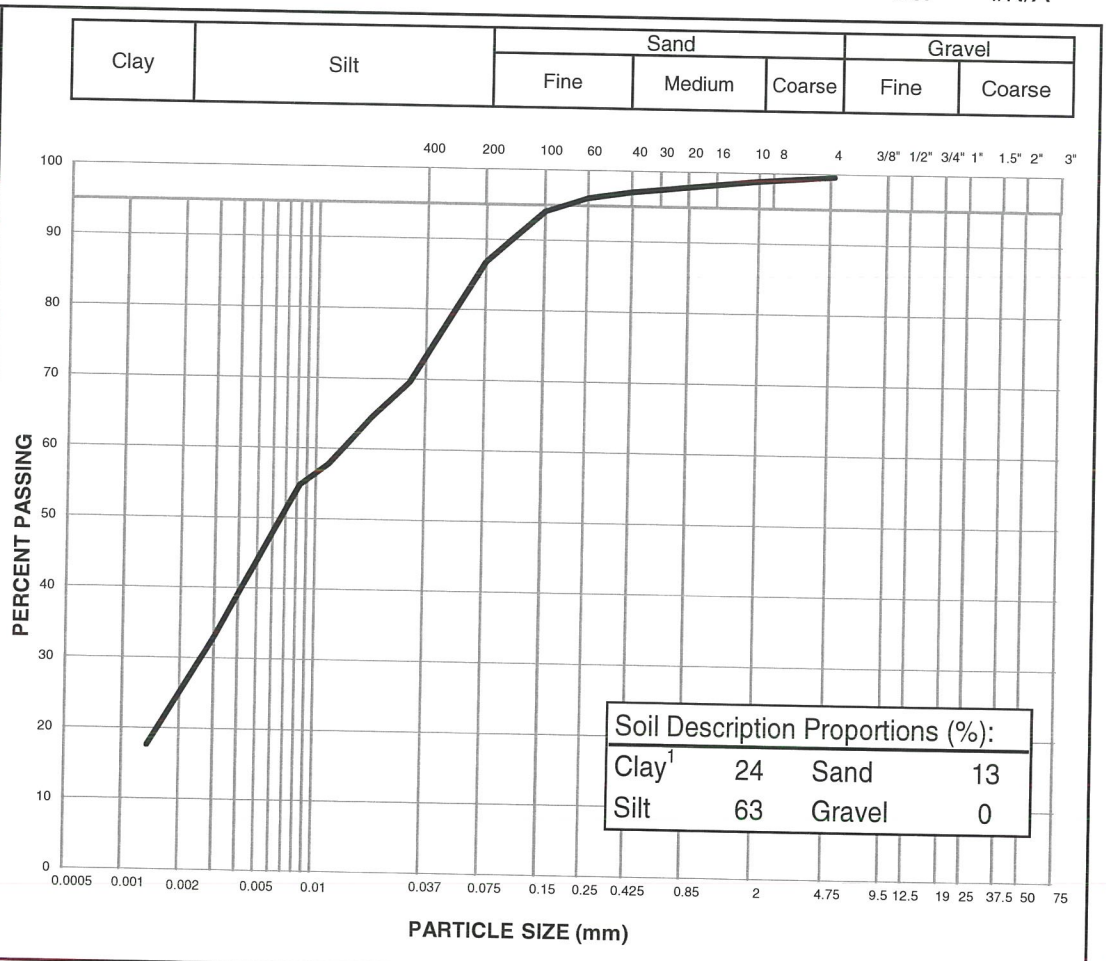
TETRA TECH

# 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 |




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:** _____

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TETRA TECH

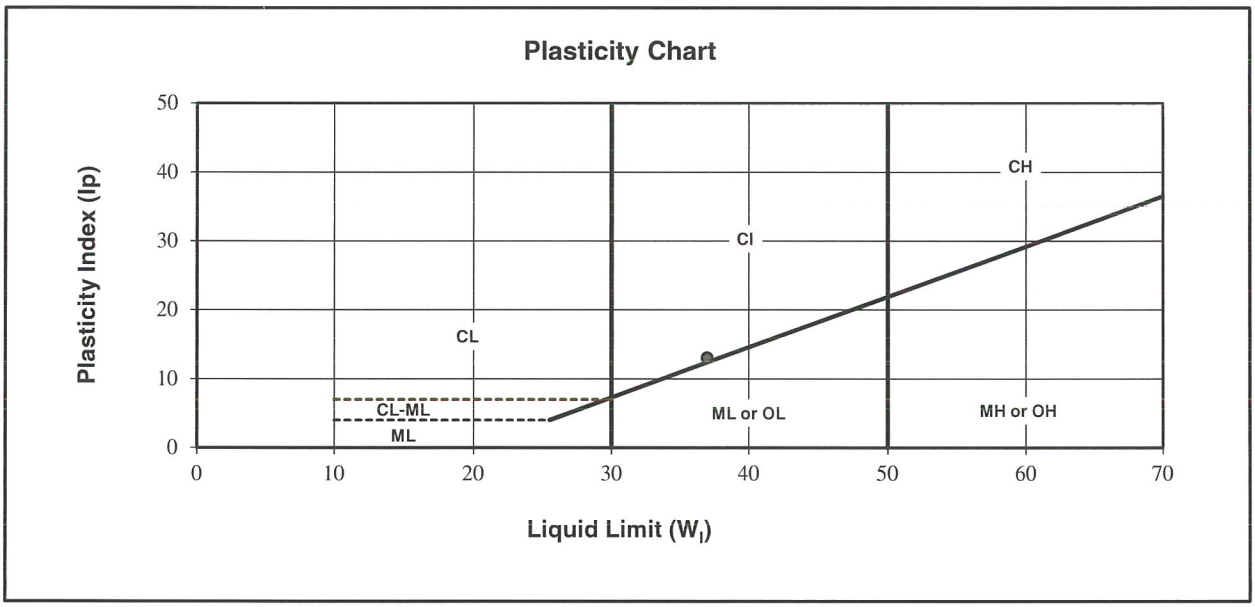
# ATTERBERG LIMITS TEST REPORT

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 |
| Attention: | Murrary McGregor | Date Sampled: | November 6, 2014 |
| Email: | | Date Tested: | March 5, 2015 |

Tested By: AMT

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.

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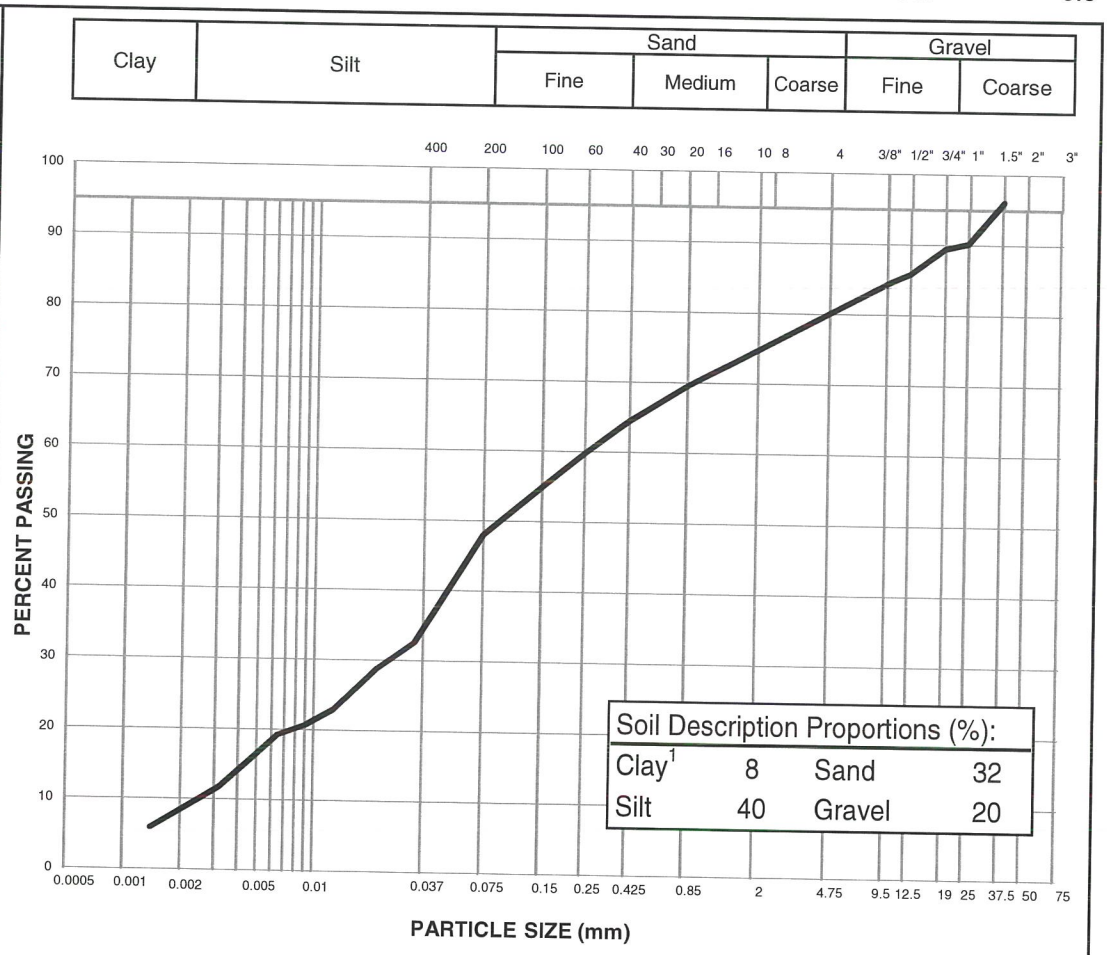
TETRA TECH

# 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 |




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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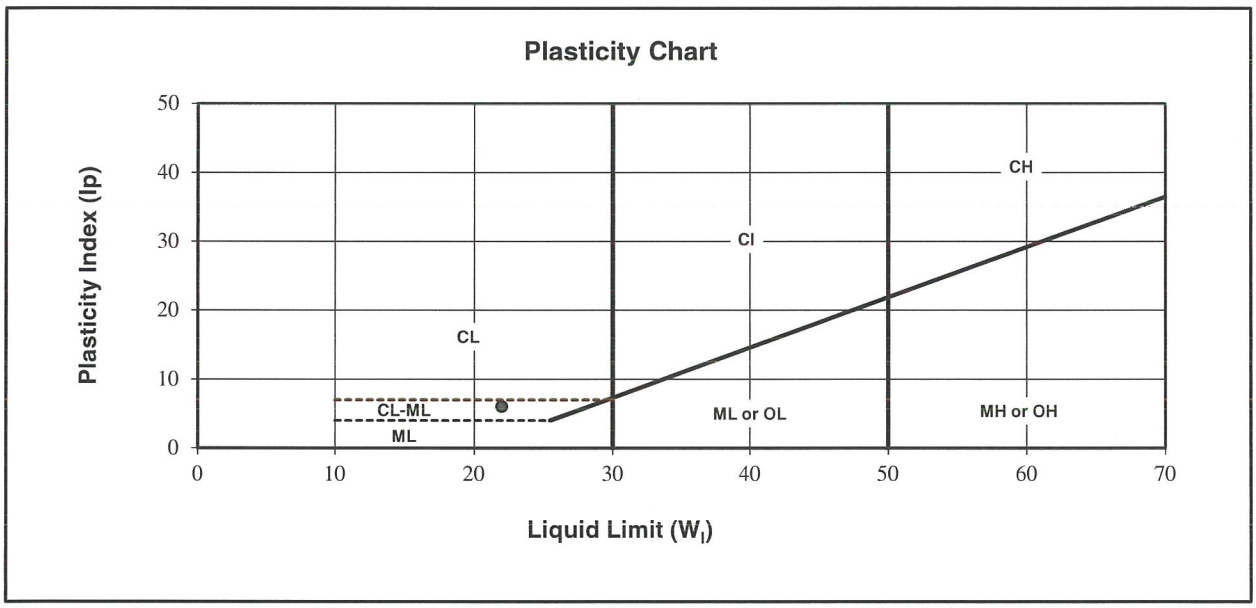
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | MM-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:** _____ C.E.T.

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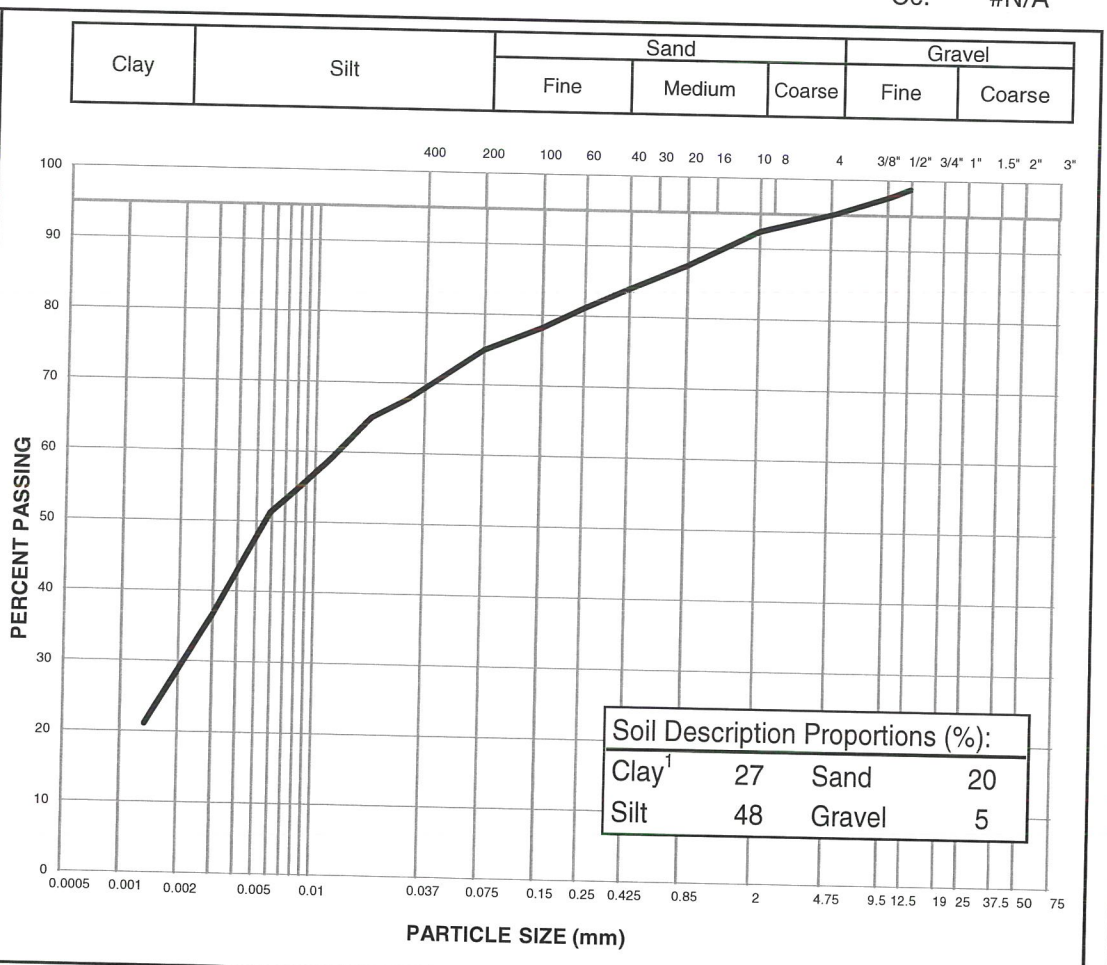
TETRA TECH

# 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 |




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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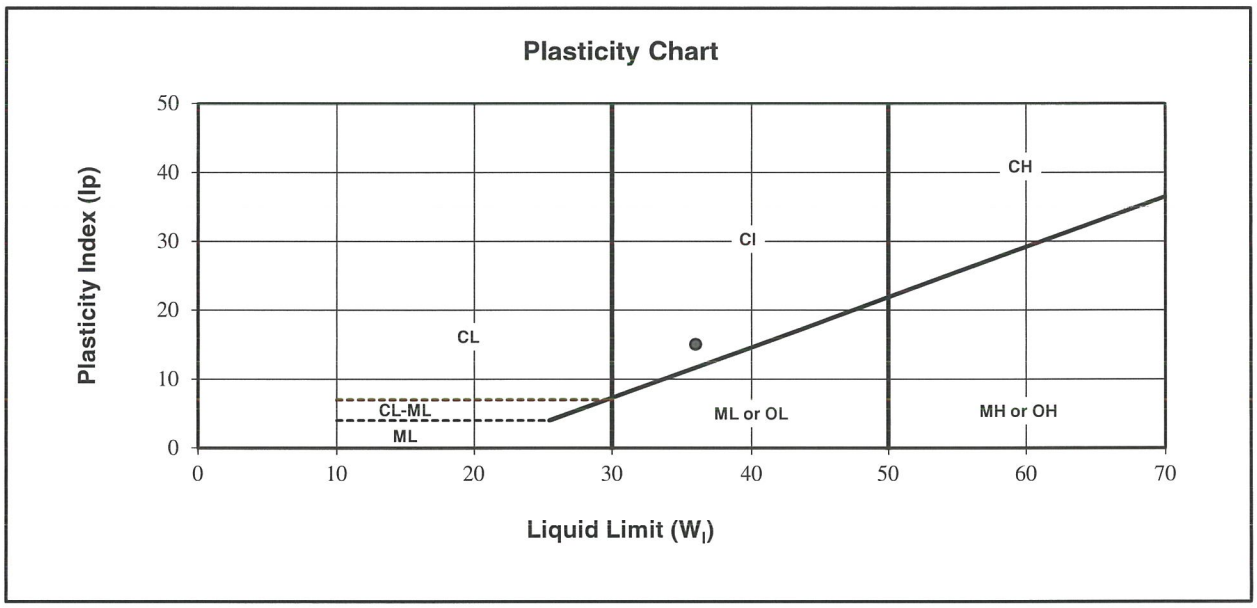
TETRA TECH

# 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:** _____ C.E.T.

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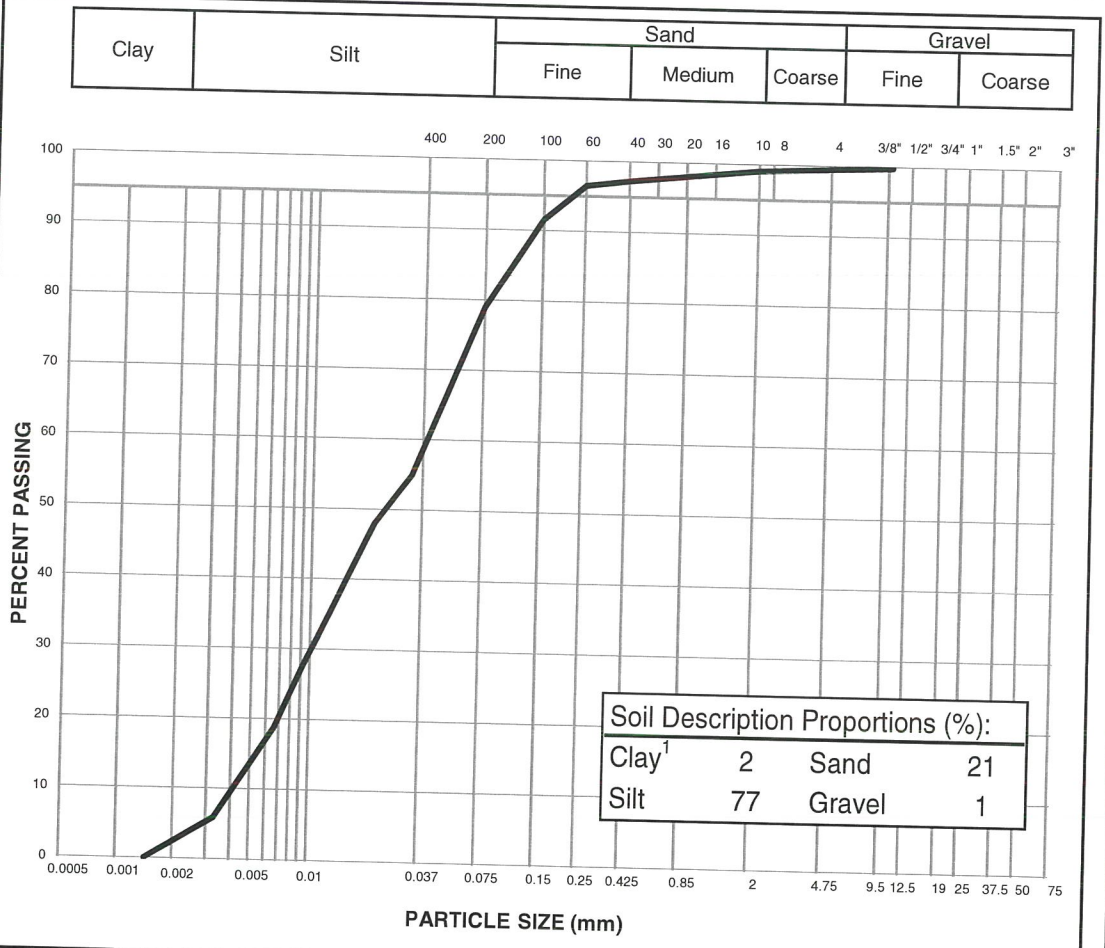
TETRA TECH

# 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 |




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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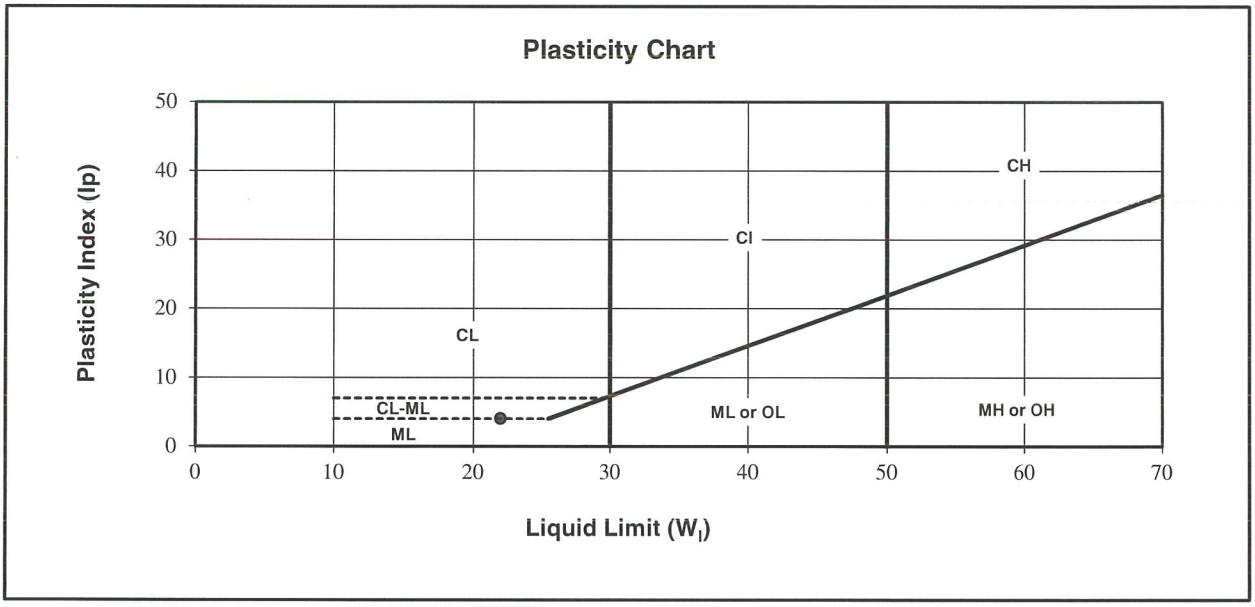
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | MM-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.

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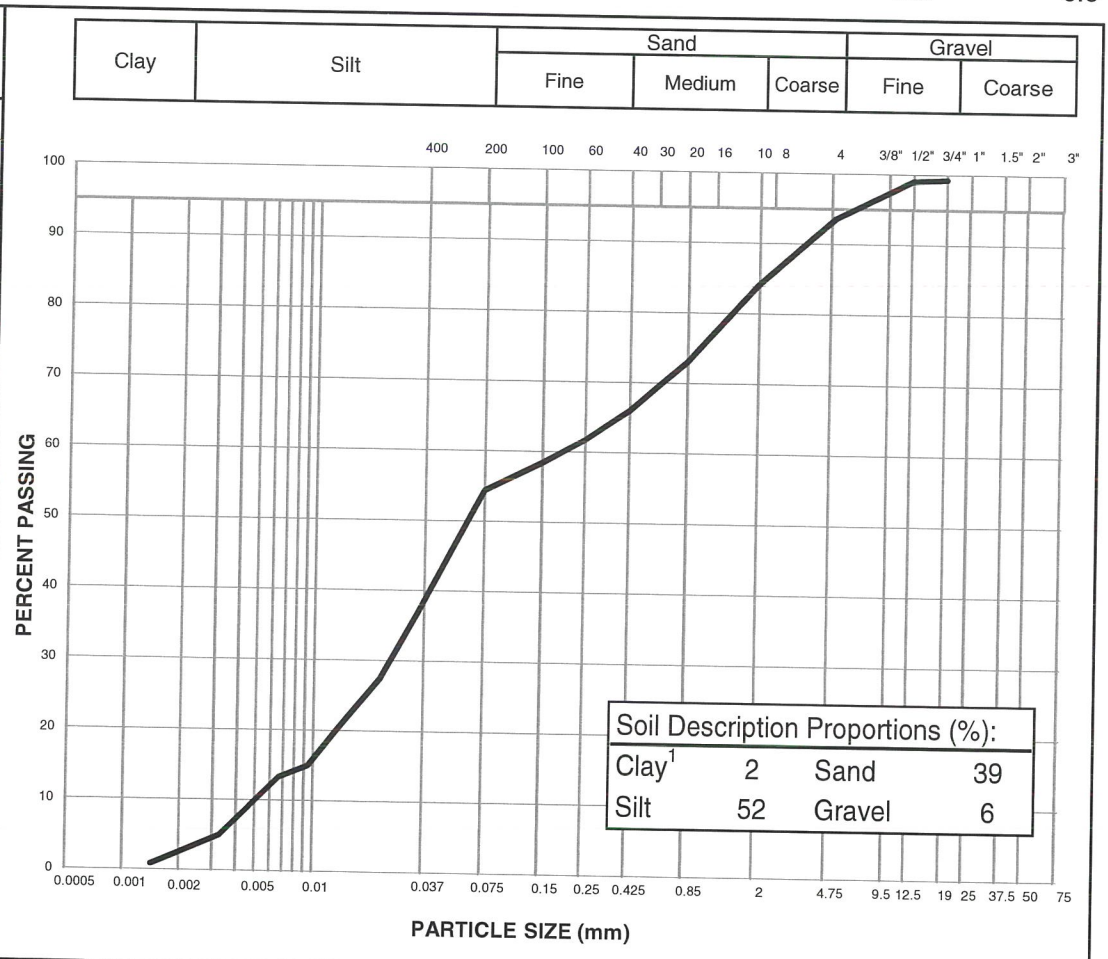
TETRA TECH

# 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 |
| | | USC Classification: | Cu: 37.1 |
| Moisture Content: | 18.8% | | 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 |




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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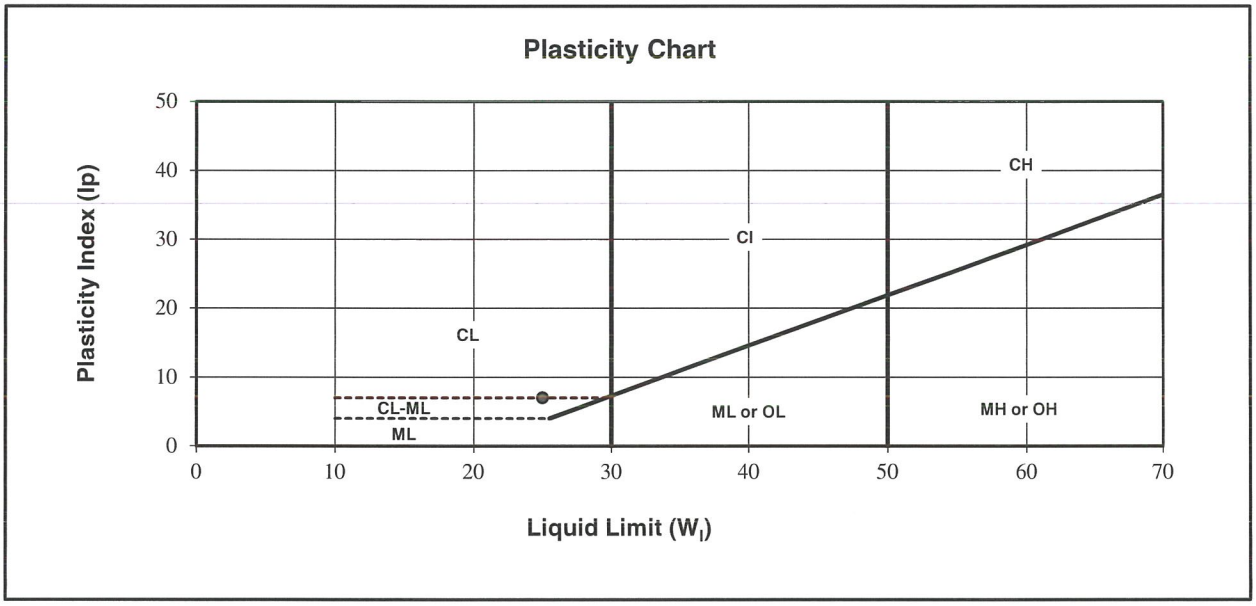
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | MM-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.

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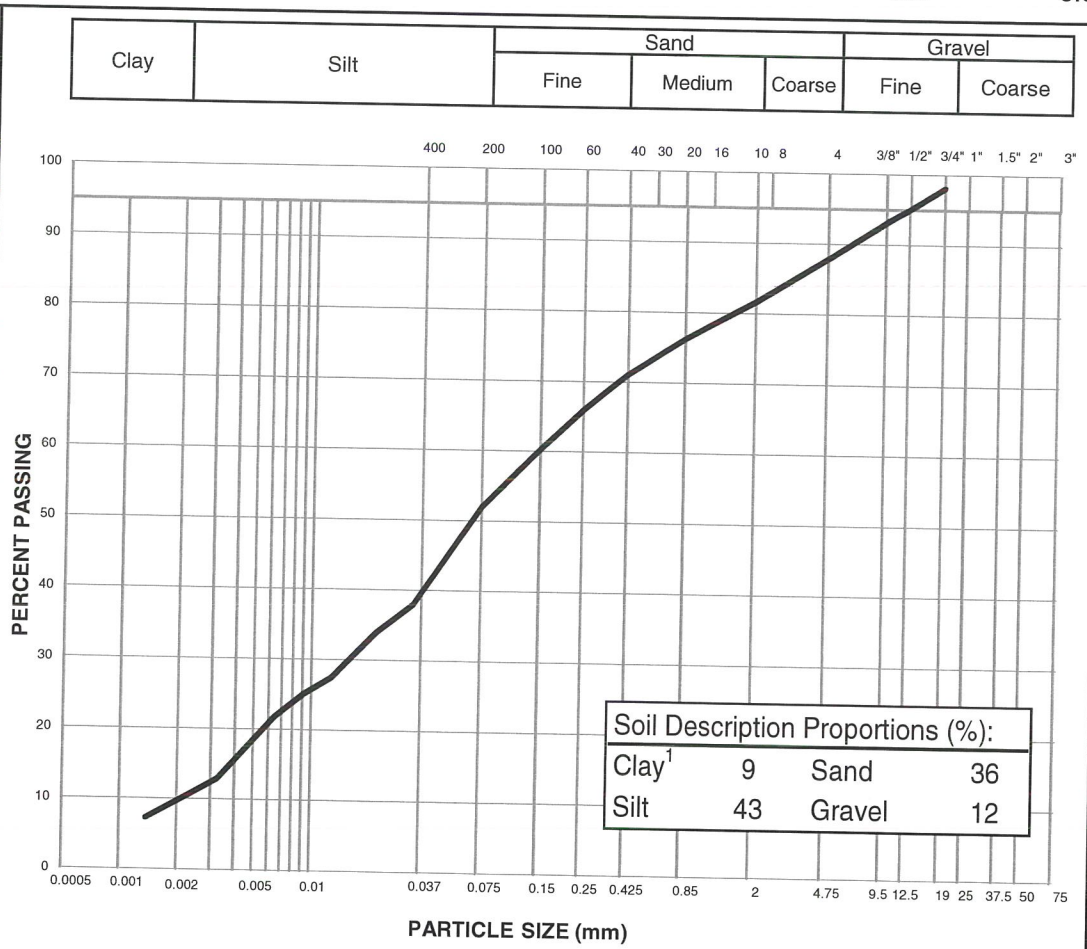
TETRA TECH

# 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 |




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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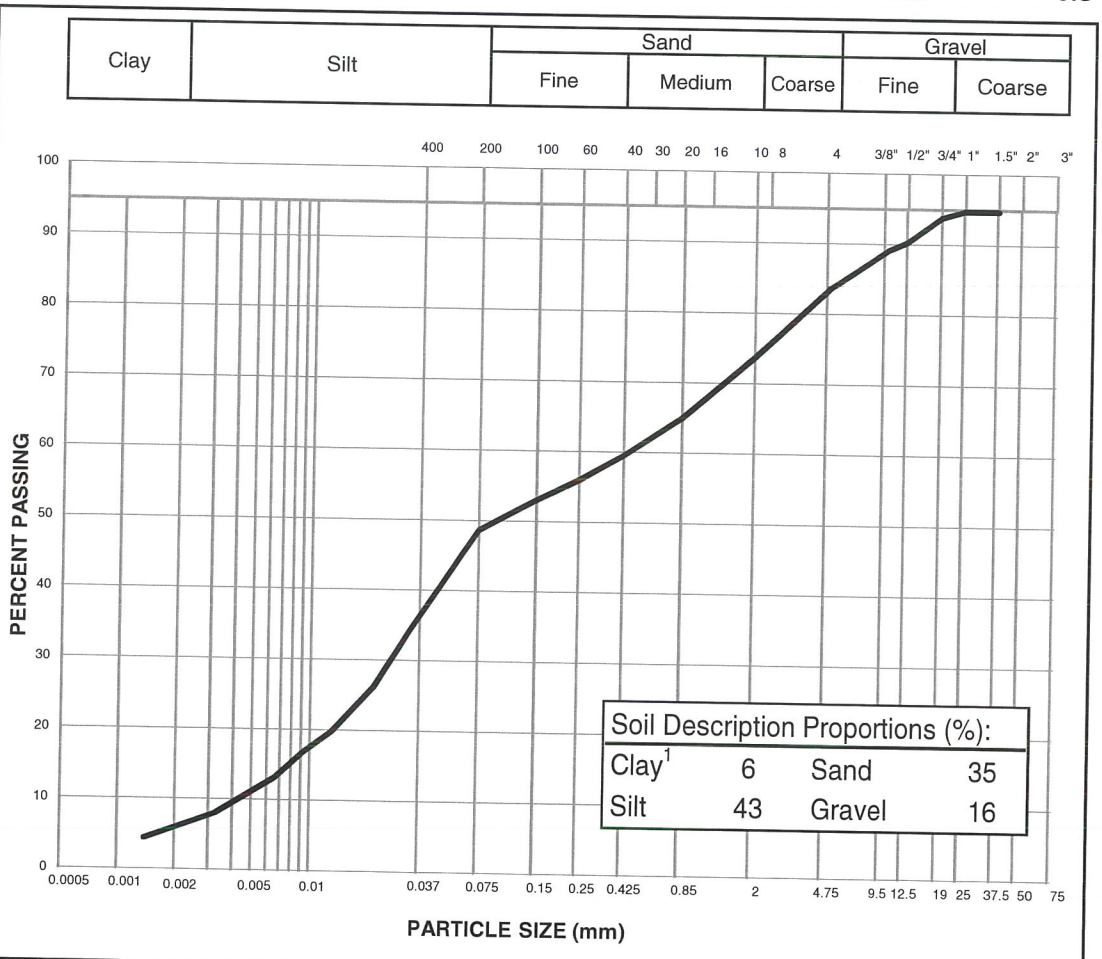
TETRA TECH

# 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 |




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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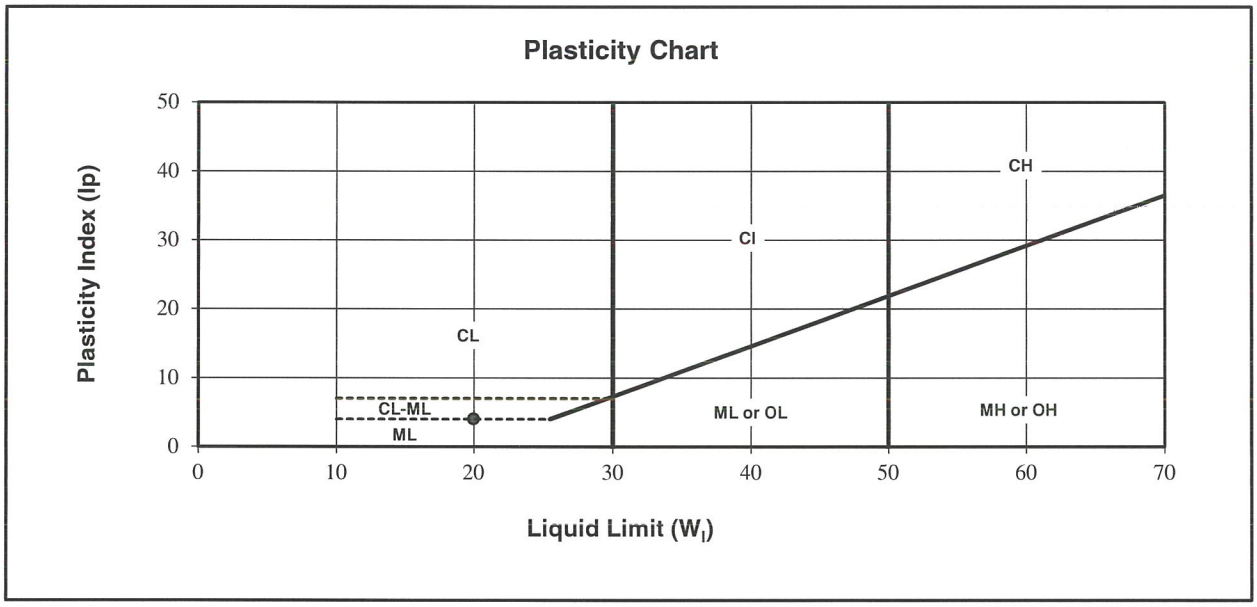
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | 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: | Murrary McGregor | Date Sampled: | February 9, 2015 |
| Email: | | Date Tested: | March 6, 2015 |

Sample Description: SILT - sandy, some gravel, trace clay




| | | | |
|---|---|---|---|
| Liquid Limit ($W_{1)}$ : | 20 | Natural Moisture (%) | 35.9 |
| Plastic Limit : | 16 | Soil Plasticity: | Low |
| Plasticity Index (Ip) : | 4 | Mod.USCS Symbol: | CL-ML |

**Remarks:**

**Reviewed By:** C.E.T.

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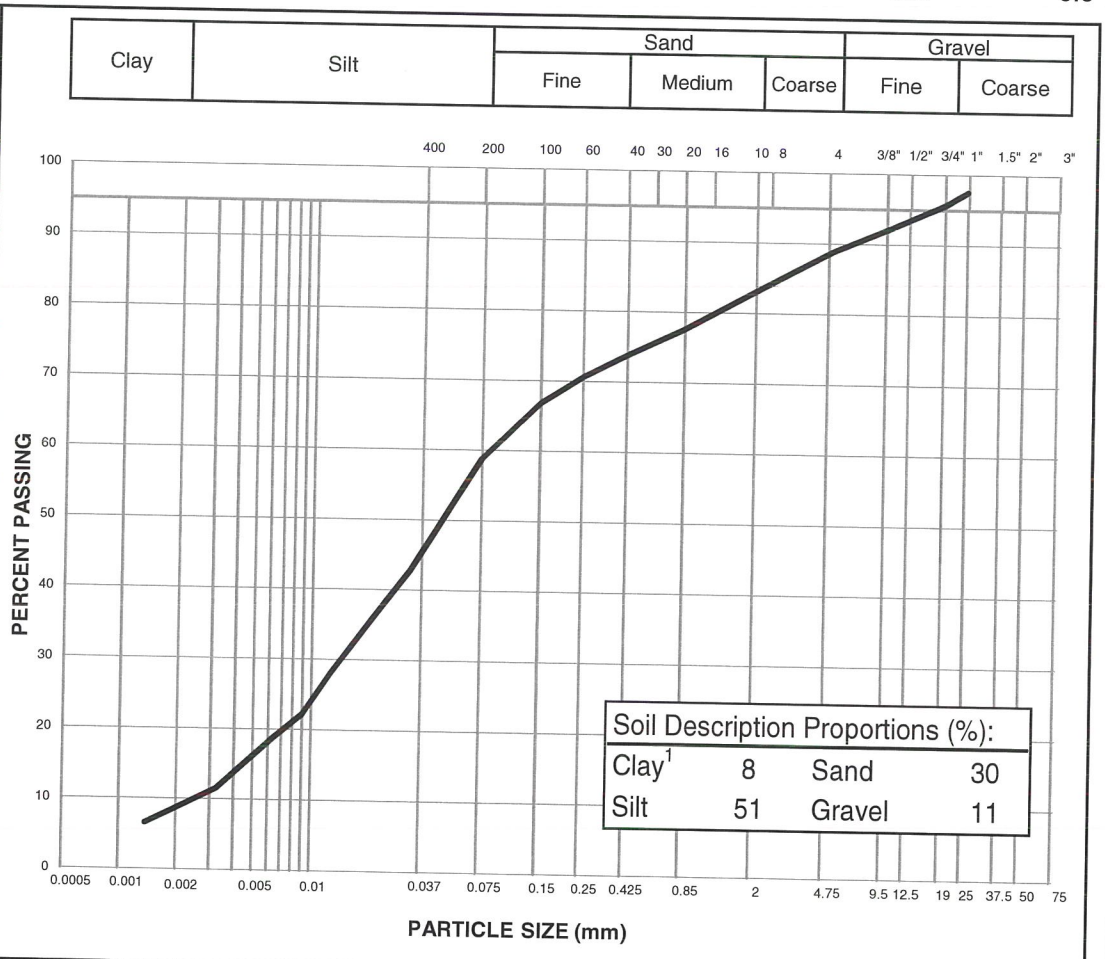
TETRA TECH

# 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 |




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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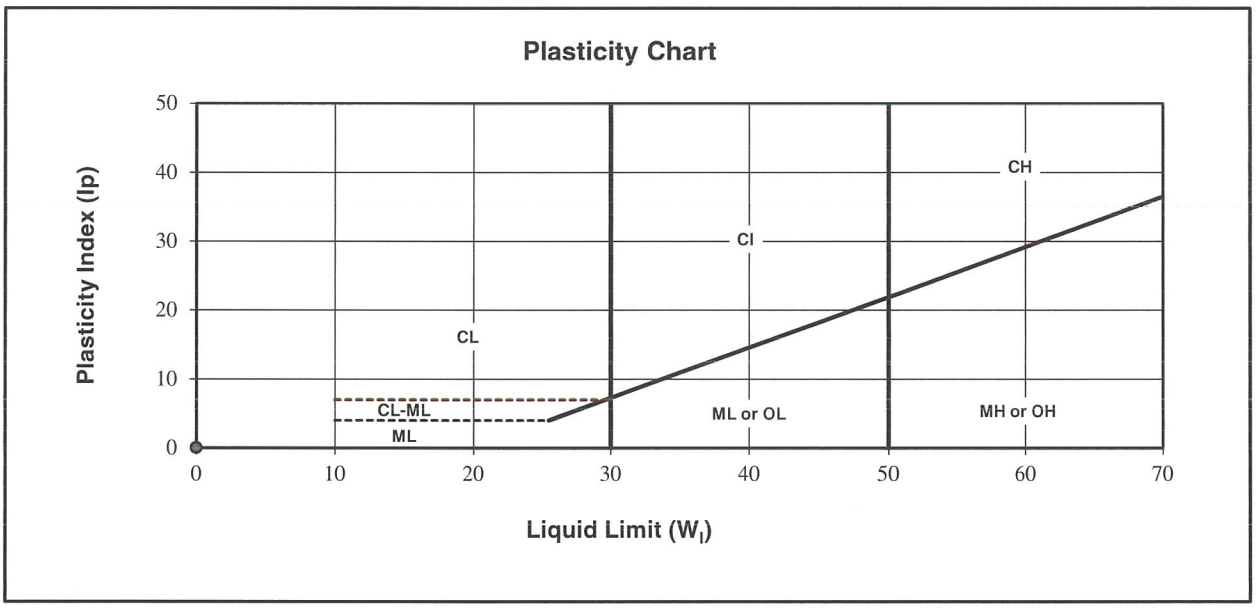
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | 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.

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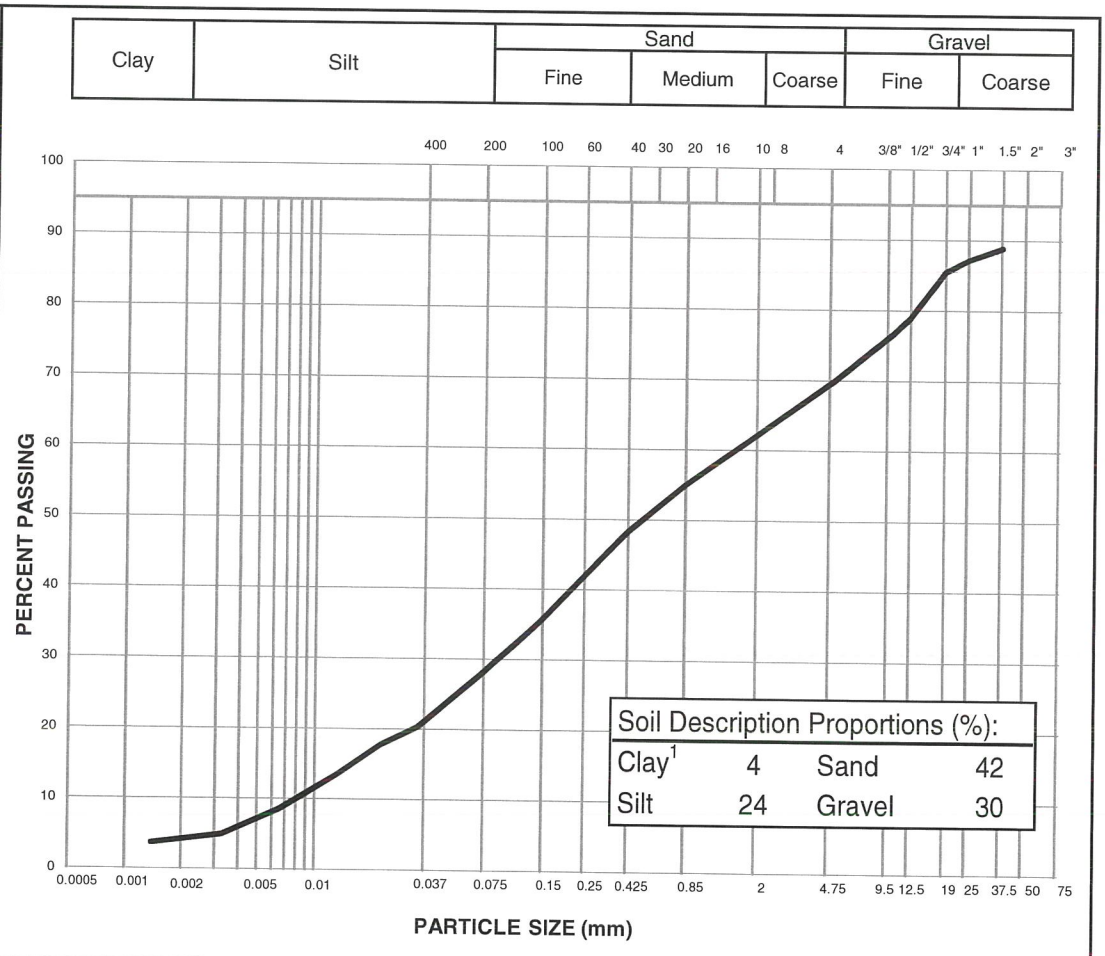
TETRA TECH

# 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 |




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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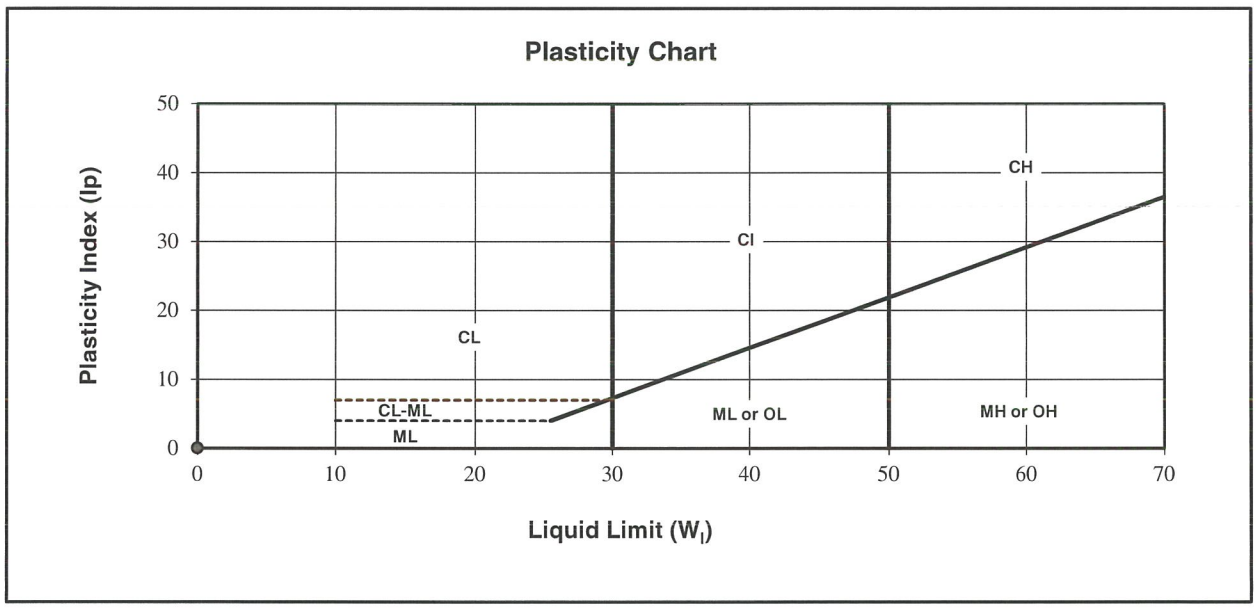
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | 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.

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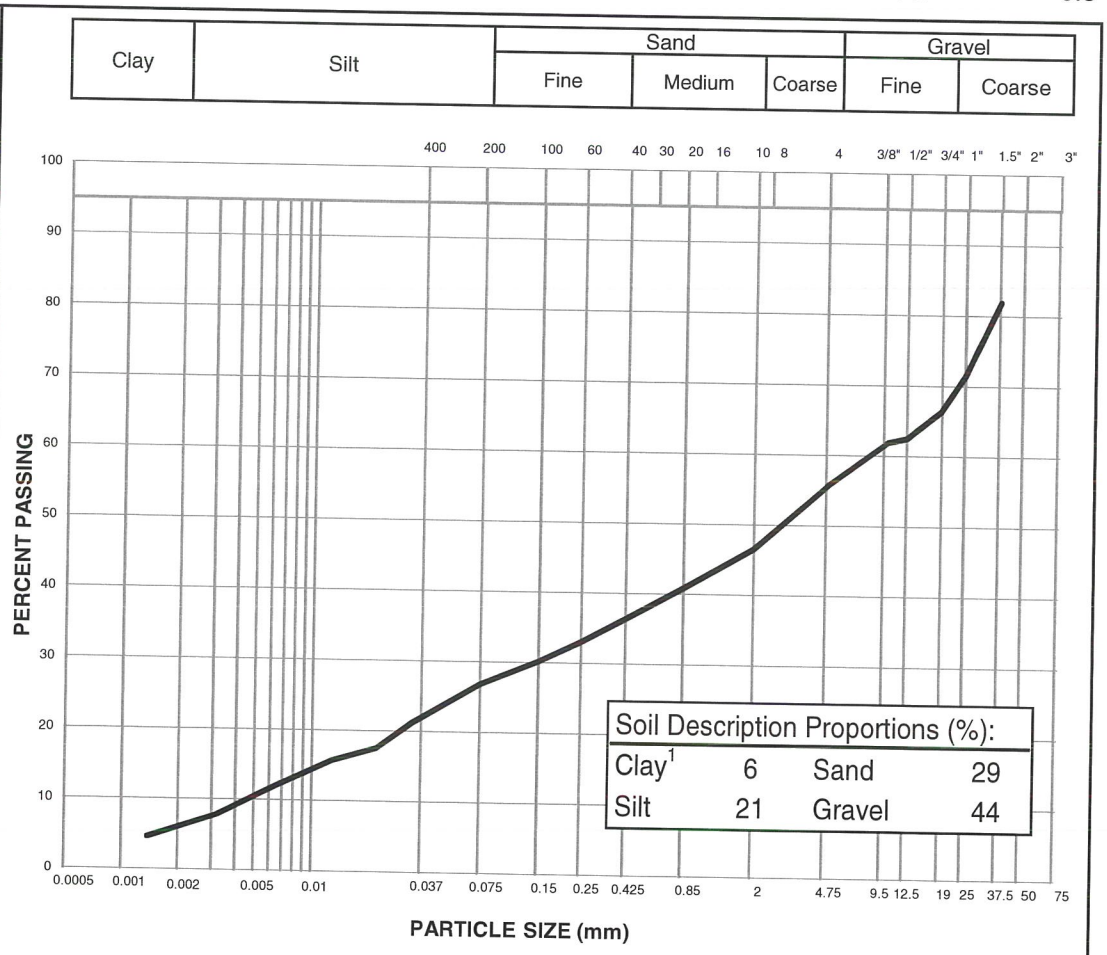
TETRA TECH

# 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 |




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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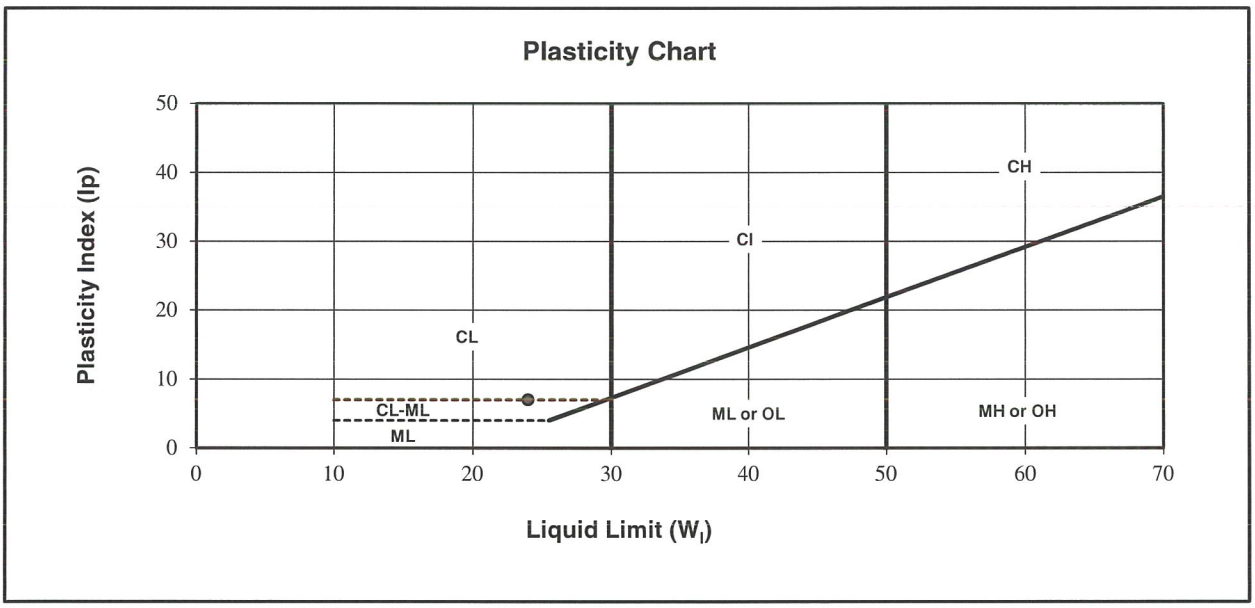
TETRA TECH

# ATTERBERG LIMITS TEST REPORT

ASTM D4318

| | | | |
|---|---|---|---|
| Project: | Minto February 2015 Lab Testing | Sample Number: | 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




| | | | |
|---|---|---|---|
| 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.

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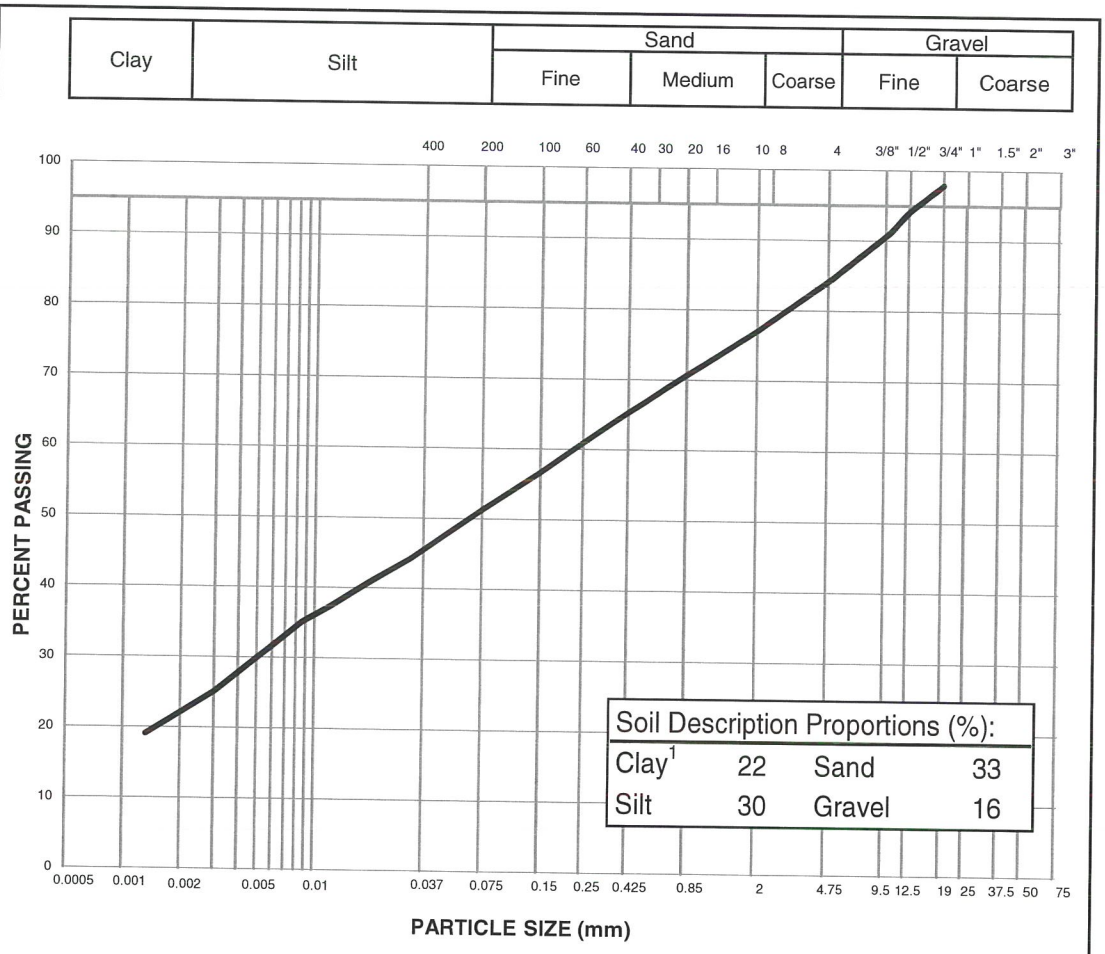
TETRA TECH

# 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.

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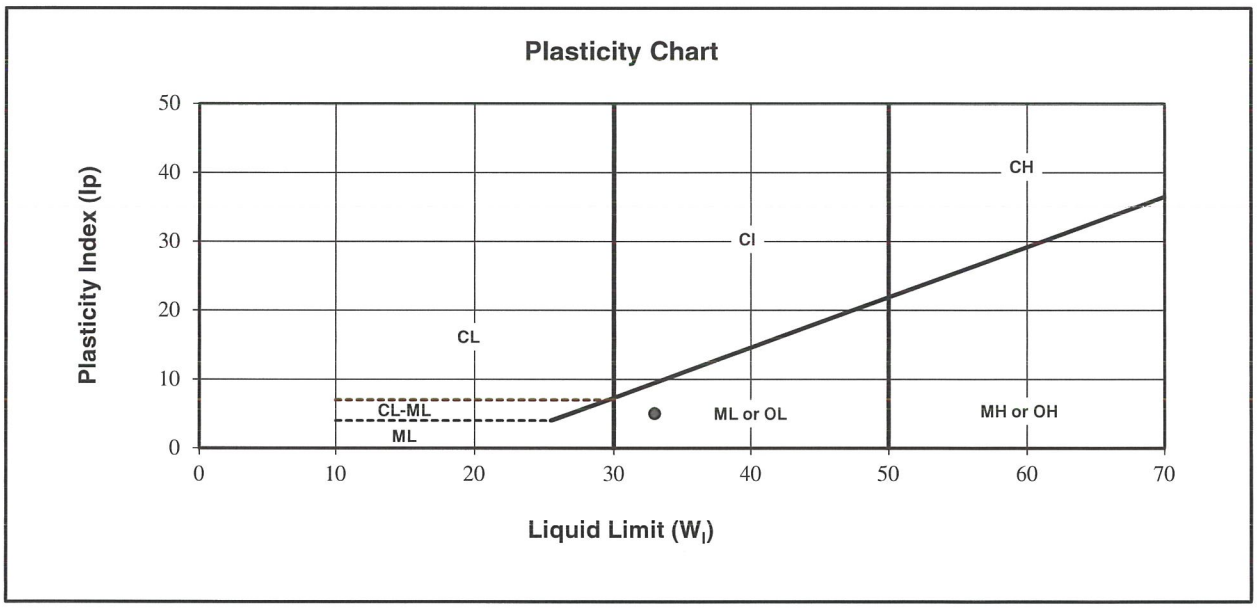
TETRA TECH

# 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 |
| Attention: | Murrary McGregor | Tested By: | AMT |
| Email: | | Date Sampled: | February 9, 2015 |
| | | 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.

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TETRA TECH

# Appendix C – Minto Closure Cover Design – Cover System Erosion Analysis

SRK Consulting (Canada) Inc.
205–2100 Airport Drive
Saskatoon, SK S7L 6M6

T: +1.306.955.4778
F: +1.306.955.4750
saskatoon@srk.com
www.srk.com

# 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.

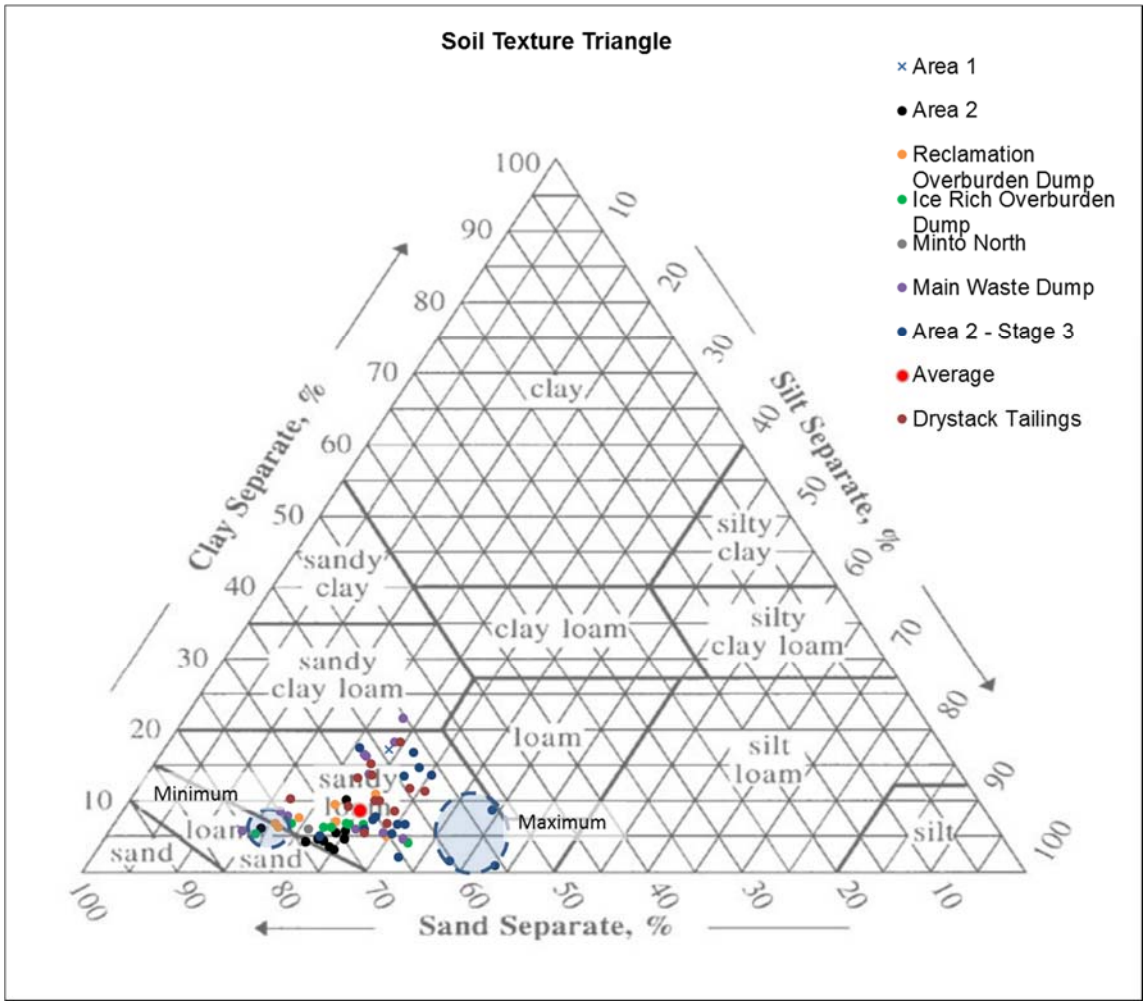


**Figure 1: Soil Texture Triangle**

## 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.

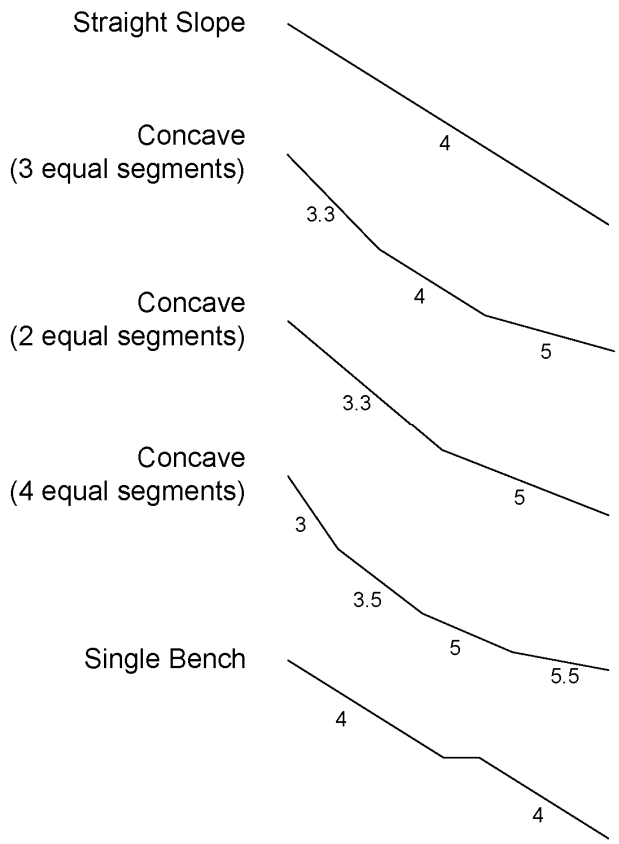


**Figure 2: Types of Slopes Assessed**

## 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.

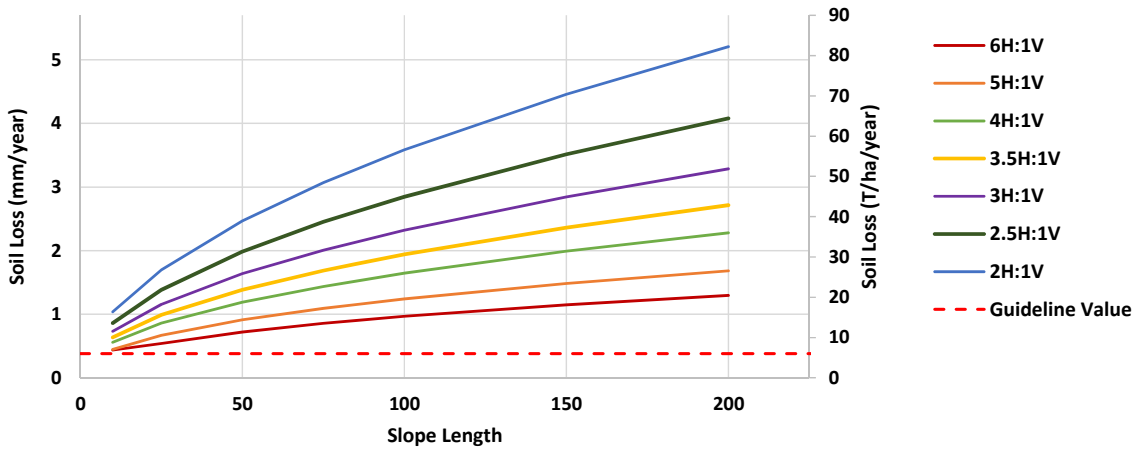


**Figure 3: Straight Slopes using Average Material with no Vegetative Cover**

## 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.

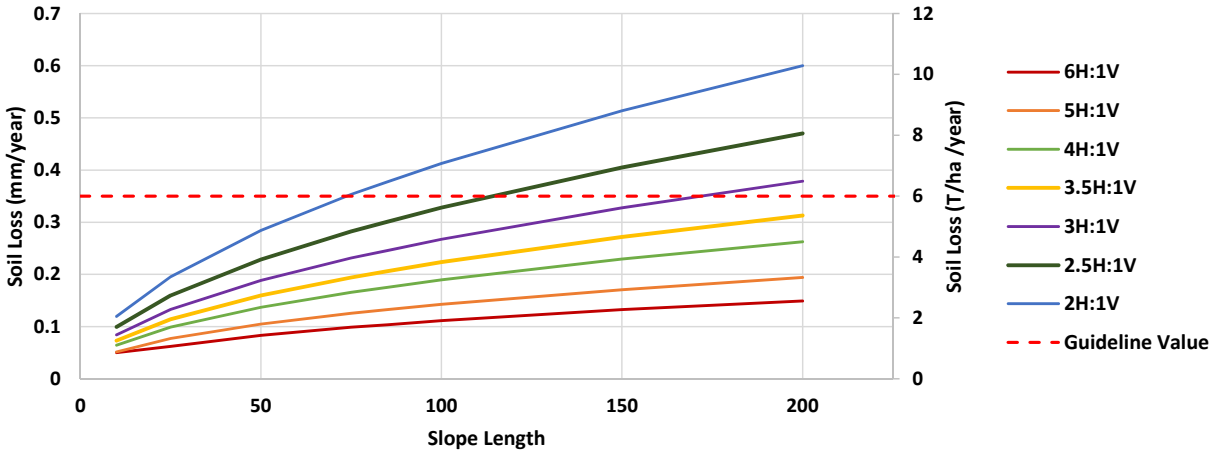


**Figure 4: Straight Slopes using Average Material with 80% Small, Short-rooted Plant Coverage and No Vegetative Canopy**

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.

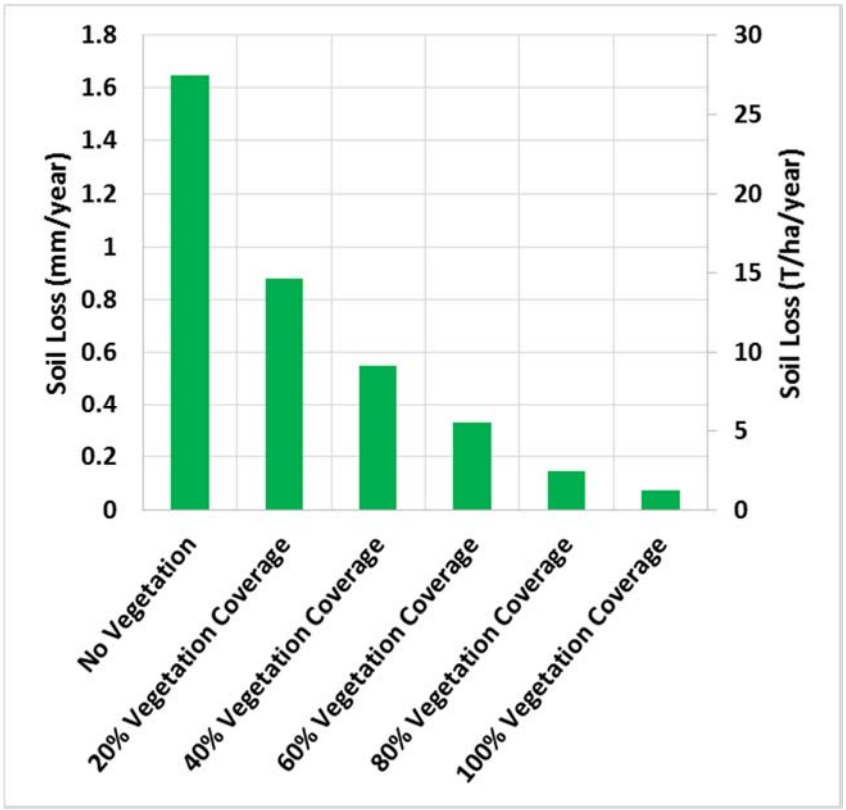


**Figure 5: The Effects of Vegetation Coverage on a 4H:1V, 100 m Slope with Average Material**

## 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.

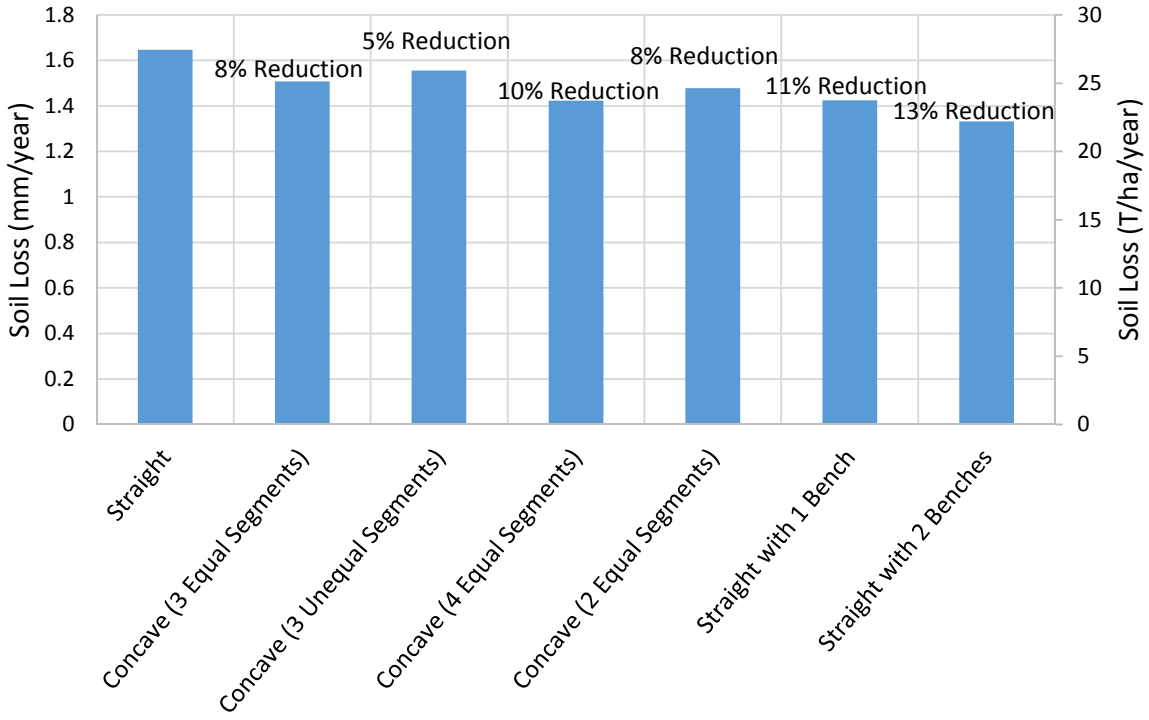


**Figure 6: Complex Slope Comparison (100 m Long at 4H:1V and No Vegetative Cover)**

## 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.

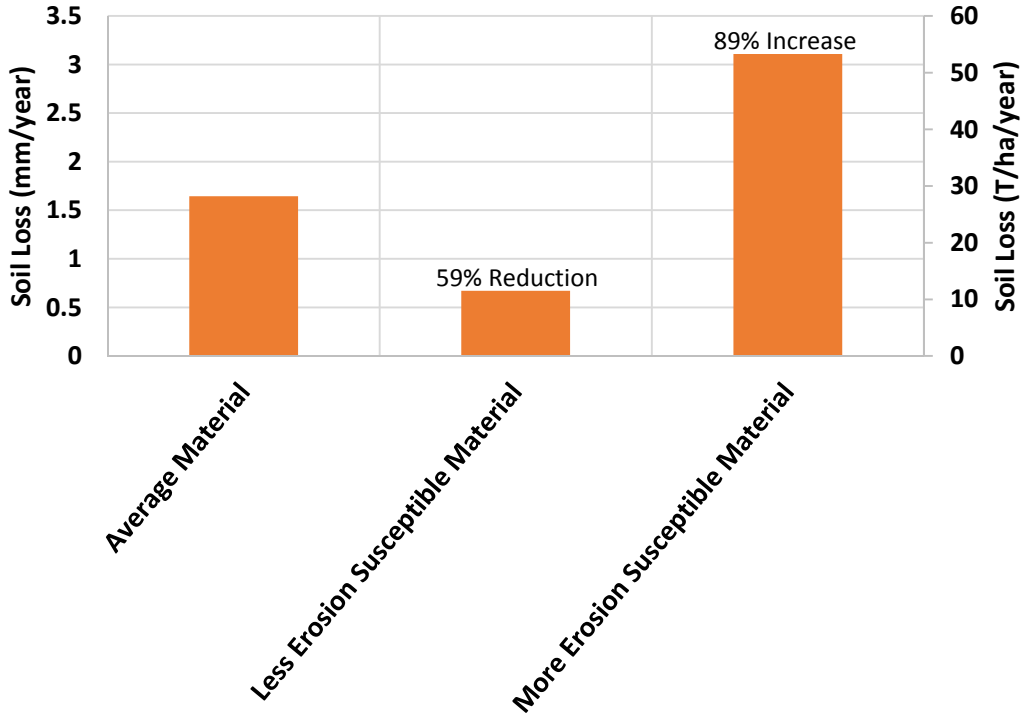


**Figure 7: Soil Type Comparison (Based on 100 m Long 4H:1V Straight Slopes)**

## 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.

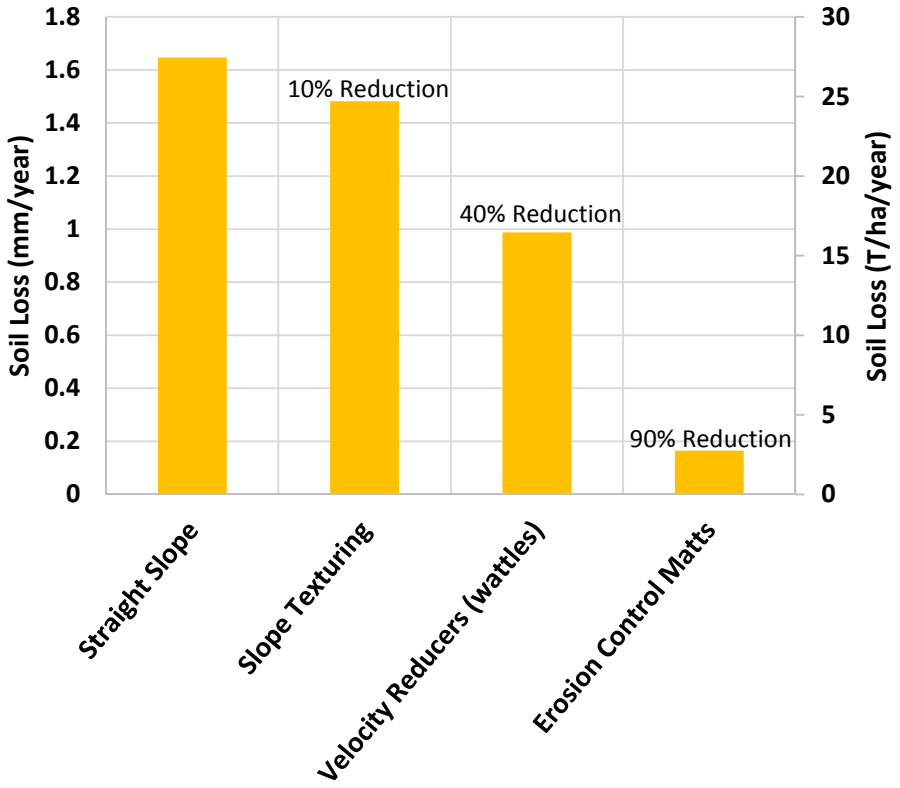


**Figure 8: Support Practice Comparison (No Vegetation)**

# 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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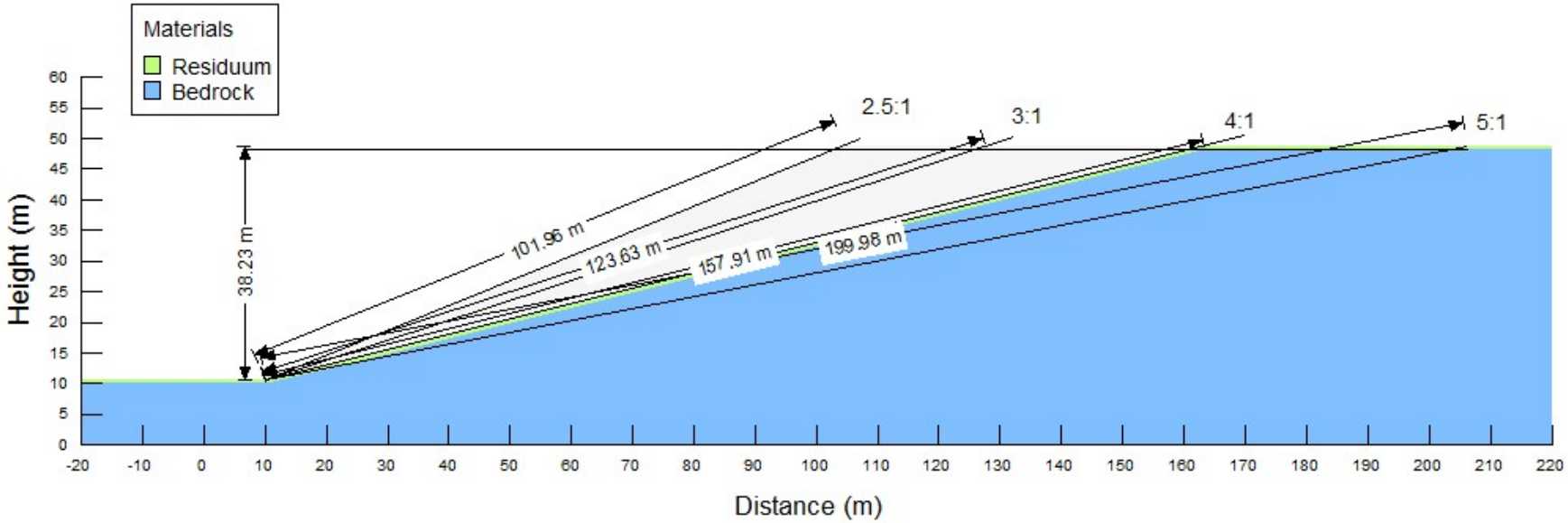
# Appendix D – Minto Closure Cover Design – Stability Assessment

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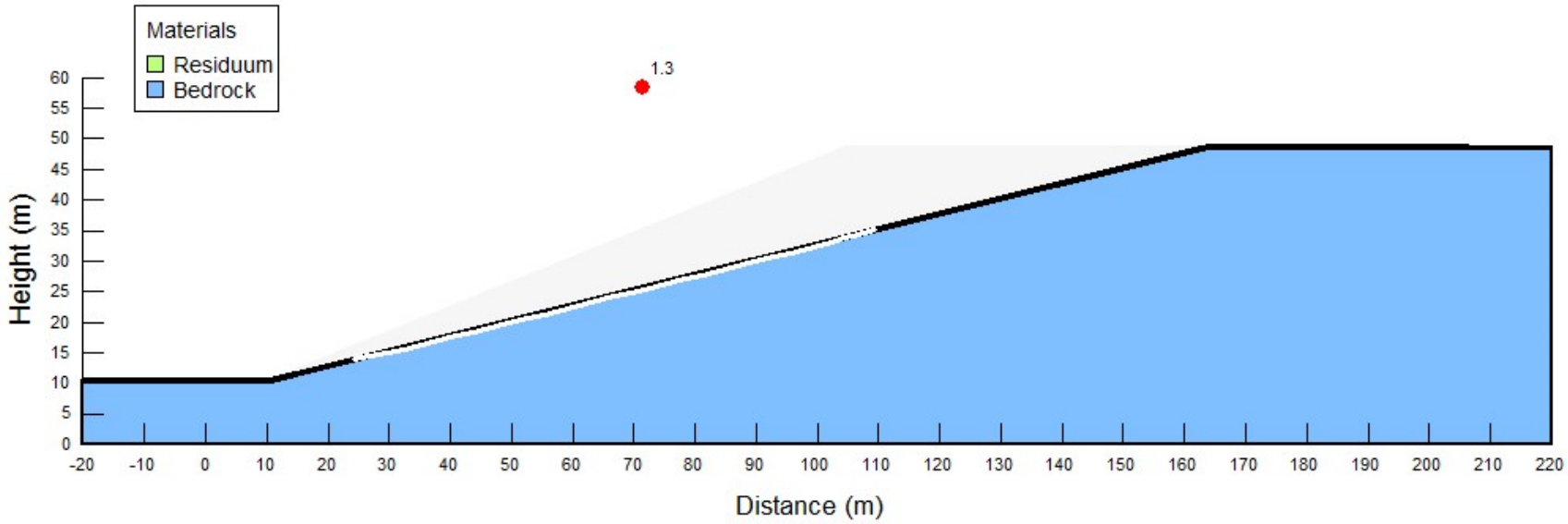


Results

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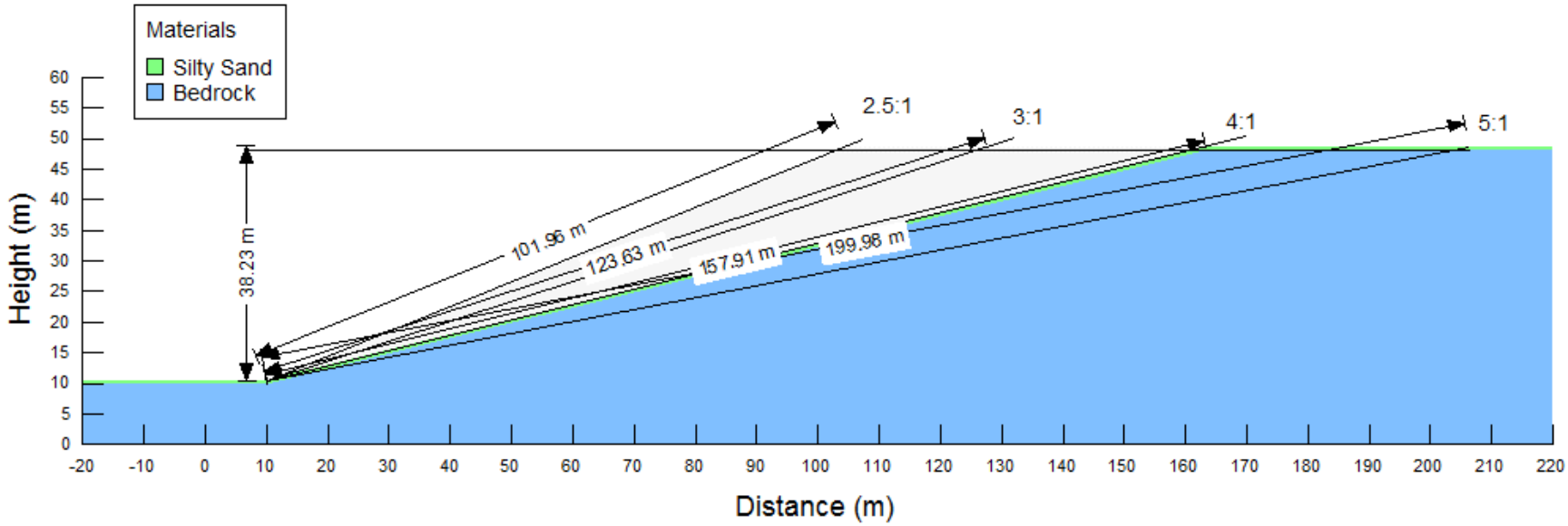


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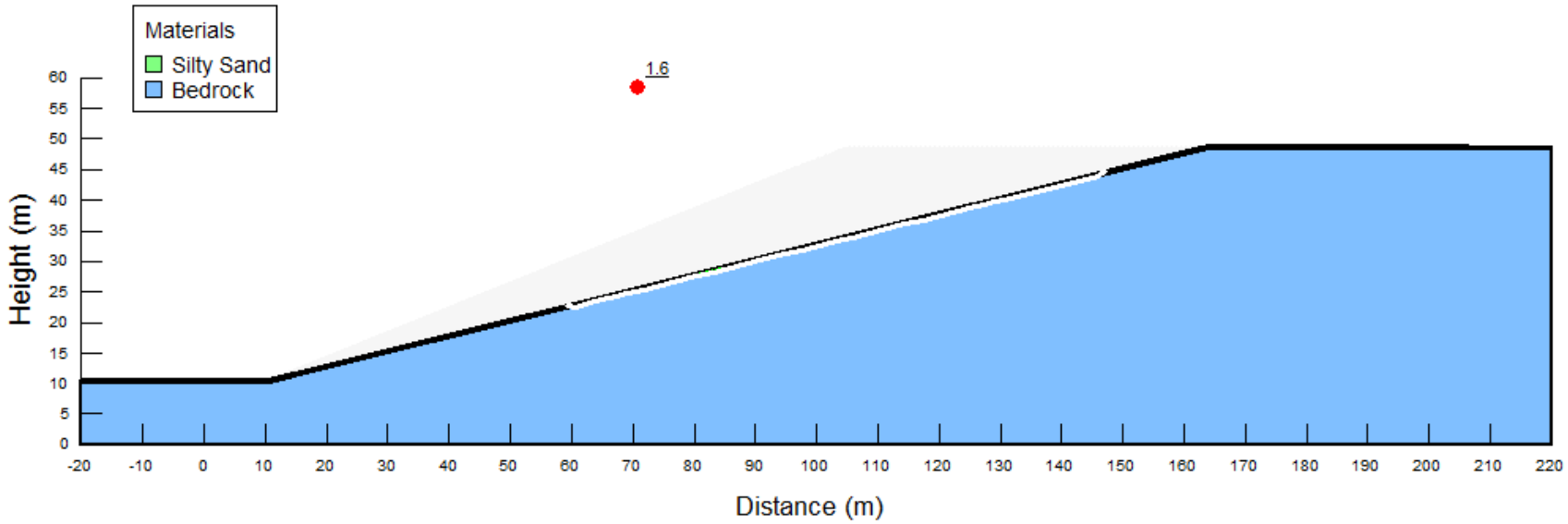


Results

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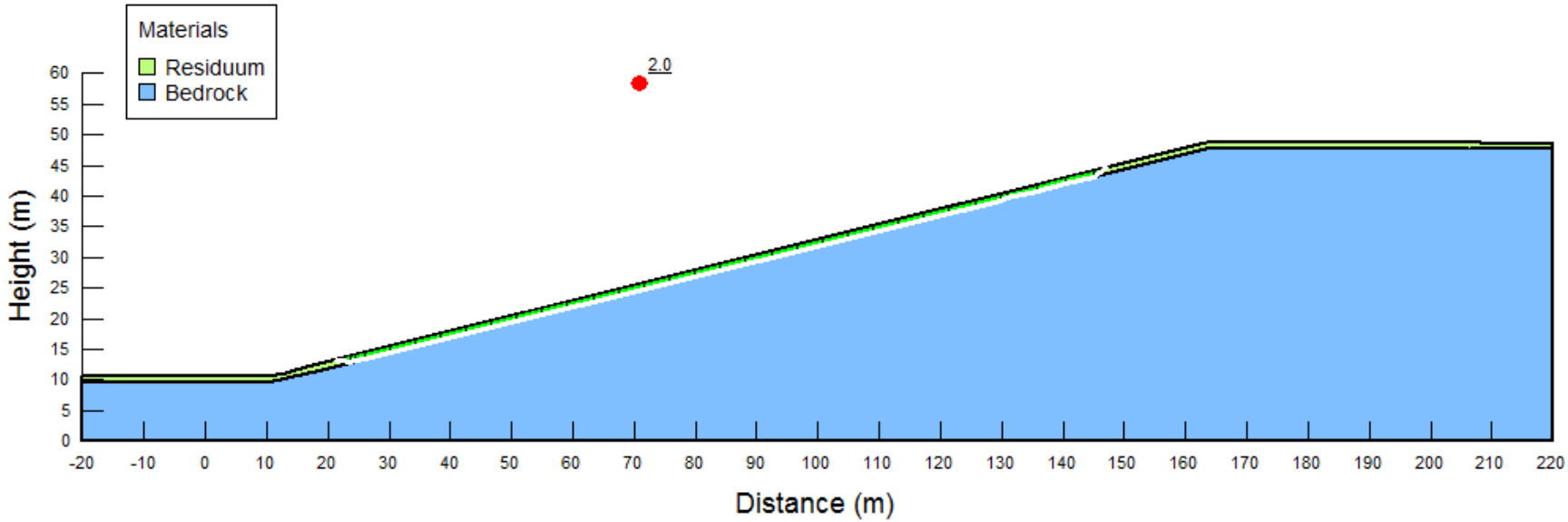
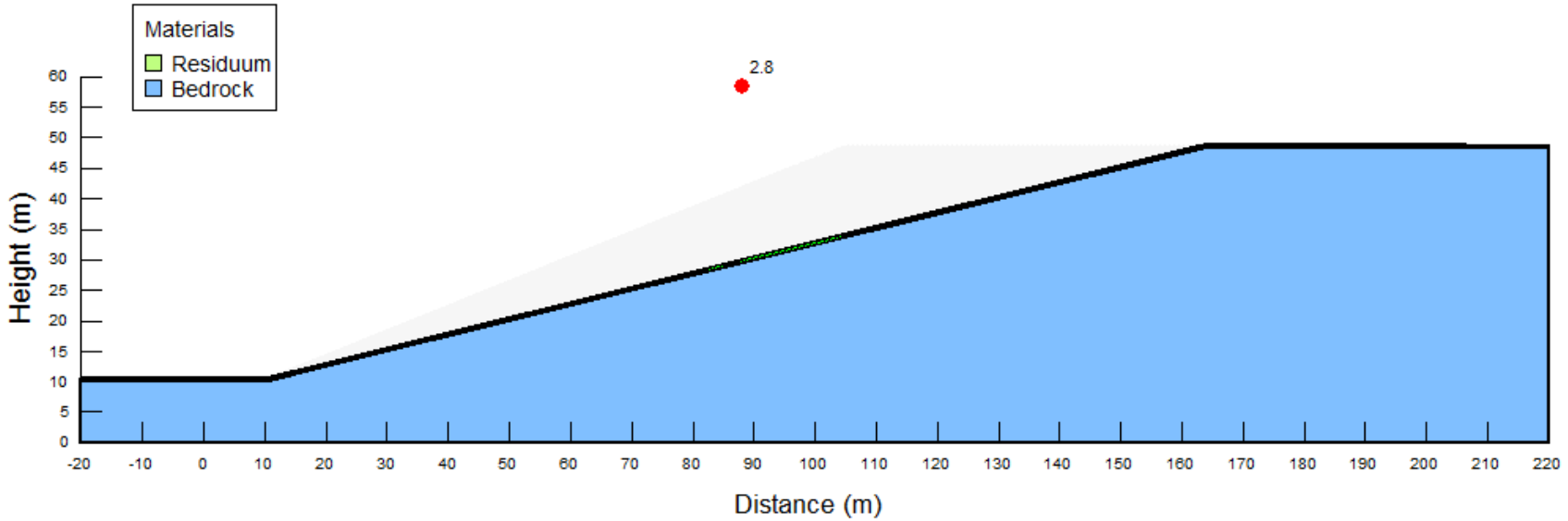



Scenario 1a




Scenario 1b

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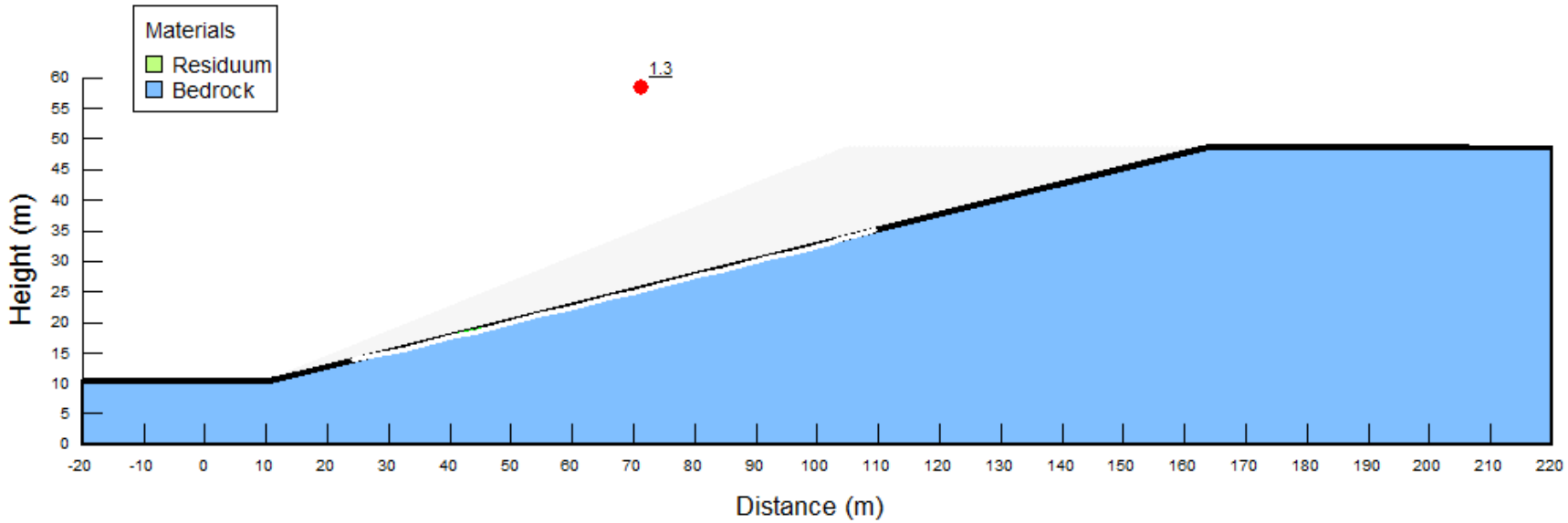
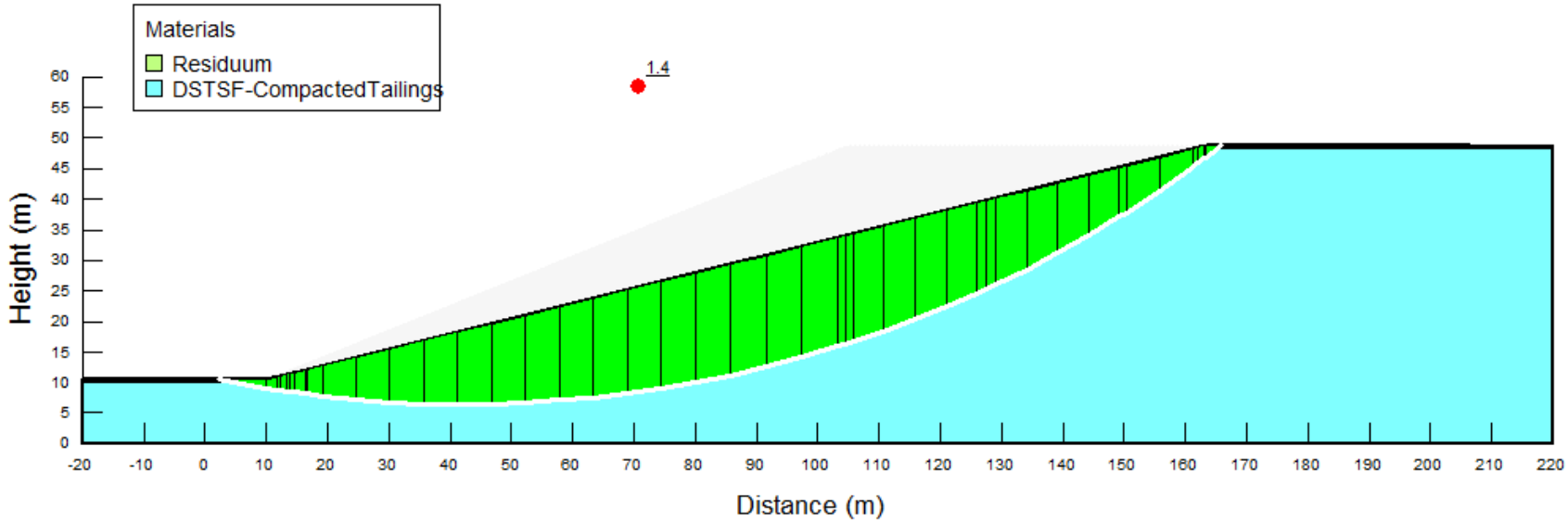



Scenario 1c




Scenario 1d

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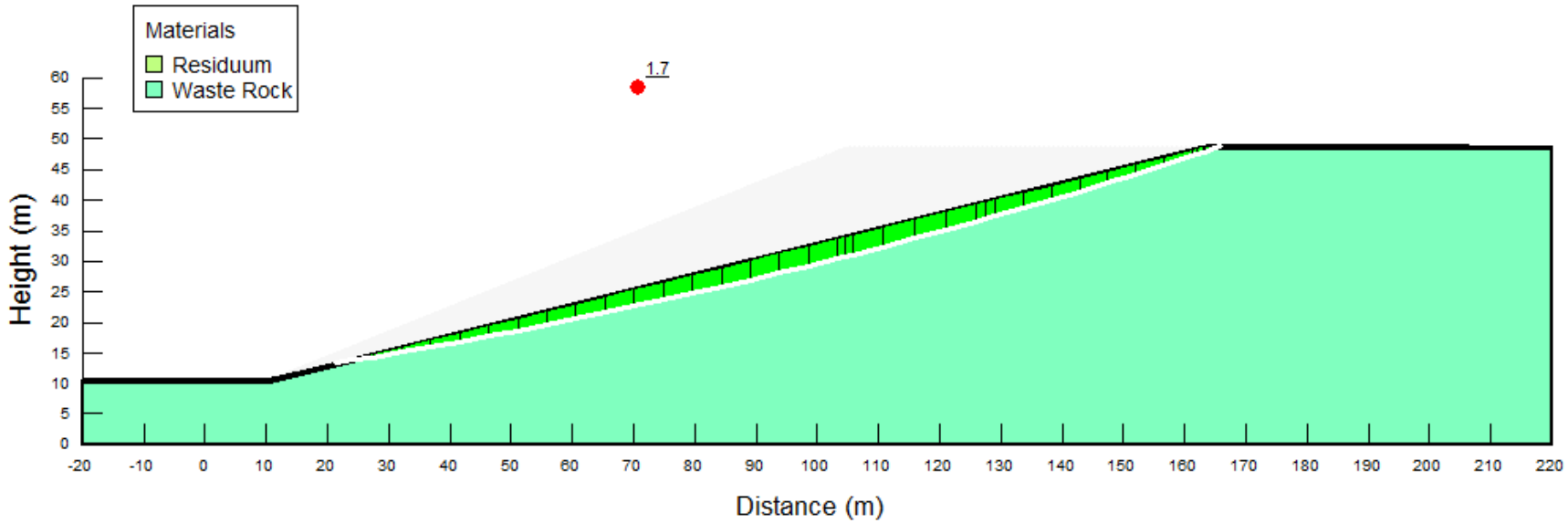
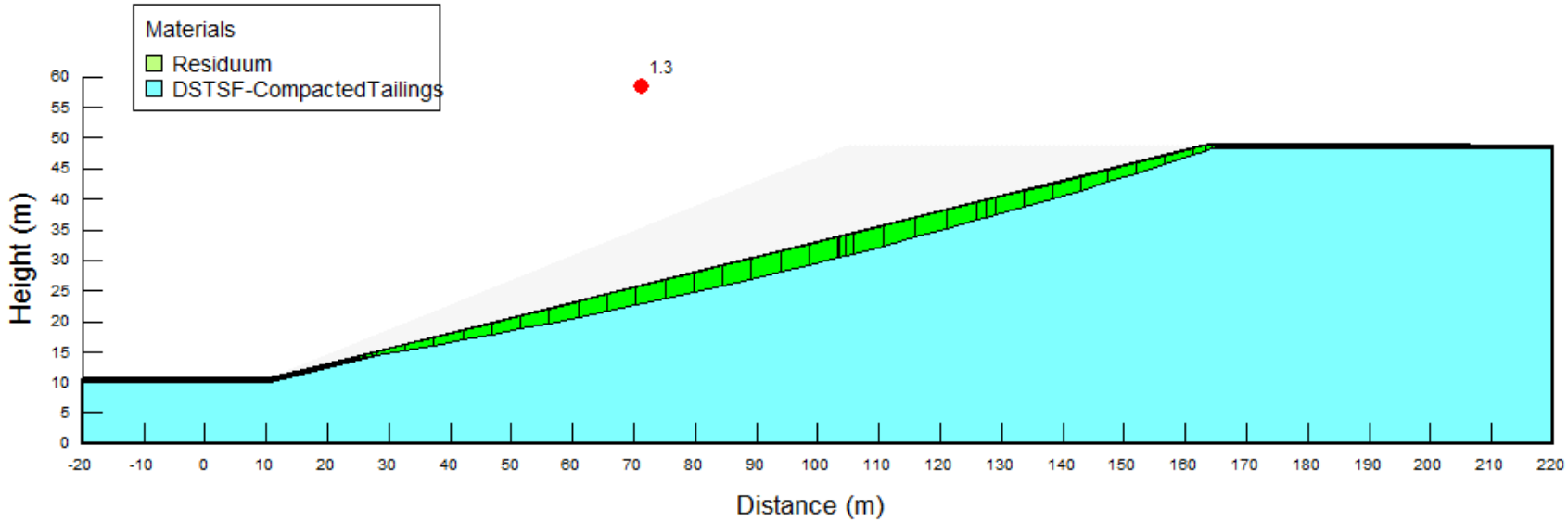



Scenario 1e




Scenario 1f

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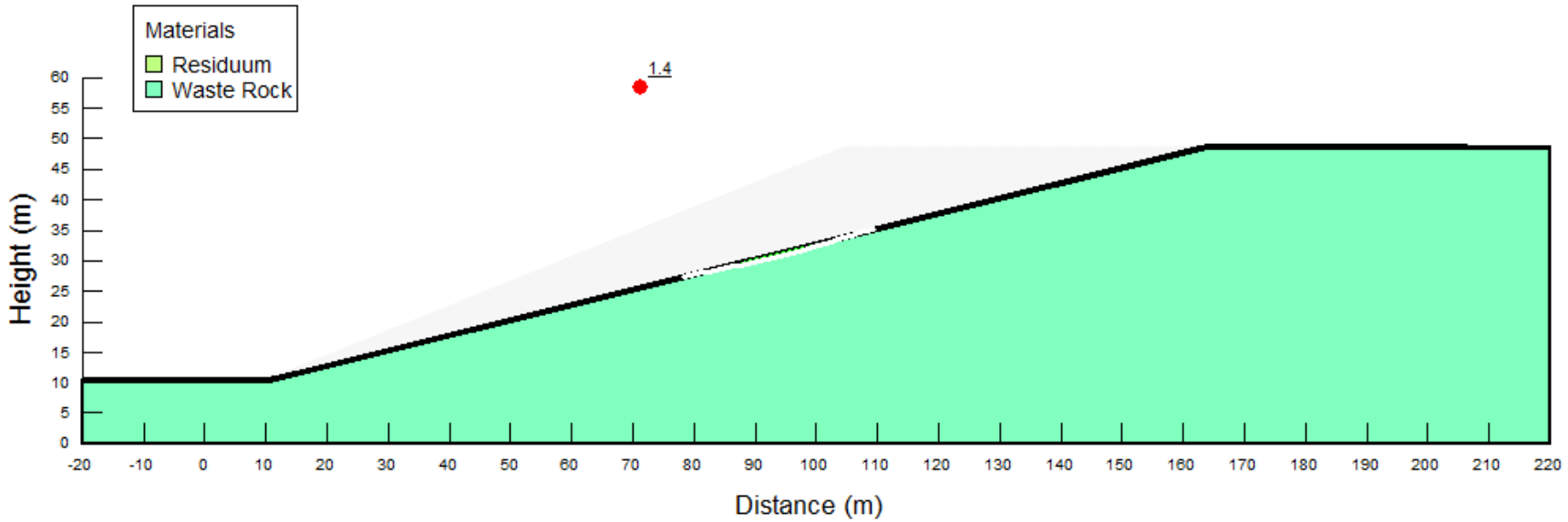
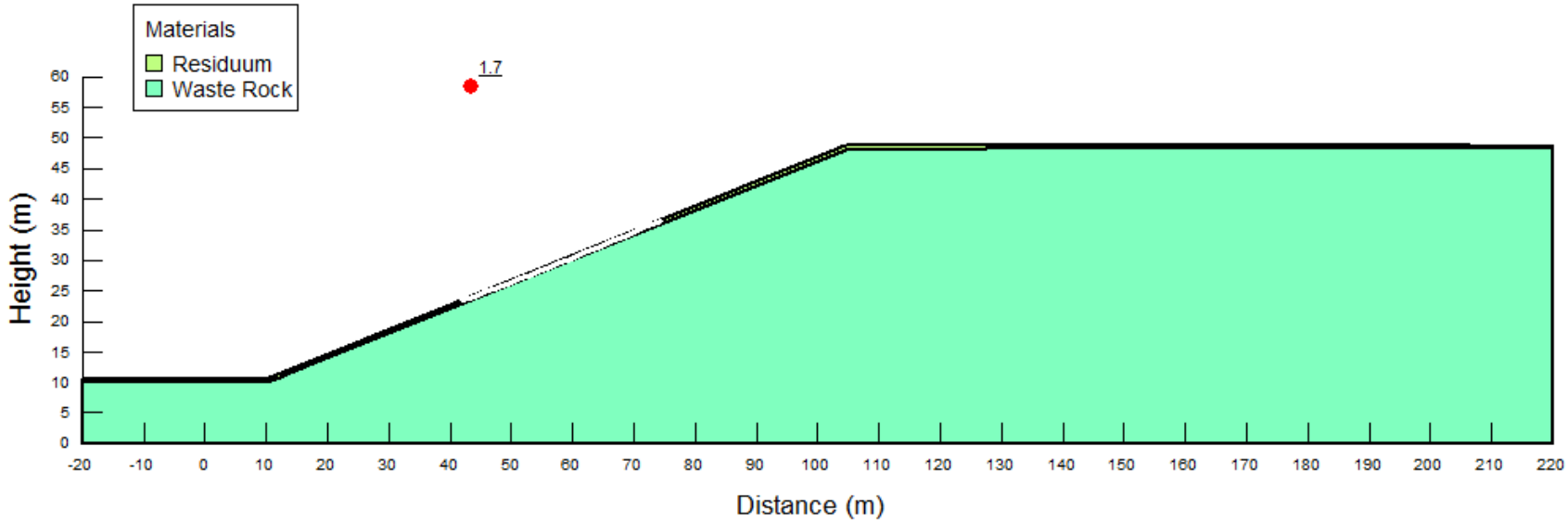



Scenario 1e




Scenario 1f

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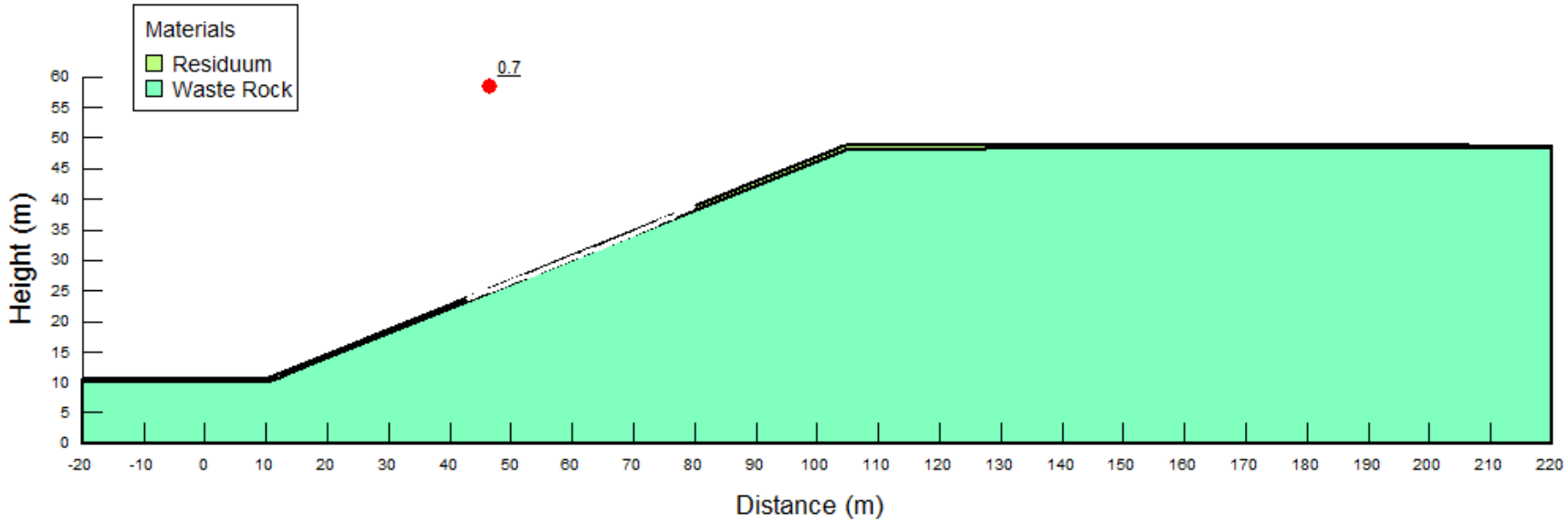


Scenario 1i

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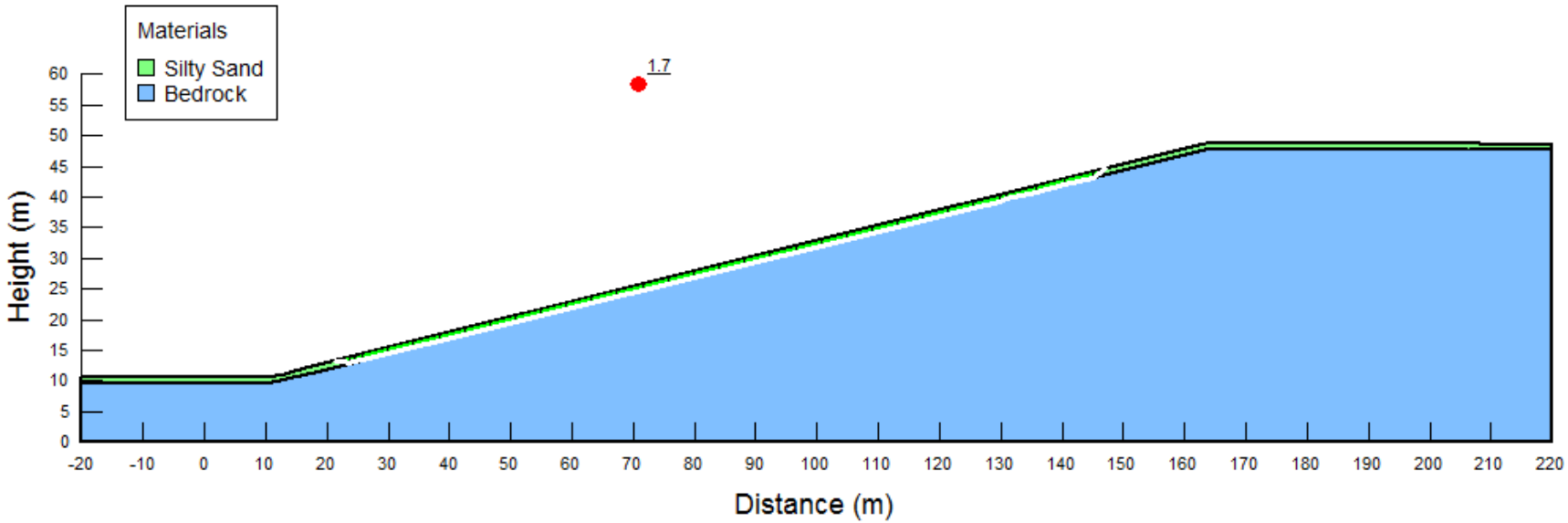
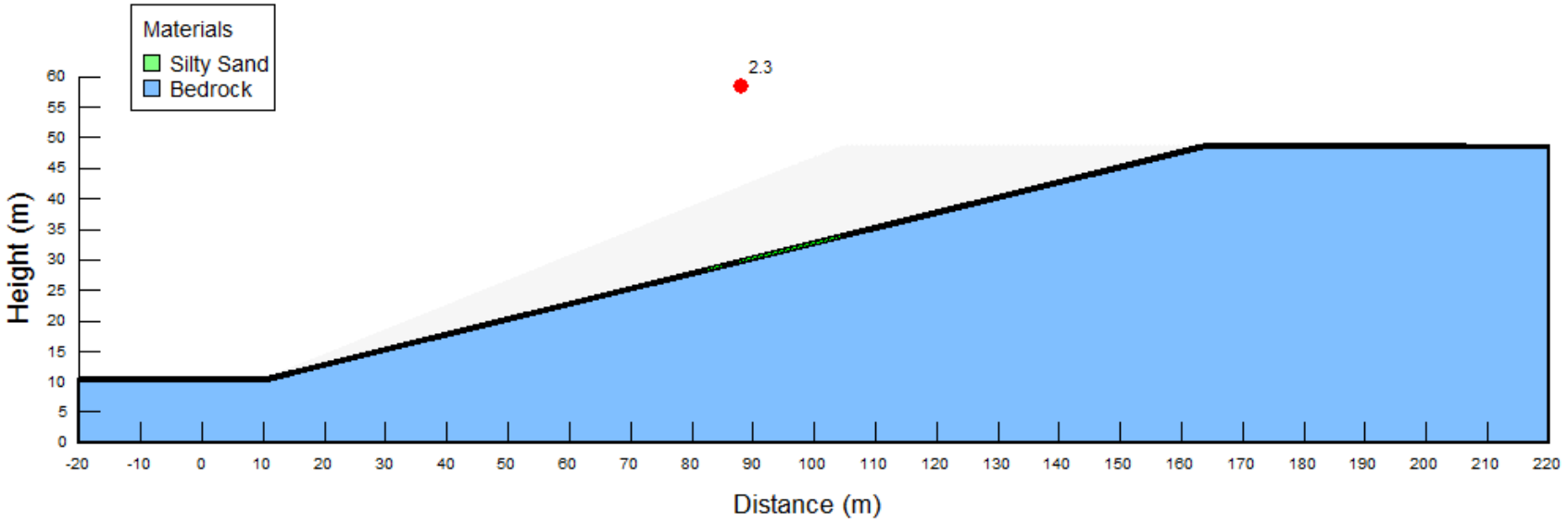



Scenario 2a




Scenario 2b

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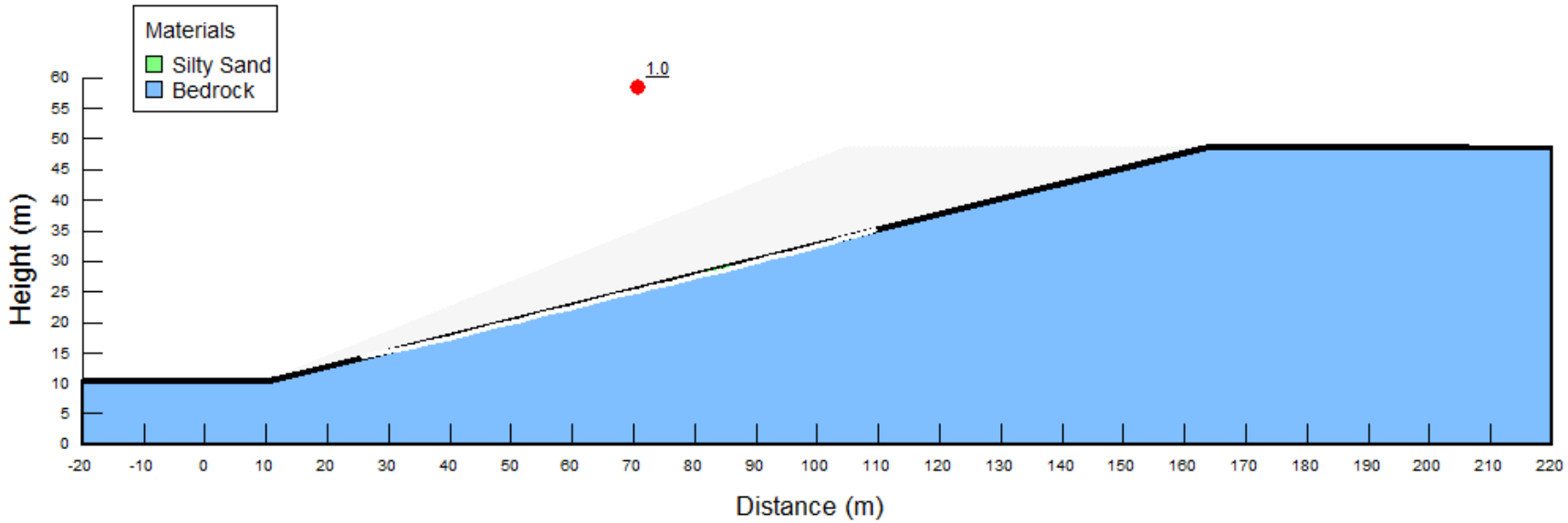
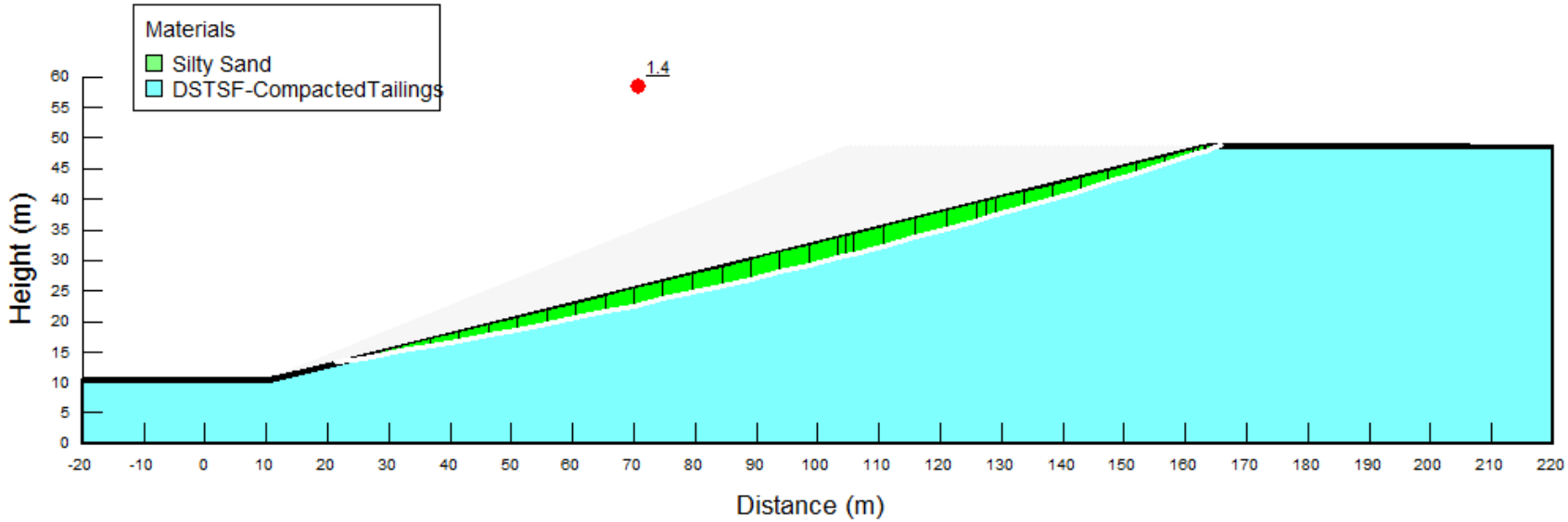



Scenario 2c




Scenario 2d

| | | |
|---|---|---|
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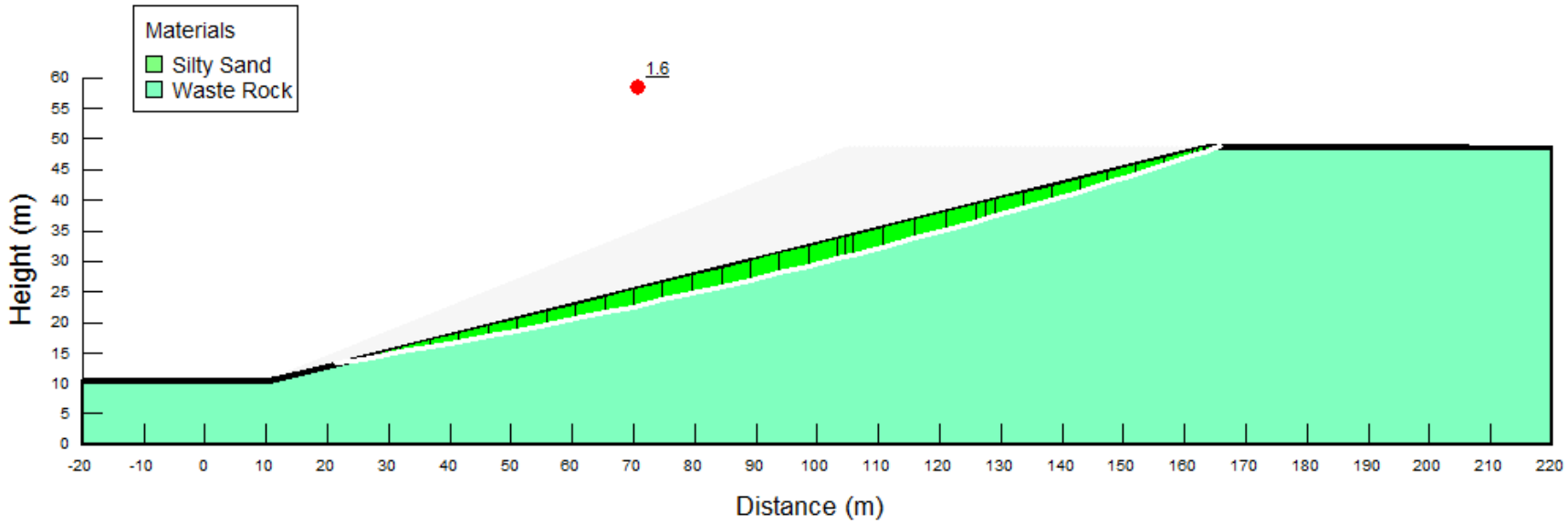
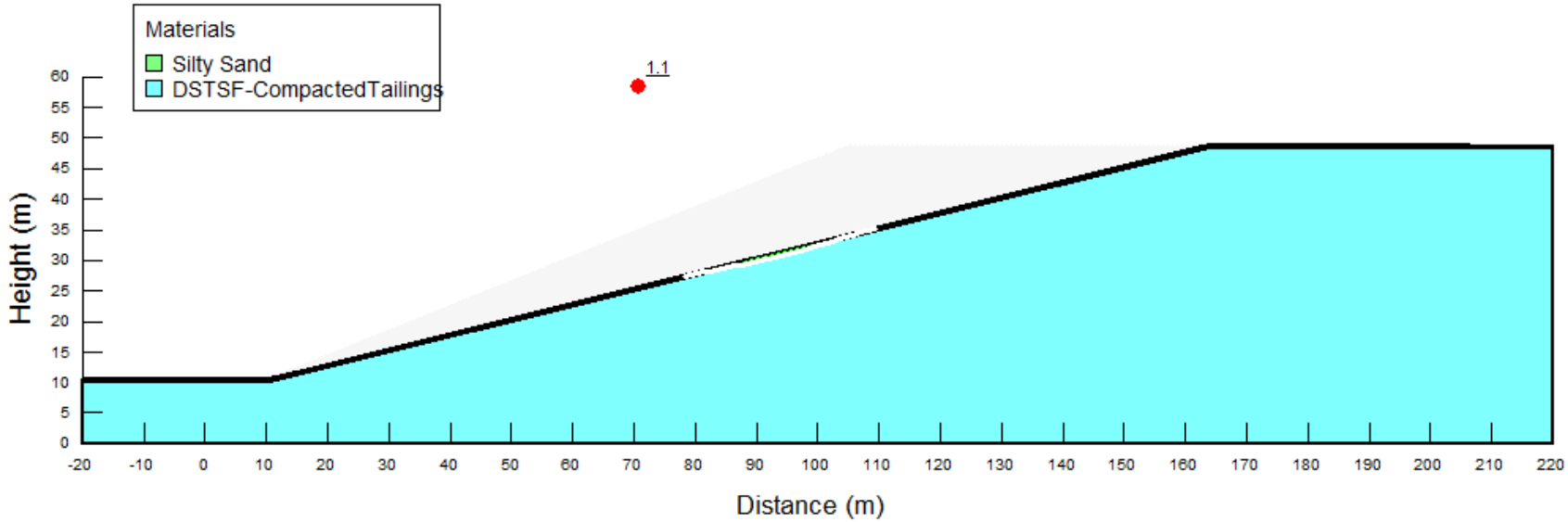
| Job No: 1CM002.049<br>Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx | Minto Closure Cover Design | **Scenario 2 Sensitivity (con't)** |
| | | Date: July 2016 / Approved: EK / Figure: **9** |

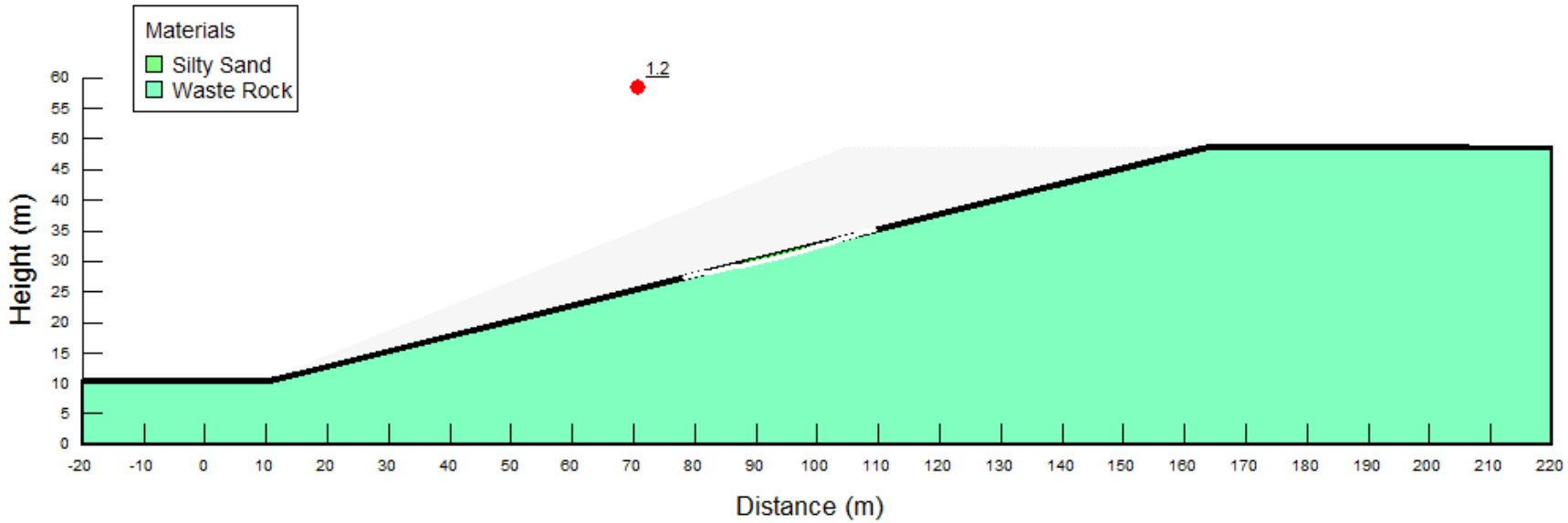



Scenario 2e

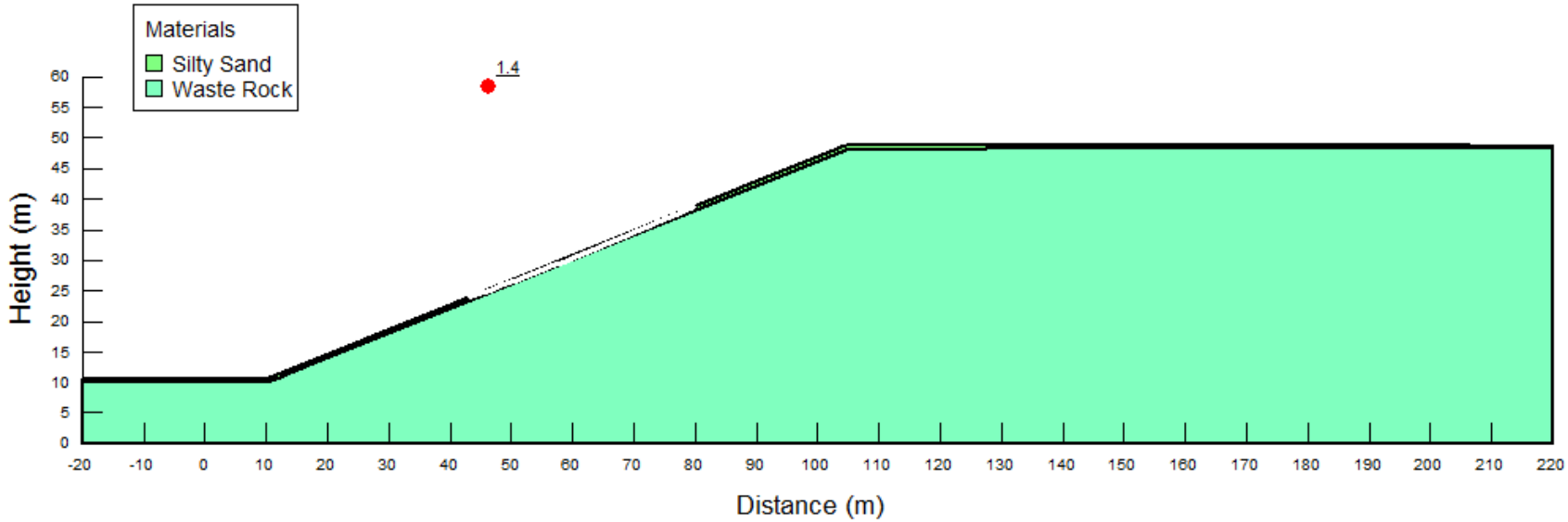



Scenario 2f

| | | |
|---|---|---|
| srk consulting | Capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD. | Stability Assessment |
| Job No: 1CM002.049<br>Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx | Minto Closure Cover Design | **Scenario 2 Sensitivity (con't)** |
| | | Date: July 2016 / Approved: EK / Figure: **10** |

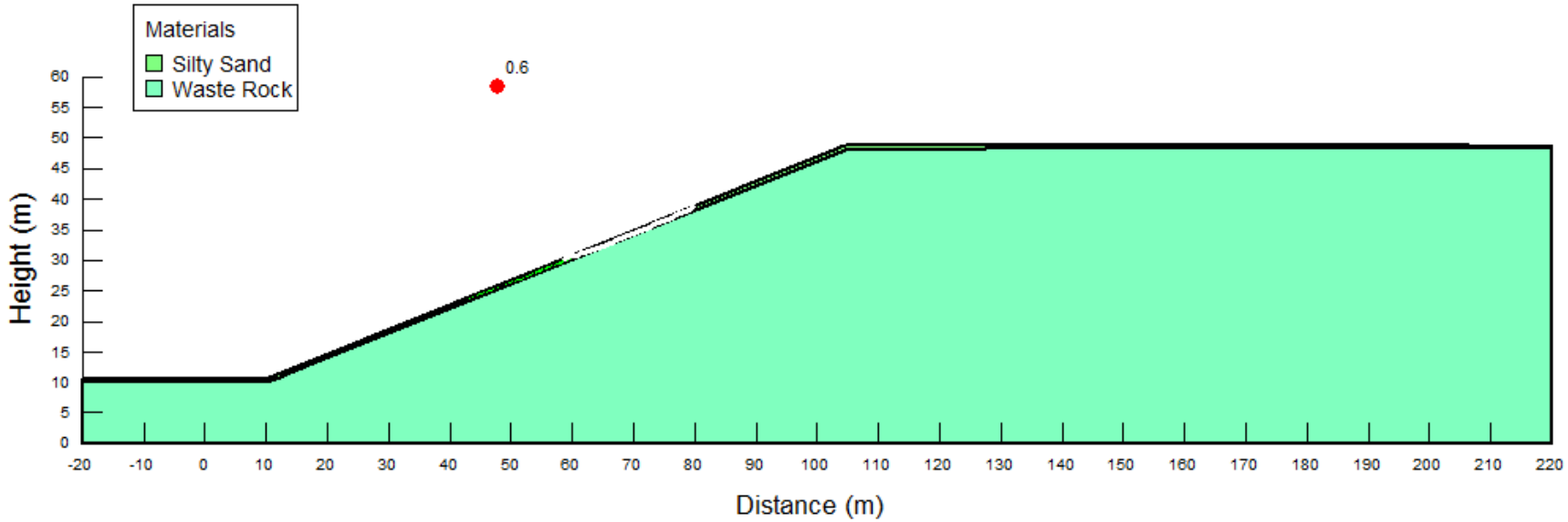



Scenario 2g




Scenario 2h

| | | |
|---|---|---|
| srk consulting | capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD. | Stability Assessment |
| Job No: 1CM002.049<br>Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx | Minto Closure Cover Design | **Scenario 2 Sensitivity (con't)** |
| | | Date: July 2016 / Approved: EK / Figure: **11** |




Scenario 1i

| | | | |
|---|---|---|---|
| srk consulting | Capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD. | Stability Assessment | |
| Job No: 1CM002.049<br>Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx | Minto Closure Cover Design | **Scenario 2 Sensitivity (con't)** | |
| | | Date: July 2016 / Approved: EK | Figure: **12** |

# Appendix E – Minto Mine Preliminary Closure Cover Revegetation Plan

IEG
Integral Ecology Group
iegconsulting.com

# 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.

1% FOR THE PLANET

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

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.

Environment Yukon 2017. Southern Lakes Boreal Low subzone (BOLsl): a field guide to ecosite identification. Boreal Low Zone Series. Department of Environment, Government of Yukon, Whitehorse, Yukon.

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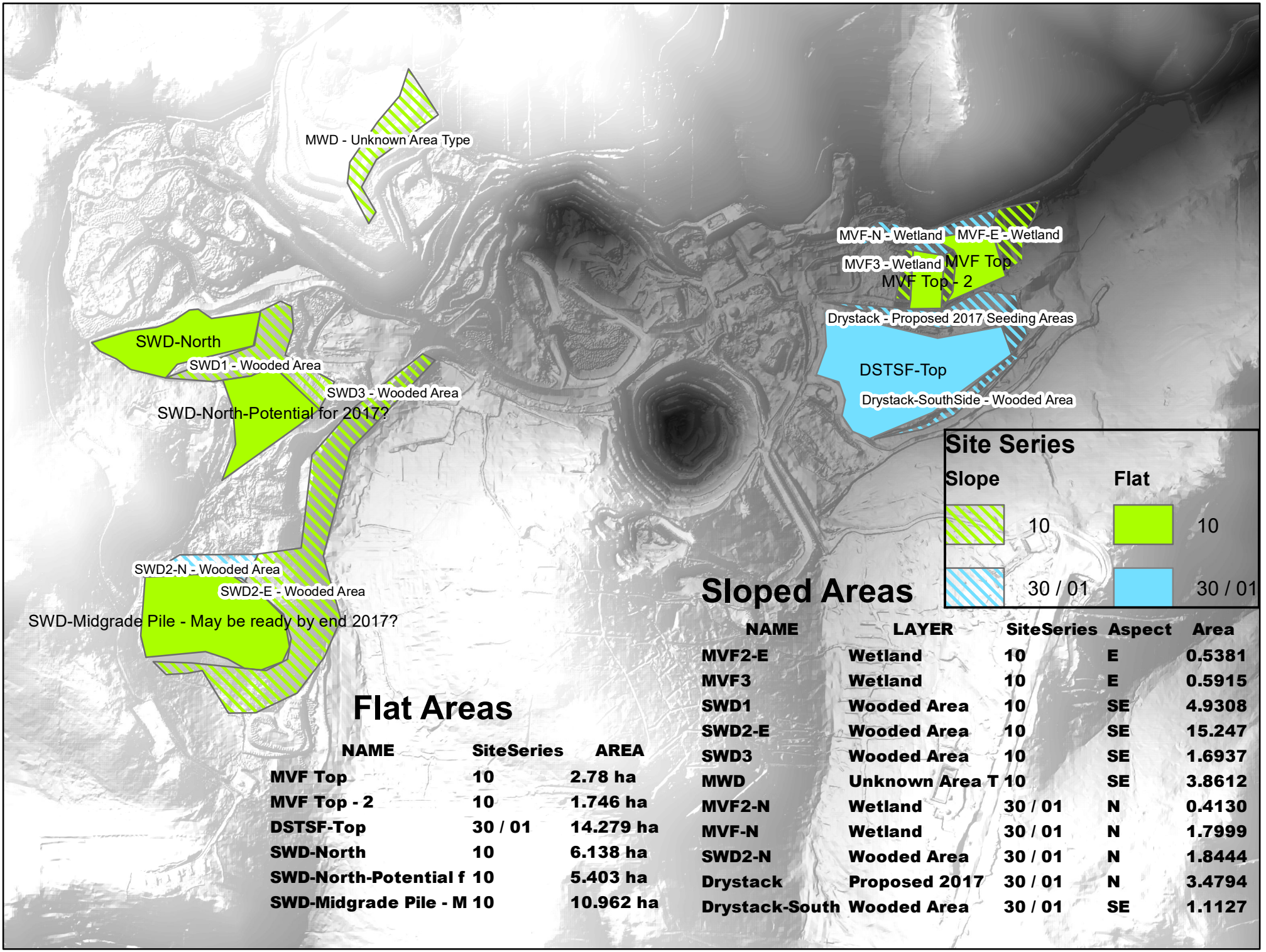
Matheus, P. and C. Omtzigt. 2013. Yukon revegetation manual: practical approaches and methods. Whitehorse, Yukon. yukonrevegetationmanual.ca

Straker, J., T. Baker, M. O'Kane, R. Shurniak, S.L. Barbour, and S. Carey. 2015a. Ecosystem reconstruction: a global assessment of methods of estimating soil water regimes for mine reclamation and closure. In Proceedings of Mine Closure 2015, Fourie, A., M. Tibbett, L. Sawatsky, and D. van Zyl (eds.). Australian Centre for Geomechanics, University of Western Australia, Perth.

Straker, J., T. Baker, S.L. Barbour, M. O'Kane, S. Carey, and D. Charest. 2015b. Mine reclamation and surface water balances: an ecohydrologic classification system for mine-affected watersheds. In Proceedings of Mine Closure 2015, Fourie, A., M. Tibbett, L. Sawatsky, and D. van Zyl (eds.). Australian Centre for Geomechanics, University of Western Australia, Perth.

**Appendix A**

Mapped revegetation units




## Flat Areas

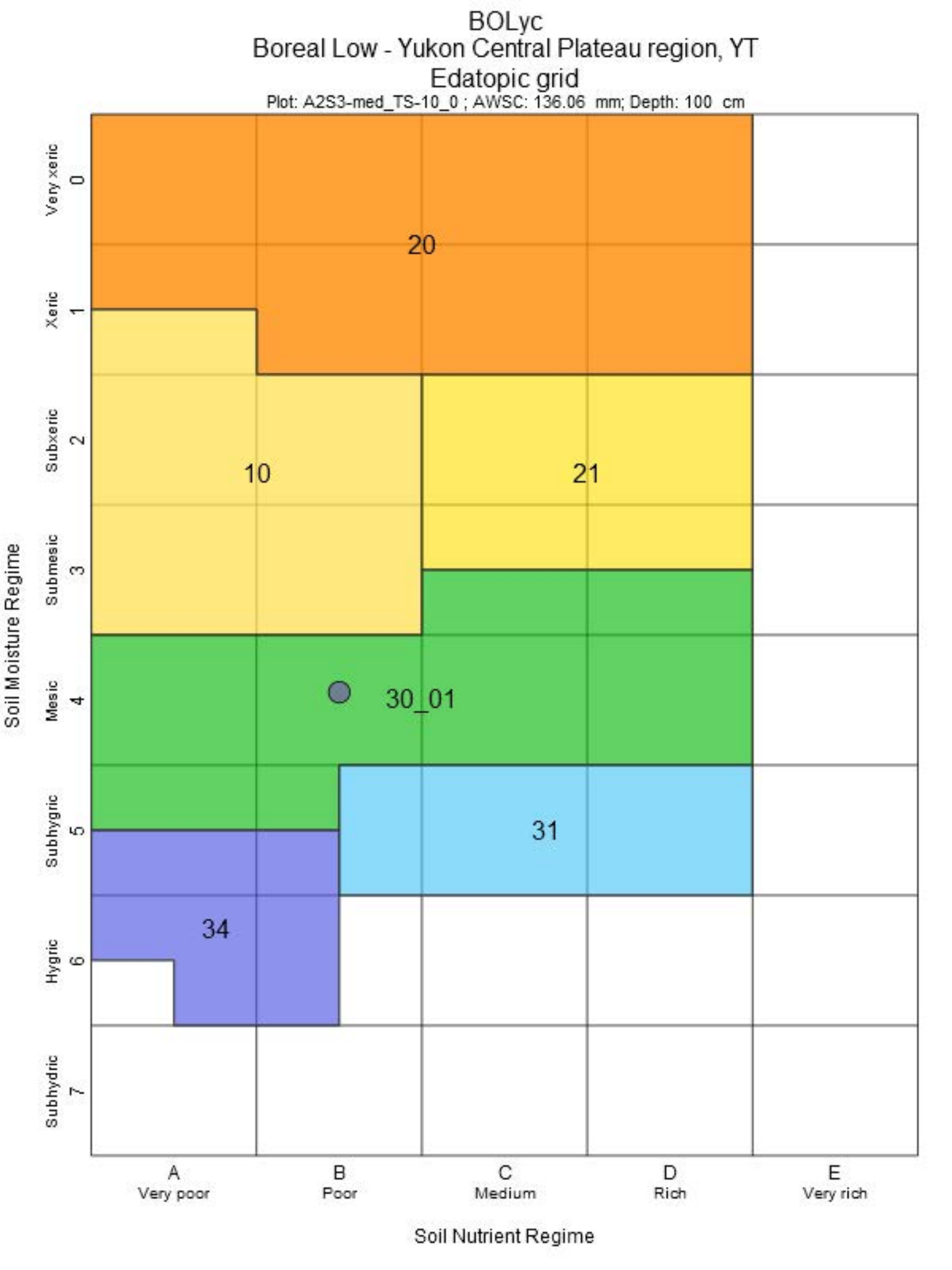
| NAME | SiteSeries | AREA |
|---|---|---|
| MVF Top | 10 | 2.78 ha |
| MVF Top - 2 | 10 | 1.746 ha |
| DSTSF-Top | 30 / 01 | 14.279 ha |
| SWD-North | 10 | 6.138 ha |
| SWD-North-Potential f | 10 | 5.403 ha |
| SWD-Midgrade Pile - M | 10 | 10.962 ha |

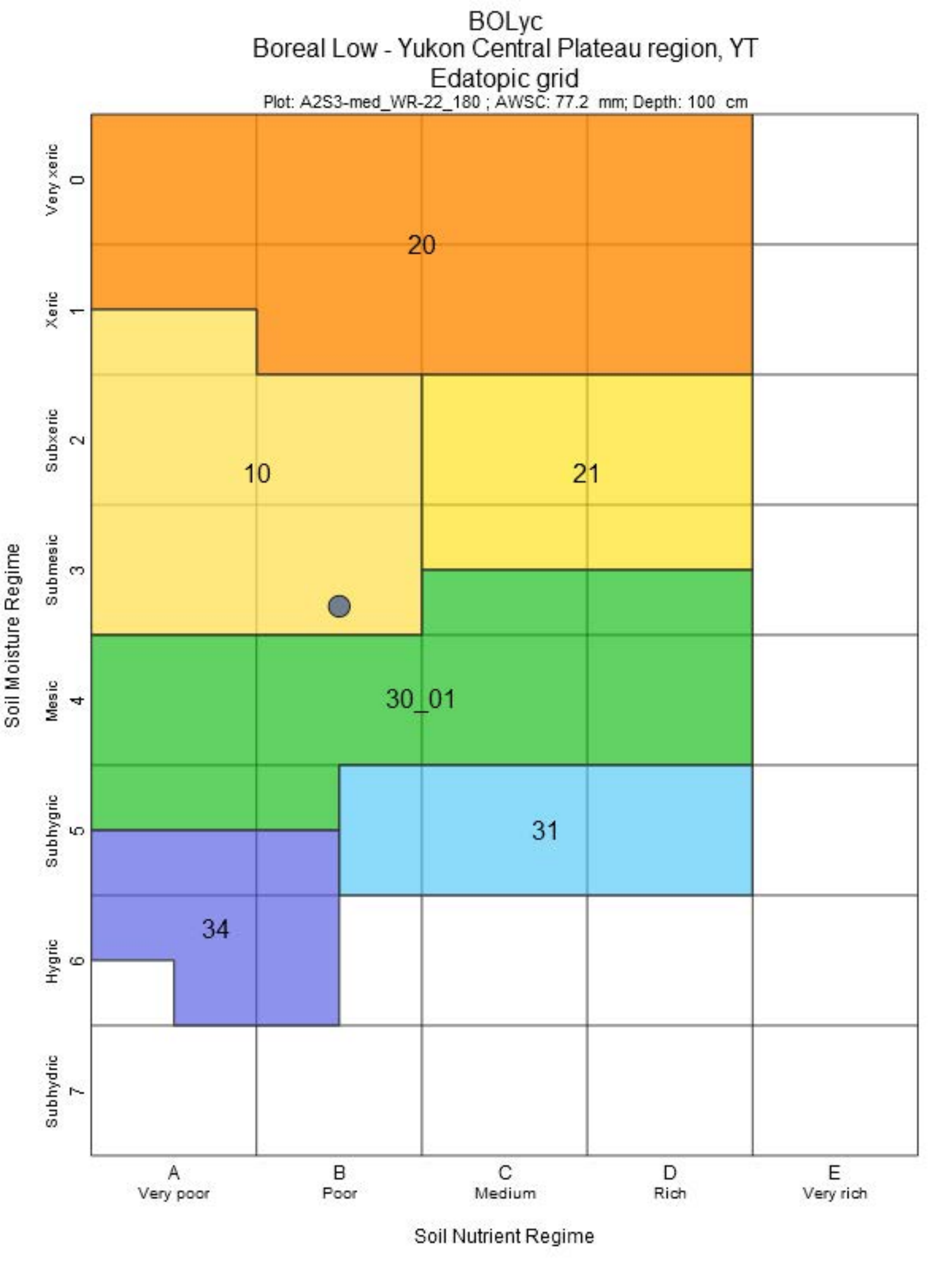
## Sloped Areas

| 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 |

**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
Soil Moisture Regime
0 Very xeric
1 Xeric
2 Subxeric
3 Submesic
4 Mesic
5 Subhygric
6 Hygric
7 Subhydric
20
10
21
30_01
31
34
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
Plot: A2S3-med_WR-22_180 ; AWSC: 77.2 mm; Depth: 100 cm
Soil Moisture Regime
0 Very xeric
1 Xeric
2 Subxeric
3 Submesic
4 Mesic
5 Subhygric
6 Hygric
7 Subhydric
20
10
21
30_01
31
34
A Very poor
B Poor
C Medium
D Rich
E Very rich
Soil Nutrient Regime

# 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 | 17.0% | 65 | 2.0 | 3 | 0.10 | 0.10 | 0.21 | 3.2 | 2.03 |
| | A18 | | | | | | | | | |
| | 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 | 22.5% | 75 | 2.0 | 3 | 0.14 | 0.14 | 0.28 | 3.7 | 2.85 |
| | A26 | | | | | | | | | |
| 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.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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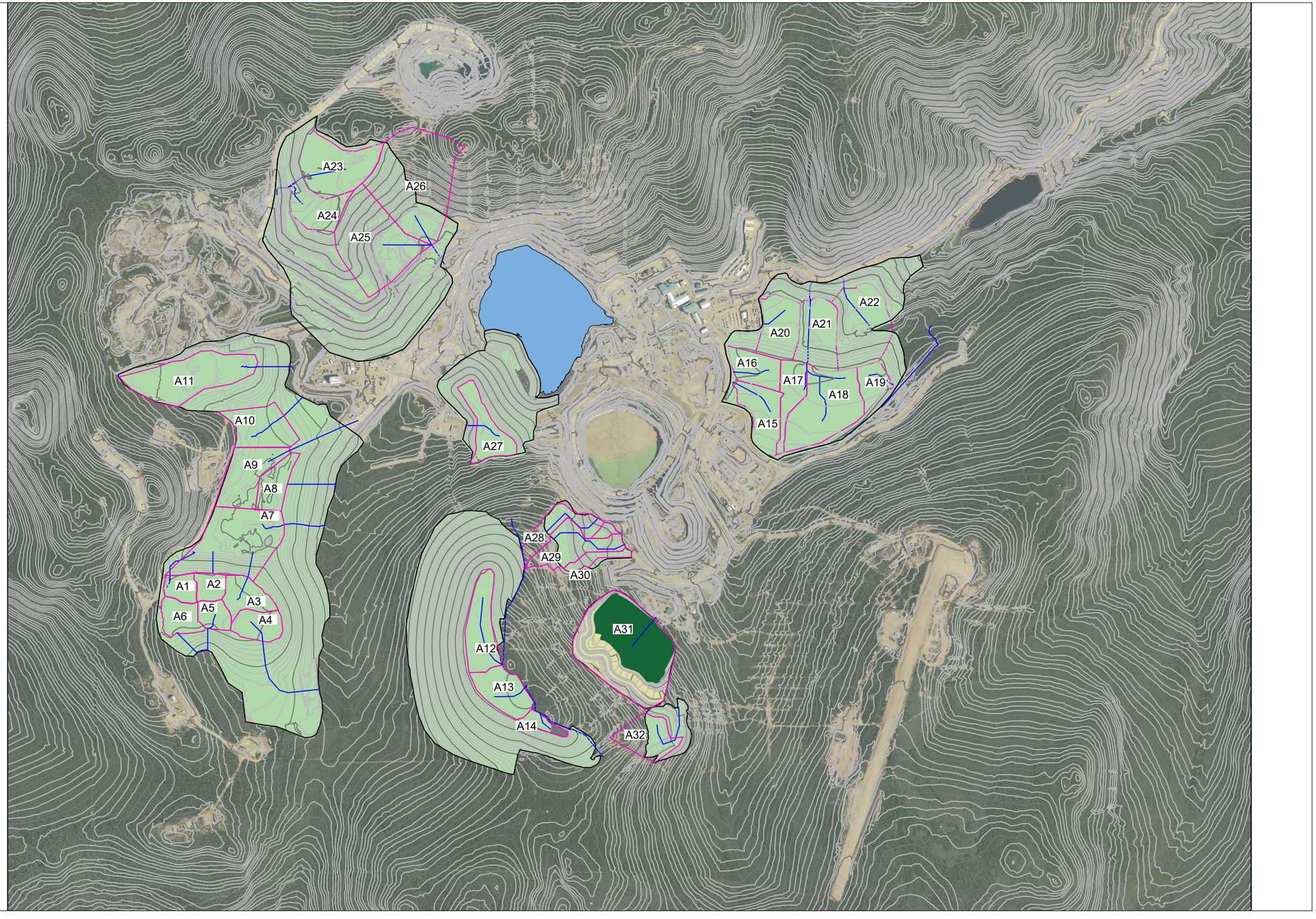
SRK Consulting, 2018. Updated Closure Cover Designs for the Minto Mine 2018 Reclamation and Closure Plan. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.049. January 2018.

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.

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Hydrotechnical Designs for Covers

Watershed Areas

SRK Project NO.: 1CM002.049

FILE NAME: 1CM002.049_2018RCP-Regrade-Catchments_R1.dwg

Minto Mine, Yukon

| DATE: | APPROVED: | FIGURE: |
|---|---|---|
| January 2018 | EK | 01 |

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# 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

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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 -0.5$^{o}$C. 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 (*$\mathrm{t/Ha}$*)*
*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.

This report, Closure Landform Design and Reclamation Landform Units for the Minto Mine, was prepared by



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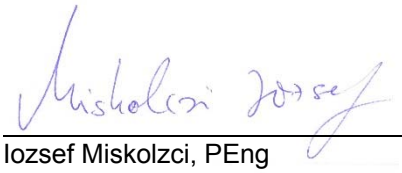

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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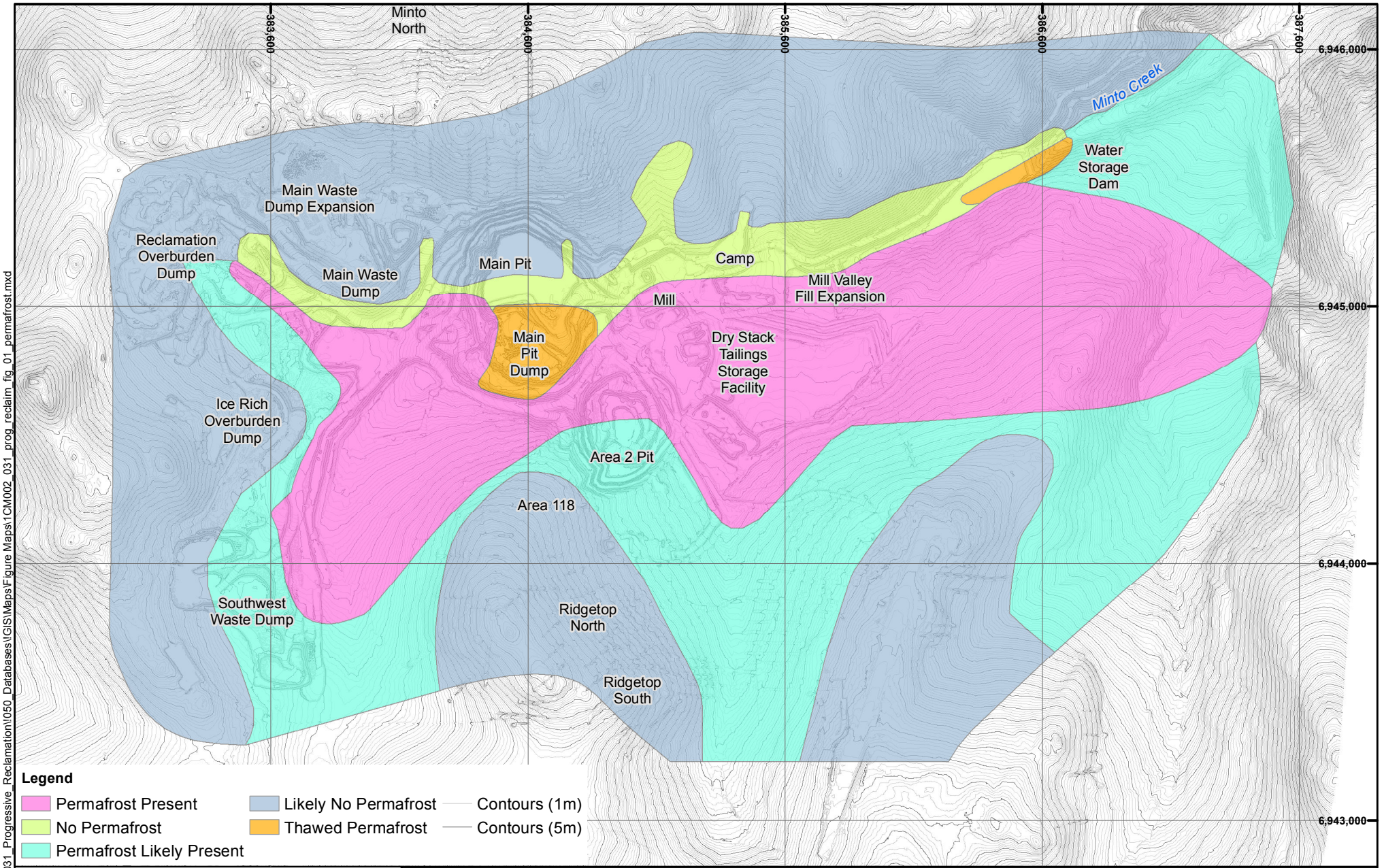
Figures

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Closure Landform Design and RLUs

**Permafrost Extent Across Site**

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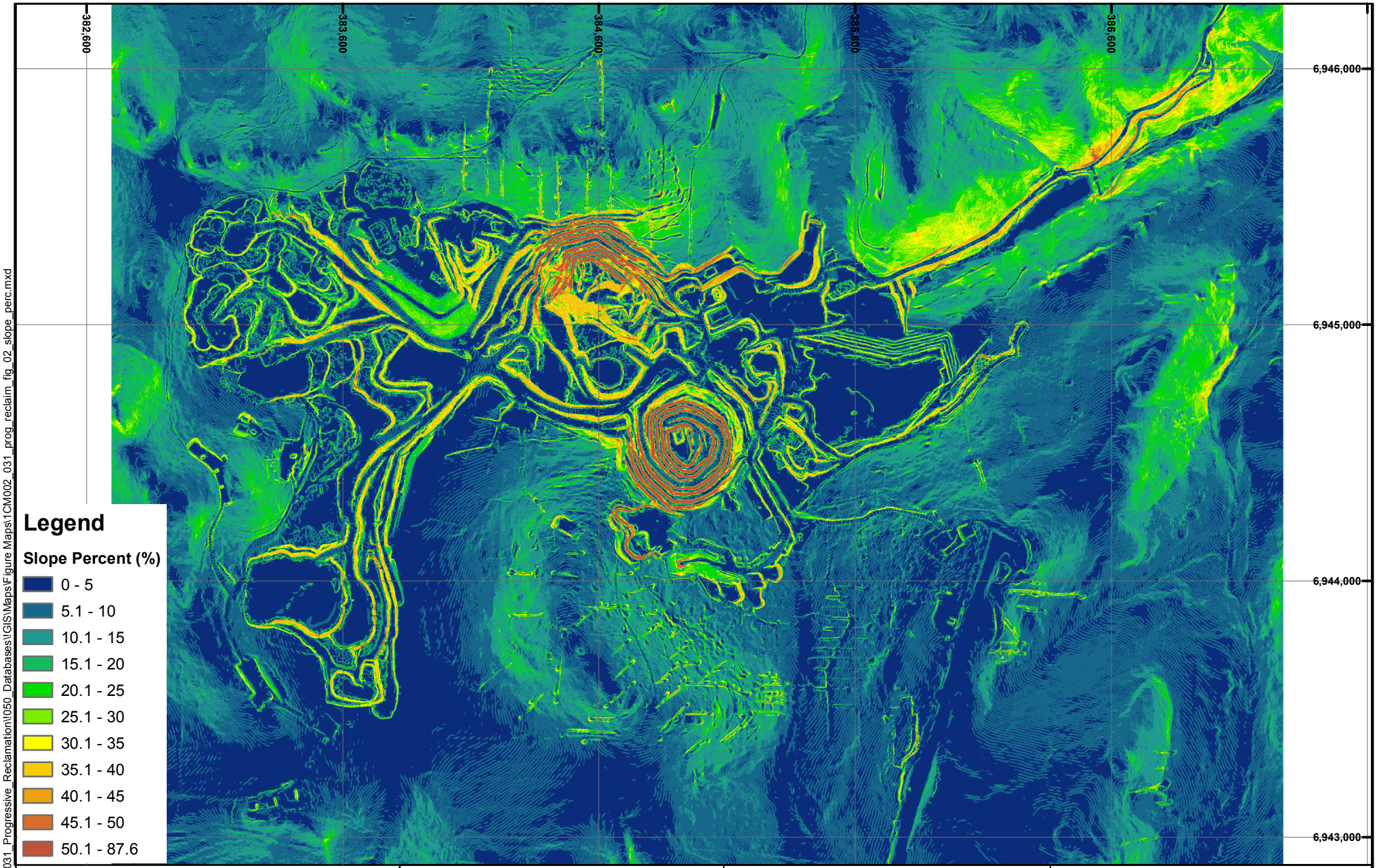


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Closure Landform Design and RLUs

**Slope Gradients**

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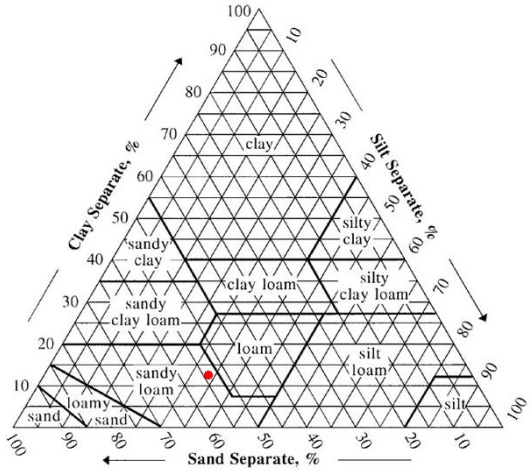
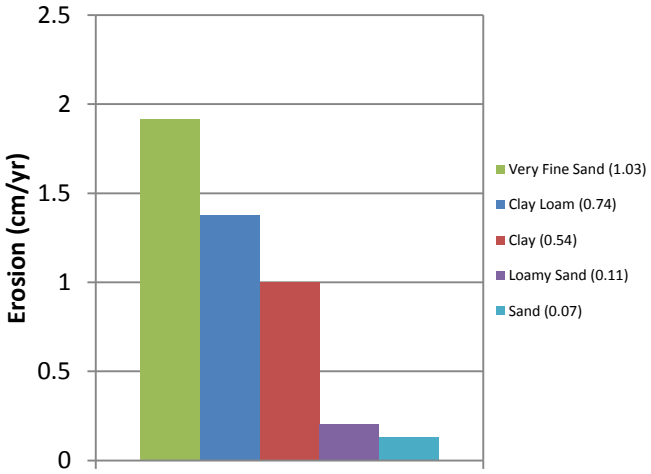



Average particle size distribution of soil in the ROD falls into the Sandy Loam category (USDA classification)

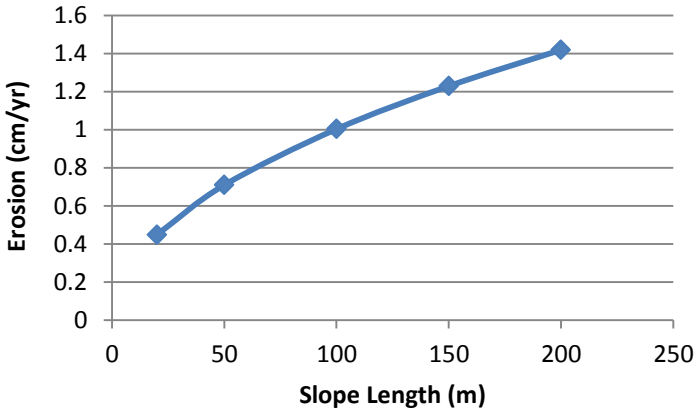
**(a)**

## Erosion by soil type



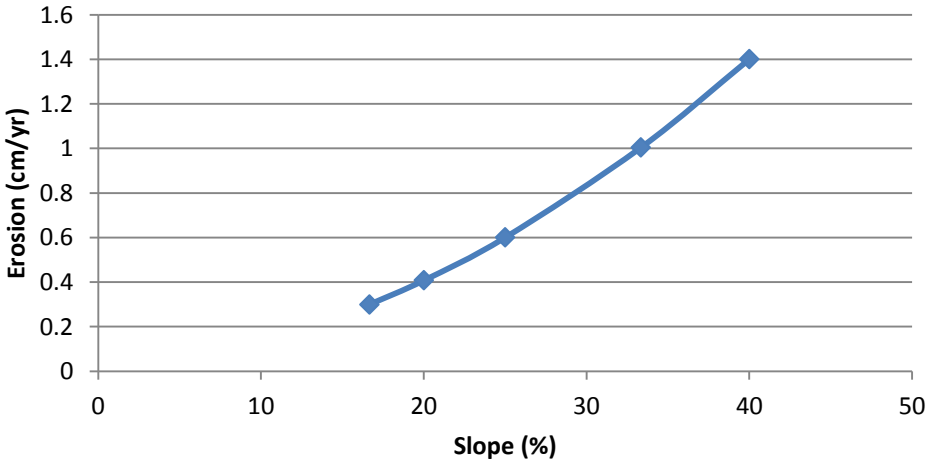

**(b)**

## Slope length (m) vs Erosion (3H:1V)



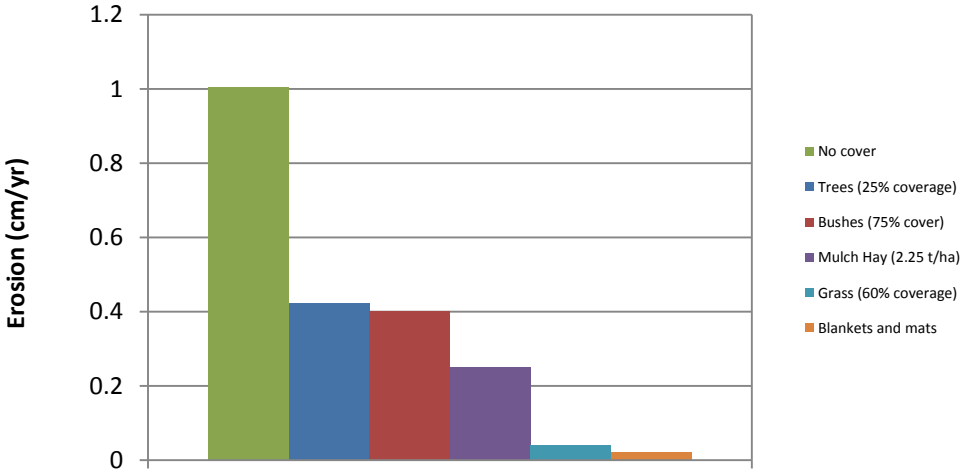

**(c)**

## Slope (%) vs Erosion




**(d)**

## Erosion by cover type




**(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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Minto Mine

Closure Landform Design and RLUs

**Erosion Analysis**

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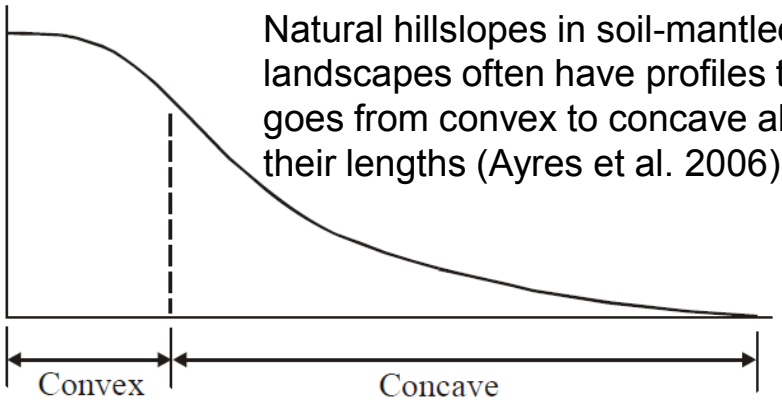
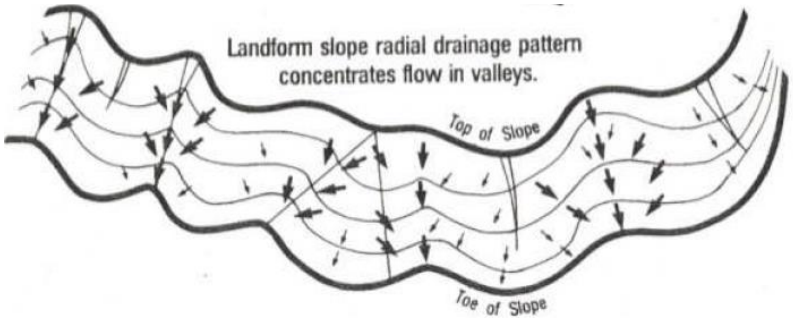



Natural hillslopes in soil-mantled landscapes often have profiles that goes from convex to concave along their lengths (Ayres et al. 2006).




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).

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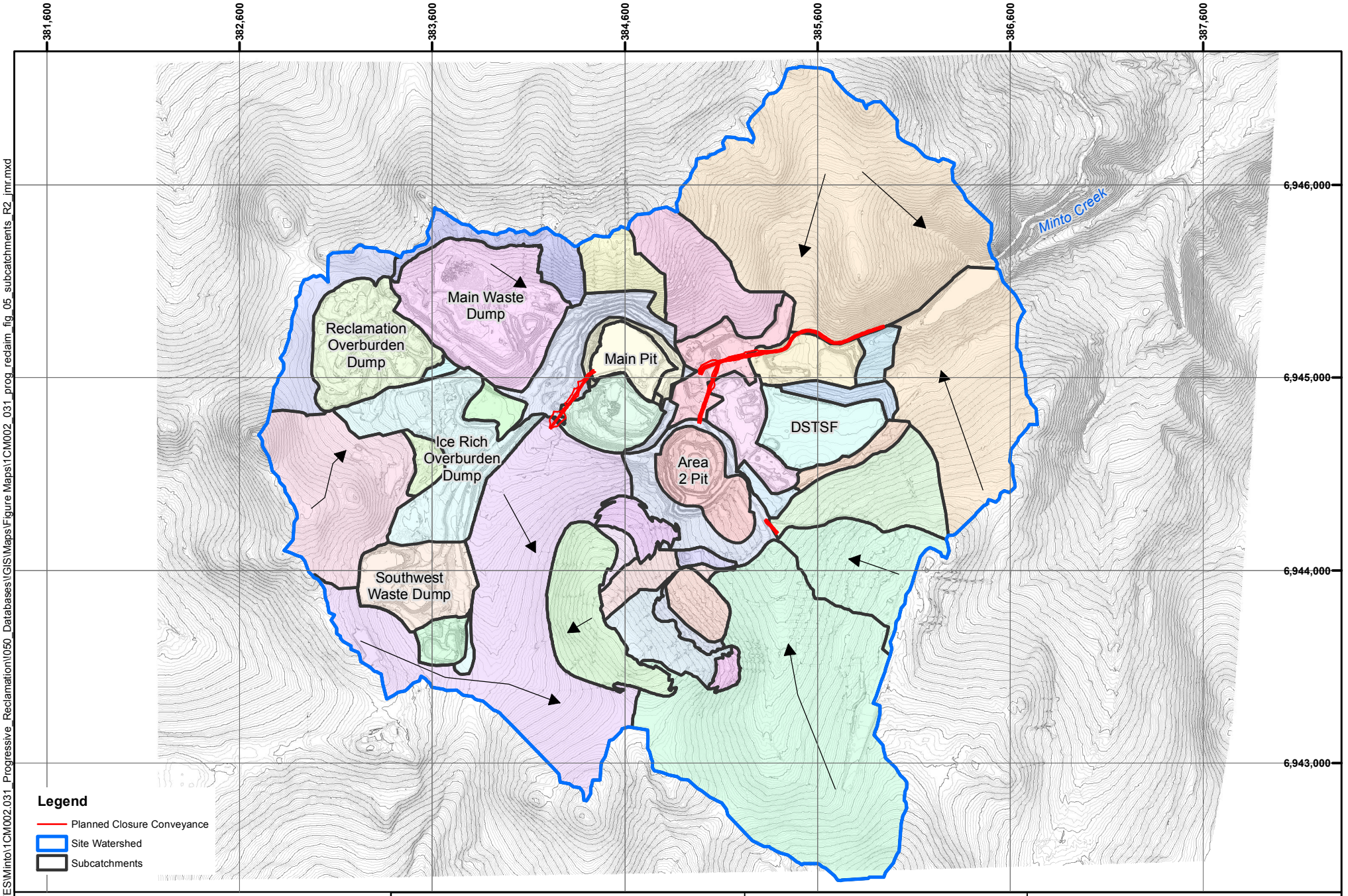
| srk consulting | capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD. | Closure Landform Design and RLUs |
| Job No: 1CM002.031<br>Filename: Fig04_LandformDesignConcepts.pptx | Minto Mine | **Geomorphic Landform Design Concepts** |
| | | Date: April 2016 / Approved: EKH / Figure: 4 |

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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_05_subcatchments_R2_jmr

Minto Mine

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# Sub-Catchment Areas

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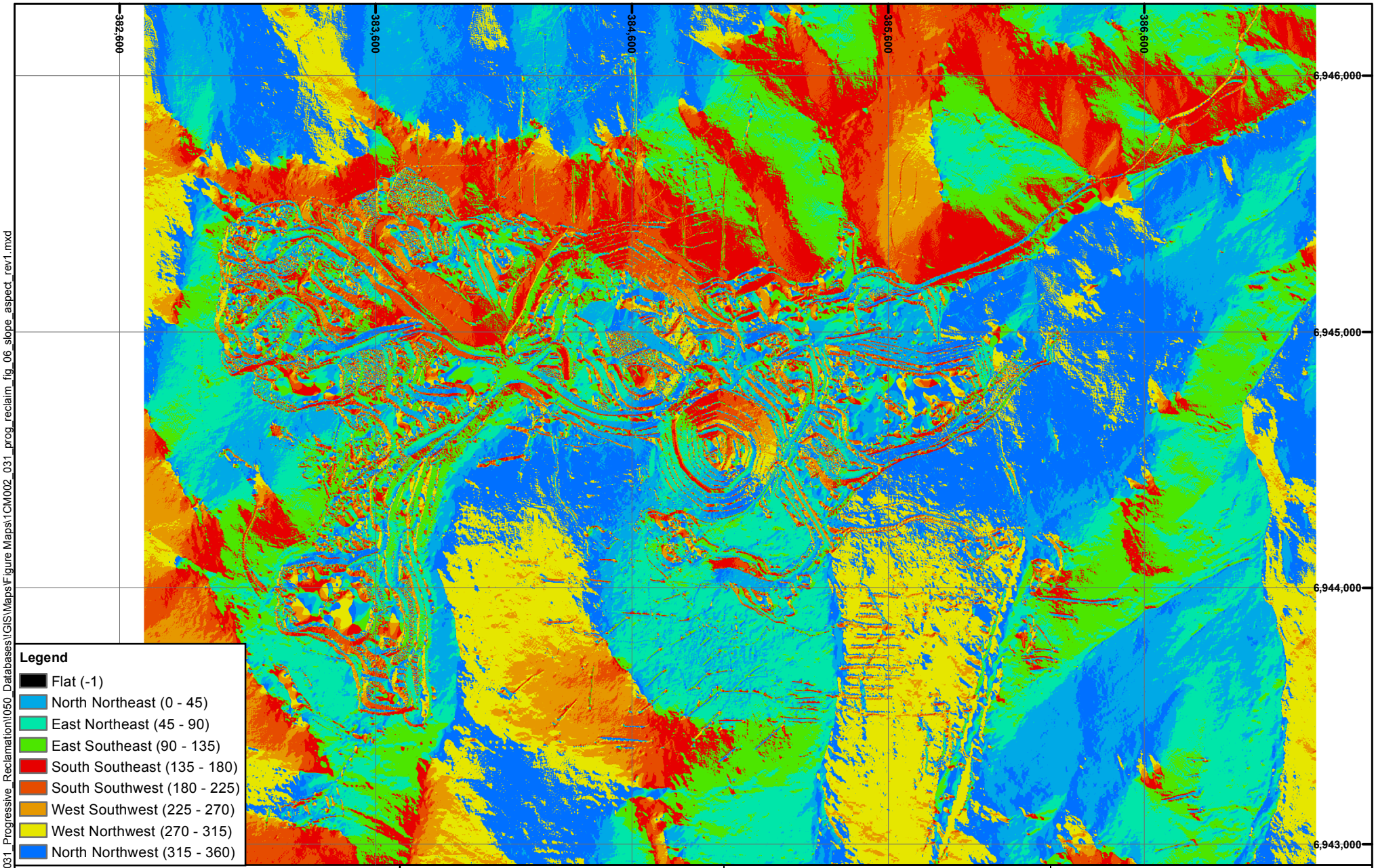
| April 2016 | EKH | 5 |




0 500 1,000 Meters

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**Slope Aspect Distribution**

Job No: 1CM002.031

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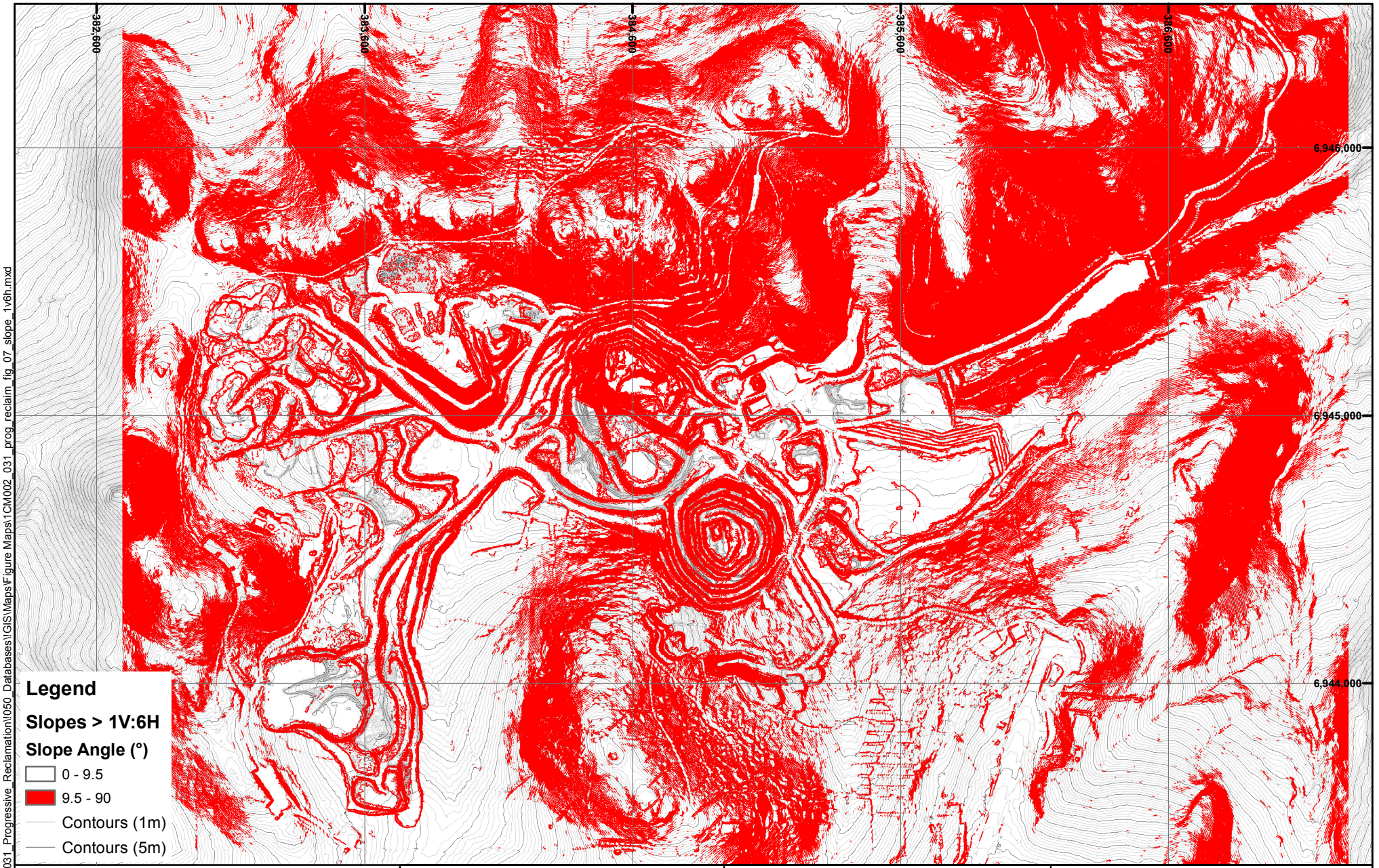


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Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_07_slope_1v6h

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Closure Landform Design and RLUs

**Distribution of Slopes Steeper than 6H:1V**

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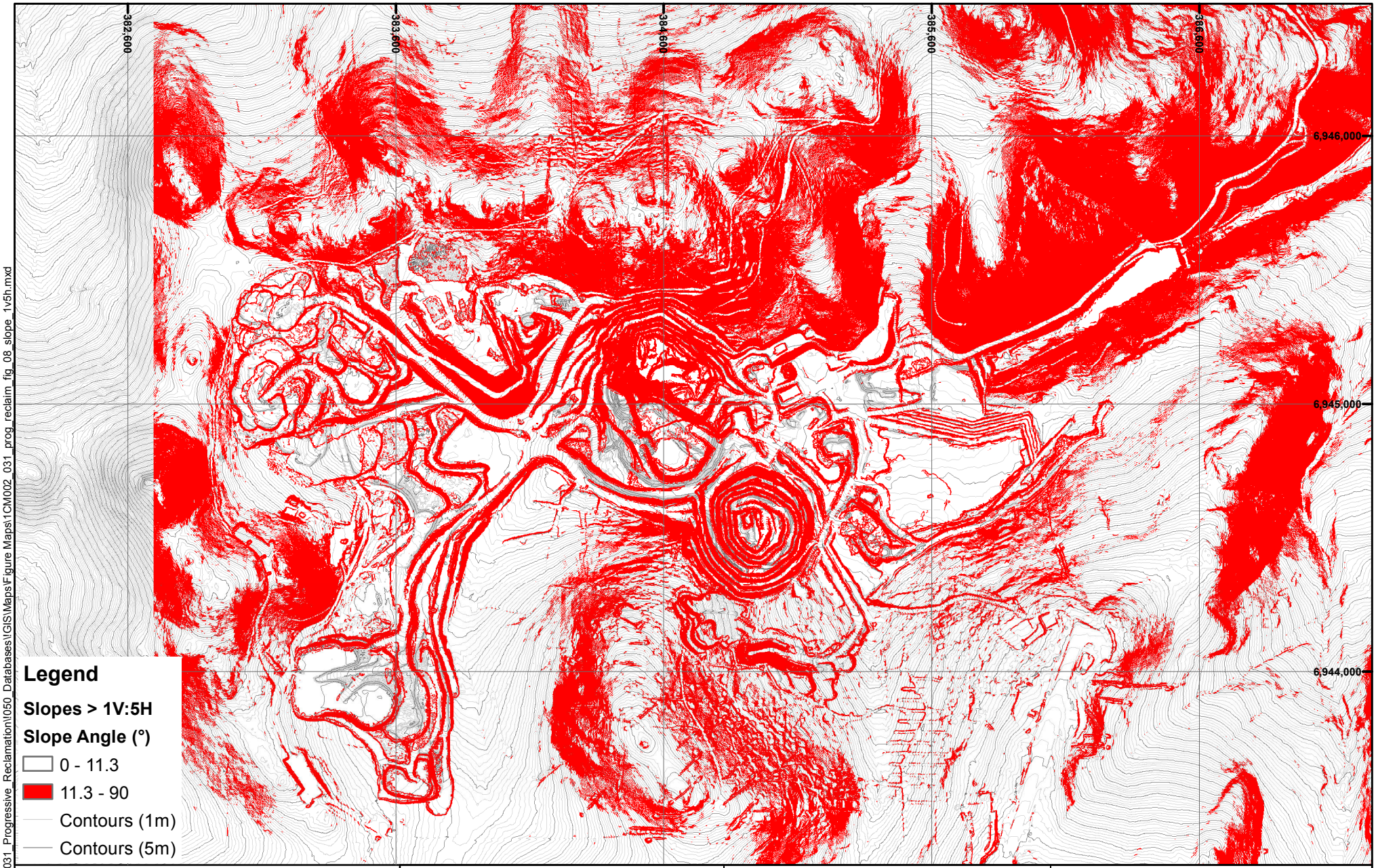
| April 2016 | EKH | 7 |

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Closure Landform Design and RLUs

**Distribution of Slopes Steeper than 5H:1V**

Job No: 1CM002.031

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Minto Mine

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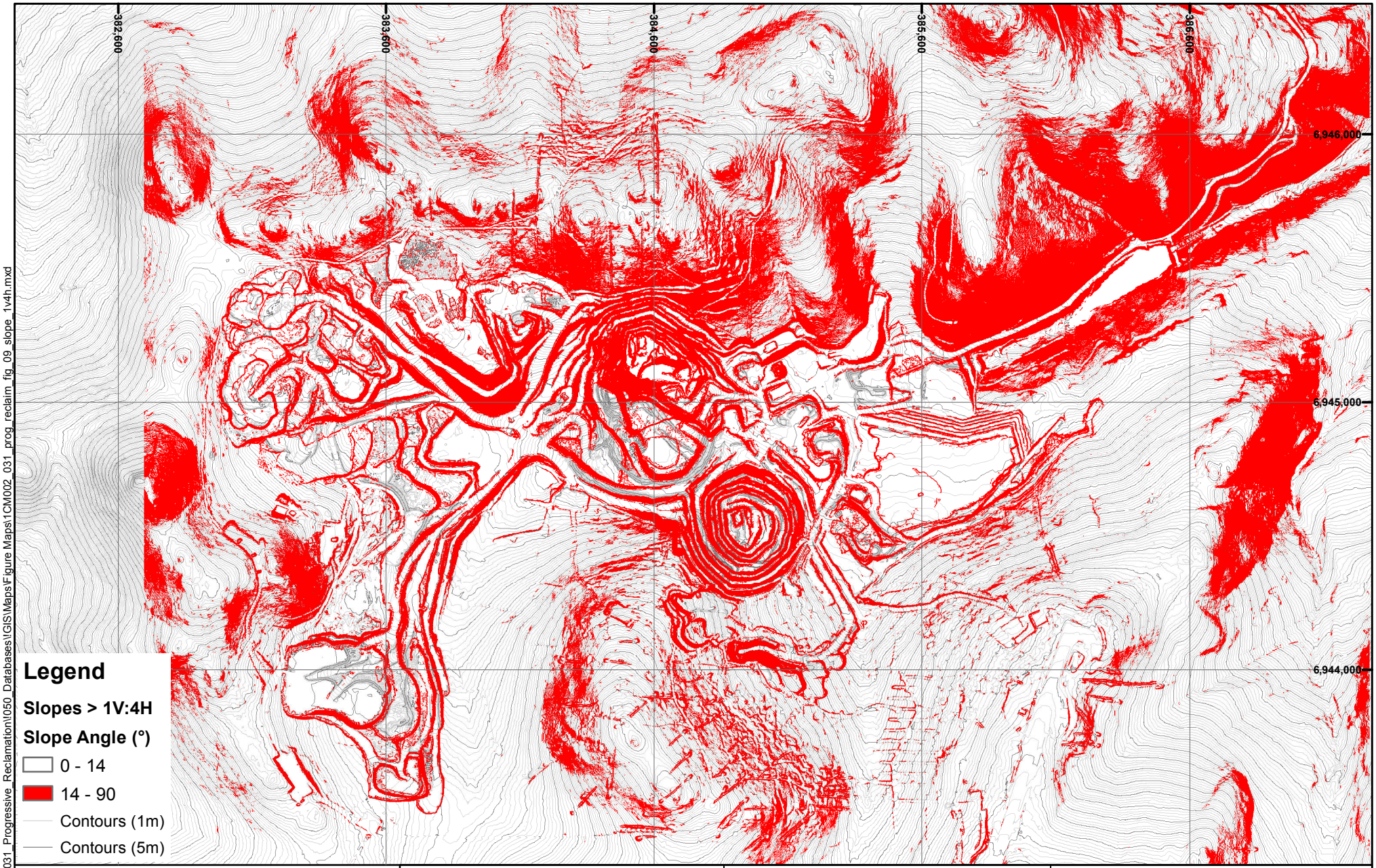


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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_09_slope_1v4h

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**Distribution of Slopes Steeper than 4H:1V**

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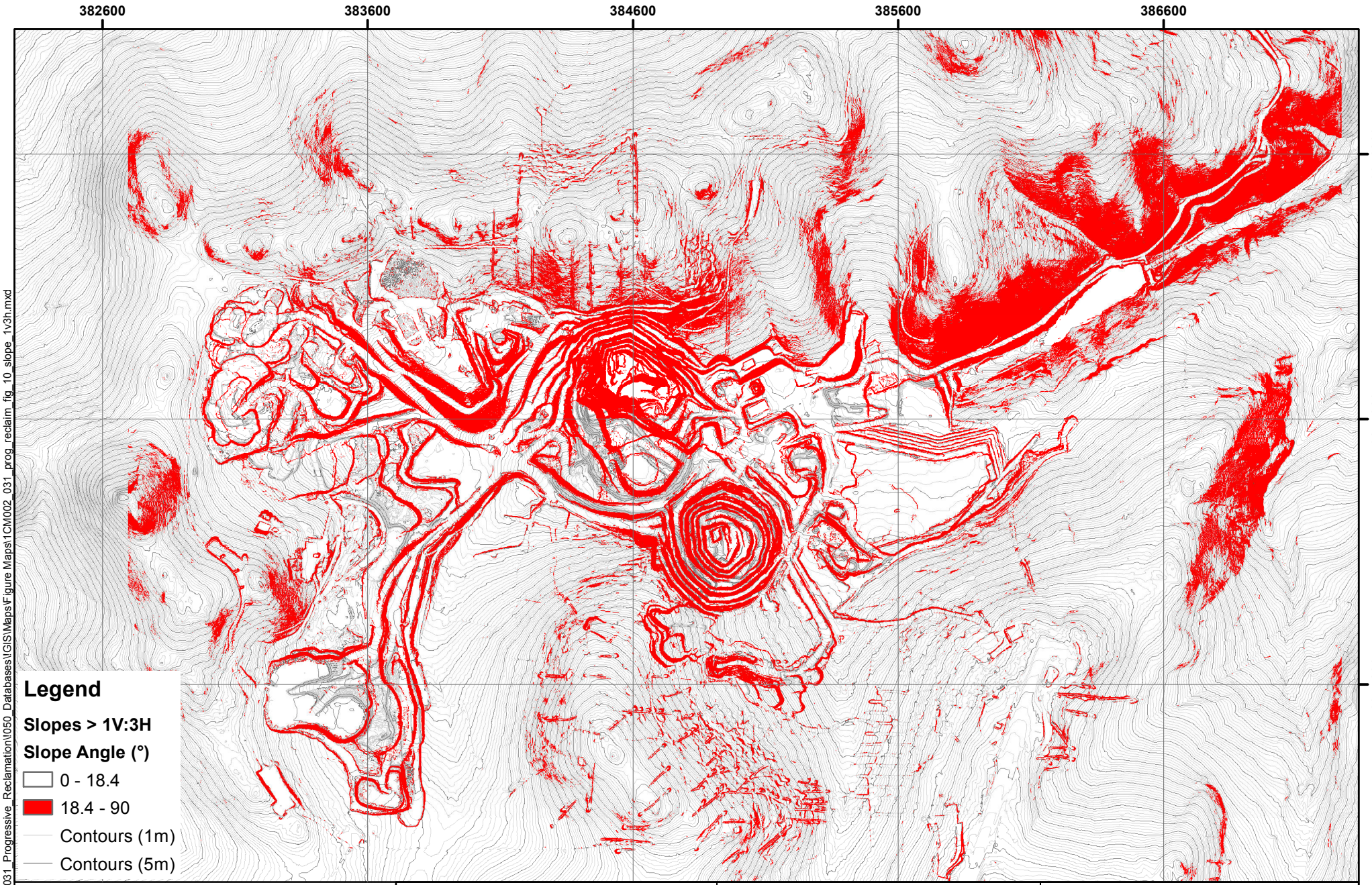
| April 2016 | EKH | 9 |

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Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_10_slope_1v3h

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**Distribution of Slopes Steeper than 3H:1V**

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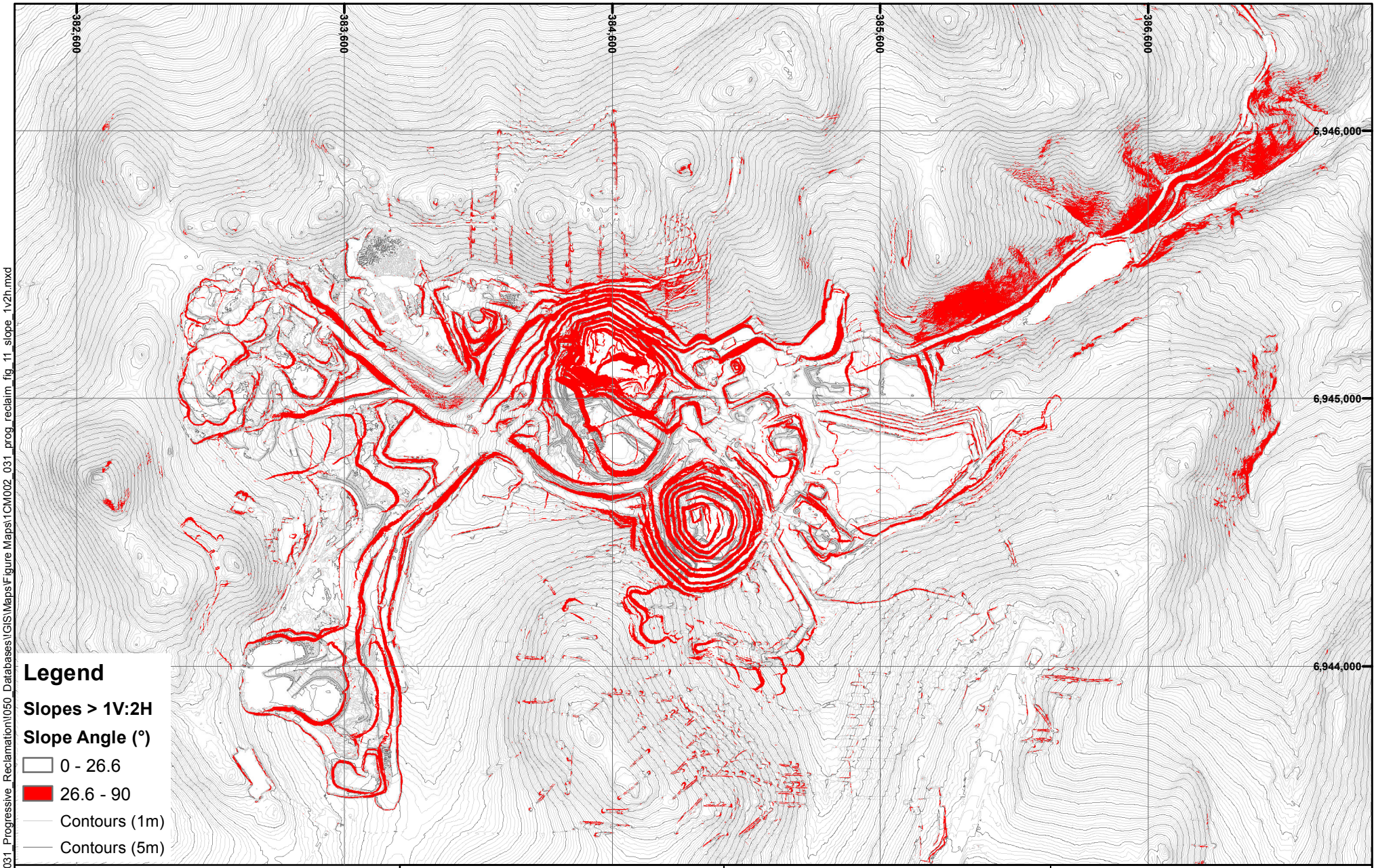


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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_11_slope_1v2h

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**Distribution of Slopes Steeper than 2H:1V**

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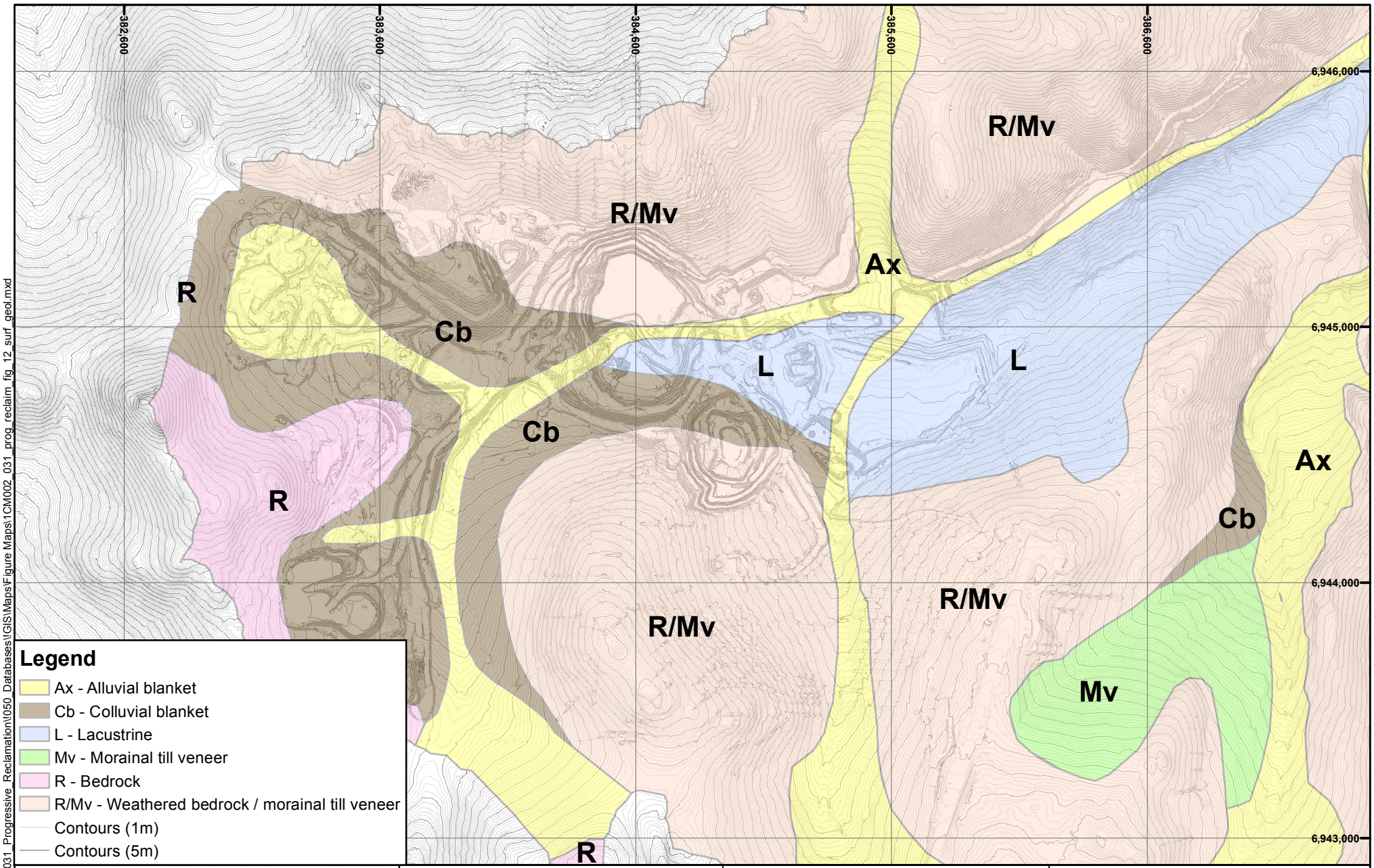
| April 2016 | EKH | **11** |




Source: SRK Consulting (US) Inc. (2014). Surficial Geology Map - Minto Creek Watershed

0 500 1,000 Meters

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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_12_surf_geol

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Closure Landform Design and RLUs

**Surficial Geology Map**

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| April 2016 | EKH | 12 |

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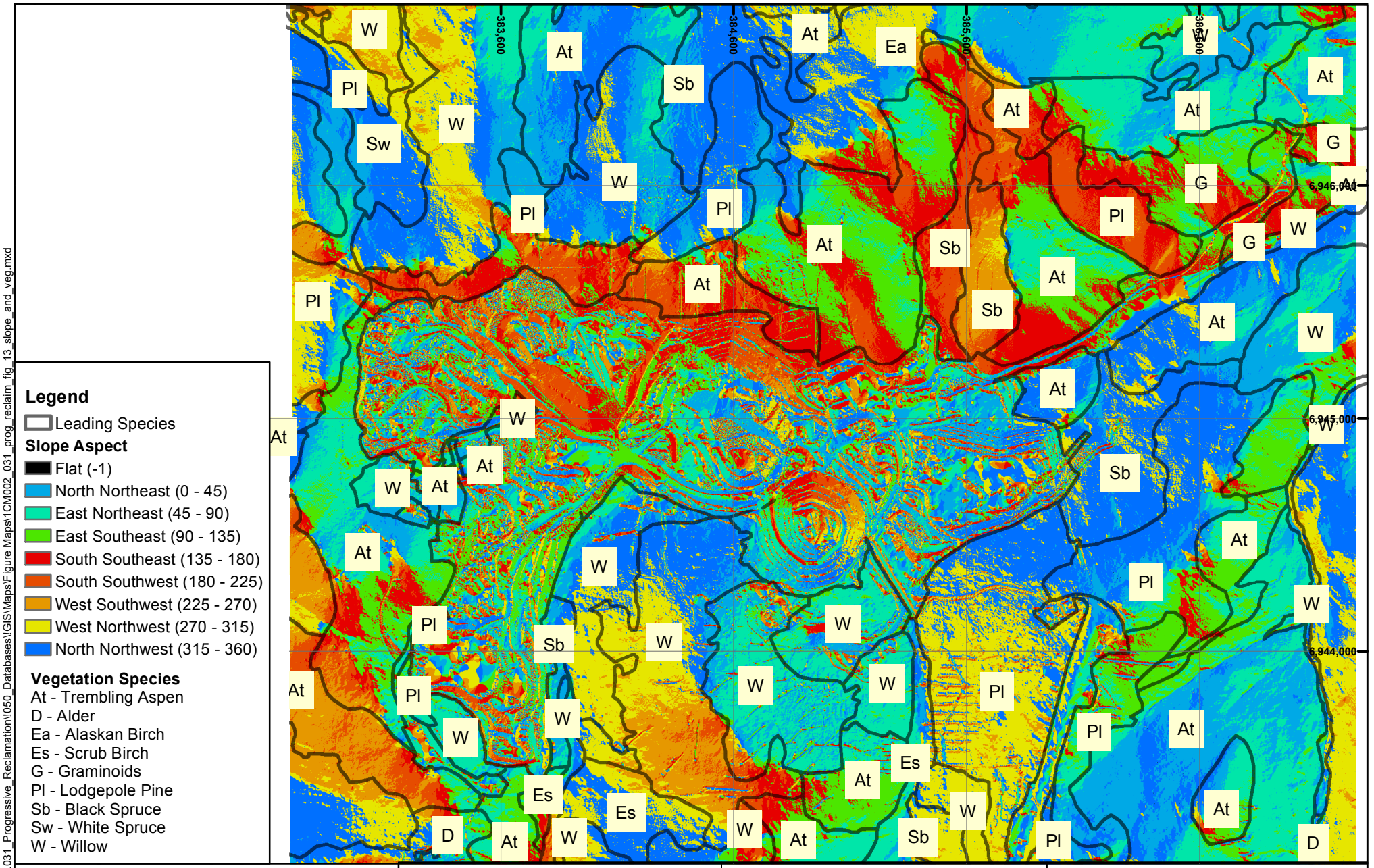


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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_13_slope_and_veg

Minto Mine

Closure Landform Design and RLUs

**Slope Aspect and Vegetation Categories**

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| April 2016 | EKH | 13 |

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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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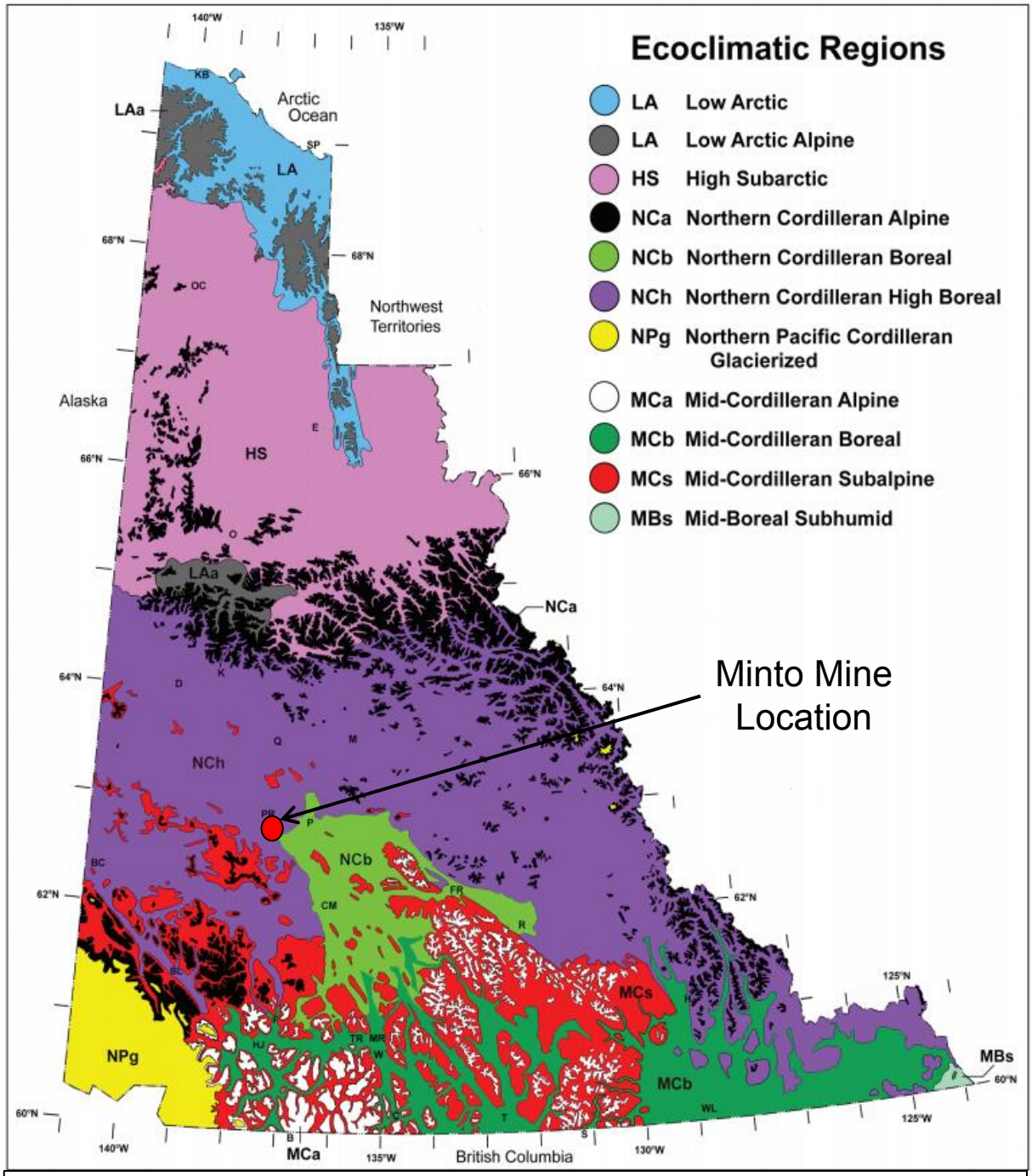
| | | **Terrestrial Ecozones of the Yukon** |
| Job No: 1CM002.031<br>Filename: Fig14_TerrestrialEcozones_rev02.pptx | Minto Mine | Date: April 2016 \| Approved: EKH \| Figure: **14** |




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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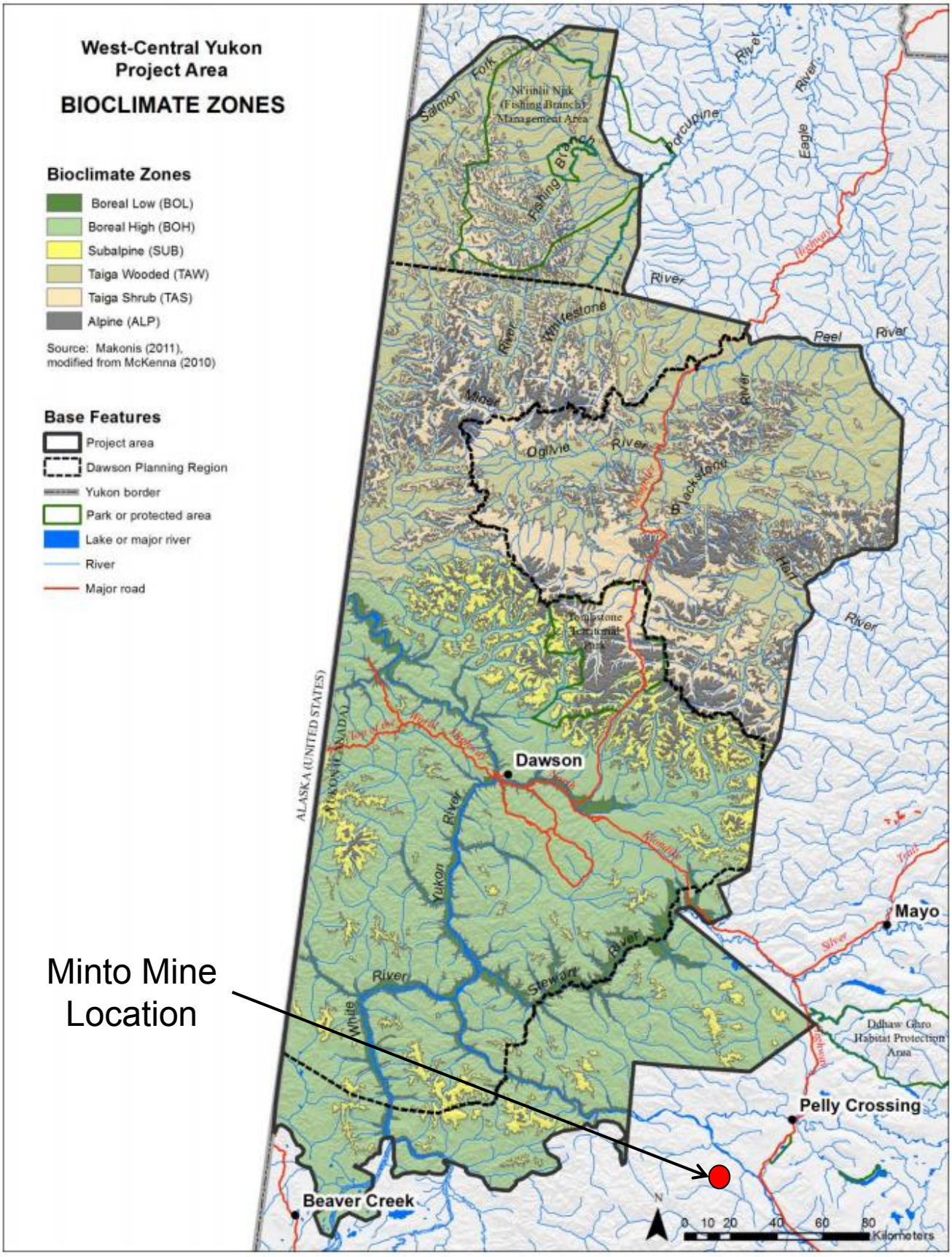
| | | **Ecoclimatic Regions of the Yukon** |
| Job No: 1CM002.031<br>Filename: Fig15_EcoclimaticZones_rev02.pptx | Minto Mine | Date: April 2016 \| Approved: EKH \| Figure: **15** |




Source: Makonis Consulting Ltd. (2012) Regional Ecosystems of West-Central Yukon

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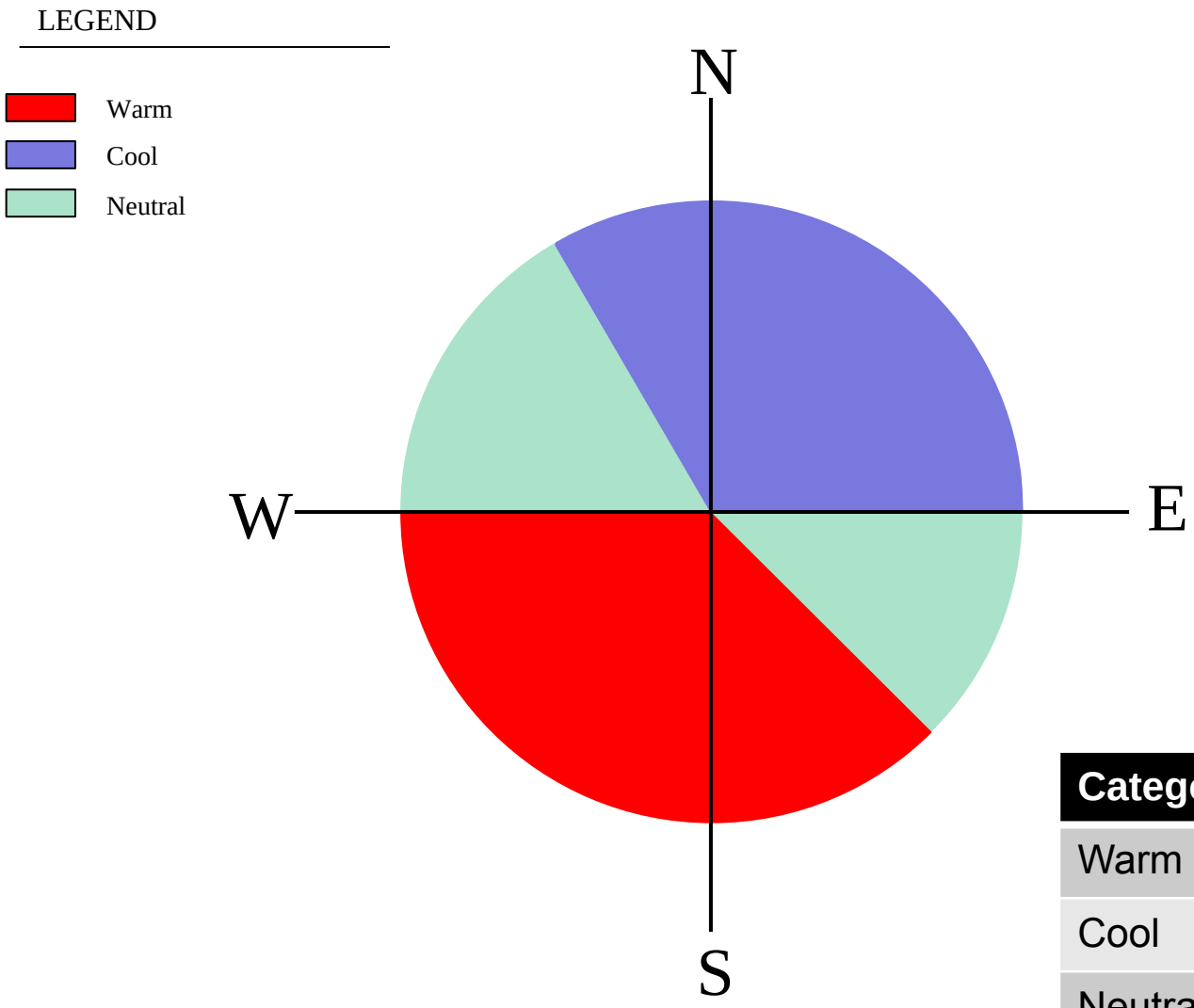
| | | **Biogeoclimatic Zones of West-Central Yukon** | | |
| Job No: 1CM002.031<br>Filename: Fig16_BiogeoclimaticZones_rev02.pptx | Minto Mine | Date: April 2016 | Approved: EKH | Figure: **16** |




| Category | Azimuth Range (º) |
|---|---|
| Warm | 135 – 270 |
| Cool | 330 – 90 |
| Neutral | 90 – 135, 270 – 330 |

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Job No: 1CM002.031
Filename: Fig17_SlopeAspectSchematic.pptx

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Closure Landform Design and RLUs

**Slope Aspect Category Limits Schematic**

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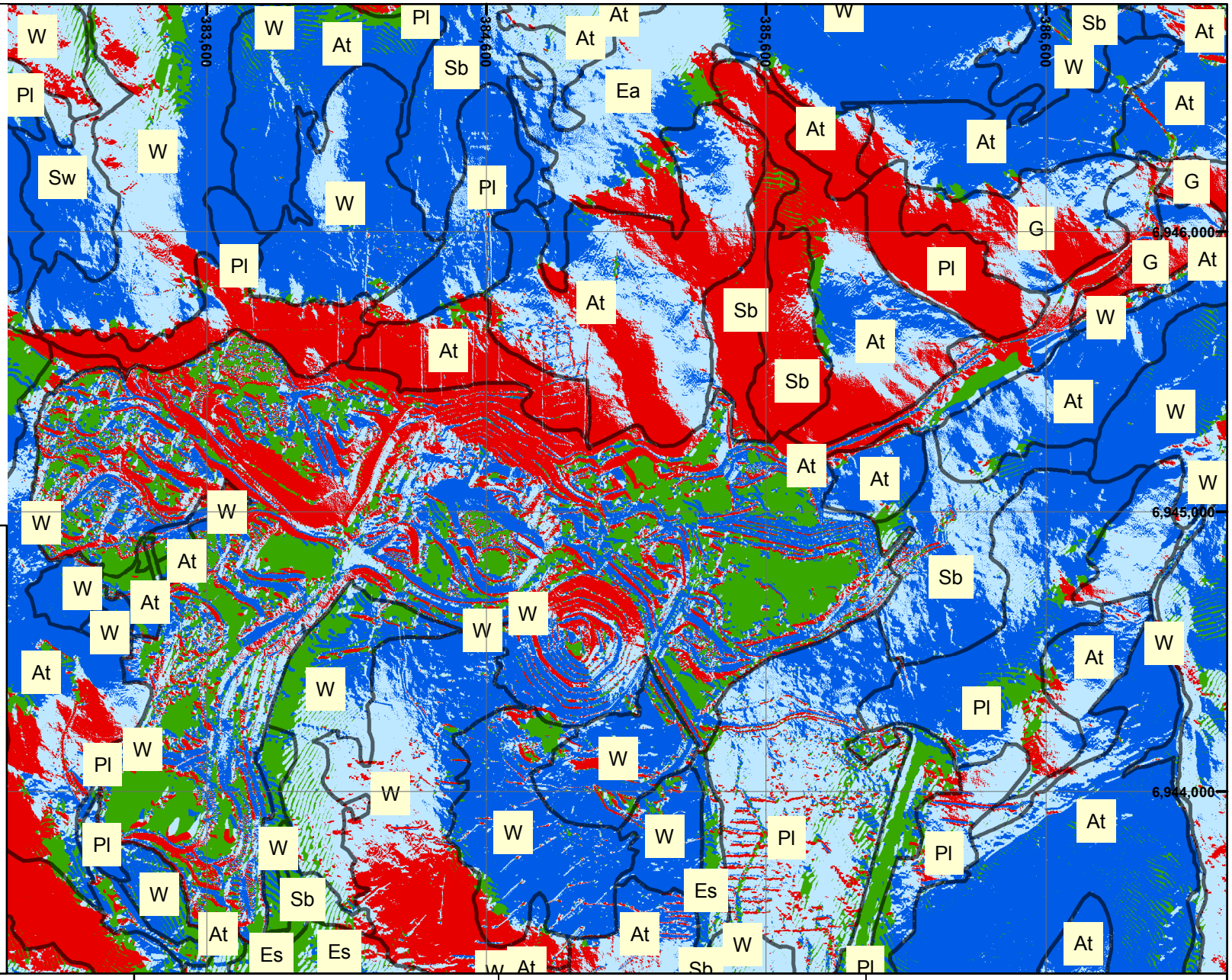
| April 2016 | IM | 17 |




## 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

0 500 1,000 Meters

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Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_18a_slope_angle_veg

Minto Mine

Closure Landform Design and RLUs

**Vegetation Categories and Slope Aspect**

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| April 2016 | EKH | 18 |

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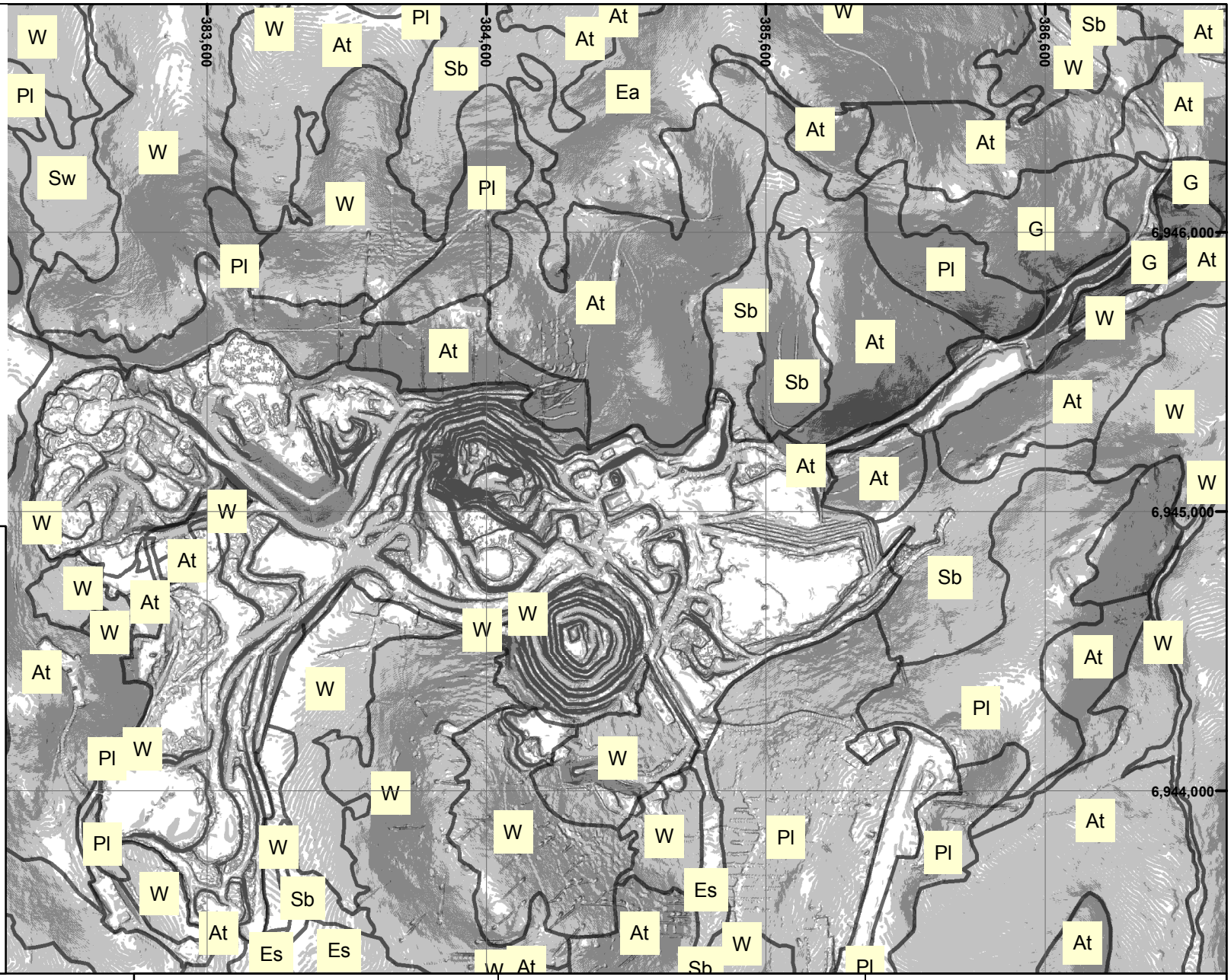


## Legend

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

0 500 1,000 Meters

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Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_18b_slope_angle_veg

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Minto Mine

Closure Landform Design and RLUs

**Vegetation Categories and Slope Angle Categories**

| Date: | Approved: | Figure: |
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| April 2016 | EKH | 19 |

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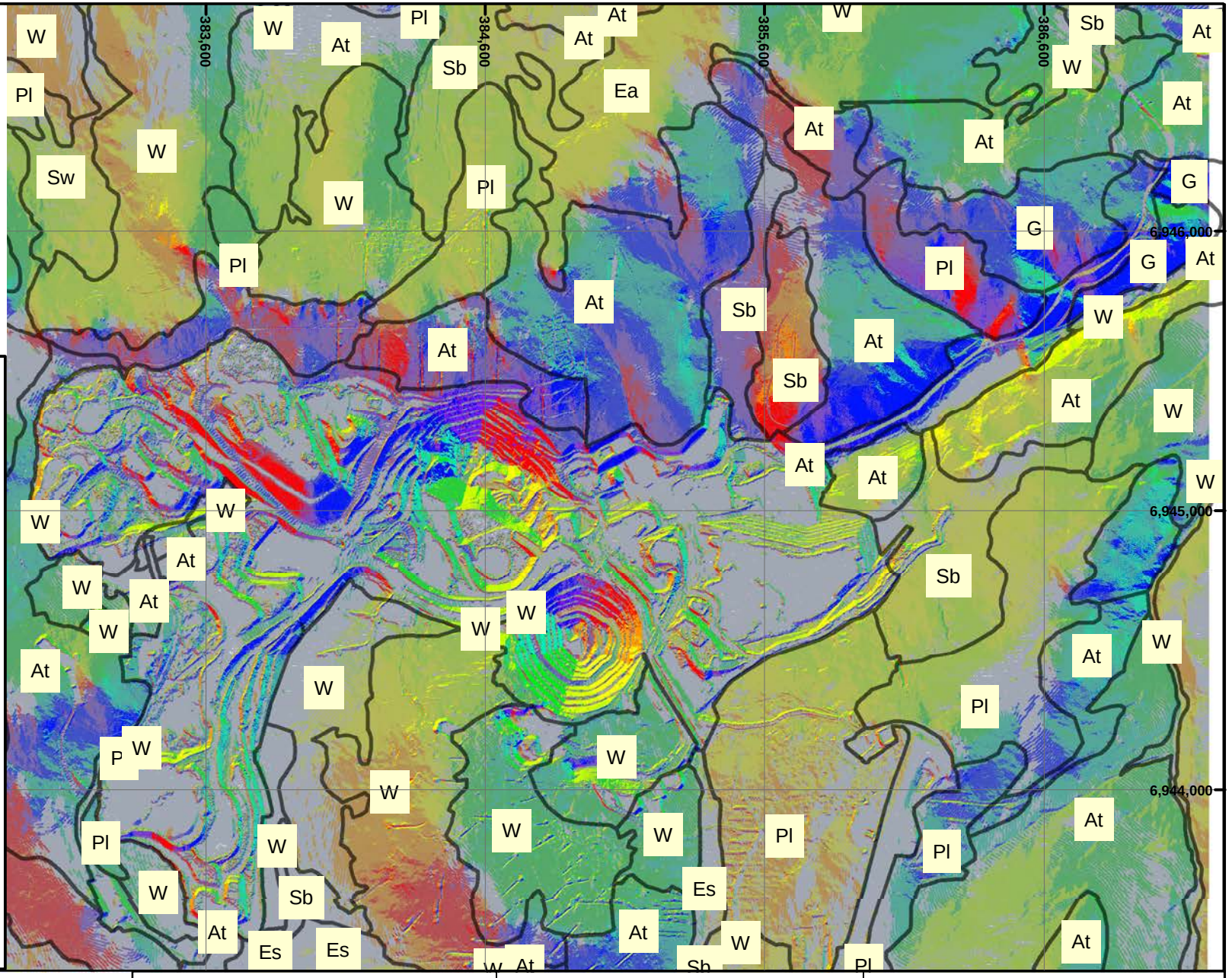
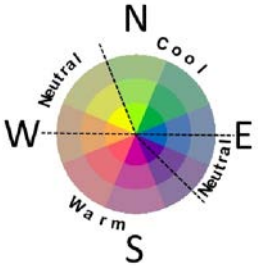



## Legend

**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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Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_19_slope_angle_veg

Minto Mine

Site-Wide RLU Designation

**Slope Aspect, Angle, and Vegetation Categories**

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| Nov 2015 | JBK | **20** |

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# Background Water Quality of Lower Minto Creek for Application in the Derivation of Post-Closure Water Quality Objectives

Report Prepared For:
Minto Explorations Ltd. Minto Mine
13-151 Industrial Road
Whitehorse, YT
Y1A 2V3

Prepared By:
Minnow Environmental Inc.
101-1025 Hillside Ave.
Victoria, BC
V8T 2A2

July 2016

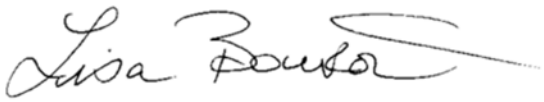
# Background Water Quality of Lower Minto Creek for Application in the Derivation of Post-Closure Water Quality Objectives

**Prepared for:**

**Minto Explorations Ltd. - Minto Mine**

**Prepared by:**

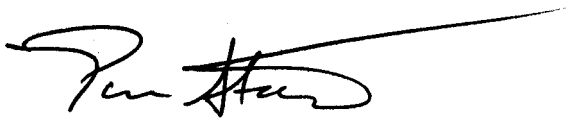
**Minnow Environmental Inc.**



**Lisa Bowron, M.Sc.**



**Tim Barrett, Ph.D.**



**Pierre Stecko, M.Sc., EP, RPBio**

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**APPENDIX A: JUNE 2ND 2016 MEETING MINUTES**
**APPENDIX B: RAW WATER QUALITY DATA**
**APPENDIX C: BOXPLOT OUTLIER EXAMINATION**
**APPENDIX D: WATER QUALITY DATA SUMMARY CALCULATIONS**

# 1.0 INTRODUCTION

## 1.1 Site Description

The Minto Mine is a high-grade copper mine located within Selkirk First Nation (SFN) Category A Settlement Land Parcel R-6A approximately 240 km northwest of Whitehorse, Yukon Territory (62°37'N latitude and 137°15'W longitude; Figure 1.1). It is owned and operated by Minto Explorations Ltd., a wholly owned subsidiary of Capstone Mining Corporation. Development of the mine was initiated in 1997, commercial operations started in October 2007 and the currently anticipated operating life is to 2018. The facility is permitted to conduct open pit and underground mining, and includes a mill with a capacity of 4,200 tonnes of ore per day. The Minto Mine produced 16,500 kilo-tonnes of copper in 2015 (average copper grade 1.38%). Mineral reserves as of January 1st 2016 were approximately 5,500 kilo-tonnes at an average copper grade of 1.87%.

In addition to open pit mines, underground mines and the mill, the Minto Mine site includes a number of waste rock dumps, a concentrate storage shed, tailings storage facilities, a water retention dam with a water storage pond, a water treatment plant, administrative offices, an airstrip and a camp (Figure 1.2). Mill tailings are stored in dry stack tailings storage facilities and in mined-out open pits. Mine-impacted seepage from the tailings storage facilities and under the Mill Valley Fill Extension (MVFE) is collected at the Mill Valley Fill Extension Stage 2 Collection Sump and is pumped to the main pit (Figure 1.2). Non-impacted water and treated mine-impacted water are collected in a Water Storage Pond (WSP; Figure 1.2). Effluent from the WSP is periodically discharged to Minto Creek under conditions specified in the Minto Mine's Water Use Licence (WUL) QZ14-031 (August 2015; YWB 2015). Minto Creek, in turn, discharges to the Yukon River approximately 7.7 km south-east of the WSP (Figure 1.2).

The Minto Mine is actively planning for closure, which could potentially occur as soon as late 2018. Conceptually, closure will include three stages: 1) an active closure period; 2) post-closure 1; and 3) post-closure 2. All major reclamation work will be completed during the active closure period. This will include re-contouring, cover placement, re-vegetation, construction of closure water conveyance channels, construction of wetland water treatment systems, and building demolition. Water will be actively managed during the active closure period. Post-closure 1 follows the completion of all major reclamation work and represents the period when the closure measures completed during the active closure period become fully established (e.g., vegetation is established, cover material self-armors, constructed wetlands are established, water flow through closure conveyances is established). Water treatment during post-closure 1 will be both active and passive. Post-closure 2 follows post-closure 1 and final




N
W E
S

160 0 160

Kilometers

MAP INFORMATION
Datum: NAD 83 Map Projection: UTM Zone 8V
Data Source: Department of Natural Resources Canada
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Creation Date: June 2016
Project No. 167202.0062

Map of Canada



**Figure 1.1: Location of the Minto Mine**

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## Features

- Final Effluent Discharge Point
- Waterbody
- Minto Creek Detention Structure
- Building
- Watercourse
- Mine Road
- Water Flow Direction

N
W E
S

0 175 350 700
Meters

MAP INFORMATION
Datum: NAD 83 Map Projection: UTM Zone 8V
Data Source: National Topographic Data Base (NTDB) compiled by Department of Natural Resources Canada at a scale of 1:50,000. All rights reserved.

Mine infrastructure data provided by Access Mining Consultants Inc.
Mine site contours derived from 2012 aerial imagery obtained from Challenger Geomatics.

Creation Date: June 2016
Project No. 167202.0062

# Figure 1.2: Minto Mine Site Layout and Receiving Environment

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A Tetra Tech Company

decommissioning (e.g., of the water treatment plant and potentially the camp). It represents the period when all closure measures are fully established, including final water conveyances. Water treatment during post-closure 2 will be by passive treatment only.

## 1.2 Background

The Minto Mine's WUL includes Water Quality Objectives (WQOs) for lower Minto Creek at water quality monitoring station W2 (Figure 1.3). These WQOs apply during the operational period and are anticipated to also apply during the active closure period and in post-closure 1. A separate set of WQOs will be developed for the post-closure 2 period. The Minto Mine's WUL requires a Reclamation and Closure Plan (RCP) that includes WQOs for post-closure that meet the criteria for non-degradation of background concentrations. Two approaches have been provided in the WUL as guidance to developing closure WQOs (YWB 2015; Clause 112):

1) Establish closure WQOs that meet the criteria for non-degradation of background concentrations in Minto and McGinty creeks; and

2) If non-degradation of water quality is not achievable, the closure WQOs shall be set at no more than 50% of the assimilative capacity of Minto Creek using the following formula:

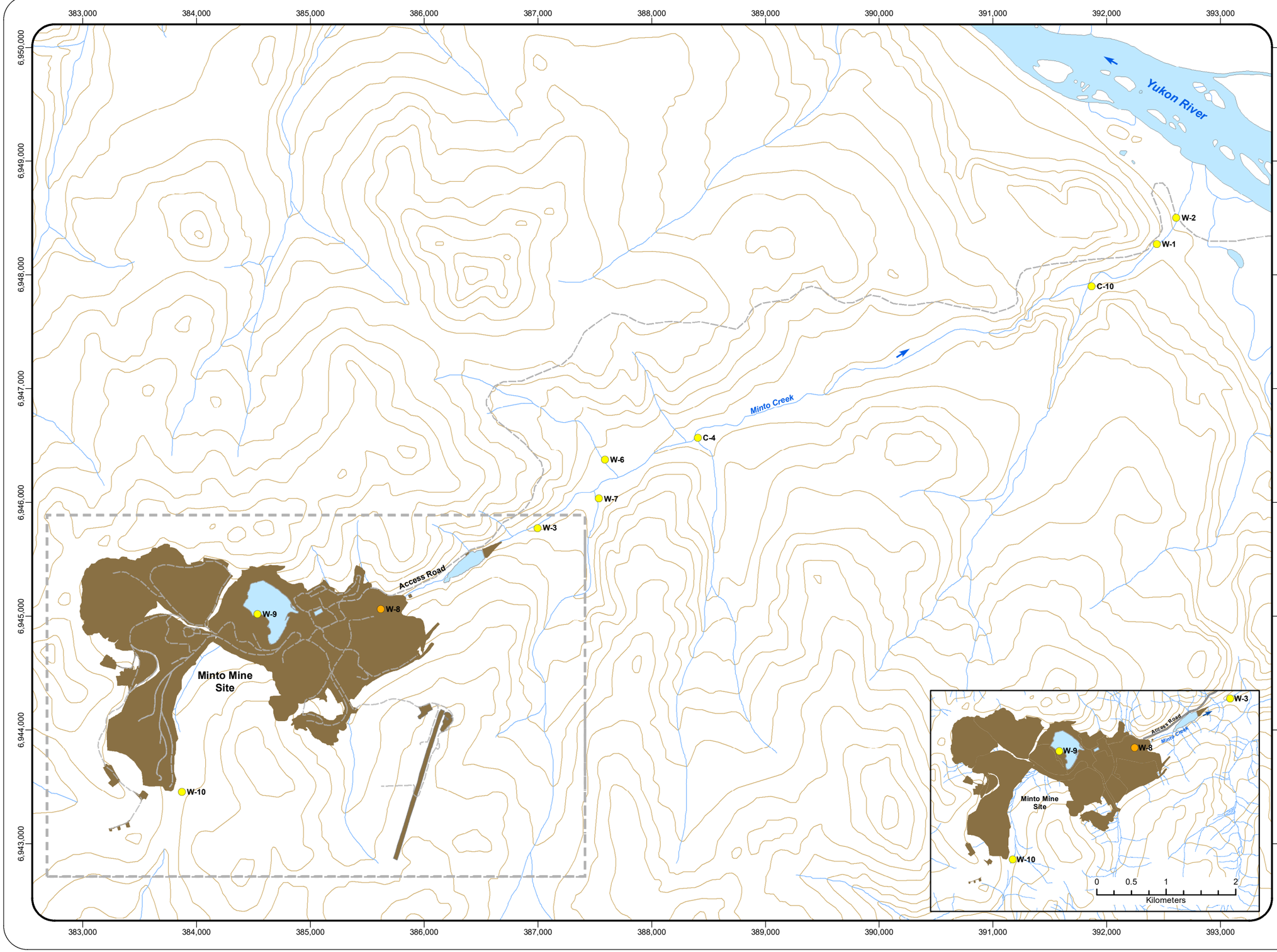
$$Closure\ WQO = BKGD + (0.5*[WQO_{Operations} - BKGD])$$

*where: BKGD = background concentration.*

Both approaches for the development of closure WQOs require a clearly-defined background water quality condition.

## 1.3 Objective

The objective of this report is to define the background water quality data set to be used to develop background water quality for lower Minto Creek and to determine background summary statistics for key analytes to be used in calculating the post-closure WQOs. This document outlines the approach used in considering what data points should be included to define background water quality. This document incorporates the outcomes of discussions among the Minto Mine, SFN, and technical consultants (Appendix A). These discussions covered a number of factors critical to the definition of background water quality, including representative sampling stations, contaminants of potential concern (COPCs), dealing with less than method detection limit (MDL) results, dealing with replicate results, identifying outliers, evaluation of possible data groupings, and designation of summary statistics. The




**Features**

- Excluded Water Quality Sampling Station
- Water Quality Sampling Station
- Waterbody
- Mine Footprint (2013)
- Watercourse
- Mine Road
- Contour
- Water Flow Direction

MAP INFORMATION
Datum: NAD 83 Map Projection: UTM Zone 8V
Data Source: National Topographic Data Base (NTDB) compiled by Department of Natural Resources Canada at a scale of 1:50,000. All rights reserved.

Mine infrastructure data provided by Access Mining Consultants Inc.
Mine site contours derived from 2012 aerial imagery obtained from Challenger Geomatics.

Creation Date: June 2016
Project No. 167202.0062

# Figure 1.3: Water Quality Sampling Stations, 2005 - 2013, used to Develop Background Concentrations

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background water quality data set is then used to calculate summary statistics for the COPCs for application as WQOs for the post-closure 2 period.

## 1.4 Report Organization

Section 2.0 provides a detailed overview of data organization and step-wise work-through the process of defining background water quality for the development of post-closure WQOs. Section 3.0 provides the proposed background water quality statistics. All references cited in the report are provided in Section 4.0.

# 2.0 DATA ORGANIZATION

Raw data from the Minto Mine's water quality database were received on May 31st, 2016. The database contained concentrations of water quality analytes measured throughout the open water season from 2005 to 2013. The database was sorted and organized as described below, to obtain a final water quality data set to be used to calculate the background concentrations of COPCs. For a few sampling dates, it was noted that water quality analyses were incomplete (e.g., incomplete dissolved metals in a multi-element scan). Minto Mine and Access Consulting Group were contacted to inquire about any missing data but older data sets were unavailable as they were collected by The North Air Group (Vancouver, BC).

## 2.1 Sampling Stations

The database included six sampling stations (W1, W2, W3, W8, W9 and W10) that were sampled during baseline studies in 2005 and were subsequently influenced by the mine (Figure 1.3; Appendix B). The database also included four reference sampling stations, W6 (2005 – 2013), W7 (2005 – 2013), C4 (2012, 2013) and C10 (2012, 2013; Figure 1.3; Appendix B).

Data collected at sampling station W8 were removed from the final background data set because water quality at station W8 was determined to poorly represent water quality at station W2 (lower Minto Creek; the point of WQO application). Data collected at W6 from 2009 to 2011 were not included, as these water quality samples were accidently collected at the Minto Creek main stem and not at the W6 tributary. These data would not represent background concentrations because the mine was operational from 2009 to 2011.

## 2.2 Contaminants of Potential Concern

The COPCs considered herein are those identified in the Water Use Licence (WUL; QZ14-031; YWB 2015). These COPCs are ammonia, pH (laboratory and field), nitrite, nitrate and the following dissolved metals; aluminum, arsenic, cadmium, chromium, copper, iron, lead, molybdenum, nickel, selenium, silver and zinc. In addition to the COPCs, several additional analytes are considered herein due to their importance as supporting parameters (e.g., parameters that may affect other WQOs). These include dissolved organic carbon (DOC), total and dissolved hardness, total suspended solids (TSS) and total dissolved solids (TDS).

## 2.3 Method Detection Limits

Concentrations that were reported as less than MDL and where the associated MDL exceeded the maximum detected concentration were removed from the data set. Such cases (and consequent removals) were observed for dissolved chromium (11% of samples) and dissolved

silver (24% of samples; Table 2.1). The remaining analytes reported as less than method detection limits (MDL) were substituted with half the MDL for calculations of summary statistics.

## 2.4 Replicate Samples

Some water samples were collected multiple times in one day at a given sampling station. To account for this, the average concentration of the analyte at a given station on the same day was used to represent the concentration for that day. The relative percent difference (RPD) of the minimum and maximum daily concentrations were calculated prior to calculating a daily mean concentration (Table 2.2). If the RPD was greater than 25% they were investigated further (Table 2.2).

Many analytes that had RPD greater than 25% were dissolved metals or TSS. Although there were instances where the RPD was greater than 25%, this is expected in multi-element scans. The investigation indicated no systemic problems (e.g., instances where all analytes had RPD greater than 25%), therefore all data were retained in the estimate of the daily mean. Regardless of RPDs between the minimum and maximum concentrations, the mean of concentrations measured on the same day were considered to best represent the concentration on that day.

## 2.5 Outliers

Outliers were evaluated based on data distributions for each analyte. The term “outlier” in the context of this report is used to refer to an observation that is unusually small or large relative to the distribution of observations. Outliers were investigated further to determine whether the value was naturally possible or whether the value could have resulted from an analytical error. The background data distributions for all analytes were non-normally distributed. Outliers were therefore identified using a non-parametric rule (the lower outer fence and upper outer fence) that is frequently used to identify outliers on boxplots (Dawson 2011).

*Lower outer fence = Q1 – 3 (IQR)*
*Upper outer fence = Q3 + 3 (IQR)*
*where: Q1 = 1$^{st}$ Quartile*
*Q3 = 3$^{rd}$ Quartile*
*IQR = Interquartile Range (Q3 – Q1)*

Observations less than the lower outer fence or greater than the upper outer fence were considered outliers. Although the rule is non-parametric, the calculation of the IQR is influenced by data transformations. The outlier evaluation was therefore conducted using untransformed and $\log_{10}$-transformed concentrations because many distributions of water

**Table 2.1: Samples with high Method Detection Limits (MDL) that were removed from the background dataset.**

| Analyte | Max Value (All Stations) | MDL greater than Max Value | Station | Total Sample Size | Number of samples that exceeded Max Value |
|---|---|---|---|---|---|
| Dissolved Chromium | 0.0017 | 0.0020 | W7 | 110 | 20 |
| Dissolved Silver | 0.000060 | 0.00010 | W6 | 23 | 1 |
| | | | W7 | 110 | 43 |

**Table 2.2: Relative Percent Difference (RPD) of maximum and minimum values for samples collected at the same sampling stations and date. Highlighted cells had RPD > 25%.**

| Station | Date | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickle (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W2 | 5/27/2005 | | | 100 | 21 | 138 | 0.026 | 0.0015 | 0.057 | 8.06 | | 0.016 | 0.00025 | 0.000025 | 0.00050 | 0.0033 | 0.16 | 0.00025 | 0.00050 | 0.0015 | 0.00050 | 0.000010 | |
| | | | | 72 | 79 | 80 | 0.010 | 0.00050 | 0.034 | 8.03 | | 0.011 | | | | | | | | | | | 0.0025 |
| **RPD** | | | | **32%** | **118%** | **53%** | **89%** | **100%** | **50%** | **0%** | | **41%** | | | | | | | | | | | |
| W10 | 5/27/2005 | | | 46 | 1.5 | 115 | 0.027 | 0.00050 | 0.0094 | 7.47 | | 0.14 | 0.00025 | 0.000025 | 0.00050 | 0.018 | 0.11 | 0.00025 | 0.00050 | 0.0016 | 0.00050 | 0.000010 | 0.0085 |
| | | | | | | | 0.010 | 0.00050 | | | | | 0.00025 | 0.000025 | 0.00050 | 0.00050 | 0.015 | 0.00025 | 0.00050 | 0.00050 | 0.00050 | 0.000010 | 0.0025 |
| **RPD** | | | | | | | **92%** | **0%** | | | | | **0%** | **0%** | **0%** | **189%** | **150%** | **0%** | **0%** | **105%** | **0%** | **0%** | **109%** |
| W7 | 6/15/2006 | | | | | | 0.027 | | | | | | | | | | | | | | | | |
| | | | 100 | | 53 | 114 | | | 0.18 | 7.86 | | 0.013 | 0.00040 | 0.0000050 | 0.00025 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.0010 | 0.00020 | | 0.00050 |
| **RPD** | | | | | | | | | | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | | | | | | 0.016 | | | | | | | | | | | | | | | | |
| | | | 128 | | 9.0 | | | | 0.18 | 7.87 | | 0.0080 | 0.00040 | 0.0000050 | 0.00025 | 0.0020 | 0.10 | 0.000050 | 0.00050 | 0.00210 | 0.00010 | | 0.00050 |
| **RPD** | | | | | | | | | | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | | | | | | 0.027 | | | | | | | | | | | | | | | | |
| | | | 129 | | | 180 | | | 0.12 | 7.92 | | 0.012 | 0.00040 | 0.0000050 | 0.00060 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00090 | 0.00010 | | 0.0030 |
| **RPD** | | | | | | | | | | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | 108 | 76 | 162 | 0.025 | 0.025 | 0.050 | 7.98 | | | | | | | | | | | | | |
| | | | | 120 | 76 | 158 | 0.025 | 0.050 | 0.050 | 7.97 | | | | | | | | | | | | | |
| | | | | 111 | 73 | 166 | 0.025 | 0.025 | 0.050 | 7.97 | | | | | | | | | | | | | |
| **RPD** | | | | **11%** | **4%** | **5%** | **0%** | **67%** | **0%** | **0%** | | | | | | | | | | | | | |
| W7 | 7/18/2007 | 14.3 | 128 | 126 | 4.0 | 170 | 0.025 | 0.025 | 0.30 | 7.72 | | 0.011 | 0.00050 | 0.0000050 | 0.0010 | 0.0020 | 0.040 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0060 |
| | | | | 125 | 7.0 | 182 | 0.025 | 0.025 | 0.30 | 7.80 | | | | | | | | | | | | | |
| | | | | 125 | 6.0 | 184 | 0.025 | 0.025 | 0.30 | 7.83 | | | | | | | | | | | | | |
| **RPD** | | | | **1%** | **55%** | **8%** | **0%** | **0%** | **0%** | **1%** | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | 0.025 | | | | | | | | | | | | | | | | |
| | | | | | | | 0.025 | | | | | | | | | | | | | | | | |
| | | | | | | | 0.025 | | | | | | | | | | | | | | | | |
| | | | | 122 | 4.0 | 198 | | 0.025 | 0.20 | 8.04 | | | | | | | | | | | | | |
| | | | | 123 | 4.0 | 192 | | 0.025 | 0.20 | 8.05 | | | | | | | | | | | | | |
| | | | | 128 | 6.0 | 186 | | 0.025 | 0.20 | 8.04 | | | | | | | | | | | | | |
| **RPD** | | | | **5%** | **0%** | **6%** | | **0%** | **0%** | **0%** | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | 130 | 3.0 | 176 | 0.025 | 0.14 | 0.010 | 7.74 | | | | | | | | | | | | | |
| | | | | 128 | 10 | 182 | 0.025 | 0.14 | 0.010 | 7.74 | | | | | | | | | | | | | |
| | | | | 130 | 7.0 | 166 | 0.025 | 0.13 | 0.010 | 7.74 | | | | | | | | | | | | | |
| | | | | | 6.0 | 172 | | 0.13 | 0.010 | 7.68 | | | | | | | | | | | | | |
| **RPD** | | | | **2%** | **108%** | **9%** | **0%** | **7%** | **0%** | **1%** | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | 186 | | 1.0 | 264 | 0.025 | 0.070 | 0.010 | 8.40 | | 0.010 | 0.00010 | 0.000040 | 0.0012 | 0.00050 | 0.010 | 0.000050 | 0.0016 | 0.00050 | 0.00030 | | 0.0010 |
| | | | 193 | | 1.0 | 274 | 0.025 | 0.040 | 0.010 | 8.41 | | 0.010 | 0.00040 | 0.000040 | 0.0014 | 0.0020 | 0.070 | 0.00010 | 0.0017 | 0.0020 | 0.00030 | | 0.0030 |
| | | | 182 | | 1.0 | 270 | 0.025 | 0.070 | 0.010 | 8.40 | | 0.010 | 0.00030 | 0.000040 | 0.00030 | 0.0010 | 0.010 | 0.000050 | 0.0017 | 0.00050 | 0.00030 | | 0.0010 |
| | | | | | 1.0 | 262 | | 0.040 | 0.010 | 8.40 | | | | | | | | | | | | | |
| **RPD** | | | **6%** | | **0%** | **4%** | **0%** | **55%** | **0%** | **0%** | | **0%** | **120%** | **0%** | **129%** | **120%** | **150%** | **67%** | **5%** | **120%** | **0%** | | **100%** |
| W7 | 6/3/2008 | | | 97 | 1.0 | 134 | 0.025 | 0.040 | 0.030 | 8.01 | | | | | | | | | | | | | |
| | | | | 96 | 19 | 132 | 0.025 | 0.040 | 0.040 | 8.01 | | | | | | | | | | | | | |
| | | | | 101 | 26 | 146 | 0.025 | 0.040 | 0.040 | 8.03 | | | | | | | | | | | | | |
| | | | 92 | | | | | | | | | 0.005 | 0.00010 | 0.000040 | 0.0013 | 0.00050 | 0.050 | 0.000050 | 0.0012 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| **RPD** | | | | **5%** | **185%** | **10%** | **0%** | **0%** | **29%** | **0%** | | | | | | | | | | | | | |

**Table 2.2: Relative Percent Difference (RPD) of maximum and minimum values for samples collected at the same sampling stations and date. Highlighted cells had RPD > 25%.**

| Station | Date | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickle (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/6/2008 | | | 123 | 92 | 162 | 0.025 | 0.0050 | 0.14 | 7.9 | | | | | | | | | | | | | |
| | | | | 123 | 139 | 168 | 0.025 | 0.0050 | 0.14 | 7.9 | | | | | | | | | | | | | |
| | | | | 125 | 85 | 170 | | 0.0050 | 0.15 | 8.0 | | | | | | | | | | | | | |
| | | 9.0 | 123 | | | | 0.025 | | | | | 0.014 | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.070 | 0.000050 | 0.0010 | 0.0010 | 0.00010 | 0.000060 | 0.0060 |
| **RPD** | | | | **2%** | **48%** | **5%** | **0%** | **0%** | **7%** | **1%** | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | 4.0 | 192 | 0.025 | | | 7.84 | | | | | | | | | | | | | |
| | | | | | 6.0 | 188 | 0.025 | | | 7.83 | | | | | | | | | | | | | |
| | | | | | 7.0 | 168 | 0.025 | | | 7.85 | | | | | | | | | | | | | |
| | | 11 | 123 | | | | | | | | | 0.0090 | 0.00050 | 0.0000050 | 0.00050 | 0.0010 | 0.078 | 0.000050 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| **RPD** | | | | | **55%** | **13%** | **0%** | | | **0%** | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | | | | | | | | | |
| | | 6.9 | 123 | | 7.0 | 180 | | | 0.12 | 7.87 | 8.24 | | | | | | | | | | | | |
| **RPD** | | | | | | | | | | | | | | | | | | | | | | | |
| W7 | 10/25/2009 | 8.7 | 126 | 141 | 2.0 | 130 | 0.010 | 0.0025 | 0.15 | 8.10 | 8.23 | 0.0070 | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |
| | | | | | 2.0 | 110 | | | | 8.00 | | | | | | | | | | | | | |
| **RPD** | | | | | **0%** | **17%** | | | | **1%** | | | | | | | | | | | | | |
| W7 | 9/12/2010 | | | 105 | | | | | | | | | | | | | | | | | | | |
| | | 17 | 107 | 102 | 11 | 210 | 0.039 | 0.0025 | 0.030 | 7.98 | 8.02 | 0.016 | 0.00050 | 0.000050 | | 0.0010 | 0.23 | 0.00010 | 0.0010 | 0.0020 | 0.00040 | | 0.0050 |
| **RPD** | | | | **3%** | | | | | | | | | | | | | | | | | | | |
| W7 | 5/6/2012 | 17 | 46 | 45 | 2.4 | 80 | 0.010 | 0.0025 | 0.010 | 6.05 | | 0.030 | 0.00043 | 0.000013 | 0.00050 | 0.0030 | 0.43 | 0.00010 | 0.00050 | 0.0011 | 0.000050 | 0.000010 | 0.0025 |
| | | 17 | 46 | 45 | 4.2 | 88 | 0.011 | 0.0025 | 0.010 | 5.74 | 7.10 | 0.044 | 0.00044 | 0.000016 | 0.00050 | 0.0027 | 0.46 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| **RPD** | | **2%** | **1%** | **0%** | **55%** | **10%** | **10%** | **0%** | **0%** | **5%** | | **39%** | **2%** | **21%** | **0%** | **10%** | **8%** | **0%** | **0%** | **9%** | **0%** | **0%** | **0%** |
| W7 | 6/19/2013 | 11 | 113 | 114 | 11 | 152 | 0.052 | 0.0025 | 0.14 | 8.08 | | 0.013 | 0.00052 | 0.0000050 | 0.00050 | 0.0012 | 0.29 | 0.00010 | 0.0015 | 0.0013 | 0.00011 | 0.000010 | 0.0025 |
| | | 11 | 114 | 115 | 10 | 164 | 0.040 | 0.0025 | 0.14 | 8.07 | 8.60 | 0.013 | 0.00051 | 0.0000050 | 0.00050 | 0.0012 | 0.29 | 0.00010 | 0.0016 | 0.0012 | 0.00019 | 0.000010 | 0.0025 |
| **RPD** | | **7%** | **1%** | **1%** | **10%** | **8%** | **26%** | **0%** | **1%** | **0%** | | **7%** | **2%** | **0%** | **0%** | **7%** | **2%** | **0%** | **6%** | **8%** | **53%** | **0%** | **0%** |
| C4 | 10/18/2013 | 13 | 129 | 142 | 16 | 214 | 0.091 | 0.0025 | 0.069 | 8.18 | | 0.022 | 0.001060 | 0.000005 | 0.00050 | 0.0011 | 1.2 | 0.00010 | 0.00050 | 0.0023 | 0.000050 | 0.000010 | 0.0025 |
| | | 13 | 129 | 139 | 16 | 220 | 0.080 | 0.0025 | 0.065 | 8.24 | 7.16 | 0.025 | 0.001070 | 0.000005 | 0.00050 | 0.0012 | 1.2 | 0.00010 | 0.0012 | 0.0025 | 0.000050 | 0.000010 | 0.0025 |
| **RPD** | | **2%** | **0%** | **2%** | **0%** | **3%** | **13%** | **0%** | **6%** | **1%** | | **12%** | **1%** | **0%** | **0%** | **5%** | **1%** | **0%** | **82%** | **8%** | **0%** | **0%** | **0%** |
| C10 | 9/8/2013 | 16 | 150 | 163 | 25 | 186 | 0.046 | 0.0076 | 0.18 | 7.94 | | 0.025 | 0.001660 | 0.0000050 | 0.00050 | 0.0013 | 1.3 | 0.00010 | 0.00050 | 0.0025 | 0.000050 | 0.000010 | 0.0025 |
| | | 16 | 150 | 162 | 22 | 206 | 0.055 | 0.0070 | 0.19 | 8.13 | 8.16 | 0.024 | 0.001580 | 0.000010 | 0.0017 | 0.0013 | 1.3 | 0.00010 | 0.00050 | 0.0025 | 0.000050 | 0.000010 | 0.0025 |
| **RPD** | | **1%** | **0%** | **1%** | **16%** | **10%** | **18%** | **8%** | **9%** | **2%** | | **5%** | **5%** | **67%** | **109%** | **6%** | **2%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** |

quality analytes are approximately log-normal. Since pH is reported on the logarithmic scale, the outlier rule was applied to the pH data that were untransformed and anti-logged. Any observations that were identified as potential outliers based on both the untransformed and $log_{10}$-transformed scale (Appendix C) were investigated further. When Q3 could not be estimated because it was below the MDL, the upper outer fence was estimated using the following formula:

$$MDL_{Q3} + 3 * MDL_{Q3}$$

*where:* $MDL_{Q3}$ *= the MDL corresponding to the observation at the third quartile*

One observation - dissolved arsenic at station C4 on November 17th 2013 (0.0056 mg/L) - was identified as an outlier based on the above rules (Table 2.3). Further investigation of this potential outlier included consideration of potential elevations of other analytes and consideration of analyte ratios (i.e., chemical signature). Hardness, dissolved iron and dissolved manganese were also elevated in this sample. Because the potential outlying value appeared to be naturally possible, was consistent with observations of elevation of other analytes, and there was no unequivocal evidence of unusual ratios of arsenic relative to other analytes (Appendix Table D.1), the concentration of dissolved arsenic at station C4 was retained in the background data set.

## 2.6 Baseline Investigation

Water samples collected in 2005 before mine operations were considered baseline data. Concentrations of COPCs were plotted using an individual value plot for all sampling stations to determine if concentrations for each station were similar to station W2 and could be used as baseline data to represent station W2 (Figure 2.1). The median and 95$^{th}$ percentile of the background data sets for each analyte were calculated separately for W2 and all sampling stations (including W2) in 2005 (Table 2.4). There appears to be close agreement between the median and 95$^{th}$ percentiles for the two data sets (i.e., W2 and all sampling stations in 2005; Table 2.4). Total hardness differed most among data sets (was greater at station W2), but summary statistics for many analytes did not differ between W2 and all sampling stations (Table 2.4). In general, the distribution of concentrations of COPCs at station W2 was similar to the distribution of concentrations of COPCs from the other sampling stations in 2005, supporting the use of the designated reference water quality data set as representative of station W2.

**Table 2.3: Outliers identified and rationale for removing or keeping the data point.**

| Station | Date | Identified Outlier | | | |
|---|---|---|---|---|---|
| | | Analyte | Value | Decision | Rationale |
| C4 | 11/17/2013 | Dissolved Arsenic (mg/L) | 0.0056 | Retained | High Hardness, dissolved iron and dissolved manganese in sample. |

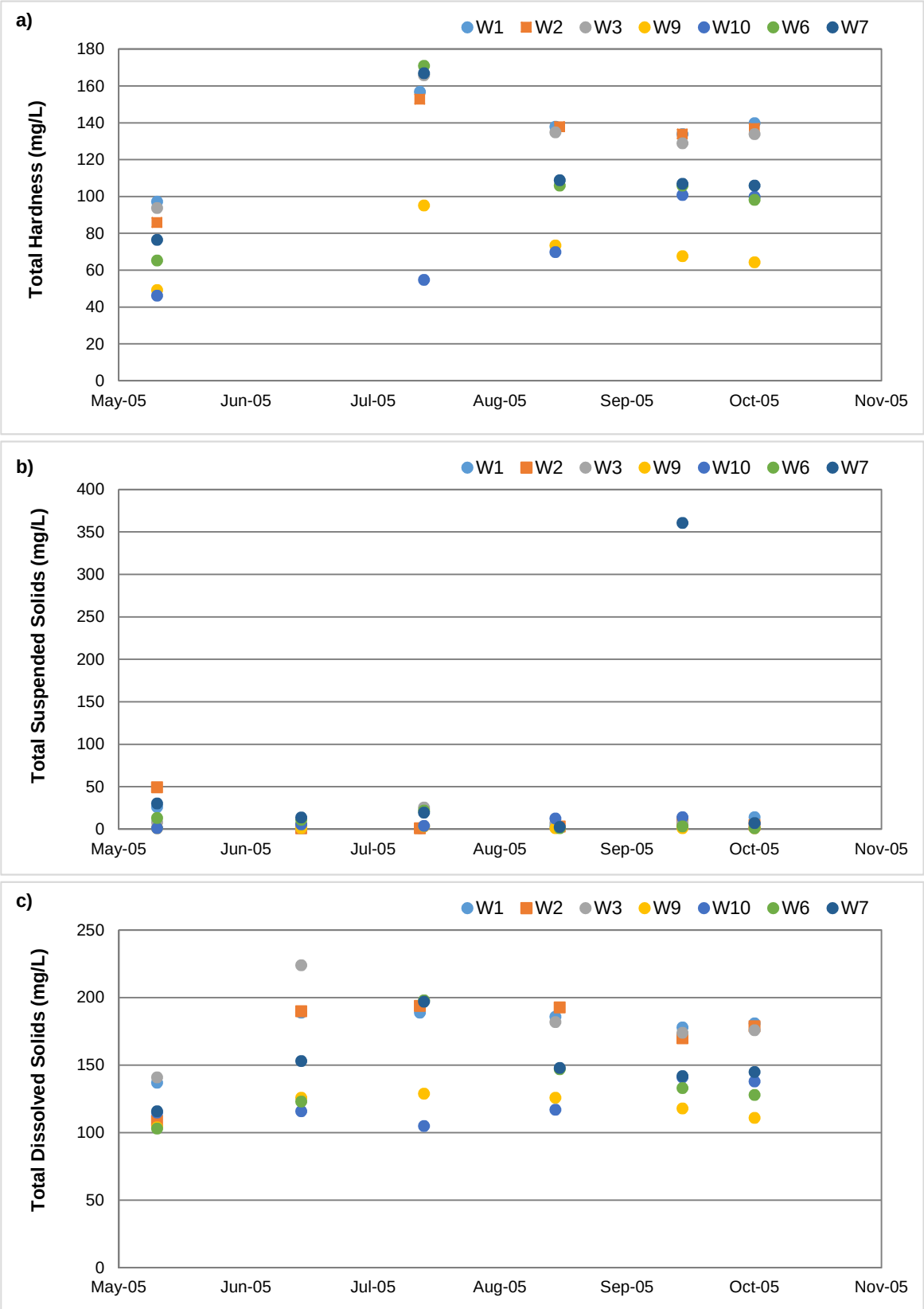



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

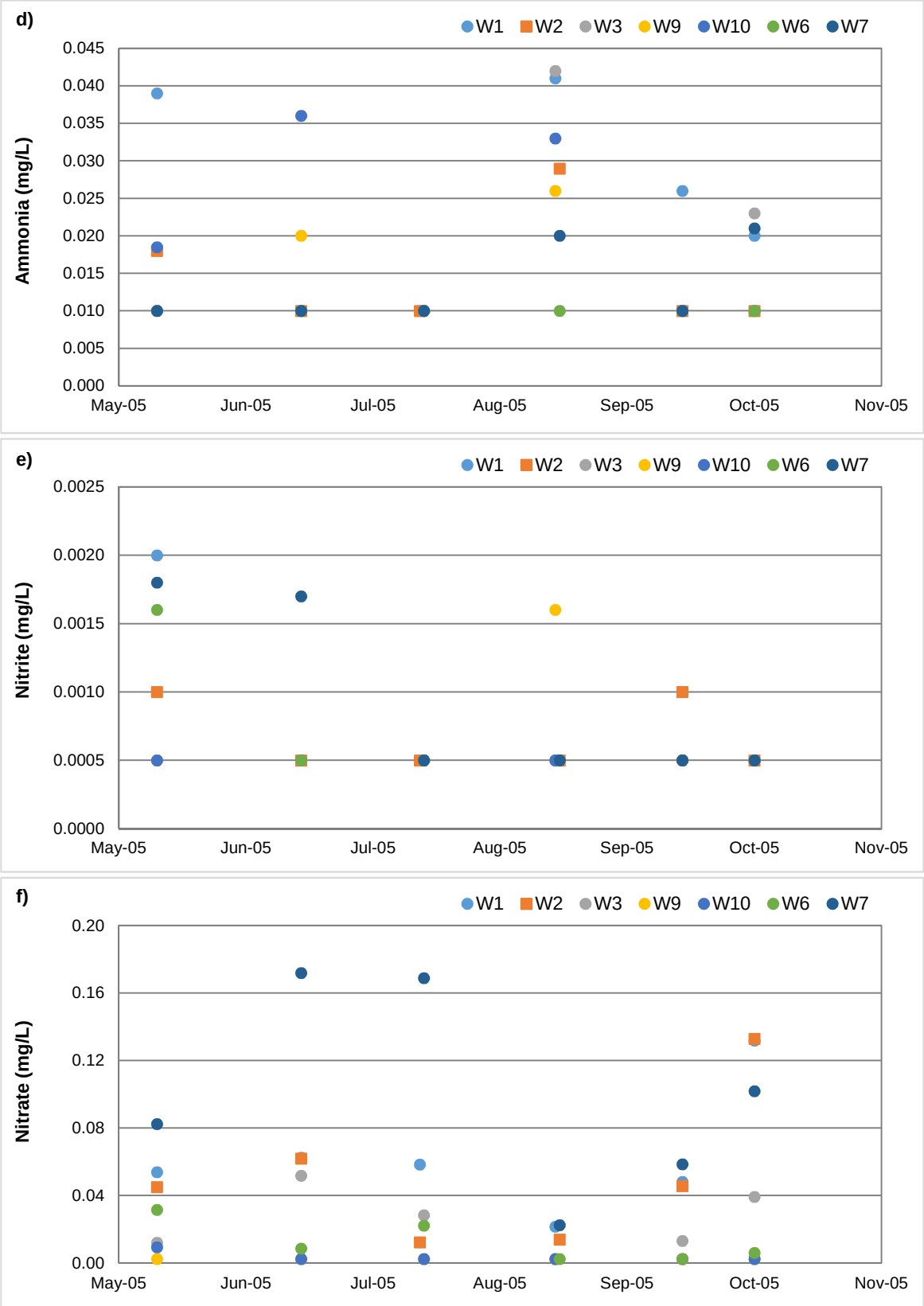



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

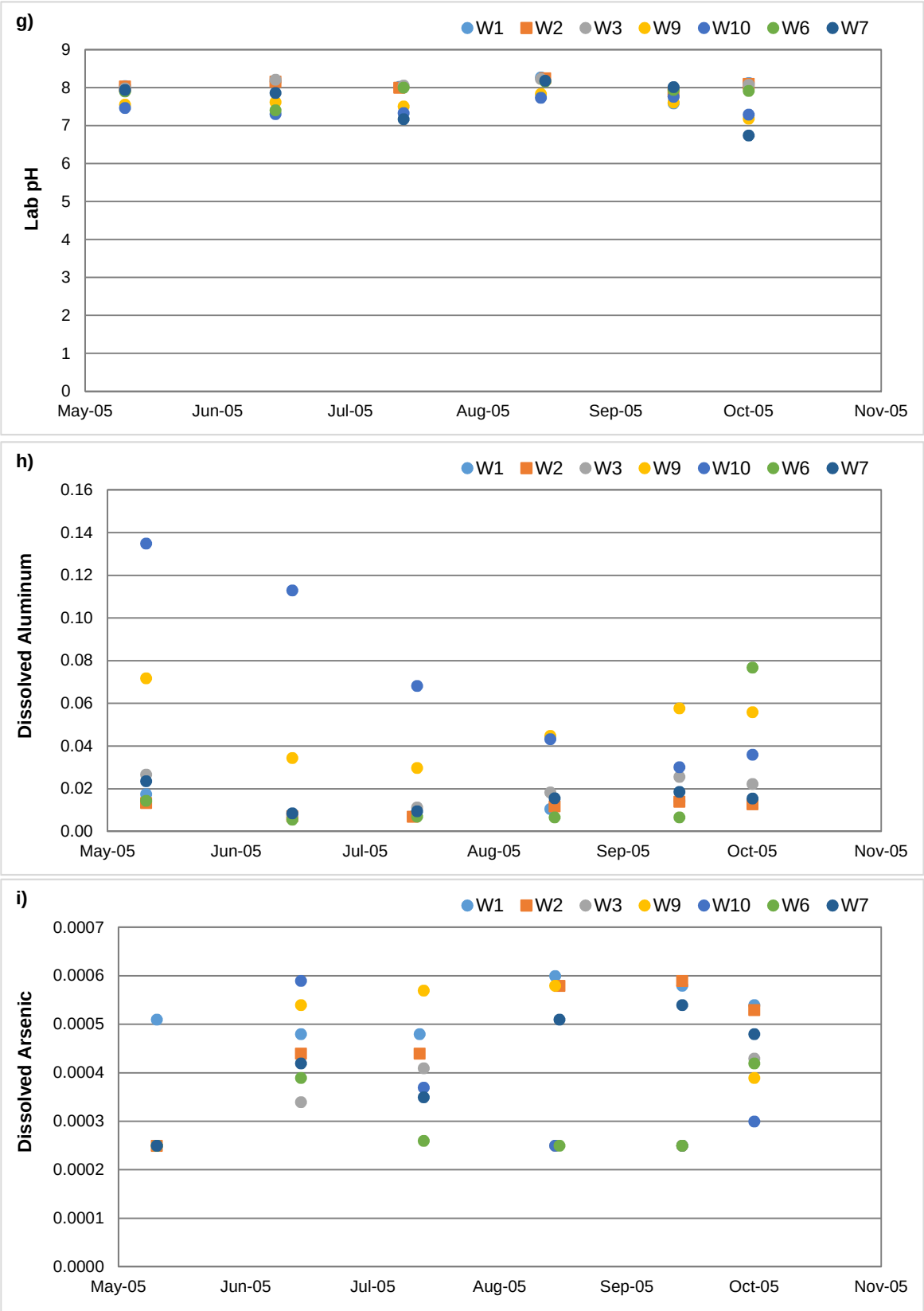



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

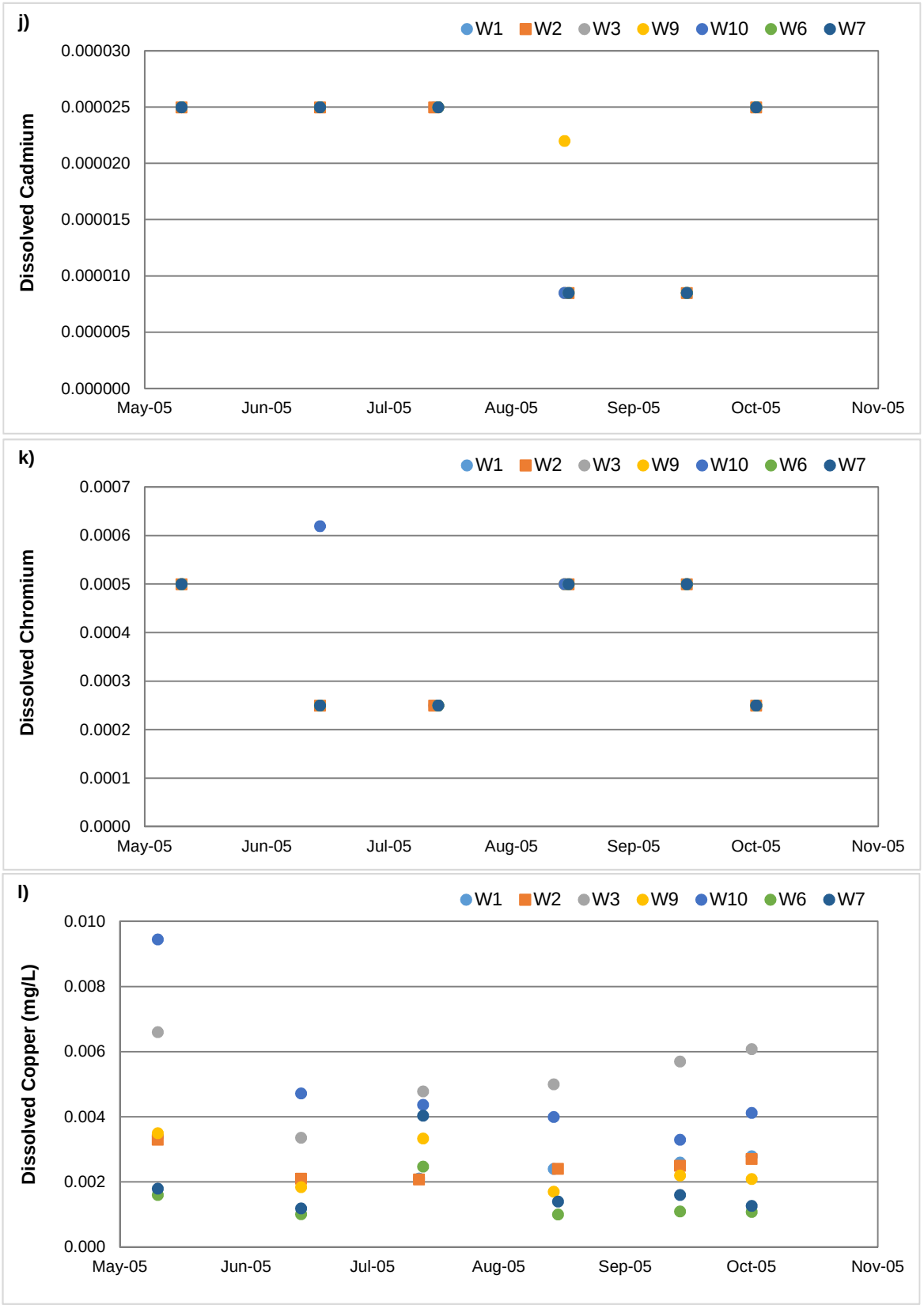



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

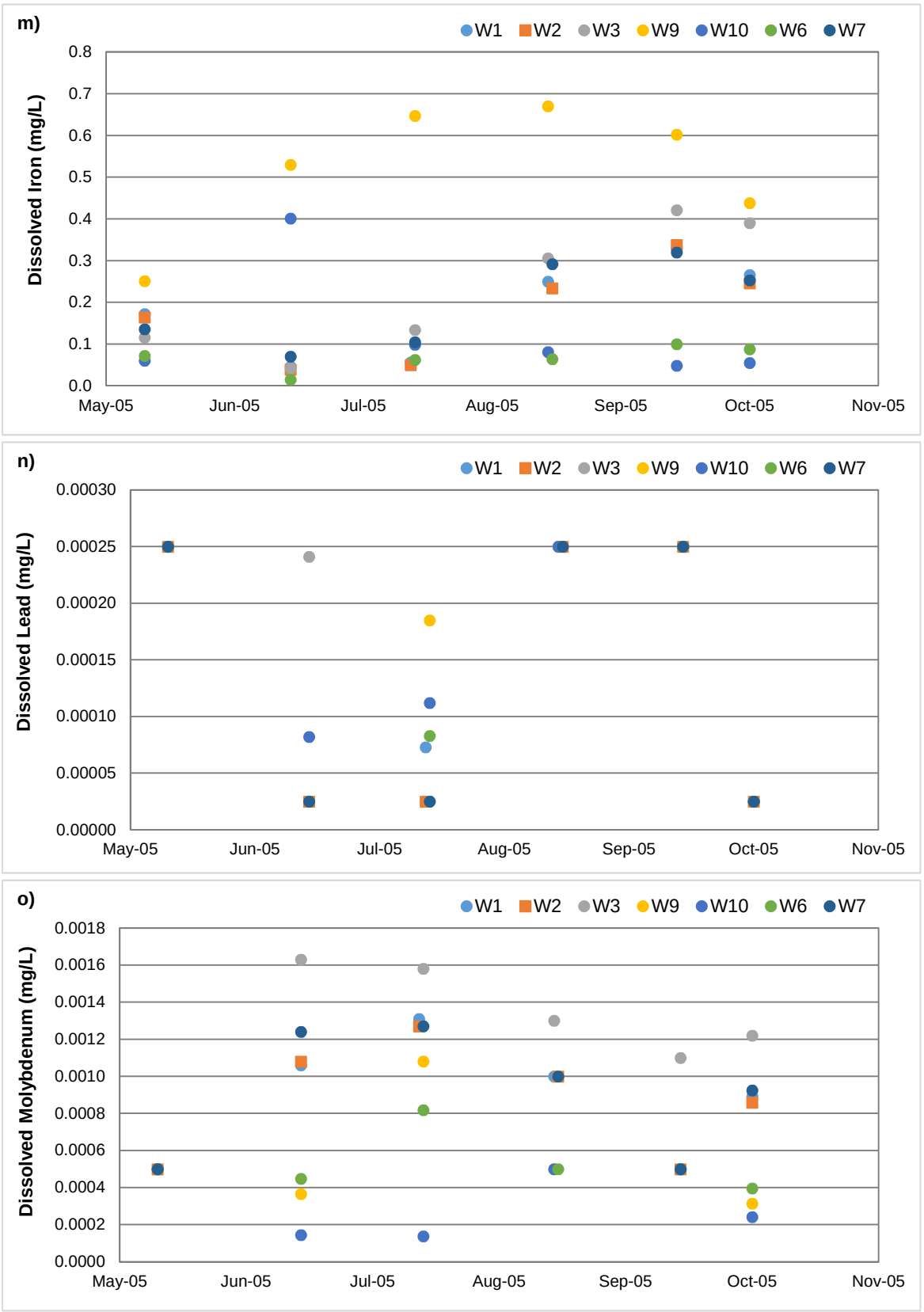



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

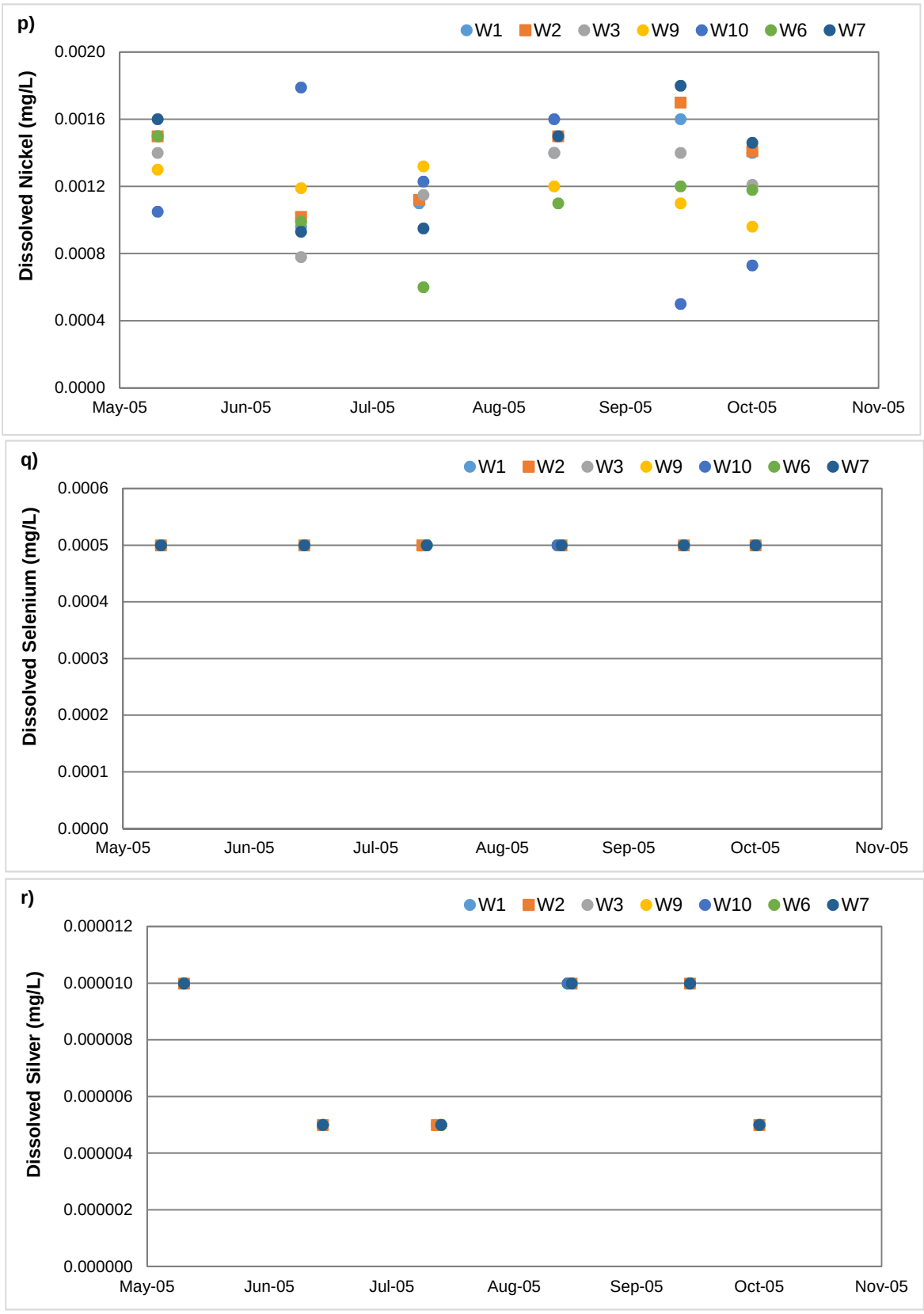



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

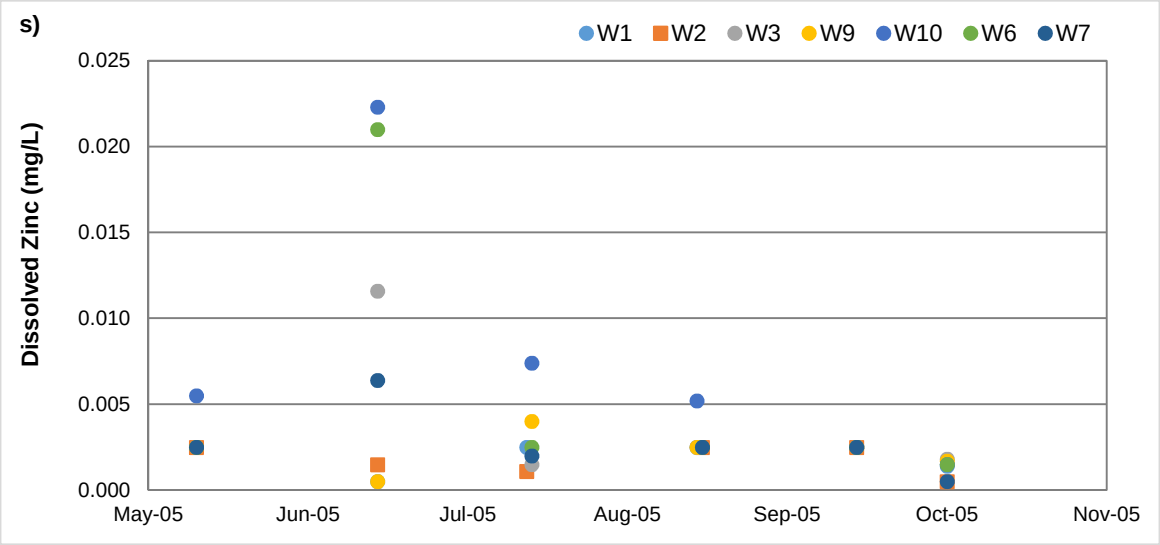



**Figure 2.1: Baseline concentrations of contaminants of potential concern, Minto Mine, 2005. Values less than method detection limits were substituted with half of the MDL value.**

**Table 2.4: Median and 95th Percentile for W2 and All sampling stations (including W2) in 2005.**

| Analyte | W2 | | | All Sampling Stations | | |
|---|---|---|---|---|---|---|
| | Sample Size | Median | 95th Percentile | Sample Size | Median | 95th Percentile |
| Total Hardness (mg/L) | 5 | 137 | 150 | 35 | 106 | 166 |
| TSS (mg/L) | 6 | 4.5 | 40 | 42 | 5.8 | 30 |
| TDS (mg/L) | 6 | 185 | 194 | 42 | 144 | 198 |
| Ammonia (mg/L) | 6 | 0.010 | 0.026 | 42 | 0.010 | 0.039 |
| Nitrite (mg/L) | 6 | 0.00050 | 0.0010 | 42 | 0.00050 | 0.0017 |
| Nitrate (mg/L) | 6 | 0.046 | 0.12 | 42 | 0.018 | 0.13 |
| Lab pH (pH Units) | 6 | 8.08 | 8.24 | 42 | 7.95 | 8.24 |
| Dissolved Aluminum (mg/L) | 6 | 0.012 | 0.014 | 42 | 0.016 | 0.077 |
| Dissolved Arsenic (mg/L) | 6 | 0.00049 | 0.00059 | 42 | 0.00042 | 0.00059 |
| Dissolved Cadmium (mg/L) | 6 | 0.000025 | 0.000025 | 42 | 0.000025 | 0.000025 |
| Dissolved Chromium (mg/L) | 6 | 0.00038 | 0.00050 | 42 | 0.00050 | 0.00050 |
| Dissolved Copper (mg/L) | 6 | 0.0025 | 0.0032 | 42 | 0.0025 | 0.0061 |
| Dissolved Iron (mg/L) | 6 | 0.20 | 0.32 | 42 | 0.15 | 0.60 |
| Dissolved Lead (mg/L) | 6 | 0.00014 | 0.00025 | 42 | 0.00025 | 0.00025 |
| Dissolved Molybdenum (mg/L) | 6 | 0.0009295 | 0.0012 | 42 | 0.00050 | 0.0013 |
| Dissolved Nickel (mg/L) | 6 | 0.0015 | 0.0017 | 42 | 0.0012 | 0.0017 |
| Dissolved Selenium (mg/L) | 6 | 0.00050 | 0.00050 | 42 | 0.00050 | 0.00050 |
| Dissolved Silver (mg/L) | 6 | 0.0000075 | 0.000010 | 42 | 0.0000075 | 0.000010 |
| Dissolved Zinc (mg/L) | 6 | 0.0020 | 0.0025 | 42 | 0.0025 | 0.011 |

## 2.7 Data Grouping

Water quality sampling was typically conducted in batches or “sampling campaigns” such that water quality samples were collected from multiple sampling stations on the same day or within a one week period. Samples collected on the same day may not be fully independent of each other, and therefore different methods of grouping the data were explored. Three options were evaluated: Option 1 did not involve any grouping (i.e., all data were used), Option 2 grouped samples by week, and Option 3 grouped samples by month (Table 2.5; Figure 2.2; Appendix Table D.1). Data were combined for Option 2 by calculating the mean from all sampling stations that were collected within a one week period (Table D.2). Data were combined for Option 3 in two steps: 1) by calculating the mean for each individual sampling station by month; and 2) then calculating the mean of the monthly sampling station means (Table D.3).

## 2.8 Summary Statistics

The designated reference water quality data set, developed as outlined above, was used to calculate summary statistics for each of the three options. For each analyte, the sample size, mean, median and 95th percentile were calculated for all stations combined over time for all three Options (Table 2.6). In addition, annual medians were calculated for each of the three options, and the 95th percentile of those annual medians was calculated (Table 2.7).

**Table 2.5: Data grouping decisions for Option 2 and Option 3.**

| Year | Month | Day | Sampling Station | | | | | | | | | Option 2 | Option 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W1 | W2 | W3 | W9 | W10 | W6 | W7 | C4 | C10 | | |
| 2005 | May | 27 | X | X | X | X | X | X | X | - | - | • Average of all sampling stations | - |
| | June | 30 | X | X | X | X | X | X | X | - | - | • Average of all sampling stations | - |
| | July | 28 | X | X | - | - | - | - | - | - | - | • Average of all sampling stations from both days | - |
| | | 29 | - | - | X | X | X | X | X | - | - | | |
| | August | 29 | X | - | X | X | X | - | - | - | - | • Average of all sampling stations from both days | - |
| | | 30 | - | X | - | - | - | X | X | - | - | | |
| | September | 28 | X | X | X | X | X | X | X | - | - | • Average of all sampling stations | - |
| | October | 15 | X | X | X | X | X | X | X | - | - | • Average of all sampling stations | - |
| 2006 | June | 2 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | • Average of W7 sampling stations<br>• Take average of W7 (averaged value) and W6 |
| | | 8 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 15 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 23 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 28 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | July | 7 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 12 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 20 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 26 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | August | 2 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations<br>• Take average of W7 (averaged value) and W6 |
| | | 10 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 25 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | |
| | | 30 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | September | 6 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | • Average of W7 sampling stations<br>• Take average of W7 (averaged value) and W6 |
| | | 13 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 20 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 28 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | October | 4 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 12 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| 2007 | June | 5 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations<br>• Take average of W7 (averaged value) and W6 |
| | | 20 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | |
| | July | 18 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | August | 24 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | September | 18 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | - |
| | October | 30 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| 2008 | April | 22 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | June | 3 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations<br>• Take average of W7 (averaged value) and W6 |
| | | 17 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | |
| | August | 6 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | September | 18 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | - |
| | October | 28 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| 2009 | April | 30 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | June | 8 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | July | 28 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | August | 6 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 25 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | | 31 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | October | 7 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 25 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |

**Table 2.5: Data grouping decisions for Option 2 and Option 3.**

| Year | Month | Day | Sampling Station | | | | | | | | | Option 2 | Option 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W1 | W2 | W3 | W9 | W10 | W6 | W7 | C4 | C10 | | |
| 2010 | April | 19 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 27 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on both days | |
| | | 29 | - | - | - | - | - | - | X | - | - | | |
| | May | 1 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | • Average of W7 sampling stations |
| | | 3 | - | - | - | - | - | - | X | - | - | | |
| | | 5 | - | - | - | - | - | - | X | - | - | | |
| | | 7 | - | - | - | - | - | - | X | - | - | | |
| | | 9 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | |
| | | 10 | - | - | - | - | - | - | X | - | - | | |
| | | 12 | - | - | - | - | - | - | X | - | - | | |
| | | 14 | - | - | - | - | - | - | X | - | - | | |
| | | 16 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | |
| | | 17 | - | - | - | - | - | - | X | - | - | | |
| | | 19 | - | - | - | - | - | - | X | - | - | | |
| | | 21 | - | - | - | - | - | - | X | - | - | | |
| | | 23 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | |
| | | 25 | - | - | - | - | - | - | X | - | - | | |
| | | 27 | - | - | - | - | - | - | X | - | - | | |
| | | 29 | - | - | - | - | - | - | X | - | - | | |
| | | 31 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | |
| | June | 2 | - | - | - | - | - | - | X | - | - | | • Average of W7 sampling stations |
| | | 4 | - | - | - | - | - | - | X | - | - | | |
| | | 6 | - | - | - | - | - | - | X | - | - | | |
| | | 14 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | |
| | | 16 | - | - | - | - | - | - | X | - | - | | |
| | | 18 | - | - | - | - | - | - | X | - | - | | |
| | | 20 | - | - | - | - | - | - | X | - | - | | |
| | | 22 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations on all four days | |
| | | 24 | - | - | - | - | - | - | X | - | - | | |
| | | 26 | - | - | - | - | - | - | X | - | - | | |
| | | 28 | - | - | - | - | - | - | X | - | - | | |
| | July | 5 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | August | 5 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | September | 12 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | October | 8 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| 2011 | April | 27 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | May | 2 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | June | 1 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 16 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | |
| | July | 1 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | August | 2 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of W7 sampling stations |
| | | 16 | - | - | - | - | - | - | X | - | - | • Average of W7 sampling stations | |
| | | 19 | - | - | - | - | - | - | X | - | - | | |
| | September | 12 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | October | 6 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | November | 22 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |

**Table 2.5: Data grouping decisions for Option 2 and Option 3.**

| Year | Month | Day | Sampling Station | | | | | | | | | Option 2 | Option 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W1 | W2 | W3 | W9 | W10 | W6 | W7 | C4 | C10 | | |
| 2012 | January | 24 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | February | 25 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | March | 5 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | April | 24 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | May | 6 | - | - | - | - | - | - | X | X | - | • Average of all sampling stations from both days | - |
| | | 12 | - | - | - | - | - | - | - | - | X | | |
| | June | 19 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | July | 17 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | • Average sampling stations separately<br>• Using station averages take average for all days |
| | | 30 | - | - | - | - | - | X | X | - | X | • Average of all sampling stations | |
| | August | 1 | - | - | - | - | - | - | - | X | - | • Use C4 sampling station | • Average sampling stations separately<br>• Using station averages take average for all days |
| | | 8 | - | - | - | - | - | - | X | X | - | • Average of all sampling stations from all days | |
| | | 9 | - | - | - | - | - | X | - | - | - | | |
| | | 10 | - | - | - | - | - | - | - | - | X | | |
| | | 23 | - | - | - | - | - | - | X | - | - | • Average of all sampling stations from all days | |
| | | 25 | - | - | - | - | - | X | - | X | - | | |
| | | 27 | - | - | - | - | - | - | - | - | X | | |
| | September | 13 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | - |
| | October | 13 | - | - | - | - | - | X | - | - | - | • Average of all sampling stations from both days | - |
| | | 16 | - | - | - | - | - | - | X | - | - | | |
| | November | 2 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | • Average of all sampling stations from both days |
| | | 12 | - | - | - | - | - | X | - | - | - | • Use W6 sampling station | |
| | December | 29 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| 2013 | April | 30 | - | - | - | - | - | - | X | - | - | • Use W7 sampling station | - |
| | May | 14 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | - |
| | June | 19 | - | - | - | - | - | - | X | - | - | • Average of all sampling stations from both days | - |
| | | 22 | - | - | - | - | - | X | - | X | X | | |
| | July | 12 | - | - | - | - | - | X | - | - | - | • Average of all sampling stations from both days | • Average of all sampling stations |
| | | 13 | - | - | - | - | - | - | X | - | - | | |
| | | 19 | - | - | - | - | - | - | - | X | - | • Average of all sampling stations from both days | |
| | | 23 | - | - | - | - | - | - | - | - | X | | |
| | August | 21 | - | - | - | - | - | - | X | - | - | • Average of all sampling stations from both days | - |
| | | 22 | - | - | - | - | - | X | - | X | X | | |
| | September | 6 | - | - | - | - | - | X | X | X | - | • Average of all sampling stations from both days | - |
| | | 8 | - | - | - | - | - | - | - | - | X | | |
| | October | 7 | - | - | - | - | - | X | - | - | - | • Use W6 sampling station | • Average of all sampling stations |
| | | 18 | - | - | - | - | - | - | - | X | X | • Average of all sampling stations from both days | |
| | | 21 | - | - | - | - | - | - | X | - | - | | |
| | November | 16 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations from both days | - |
| | | 17 | - | - | - | - | - | - | - | X | - | | |
| | December | 7 | - | - | - | - | - | X | X | - | - | • Average of all sampling stations | - |

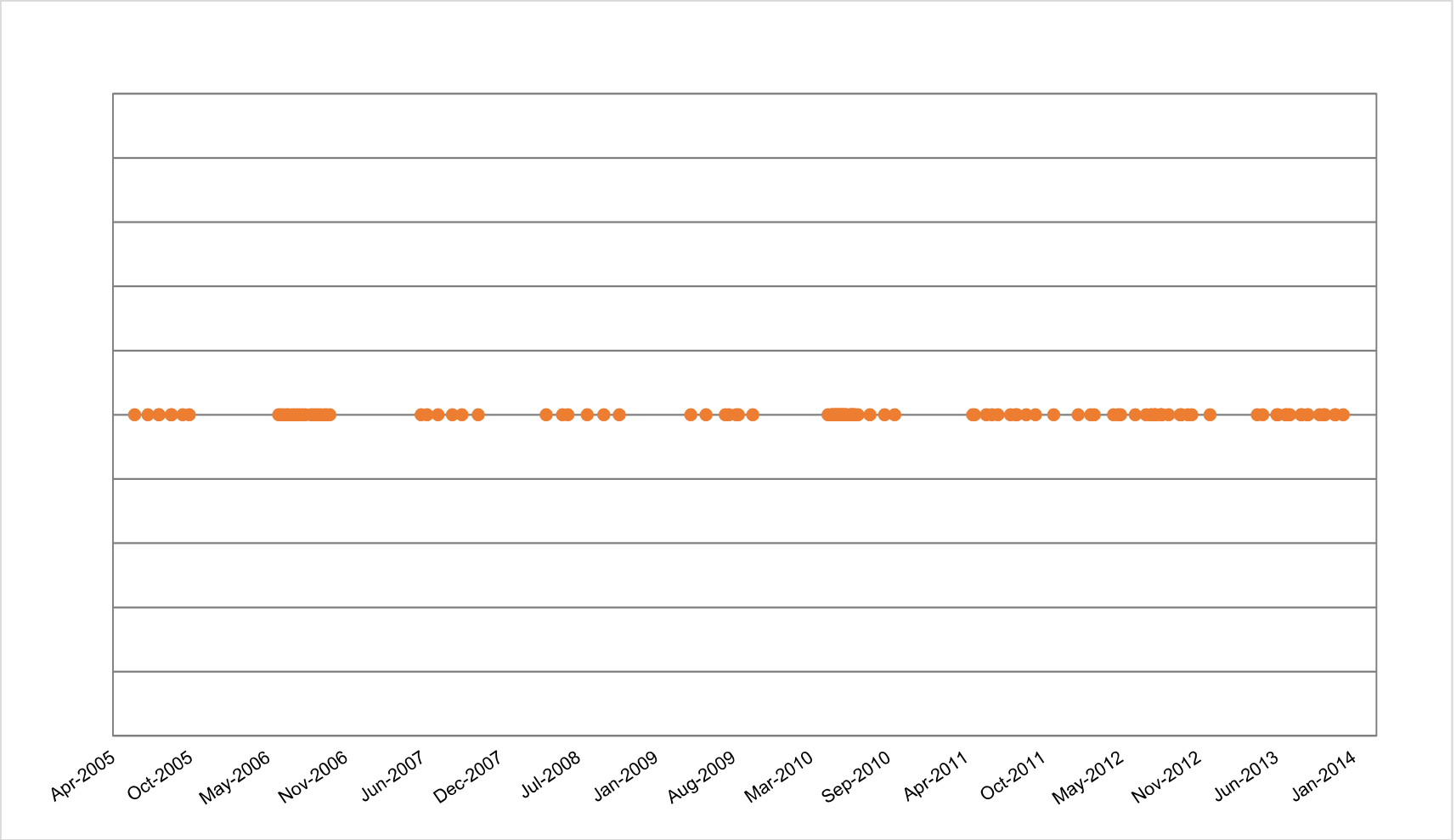



**Figure 2.2: Distribution of water quality sampling events from 2005 to 2013.**

**Table 2.6: Summary statistics for Options 1, 2 and 3.**

| Analytes | Option 1 (No Grouping) | | | | Option 2 (Grouped by Week) | | | | Option 3 (Grouped by Month) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sample Size | Mean | Median | 95th Percentile | Sample Size | Mean | Median | 95th Percentile | Sample Size | Mean | Median | 95th Percentile |
| DOC (mg/L) | 108 | 12 | 11 | 22 | 59 | 12 | 12 | 21 | 46 | 13 | 12 | 21 |
| Dissolved Hardness (mg/L) | 134 | 113 | 117 | 162 | 80 | 115 | 120 | 169 | 53 | 113 | 118 | 181 |
| Total Hardness (mg/L) | 149 | 120 | 121 | 200 | 66 | 120 | 121 | 185 | 49 | 120 | 124 | 185 |
| TSS (mg/L) | 184 | 114 | 11 | 772 | 89 | 89 | 11 | 485 | 61 | 77 | 11 | 278 |
| TDS (mg/L) | 178 | 153 | 150 | 217 | 83 | 156 | 158 | 216 | 62 | 158 | 160 | 226 |
| Ammonia (mg/L) | 175 | 0.040 | 0.021 | 0.15 | 83 | 0.036 | 0.025 | 0.12 | 56 | 0.037 | 0.025 | 0.12 |
| Nitrite (mg/L) | 161 | 0.0071 | 0.0025 | 0.025 | 67 | 0.010 | 0.0025 | 0.038 | 52 | 0.010 | 0.0025 | 0.040 |
| Nitrate (mg/L) | 181 | 0.085 | 0.067 | 0.21 | 85 | 0.10 | 0.090 | 0.22 | 57 | 0.091 | 0.075 | 0.22 |
| Lab pH (pH Units) | 187 | 7.93 | 8.00 | 8.26 | 91 | 7.92 | 7.97 | 8.20 | 61 | 7.90 | 7.96 | 8.18 |
| Field pH (pH Units) | 93 | 7.73 | 7.76 | 8.30 | 46 | 7.72 | 7.77 | 8.24 | 33 | 7.71 | 7.80 | 8.13 |
| Dissolved Aluminum (mg/L) | 179 | 0.026 | 0.016 | 0.071 | 88 | 0.025 | 0.014 | 0.056 | 59 | 0.023 | 0.019 | 0.053 |
| Dissolved Arsenic (mg/L) | 179 | 0.00057 | 0.00044 | 0.0015 | 88 | 0.00053 | 0.00041 | 0.0013 | 59 | 0.00053 | 0.00041 | 0.0011 |
| Dissolved Cadmium (mg/L) | 179 | 0.000019 | 0.0000085 | 0.000050 | 88 | 0.000020 | 0.0000053 | 0.000050 | 59 | 0.000019 | 0.000010 | 0.000050 |
| Dissolved Chromium (mg/L) | 159 | 0.00054 | 0.00050 | 0.0011 | 81 | 0.00060 | 0.00050 | 0.0013 | 55 | 0.00057 | 0.00050 | 0.0011 |
| Dissolved Copper (mg/L) | 179 | 0.0021 | 0.0016 | 0.0050 | 88 | 0.0021 | 0.0015 | 0.0051 | 59 | 0.0024 | 0.0017 | 0.0054 |
| Dissolved Iron (mg/L) | 179 | 0.38 | 0.11 | 1.2 | 88 | 0.31 | 0.11 | 0.95 | 59 | 0.34 | 0.15 | 0.91 |
| Dissolved Lead (mg/L) | 179 | 0.00012 | 0.00010 | 0.00025 | 88 | 0.00012 | 0.00010 | 0.00028 | 59 | 0.00012 | 0.00010 | 0.00025 |
| Dissolved Molybdenum (mg/L) | 179 | 0.00096 | 0.0010 | 0.0020 | 88 | 0.00097 | 0.0010 | 0.0017 | 59 | 0.00094 | 0.0010 | 0.0015 |
| Dissolved Nickel (mg/L) | 179 | 0.0013 | 0.0011 | 0.0027 | 88 | 0.0013 | 0.0011 | 0.0024 | 59 | 0.0012 | 0.0011 | 0.0020 |
| Dissolved Selenium (mg/L) | 179 | 0.00027 | 0.00020 | 0.00050 | 88 | 0.00023 | 0.00011 | 0.00050 | 59 | 0.00025 | 0.00015 | 0.00050 |
| Dissolved Silver (mg/L) | 137 | 0.0000092 | 0.000010 | 0.000010 | 60 | 0.0000098 | 0.000010 | 0.000010 | 47 | 0.000010 | 0.000010 | 0.000010 |
| Dissolved Zinc (mg/L) | 179 | 0.0032 | 0.0025 | 0.0060 | 88 | 0.0029 | 0.0025 | 0.0060 | 59 | 0.0033 | 0.0025 | 0.0084 |

**Table 2.7: Annual Medians and the 95th percentile of annual medians for Option 1, 2 and 3.**

| Option | Year | Annual Medians | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
| Option 1 (No Group) | 2005 | - | - | 106 | 5.8 | 144 | 0.010 | 0.00050 | 0.018 | 7.95 | - | 0.016 | 0.00042 | 0.000025 | 0.00050 | 0.0025 | 0.15 | 0.00025 | 0.00050 | 0.0012 | 0.00050 | 0.0000075 | 0.0025 |
| | 2006 | - | 128 | - | 4.0 | 164 | 0.015 | 0.0010 | 0.11 | 7.85 | - | 0.0080 | 0.00042 | 0.0000050 | 0.00070 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.00090 | 0.00010 | 0.0000050 | 0.0010 |
| | 2007 | 11 | 110 | 119 | 7.3 | 173 | 0.025 | 0.025 | 0.08 | 7.90 | - | 0.011 | 0.00040 | 0.0000050 | 0.0010 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | - | 0.0040 |
| | 2008 | 14 | 123 | 98 | 13 | 161 | 0.025 | 0.040 | 0.030 | 7.91 | - | 0.012 | 0.00030 | 0.000005 | 0.0013 | 0.0012 | 0.070 | 0.000050 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | 2009 | 8.7 | 121 | 141 | 2.8 | 148 | 0.010 | 0.0025 | 0.15 | 8.02 | 7.89 | 0.010 | 0.00030 | 0.000040 | 0.00050 | 0.0020 | 0.050 | 0.00010 | 0.0010 | 0.00050 | 0.00030 | 0.0000050 | 0.0025 |
| | 2010 | 9.2 | 99 | 106 | 18 | 140 | 0.022 | 0.0025 | 0.070 | 8.10 | 7.72 | 0.017 | 0.00040 | 0.000050 | 0.00050 | 0.0017 | 0.07 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | 0.000010 | 0.0050 |
| | 2011 | 18 | 93 | 94 | 22 | 130 | 0.015 | 0.0025 | 0.055 | 7.96 | 7.79 | 0.033 | 0.00060 | 0.000010 | 0.00050 | 0.0019 | 0.35 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | 2012 | 12 | 129 | 145 | 45 | 166 | 0.025 | 0.0025 | 0.078 | 8.11 | 7.84 | 0.019 | 0.00078 | 0.0000050 | 0.00050 | 0.0016 | 0.58 | 0.00010 | 0.0011 | 0.0015 | 0.00012 | 0.000010 | 0.0025 |
| | 2013 | 11 | 129 | 153 | 23 | 176 | 0.049 | 0.0025 | 0.10 | 8.09 | 7.75 | 0.014 | 0.00059 | 0.0000050 | 0.00050 | 0.0012 | 0.36 | 0.00010 | 0.0011 | 0.0013 | 0.000050 | 0.000010 | 0.0025 |
| | **95th Percentile of Annual Medians** | **17** | **129** | **150** | **36** | **175** | **0.040** | **0.034** | **0.13** | **8.11** | **7.88** | **0.027** | **0.00071** | **0.000046** | **0.0012** | **0.0023** | **0.49** | **0.00019** | **0.0011** | **0.0018** | **0.00046** | **0.000010** | **0.0046** |
| Option 2 (Grouped by Week) | 2005 | - | - | 111 | 8.4 | 154 | 0.015 | 0.00061 | 0.040 | 7.83 | - | 0.025 | 0.00042 | 0.000025 | 0.00040 | 0.0028 | 0.21 | 0.00016 | 0.00076 | 0.0013 | 0.00050 | 0.0000075 | 0.0027 |
| | 2006 | - | 126 | - | 4.0 | 170 | 0.014 | 0.0010 | 0.12 | 7.85 | - | 0.0080 | 0.00040 | 0.0000050 | 0.00070 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.00085 | 0.00010 | 0.0000050 | 0.0010 |
| | 2007 | 11 | 110 | 119 | 8.8 | 176 | 0.025 | 0.025 | 0.13 | 7.89 | - | 0.011 | 0.00040 | 0.0000050 | 0.0010 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | - | 0.0040 |
| | 2008 | 11 | 123 | 98 | 14 | 163 | 0.025 | 0.040 | 0.037 | 7.90 | - | 0.012 | 0.00031 | 0.000023 | 0.0011 | 0.0011 | 0.070 | 0.000050 | 0.0012 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | 2009 | 8.7 | 121 | 141 | 2.8 | 148 | 0.010 | 0.0025 | 0.15 | 8.02 | 7.89 | 0.010 | 0.00030 | 0.000040 | 0.00050 | 0.0020 | 0.050 | 0.00010 | 0.0010 | 0.00050 | 0.00030 | 0.0000050 | 0.0025 |
| | 2010 | 12 | 106 | 106 | 13 | 145 | 0.027 | 0.0036 | 0.070 | 8.06 | 7.69 | 0.017 | 0.00033 | 0.000050 | 0.00050 | 0.0020 | 0.10 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | 0.000010 | 0.0050 |
| | 2011 | 16 | 94 | 95 | 23 | 125 | 0.015 | 0.0025 | 0.050 | 7.98 | 7.79 | 0.029 | 0.00050 | 0.000010 | 0.00050 | 0.0019 | 0.28 | 0.00010 | 0.00050 | 0.0016 | 0.00010 | 0.000010 | 0.0025 |
| | 2012 | 11 | 129 | 154 | 30 | 164 | 0.025 | 0.0025 | 0.083 | 8.08 | 7.80 | 0.021 | 0.00060 | 0.0000050 | 0.00050 | 0.0016 | 0.50 | 0.00010 | 0.0011 | 0.0014 | 0.00012 | 0.000010 | 0.0025 |
| | 2013 | 12 | 129 | 151 | 34 | 179 | 0.078 | 0.0025 | 0.10 | 8.09 | 7.80 | 0.015 | 0.00088 | 0.0000050 | 0.00050 | 0.0012 | 0.59 | 0.00010 | 0.0010 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | **95th Percentile of Annual Medians** | **15** | **129** | **153** | **33** | **178** | **0.058** | **0.034** | **0.14** | **8.09** | **7.87** | **0.027** | **0.00077** | **0.000046** | **0.0011** | **0.0025** | **0.55** | **0.00014** | **0.0011** | **0.0017** | **0.00046** | **0.000010** | **0.0046** |
| Option 3 (Grouped by Month) | 2005 | - | - | 111 | 8.4 | 154 | 0.015 | 0.00061 | 0.038 | 7.83 | - | 0.025 | 0.00042 | 0.000025 | 0.00040 | 0.0028 | 0.21 | 0.00016 | 0.00076 | 0.0013 | 0.00050 | 0.0000075 | 0.0029 |
| | 2006 | - | 120 | - | 3.8 | 175 | 0.017 | 0.0010 | 0.083 | 7.78 | - | 0.0079 | 0.00046 | 0.0000050 | 0.00059 | 0.0011 | 0.10 | 0.000050 | 0.00088 | 0.00083 | 0.00013 | 0.0000050 | 0.0017 |
| | 2007 | 11 | 110 | 124 | 6.5 | 177 | 0.025 | 0.025 | 0.14 | 7.84 | - | 0.011 | 0.00040 | 0.0000050 | 0.0010 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | - | 0.0040 |
| | 2008 | 11 | 123 | 108 | 15 | 167 | 0.025 | 0.030 | 0.033 | 7.90 | - | 0.013 | 0.00035 | 0.0000050 | 0.0010 | 0.0012 | 0.070 | 0.000050 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | 2009 | 10 | 96 | 141 | 4.0 | 149 | 0.010 | 0.0025 | 0.16 | 7.90 | 7.73 | 0.019 | 0.00028 | 0.000035 | 0.00055 | 0.0028 | 0.060 | 0.00010 | 0.00092 | 0.00067 | 0.00030 | 0.0000050 | 0.0033 |
| | 2010 | 13 | 107 | 106 | 32 | 150 | 0.037 | 0.0031 | 0.070 | 8.04 | 7.85 | 0.016 | 0.00038 | 0.000050 | 0.00050 | 0.0020 | 0.13 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | 0.000010 | 0.0050 |
| | 2011 | 19 | 79 | 89 | 17 | 125 | 0.016 | 0.0025 | 0.050 | 7.81 | 7.79 | 0.036 | 0.00050 | 0.000016 | 0.00050 | 0.0029 | 0.26 | 0.00010 | 0.00050 | 0.0012 | 0.00010 | 0.000010 | 0.000010 |
| | 2012 | 11 | 128 | 156 | 19 | 167 | 0.024 | 0.0025 | 0.092 | 8.10 | 7.59 | 0.021 | 0.00056 | 0.0000056 | 0.00050 | 0.0018 | 0.45 | 0.00010 | 0.0011 | 0.0014 | 0.00014 | 0.000010 | 0.0025 |
| | 2013 | 12 | 130 | 151 | 40 | 185 | 0.080 | 0.0037 | 0.11 | 8.09 | 7.90 | 0.019 | 0.0011 | 0.0000056 | 0.00050 | 0.0012 | 0.65 | 0.00010 | 0.0011 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | **95th Percentile of Annual Medians** | **17** | **129** | **154** | **37** | **182** | **0.063** | **0.028** | **0.15** | **8.10** | **7.89** | **0.032** | **0.00086** | **0.000044** | **0.00099** | **0.0029** | **0.57** | **0.00014** | **0.0011** | **0.0016** | **0.00046** | **0.000010** | **0.0046** |

# 3.0 BACKGROUND WATER QUALITY SUMMARY STATISTICS

Based primarily on consideration of potential water quality monitoring frequencies at the post-closure 2 stage (proposed spring, summer, fall), Option 3 is put forward as the proposed basis for defining background water quality. Two key sets of background water quality statistics are appropriate for defining background water quality:

1. the 95$^{th}$ percentile of the background data; and
2. the 95$^{th}$ percentile of the annual medians of the background data.

The intended use of the former (Table 3.1; Appendix Table D.4) is as an “individual data point evaluator” and the intended use of the latter (Table 3.1; Appendix Tables D.5 and D.6) is as a “central tendency evaluator”.

Although application of the WQOs in defining attainment is the subject of ongoing discussion between the Minto Mine and Selkirk First Nation, a fundamental guiding principle is that, because the summary statistics are 95$^{th}$ percentiles, they will be exceeded at an average rate of 5% in the absence of any mine influence on water quality. Thus, definition of attainment must consider natural exceedance rate, and initial response to any observed exceedance must be focussed on distinguishing a mine related influence from natural variability.

**Table 3.1: Background water quality summary statistics representing lower Minto Creek (Minnow 2016) [1]**

| Analytes | Background Concentration Summary Statistics | |
|---|---|---|
| | Individual Data Point Evaluator (95th percentile) | Central Tendency Evaluator (95th percentile of annual medians) |
| Ammonia (mg/L) | 0.12 | 0.063 |
| Nitrite (mg/L) | 0.040 | 0.028 |
| Nitrate (mg/L) | 0.22 | 0.15 |
| Dissolved Aluminum (mg/L) | 0.053 | 0.032 |
| Dissolved Arsenic (mg/L) | 0.0011 | 0.00086 |
| Dissolved Cadmium (mg/L) | 0.000050 | 0.000044 |
| Dissolved Chromium (mg/L) | 0.0011 | 0.0010 |
| Dissolved Copper (mg/L) | 0.0054 | 0.0029 |
| Dissolved Iron (mg/L) | 0.91 | 0.57 |
| Dissolved Lead (mg/L) | 0.00025 | 0.00014 |
| Dissolved Molybdenum (mg/L) | 0.0015 | 0.0011 |
| Dissolved Nickel (mg/L) | 0.0020 | 0.0016 |
| Dissolved Selenium (mg/L) | 0.00050 | 0.00046 |
| Dissolved Silver (mg/L) | 0.000010 | 0.000010 |
| Dissolved Zinc (mg/L) | 0.0084 | 0.0046 |

[1] for contaminants of potential concern (COPCs)

# 4.0 REFERENCES

Dawson, R. 2011. How significant is a boxplot outlier? Journal of Statistics Education 19: 2.

YWB (Yukon Water Board). 2015. Minto Mine Type A Water Use Licence Number QZ14-031. Issued to Minto Explorations Ltd. August 2015.

# APPENDIX A

# JUNE 2ND, 2016 MEETING MINUTES

# Minto Mine Bilateral Technical Working Group Meeting
# Characterizing Background Water Quality for Use as Water Quality Objectives
# SRK Consulting – Vancouver, June 2, 2016
# Meeting Notes

**Attendees: Bill Slater, Don MacDonald, Jesse Sinclair, Ryan Herbert, Pierre Stecko, Dylan MacGregor**

## Agenda (developed jointly)

- Background Dataset
- Dealing with Duplicates
- Multiple locations per sampling date
- Dealing with Outliers
- Method Detection Limits
- Conditions / Binning
- Summary Statistics
- Attainment
- Confirmation of COPC list
- Water Quality Predictions Use

**Key**

Black text = items discussed
Blue text = agreed path forward
Red text = action item

### 1. Background Dataset

- Rationalize stations
- Test differences? Necessary?
- NOTE → W6 samples were taken at the wrong location in 2009-2011 (see extreme copper concentration from April 09) … exclude W6 for this timeframe
- Exclude W8
- "Background Dataset" was agreed upon … see PHOTOGRAPH of whiteboard matrix
- As with Access 2014, removed W6 data from 2009 to 2011 due to uncertainty about sampling location (may have been sampled in Minto Creek mainstem at some times)
- Prepare the dataset per spreadsheet
- Check against Access 2014. The only difference should be the exclusion of W8

### 2. Dealing with Duplicates

- There are duplicates in the database, some instances of greater replication
- Approach to consolidate to one data point per site per sampling

- Average discussed. Simple decision when they agree well. What if they do not?
- Average by site and date
- Identify the replicates and compare
- If good agreement, use average

3. **Multiple locations per sampling date**
   - This was an MESL addition to the agenda
   - Objective is to best represent water quality at Station W2
   - Is there pseudo-replication by including numerous reference sites to represent W2 on a given date when an alternative (better?) approach might be to use the reference dataset to identify an surrogate W2 value for that date (or campaign if within a few days)
   - Option 1 → use all data as independent
   - Option 2 → consolidate by sampling date (or campaign) to get one estimate of "W2 background" for that date and then use those data for summary statistics
   - Jesse Sinclair ran scenarios on the spot (using R?)
     - D Copper Option 1 → N 184 95$^{th}$ 6.52 median 1.70
     - D Copper Option 2 → N 124 95$^{th}$ 4.94 median 1.46
     - Not much difference for TDS or NO3
   - Tim Barrett to apply this approach and indicate implications overall (e.g., lower BG for copper [but perhaps better representative of W2])
   - Alternative from Don MacDonald = only consider W2 in 2005?
   - Group … no, now that we have agreed on background dataset, stick with it
   - Check → in baseline ONLY (2005), how would Option 1 versus Option 2 compare to actual W2 (admittedly small dataset!)

4. **Dealing with Outliers**
   - Box plot approach suggested by Tim is appropriate.
   - MESL agrees with boxplot approach, indicates that there is more than one way, but that the 3IQR method is appropriate
   - Go ahead and complete the identification of potential outliers
   - Evaluate concurrent conditions
   - Provide list of outliers to Ryan Herbert at Minto Mine
   - Ryan can help decide what is feasible to investigate. If we can't investigate may have to make a (or practical to just toss)
   - Prepare a final list of proposed outliers to be eliminated
   - Provide list to SFN / MESL

5. **Method Detection Limits**
   - Significant issue for a number of COPCs
   - Pierre Stecko → issue could potentially be avoided by using non-parametric statistics
   - How does ½ substitution affect results if MDLs decrease in the future?
   - Pierre → acknowledge ABOVE in the document and propose a defensible way to deal with them. Part of our responsibility is to make sure that this set up in a way that can be easily

picked up in future reviews. Implications of method changes need to be identified and, to the extent possible, guidance provided on how they should be dealt with (e.g., Tim suggests the Kaplan-Meier method).

6. **Conditions / Binning**
   - Desirable not to bin
   - Evidence of seasonal patterns that indicate a need to "bin"
   - Investigated "under ice" versus "ice free"
   - Ice April to October = ice free; "under ice" = Nov 1 to Apr 1
   - Is under ice necessary? Frozen solid, no source?
   - AGREE … no need to apply under ice (background characterization of "under ice" period is not required
   - Ascending versus descending hydrograph (divisions from MESL 2013)
   - Box plots appear comparable for the analytes that we looked at (copper, nitrate, TDS)
   - Compare these two "bins" for each of the COPCs
   - Statistical contrast of the two groups
   - Discuss with SFN / MESL and make final decisions
   - It is possible that some analytes require binning whereas others do not

7. **Summary Statistics**
   - Two types – "Individual" (applies to grab sample) and "Central Tendency" (applies to average over a specified time frame [year?])
   - Individual
     - $95^{th}$ percentiles are appropriate
     - See attainment
     - Calculate following agreement on final dataset and approach (all previous items) with SFN / MESL
   - Central Tendency
     - Fairly brief discussion on this
     - PS indicated preference for non-parametric if feasible and defensible (e.g., $95^{th}$ percentile of medians), but key questions is whether data supports this in a defensible way
     - Calculate the $95^{th}$ percentile on medians; is this defensible with the given data
     - Calculate other measures of central tendency (UCL of the mean)
     - Compare the methods
     - Select more appropriate

8. **Attainment**
   - Individual ($95^{th}$ percentiles)
     - Exceedances on 2 consecutive samples. If independent, 5% * 5% probability = 0.25%
     - Sufficient time between sample to have reasonable assurance
     - This approach allows a more rapid response than waiting to evaluate exceedance rates

    - Incorporate the final concept(s) into background report
- Central Tendency
    - Evaluate compliance annually. Does the annual median or mean fall within the range of background medians or means.
    - As above, must still recognize small chance of exceedance in the absence of any change.
    - Functionally, this could be an annual review item. Presumably, if the "central tendency" WQO has been exceeded, some "individual" exceedance has also occurred. The annual review should include investigation.
        - One analyte or many?
        - Frequency of exceedance of the "individual WQO"
        - Trending
        - Other?
    - Incorporate the final concept(s) into background report
- Bill Slater → these concepts work well when we are just considering future water quality relative to background, but become more complicated when considering a WQO that is a composite of background and the operation WQO.
- Don MacDonald – SFN would like to see WQO set somewhere between background and 50% of current operational WQO (WUL definition of assimilative capacity).

**COPC List**

- Don MacDonald – Would like to include TDS as a COPC with reasoning around making it easier to apply it is a communication piece with SFN. Don discussed having TDS as a major ion to follow and show the community that there are no problems with the WQ in Minto Creek.
- The group generally agrees that TDS is not expected to be an issue in closure as it relates to effects on aquatic life.
- No agreement on the inclusion of TDS in the COPC list was confirmed.
- Minto's team to discuss internally the merits of including TDS as a COPC.
- Don MacDonald – asked if we need to develop a framework to evaluating COPC's.
- Dylan MacGregor – Given the time remaining (until August 5$^{th}$) it was probably not the best use of resources. The group as whole generally agreed.

**Water Quality Prediction Appropriate Use**

- Dylan MacGregor –Will have updated water quality predictions including CWTS performance expectations near end of month. Dylan has concerns regarding how water quality predictions will be used.
- Don MacDonald – we have to use predictions to determine where WQO should be set.
- Dylan MacGregor – we could use the current predictions as we have said we expect to have the CWTS performance to range from 0 to some upper percentage of removal therefore CWTS performance may not have an impact.
- Further discussions need to be had to agree on how best to use WQ predictions.

**TIMING**

- Items 1 to 6 by week of June 13th …
- Discuss week of June 20th ??

# APPENDIX B

# RAW WATER QUALITY DATA

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Coliforms | Fecal Coliforms | E.Coli | COD (mg/L) | Specific Conductivity in Field (µS/cm) | Radium - 226 (Bq/L) | CBOD (mg/L) | LC50 (%) | LT50 (h) | BOD5 (mg/L) | DO (mg/L) | Cond-F (µS/cm) | DO (%) | ORP (mV) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | | | | | | | | | | | | | | |
| W1 | 6/30/2005 | | | | | | <0.0050 | | | | | | | | |
| W1 | 7/28/2005 | | | | | | <0.0050 | | | | | | | | |
| W1 | 8/29/2005 | | | | | | <0.0050 | | | | | | | | |
| W1 | 9/28/2005 | | | | | | <0.0050 | | | | | | | | |
| W1 | 10/15/2005 | | | | | | <0.0050 | | | | | | | | |
| W2 | 5/27/2005 | | | | | | | | | | | | | | |
| W2 | 5/27/2005 | | | | | | | | | | | | | | |
| W2 | 6/30/2005 | | | | | | <0.0050 | | | | | | | | |
| W2 | 7/28/2005 | | | | | | <0.0050 | | | | | | | | |
| W2 | 8/30/2005 | | | | | | <0.0050 | | | | | | | | |
| W2 | 9/28/2005 | | | | | | 0.007 | | | | | | | | |
| W2 | 10/15/2005 | | | | | | <0.0050 | | | | | | | | |
| W3 | 5/27/2005 | | | | | | | | | | | | | | |
| W3 | 6/30/2005 | | | | | | <0.0050 | | | | | | | | |
| W3 | 7/29/2005 | | | | | | <0.0050 | | | | | | | | |
| W3 | 8/29/2005 | | | | | | <0.0050 | | | | | | | | |
| W3 | 9/28/2005 | | | | | | <0.0050 | | | | | | | | |
| W3 | 10/15/2005 | | | | | | <0.0050 | | | | | | | | |
| W8 | 5/27/2005 | | | | | | | | | | | | | | |
| W8 | 6/30/2005 | | | | | | | | | | | | | | |
| W8 | 7/29/2005 | | | | | | | | | | | | | | |
| W8 | 8/30/2005 | | | | | | | | | | | | | | |
| W8 | 9/28/2005 | | | | | | | | | | | | | | |
| W8 | 10/15/2005 | | | | | | | | | | | | | | |
| W9 | 5/27/2005 | | | | | | | | | | | | | | |
| W9 | 6/30/2005 | | | | | | <0.0050 | | | | | | | | |
| W9 | 7/29/2005 | | | | | | 0.007 | | | | | | | | |
| W9 | 8/29/2005 | | | | | | <0.0050 | | | | | | | | |
| W9 | 9/28/2005 | | | | | | <0.0050 | | | | | | | | |
| W9 | 10/15/2005 | | | | | | <0.0050 | | | | | | | | |
| W10 | 5/27/2005 | | | | | | | | | | | | | | |
| W10 | 5/27/2005 | | | | | | | | | | | | | | |
| W10 | 6/30/2005 | | | | | | <0.0050 | | | | | | | | |
| W10 | 7/29/2005 | | | | | | <0.0050 | | | | | | | | |
| W10 | 8/29/2005 | | | | | | <0.0050 | | | | | | | | |
| W10 | 9/28/2005 | | | | | | <0.0050 | | | | | | | | |
| W10 | 10/15/2005 | | | | | | 0.007 | | | | | | | | |
| W6 | 5/27/2005 | | | | | | | | | | | | | | |
| W6 | 6/30/2005 | | | | | | | | | | | | | | |
| W6 | 7/29/2005 | | | | | | | | | | | | | | |
| W6 | 8/30/2005 | | | | | | | | | | | | | | |
| W6 | 9/28/2005 | | | | | | | | | | | | | | |
| W6 | 10/15/2005 | | | | | | | | | | | | | | |
| W6 | 6/2/2006 | | | | | | | | | | | | | | |
| W6 | 8/25/2006 | | | | | | | | | | | | | | |
| W6 | 9/6/2006 | | | | | | | | | | | | | | |
| W6 | 6/20/2007 | | | | | | | | | | | | | | |
| W6 | 9/18/2007 | | | | | | | | | | | | | | |
| W6 | 6/17/2008 | | | | | | | | | | | | | | |
| W6 | 9/18/2008 | | | | | | | | | | | | | | |
| W6 | 4/14/2009 | | | | | | | | | | | | | | |
| W6 | 4/30/2009 | | | | | | | | | | | | 0.17 | 170 | |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | 4.25 | | |
| W6 | 8/18/2009 | | | | | | | | | | | | | | |
| W6 | 8/25/2009 | | | | | | | | | | | | 415 | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | 485 | 108.5 | |
| W6 | 10/25/2009 | | | | | | | | | | | | 502 | 99.4 | |
| W6 | 4/19/2010 | | | | | | | | | | | | 283 | | |
| W6 | 5/16/2010 | | | | | | | | | | | | 192.4 | | |
| W6 | 5/17/2010 | | | | | | | | | | | | 124.4 | | |
| W6 | 5/19/2010 | | | | | | | | | | | | 196.2 | | |
| W6 | 5/21/2010 | | | | | | | | | | | | 164.3 | | |
| W6 | 5/23/2010 | | | | | | | | | | | | 216 | | |
| W6 | 5/25/2010 | | | | | | | | | | | | 177 | | |
| W6 | 5/29/2010 | | | | | | | | | | | | 152.3 | | |
| W6 | 6/2/2010 | | | | | | | | | | | | 448 | | |
| W6 | 6/4/2010 | | | | | | | | | | | | 182.2 | | |
| W6 | 6/6/2010 | | | | | | | | | | | | 191 | | |
| W6 | 6/14/2010 | | | | | | | | | | | | 197 | | |
| W6 | 6/16/2010 | | | | | | | | | | | | 287 | | |
| W6 | 6/18/2010 | | | | | | | | | | | | 279 | | |
| W6 | 6/20/2010 | | | | | | | | | | | | 279 | | |
| W6 | 6/22/2010 | | | | | | | | | | | | 186 | 102 | |
| W6 | 6/24/2010 | | | | | | | | | | | | 187 | 101.2 | |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/26/2010 | | | | | | | | | | | | 189 | 99.4 | |
| W6 | 6/28/2010 | | | | | | | | | | | | 178 | 101.7 | |
| W6 | 7/5/2010 | | | | | | | | | | | | 164 | 101.4 | |
| W6 | 8/5/2010 | | | | | | | | | | | | 205 | 76.7 | |
| W6 | 9/9/2010 | | | | | | | | | | | | 205 | 79.6 | |
| W6 | 10/8/2010 | | | | | | | | | | | | 209 | 94.2 | |
| W6 | 8/19/2011 | | | | | | | | | | | | | | |
| W6 | 7/17/2012 | | | | | 193.9 | | | | | | 117 | 118.9 | 92.3 | 74.9 |
| W6 | 7/30/2012 | | | | | 174.4 | | | | | | 12.56 | 108.3 | 98.8 | 22.5 |
| W6 | 8/9/2012 | | | | | 217.6 | | | | | | 12.03 | 140.2 | 97.9 | -22.9 |
| W6 | 8/25/2012 | | | | | 196 | | | | | | 11.94 | 120.1 | 92.8 | 134.6 |
| W6 | 9/13/2012 | | | | | 171.5 | | | | | | 13.7 | 95.8 | 94.3 | 64.9 |
| W6 | 10/13/2012 | | | | | 194.5 | | | | | | 13.83 | 101.6 | 94.7 | 27.8 |
| W6 | 11/12/2012 | | | | | 365.5 | | | | | | | 190 | | 249.6 |
| W6 | 5/14/2013 | | | | | 53.6 | | | | | | 13.22 | 28.1 | 92.1 | 137.8 |
| W6 | 6/22/2013 | | | | | 172.6 | | | | | | 12.33 | | 88.6 | 79.4 |
| W6 | 7/12/2013 | | | | | 180.5 | | | | | | 11.38 | 109 | 87.7 | 93.3 |
| W6 | 8/22/2013 | | | | | 204.1 | | | | | | 11.81 | 127.8 | 102.4 | 22.8 |
| W6 | 9/6/2013 | | | | | 201.8 | | | | | | 11.85 | 122.7 | 98.7 | 20.4 |
| W6 | 10/7/2013 | | | | | 191 | | | | | | 14.61 | 104.1 | 102.3 | 36.2 |
| W6 | 11/16/2013 | | | | | 196.2 | | | | | | 8.31 | 102.6 | 68.3 | 98.6 |
| W6 | 12/7/2013 | | | | | | | | | | | | 231 | | |
| W7 | 5/27/2005 | | | | | | | | | | | | | | |
| W7 | 6/30/2005 | | | | | | | | | | | | | | |
| W7 | 7/29/2005 | | | | | | | | | | | | | | |
| W7 | 8/30/2005 | | | | | | | | | | | | | | |
| W7 | 9/28/2005 | | | | | | | | | | | | | | |
| W7 | 10/15/2005 | | | | | | | | | | | | | | |
| W7 | 6/2/2006 | | | | | | | | | | | | | | |
| W7 | 6/8/2006 | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Coliforms | Fecal Coliforms | E.Coli | COD (mg/L) | Specific Conductivity in Field (µS/cm) | Radium - 226 (Bq/L) | CBOD (mg/L) | LC50 (%) | LT50 (h) | BOD5 (mg/L) | DO (mg/L) | Cond-F (µS/cm) | DO (%) | ORP (mV) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/23/2006 | | | | | | | | | | | | | | |
| W7 | 6/28/2006 | | | | | | | | | | | | | | |
| W7 | 7/7/2006 | | | | | | | | | | | | | | |
| W7 | 7/12/2006 | | | | | | | | | | | | | | |
| W7 | 7/20/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 8/2/2006 | | | | | | | | | | | | | | |
| W7 | 8/10/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/30/2006 | | | | | | | | | | | | | | |
| W7 | 9/6/2006 | | | | | | | | | | | | | | |
| W7 | 9/13/2006 | | | | | | | | | | | | | | |
| W7 | 9/20/2006 | | | | | | | | | | | | | | |
| W7 | 9/28/2006 | | | | | | | | | | | | | | |
| W7 | 10/4/2006 | | | | | | | | | | | | | | |
| W7 | 10/12/2006 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/20/2007 | | | | | | | | | | | | | | |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 9/18/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/17/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 9/18/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 4/30/2009 | | | | | | <0.006 | | | | | | 37.6 | 183 | |
| W7 | 6/8/2009 | | | | | | | | | | | | 211 | | |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | | | | | | | | | | | | 289 | | |
| W7 | 8/24/2009 | | | | | | 0.01 | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | 253 | | |
| W7 | 8/31/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | <0.005 | | | | | | 258 | 109 | |
| W7 | 10/25/2009 | | | | | | <0.005 | | | | | | 269 | 88 | |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | | | | | | | | | | | | 437 | | |
| W7 | 4/27/2010 | | | | | | | | | | | | 67 | 59.2 | |
| W7 | 4/29/2010 | | | | | | | | | | | | 35 | 8.8 | |
| W7 | 5/1/2010 | | | | | | | | | | | | 82 | 102.2 | |
| W7 | 5/3/2010 | | | | | | | | | | | | 89 | 90.2 | |
| W7 | 5/5/2010 | | | | | | | | | | | | | | |
| W7 | 5/7/2010 | | | | | | | | | | | | 118 | 83.3 | |
| W7 | 5/9/2010 | | | | | | | | | | | | 171 | 129.2 | |
| W7 | 5/10/2010 | | | | | | | | | | | | 175 | 133.9 | |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/14/2010 | | | | | | | | | | | | 145 | | |
| W7 | 5/16/2010 | | | | | | | | | | | | 167.4 | | |
| W7 | 5/17/2010 | | | | | | | | | | | | 161.6 | | |
| W7 | 5/19/2010 | | | | | | | | | | | | 199.4 | | |
| W7 | 5/21/2010 | | | | | | | | | | | | 191 | | |
| W7 | 5/23/2010 | | | | | | | | | | | | 216 | | |
| W7 | 5/25/2010 | | | | | | | | | | | | 224 | | |
| W7 | 5/27/2010 | | | | | | | | | | | | 234 | | |
| W7 | 5/29/2010 | | | | | | | | | | | | 243 | | |
| W7 | 5/31/2010 | | | | | | | | | | | | 249 | | |
| W7 | 6/2/2010 | | | | | | | | | | | | 254 | | |
| W7 | 6/4/2010 | | | | | | | | | | | | 667 | | |
| W7 | 6/6/2010 | | | | | | | | | | | | 262 | | |
| W7 | 6/14/2010 | | | | | | | | | | | | 297 | | |
| W7 | 6/16/2010 | | | | | | | | | | | | 364 | | |
| W7 | 6/18/2010 | | | | | | | | | | | | 360 | | |
| W7 | 6/20/2010 | | | | | | | | | | | | 342 | | |
| W7 | 6/22/2010 | | | | | | | | | | | | 205 | 107.1 | |
| W7 | 6/24/2010 | | | | | | | | | | | | 211 | 105.6 | |
| W7 | 6/26/2010 | | | | | | | | | | | | 229 | 107.3 | |
| W7 | 6/28/2010 | | | | | | | | | | | | 245 | 105.1 | |
| W7 | 7/5/2010 | | | | | | | | | | | | 194 | 104.5 | |
| W7 | 8/5/2010 | | | | | | | | | | | | 240 | 78.1 | |
| W7 | 9/12/2010 | | | | | | | | | | | | | | |
| W7 | 9/12/2010 | | | | | | <0.005 | | | | | | 210 | 84.5 | |
| W7 | 10/8/2010 | | | | | | | | | | | | 235 | 100.3 | |
| W7 | 4/27/2011 | | | | | | | | | | | | | | |
| W7 | 5/2/2011 | | | | | | | | | | | | | | |
| W7 | 6/1/2011 | | | | | | | | | | | | | | |
| W7 | 6/16/2011 | | | | | | | | | | | | | | |
| W7 | 7/1/2011 | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Coliforms | Fecal Coliforms | E.Coli | COD (mg/L) | Specific Conductivity in Field (µS/cm) | Radium - 226 (Bq/L) | CBOD (mg/L) | LC50 (%) | LT50 (h) | BOD5 (mg/L) | DO (mg/L) | Cond-F (µS/cm) | DO (%) | ORP (mV) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | | | | | | | | | | | | | | |
| W7 | 8/16/2011 | | | | | | | | | | | | | | |
| W7 | 8/19/2011 | | | | | | | | | | | | | | |
| W7 | 9/12/2011 | | | | | | | | | | | 18.55 | 204.1 | 133.5 | |
| W7 | 10/6/2011 | | | | | | | | | | | 12.13 | 250.8 | 83.1 | |
| W7 | 11/22/2011 | | | | | | | | | | | | | | |
| W7 | 1/24/2012 | | | | | | | | | | | | | | |
| W7 | 2/25/2012 | | | | | 296.9 | | | | | | 10.92 | 155.2 | 74.6 | |
| W7 | 3/5/2012 | | | | | 272.6 | | | | | | 11.47 | 142.3 | 78.9 | |
| W7 | 4/24/2012 | | | | | 75.6 | | | | | | 15.55 | 39.5 | 106.3 | |
| W7 | 5/6/2012 | | | | | | | | | | | | | | |
| W7 | 5/6/2012 | | | | | 88.8 | | | | | | 8.53 | 46.4 | 58.4 | 116.8 |
| W7 | 6/19/2012 | | | | | 202.6 | | | | | | 12.45 | 121.6 | 95.1 | 44.5 |
| W7 | 7/17/2012 | | | | | 244.2 | | | | | | 12.31 | 152.9 | 97.4 | 45.6 |
| W7 | 7/30/2012 | | | | | 235.1 | | | | | | 12.64 | 142.6 | 97.6 | 16 |
| W7 | 8/8/2012 | | | | | 268.5 | | | | | | 12.65 | 164.5 | 98.5 | -6.2 |
| W7 | 8/23/2012 | | | | | 264.6 | | | | | | 10.94 | 161.3 | 84.8 | -2.4 |
| W7 | 9/13/2012 | | | | | 224 | | | | | | 13.04 | 126.2 | 94.1 | 76.7 |
| W7 | 10/16/2012 | | | | | 258.9 | | | | | | 17.1 | 137.8 | 118.3 | 18 |
| W7 | 11/2/2012 | | | | | | | | | | | | | | |
| W7 | 12/29/2012 | | | | | 2107 | | | | | | 9.38 | 1090 | 72.5 | 289.9 |
| W7 | 4/30/2013 | | | | | 365.3 | | | | | | | 190.6 | 101.8 | -50 |
| W7 | 5/14/2013 | | | | | 59.7 | | | | | | 13.46 | 31.1 | 92.4 | 109.7 |
| W7 | 6/19/2013 | | | | | | | | | | | | | | |
| W7 | 6/19/2013 | | | | | | | | | | | | 249 | | |
| W7 | 7/13/2013 | | | | | 250.7 | | | | | | 11.92 | 148 | 90 | 108.7 |
| W7 | 8/21/2013 | | | | | 280.6 | | | | | | 12.06 | 168 | 101 | 32.7 |
| W7 | 9/6/2013 | | | | | 277.3 | | | | | | 11.37 | 166.3 | 93.5 | 38.1 |
| W7 | 10/21/2013 | | | | | 286.3 | | | | | | 11.57 | 149.3 | 77.7 | 16.6 |
| W7 | 11/16/2013 | | | | | 197.6 | | | | | | 7.17 | 104.3 | 61.8 | 94.7 |
| W7 | 12/7/2013 | | | | | | | | | | | | 198 | | |
| C4 | 5/6/2012 | | | | | 100.1 | | | | | | 10.69 | 52.4 | 73.1 | 63.9 |
| C4 | 8/1/2012 | | | | | 196.8 | | | | | | 10.45 | 138.1 | 91.3 | -38.1 |
| C4 | 8/8/2012 | | | | | 246.3 | | | | | | 11.52 | 165.3 | 97.1 | -54.1 |
| C4 | 8/25/2012 | | | | | 230.8 | | | | | | 11.18 | 148.8 | 91 | -21.8 |
| C4 | 6/22/2013 | | | | | 223.8 | | | | | | 10.58 | | 87.9 | 93.7 |
| C4 | 7/19/2013 | | | | | | | | | | | | 260 | | |
| C4 | 8/22/2013 | | | | | 246.6 | | | | | | 11.35 | 166.1 | 103.6 | 11.6 |
| C4 | 9/6/2013 | | | | | 246.2 | | | | | | 11.56 | 153.8 | 98.7 | -28.8 |
| C4 | 10/18/2013 | | | | | | | | | | | | | | |
| C4 | 10/18/2013 | | | | | 257.1 | | | | | | 13.73 | 134.1 | 92.3 | -20.1 |
| C4 | 11/17/2013 | | | | | 274.1 | | | | | | 4.27 | 142.7 | 28.4 | 101.5 |
| C10 | 5/12/2012 | | | | | 144 | | | | | | 13.64 | 82 | 99.9 | 45.3 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 7/30/2012 | | | | | 216.7 | | | | | | 9.03 | 159.3 | 3 | 44.8 |
| C10 | 8/10/2012 | | | | | 269 | | | | | | 12.15 | 179 | 101.3 | -28.1 |
| C10 | 8/27/2012 | | | | | 257.4 | | | | | | 11.33 | 170.7 | 94.1 | 27 |
| C10 | 6/22/2013 | | | | | 242.7 | | | | | | 9.91 | | 91.1 | 85.9 |
| C10 | 7/23/2013 | | | | | 227.6 | | | | | | 11.31 | 153 | 95.3 | 97.7 |
| C10 | 8/22/2013 | | | | | 304.4 | | | | | | 11.25 | 206.6 | 101.4 | 143.1 |
| C10 | 9/8/2013 | | | | | | | | | | | | | | |
| C10 | 9/8/2013 | | | | | 213.8 | | | | | | 10.32 | 146.2 | 96.1 | 103.3 |
| C10 | 10/18/2013 | | | | | 262.4 | | | | | | 14.43 | 137.1 | 96.2 | 84.9 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Field pH (pH units) | Field Turbidity (NTU) | Field Temp (° C) | Sulphide (mg/L) | Dissolved SO4 (mg/L) | Total SO4 (mg/L) | TT CN (mg/L) | Chloride (mg/L) | Bromine (mg/L) | Fluoride (mg/L) | Chromium 6 (mg/L) | Chromium III (mg/L) | Cu-D-IH (mg/L) | Al-D-IH (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | | | | | 19.7 | 12.8 | | <0.50 | | | | | | |
| W1 | 6/30/2005 | | | | | 22.4 | 22.4 | 0.011 | 1.2 | | | | | | |
| W1 | 7/28/2005 | | | | | | 19.1 | 0.0054 | 0.64 | | | | | | |
| W1 | 8/29/2005 | | | | | 12.4 | 12.4 | 0.0065 | 0.52 | | | | | | |
| W1 | 9/28/2005 | | | | | 11.8 | 11.8 | 0.0118 | 0.73 | | | | | | |
| W1 | 10/15/2005 | | | | | | 13.9 | 0.125 | 0.91 | | | | | | |
| W2 | 5/27/2005 | | | | | | 12.8 | | <0.50 | | | | | | |
| W2 | 5/27/2005 | | | | | 9.64 | | | <0.5 | | | | | | |
| W2 | 6/30/2005 | | | | | 22.1 | 22.1 | <0.0050 | 1.23 | | | | | | |
| W2 | 7/28/2005 | | | | | | 19 | <0.0050 | 0.66 | | | | | | |
| W2 | 8/30/2005 | | | | | 12.6 | 12.6 | 0.0053 | 0.53 | | | | | | |
| W2 | 9/28/2005 | | | | | 11.6 | 11.6 | 0.0106 | 0.72 | | | | | | |
| W2 | 10/15/2005 | | | | | | 14 | 0.0101 | 0.88 | | | | | | |
| W3 | 5/27/2005 | | | | | 2.4 | 19.7 | | <0.50 | | | | | | |
| W3 | 6/30/2005 | | | | | 45.5 | 45.5 | <0.0050 | 0.86 | | | | | | |
| W3 | 7/29/2005 | | | | | | 29.6 | <0.0050 | <0.50 | | | | | | |
| W3 | 8/29/2005 | | | | | 25.5 | 25.5 | 0.0091 | <0.50 | | | | | | |
| W3 | 9/28/2005 | | | | | 23.9 | 23.9 | 0.013 | <0.50 | | | | | | |
| W3 | 10/15/2005 | | | | | | 24.7 | 0.014 | <0.50 | | | | | | |
| W8 | 5/27/2005 | | | | | 166 | 7.62 | | <0.50 | | | | | | |
| W8 | 6/30/2005 | | | | | <1 | <1.0 | | 0.86 | | | | | | |
| W8 | 7/29/2005 | | | | | | 7.08 | | <0.50 | | | | | | |
| W8 | 8/30/2005 | | | | | 5.1 | 5.1 | | <0.50 | | | | | | |
| W8 | 9/28/2005 | | | | | 7.72 | 7.72 | | <0.50 | | | | | | |
| W8 | 10/15/2005 | | | | | | 24.8 | | <0.50 | | | | | | |
| W9 | 5/27/2005 | | | | | 35.3 | 11.8 | | <0.50 | | | | | | |
| W9 | 6/30/2005 | | | | | 18.4 | 18.4 | <0.0050 | <5.0 | | | | | | |
| W9 | 7/29/2005 | | | | | | 16.5 | <0.0050 | <0.50 | | | | | | |
| W9 | 8/29/2005 | | | | | 17.9 | 17.9 | 0.0124 | <0.50 | | | | | | |
| W9 | 9/28/2005 | | | | | 16.7 | 16.7 | 0.0128 | <0.50 | | | | | | |
| W9 | 10/15/2005 | | | | | | 17.4 | 0.0164 | <0.50 | | | | | | |
| W10 | 5/27/2005 | | | | | | <0.50 | | <0.50 | | | | | | |
| W10 | 5/27/2005 | | | | | | | | <0.5 | | | | | | |
| W10 | 6/30/2005 | | | | | <10 | <10 | <0.0050 | <5.0 | | | | | | |
| W10 | 7/29/2005 | | | | | | 1.56 | <0.0050 | <0.50 | | | | | | |
| W10 | 8/29/2005 | | | | | 1.82 | 1.82 | 0.0226 | <0.50 | | | | | | |
| W10 | 9/28/2005 | | | | | 4.13 | 4.13 | 0.0136 | <0.50 | | | | | | |
| W10 | 10/15/2005 | | | | | | 4.19 | 0.018 | <0.50 | | | | | | |
| W6 | 5/27/2005 | | | | | 11.8 | 2.4 | | <0.50 | | | | | | |
| W6 | 6/30/2005 | | | | | <1 | <1.0 | | 0.73 | | | | | | |
| W6 | 7/29/2005 | | | | | | 29.2 | | <0.50 | | | | | | |
| W6 | 8/30/2005 | | | | | 2.62 | 2.62 | | <0.50 | | | | | | |
| W6 | 9/28/2005 | | | | | 4.04 | 4.04 | | 0.5 | | | | | | |
| W6 | 10/15/2005 | | | | | | 4.69 | | 0.52 | | | | | | |
| W6 | 6/2/2006 | | | | | 1.88 | | | <0.5 | <0.05 | 0.176 | | | | |
| W6 | 8/25/2006 | | | | | 2.4 | | | | | | | | | |
| W6 | 9/6/2006 | | | | | 2.3 | | | | | | | | | |
| W6 | 6/20/2007 | | | | | 2.1 | | | 0.4 | | | | | | |
| W6 | 9/18/2007 | | | | | 2.51 | | | 0.59 | | | | | | |
| W6 | 6/17/2008 | | | | | 1.64 | | | 0.29 | | | | | | |
| W6 | 9/18/2008 | | | | | 3.29 | | | 0.41 | | | | | | |
| W6 | 4/14/2009 | | | | | 6.28 | | | 6.32 | | | | | | |
| W6 | 4/30/2009 | 8.2 | | 5.6 | | 7.44 | | | 0.76 | | | | | | |
| W6 | 7/28/2009 | | | | | 42.9 | | | 6.17 | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | 7.25 | | 9.6 | | 48.4 | | | 9.84 | | | | | | |
| W6 | 8/18/2009 | | | | | | | | | | | | | | |
| W6 | 8/25/2009 | 7.82 | | 10.8 | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | 62.2 | | | 27.8 | | | | | | |
| W6 | 10/7/2009 | 8.14 | | 4.22 | | 63.3 | | | 33.3 | | | | | | |
| W6 | 10/25/2009 | 8.12 | | 2.36 | | | | | | | | | | | |
| W6 | 4/19/2010 | 6.6 | | 1 | | 30.3 | | | <0.02 | | | | | | |
| W6 | 5/16/2010 | 7.52 | | 1.1 | | 6.2 | | | 1 | <0.4 | 0.56 | | | | |
| W6 | 5/17/2010 | 7.7 | | 1.1 | | 8.1 | | | 0.8 | <0.4 | 0.22 | | | | |
| W6 | 5/19/2010 | 7.87 | | 1.1 | | 13 | | | 1 | <0.4 | 0.27 | | | | |
| W6 | 5/21/2010 | 8.01 | | 2.6 | | 7.2 | | | 0.9 | <0.4 | 0.26 | | | | |
| W6 | 5/23/2010 | 7.34 | | 1 | | 16 | | | 2.1 | <0.4 | 0.31 | | | | |
| W6 | 5/25/2010 | 7.48 | | 1 | | 17 | | | 1.4 | <0.4 | 0.29 | | | | |
| W6 | 5/29/2010 | 7.79 | | 1.4 | | 3.5 | | | 0.8 | <0.4 | 0.24 | | | | |
| W6 | 6/2/2010 | 7.38 | | 1.5 | | 49 | | | 6.4 | <0.4 | 0.43 | | | | |
| W6 | 6/4/2010 | 7.87 | | 2.6 | | <0.5 | | | <0.5 | <0.4 | 0.2 | | | | |
| W6 | 6/6/2010 | | | 1.6 | | <0.5 | | | <0.5 | <0.4 | 0.21 | | | | |
| W6 | 6/14/2010 | 6.65 | | 3.8 | | 1.4 | | | <0.5 | <0.4 | 0.23 | | | | |
| W6 | 6/16/2010 | 6.8 | | 2.5 | | <0.5 | | | <0.5 | <0.4 | 0.22 | | | | |
| W6 | 6/18/2010 | 7.03 | | 2.9 | | <0.5 | | | <0.5 | <0.4 | 0.23 | | | | |
| W6 | 6/20/2010 | 6.38 | | 3.1 | | 0.7 | | | <0.5 | <0.4 | 0.23 | | | | |
| W6 | 6/22/2010 | 7.8 | -0.2 | 1.92 | | <0.5 | | | <0.5 | <0.4 | 0.23 | | | | |
| W6 | 6/24/2010 | 7.91 | -1.2 | 2.38 | | <0.5 | | | <0.5 | <0.4 | 0.25 | | | | |
| W6 | 6/26/2010 | | | | | <0.5 | | | <0.5 | <0.4 | 0.24 | | | | |
| W6 | 6/26/2010 | 7.78 | -1 | 2.45 | | | | | | | | | | | |
| W6 | 6/28/2010 | 7.99 | 5.2 | 2.79 | | <0.5 | | | <0.5 | <0.4 | 0.22 | | | | |
| W6 | 7/5/2010 | 7.99 | 23.1 | 3.71 | | <0.5 | | | <0.5 | <0.4 | 0.2 | | | | |
| W6 | 8/5/2010 | 7.96 | -0.4 | 6.72 | | <0.5 | | | 0.5 | <0.4 | 0.23 | | | | |
| W6 | 9/9/2010 | 7.99 | 9.5 | 5.1 | | <0.5 | | | 0.7 | <0.4 | 0.26 | | | | |
| W6 | 10/8/2010 | 7.75 | -1.3 | -0.18 | | 2.1 | | | <0.5 | <0.4 | 0.21 | | | | |
| W6 | 8/19/2011 | | | | | | | | | | | | | | |
| W6 | 7/17/2012 | 7.92 | | 4.8 | | 1.82 | | | 1 | | 0.25 | | | | |
| W6 | 7/30/2012 | 7.89 | | 5.2 | | <0.50 | | | 0.58 | | 0.3 | | | | |
| W6 | 8/9/2012 | 8.09 | | 6.4 | | 0.64 | | | 1.1 | | 0.28 | | | | |
| W6 | 8/25/2012 | 7.76 | | 4.7 | | <0.50 | | | 0.92 | | 0.28 | | | | |
| W6 | 9/13/2012 | 7.95 | | 1.9 | | 0.62 | | | 1.1 | | 0.22 | | | | |
| W6 | 10/13/2012 | 8.3 | | 0 | | 1.52 | | | 0.87 | | 0.23 | | | | |
| W6 | 11/12/2012 | 6.69 | | -0.1 | | 5.81 | | | 1.1 | | 0.23 | | | | |
| W6 | 5/14/2013 | 7.6 | | 0.1 | | <0.50 | | | 1.5 | | 0.083 | | | | |
| W6 | 6/22/2013 | 7.61 | | 1.6 | | 1.88 | | | 1.1 | | 0.22 | | | | |
| W6 | 7/12/2013 | 7.69 | | 4.4 | | 1.27 | | | 1 | | 0.23 | | | | |
| W6 | 8/22/2013 | 7.81 | | 5.4 | | 0.53 | | | 0.84 | | 0.23 | | | | |
| W6 | 9/6/2013 | 7.60 | | 4.5 | | 0.62 | | | 1.2 | | 0.26 | | | | |
| W6 | 10/7/2013 | 7.66 | | 1.2 | | 1.89 | | | 0.8 | | 0.25 | | | | |
| W6 | 11/16/2013 | 7.96 | | -0.1 | | 1.48 | | | 0.78 | | 0.24 | | | | |
| W6 | 12/7/2013 | 7.50 | | 0 | | 5.36 | | | 1.4 | | 0.28 | | | | |
| W7 | 5/27/2005 | | | | | <0.5 | 6.18 | | <0.50 | | | | | | |
| W7 | 6/30/2005 | | | | | 10.2 | 10.2 | | 0.92 | | | | | | |
| W7 | 7/29/2005 | | | | | | 29.9 | | <0.50 | | | | | | |
| W7 | 8/30/2005 | | | | | 6.02 | 6.02 | | <0.50 | | | | | | |
| W7 | 9/28/2005 | | | | | 5.62 | 5.62 | | <0.50 | | | | | | |
| W7 | 10/15/2005 | | | | | | 7.47 | | <0.50 | | | | | | |
| W7 | 6/2/2006 | | | | | 2.98 | | | <0.5 | <0.05 | 0.155 | | | | |
| W7 | 6/8/2006 | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Field pH (pH units) | Field Turbidity (NTU) | Field Temp (° C) | Sulphide (mg/L) | Dissolved SO4 (mg/L) | Total SO4 (mg/L) | TT CN (mg/L) | Chloride (mg/L) | Bromine (mg/L) | Fluoride (mg/L) | Chromium 6 (mg/L) | Chromium III (mg/L) | Cu-D-IH (mg/L) | Al-D-IH (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | | | | | 10.5 | | | | | | | | | |
| W7 | 6/23/2006 | | | | | 15.1 | | | | | | | | | |
| W7 | 6/28/2006 | | | | | | | | | | | | | | |
| W7 | 7/7/2006 | | | | | 10.8 | | | | | | | | | |
| W7 | 7/12/2006 | | | | | 10.4 | | | | | | | | | |
| W7 | 7/20/2006 | | | | | 10.5 | | | | | | | | | |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | | | | | 11.6 | | | | | | | | | |
| W7 | 8/2/2006 | | | | | 10 | | | | | | | | | |
| W7 | 8/10/2006 | | | | | 10 | | | | | | | | | |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | | | | | 11 | | | | | | | | | |
| W7 | 8/30/2006 | | | | | 10.5 | | | | | | | | | |
| W7 | 9/6/2006 | | | | | 10.3 | | | | | | | | | |
| W7 | 9/13/2006 | | | | | 10 | | | | | | | | | |
| W7 | 9/20/2006 | | | | | 11 | | | | | | | | | |
| W7 | 9/28/2006 | | | | | 11 | | | | | | | | | |
| W7 | 10/4/2006 | | | | | 10.9 | | | | | | | | | |
| W7 | 10/12/2006 | | | | | 11.3 | | | | | | | | | |
| W7 | 6/5/2007 | | | | | 11 | | | 0.7 | | | | | | |
| W7 | 6/5/2007 | | | | | 11 | | | 0.7 | | | | | | |
| W7 | 6/5/2007 | | | | | 11 | | | 0.7 | | | | | | |
| W7 | 6/20/2007 | | | | | 12.2 | | | 0.6 | | | | | | |
| W7 | 7/18/2007 | | | | | 11.9 | | | 0.6 | | | | | | |
| W7 | 7/18/2007 | | | | | 11.9 | | | 0.6 | | | | | | |
| W7 | 7/18/2007 | | | | | 11.9 | | | 0.6 | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | 10.3 | | | 0.3 | | | | | | |
| W7 | 8/24/2007 | | | | | 10.2 | | | 0.3 | | | | | | |
| W7 | 8/24/2007 | | | | | 10.3 | | | 0.3 | | | | | | |
| W7 | 9/18/2007 | | | | | 8.21 | | | 0.46 | | | | | | |
| W7 | 10/30/2007 | | | | | 13 | | | 0.96 | | | | | | |
| W7 | 10/30/2007 | | | | | 13.6 | | | 1.32 | | | | | | |
| W7 | 10/30/2007 | | | | | 13 | | | 0.88 | | | | | | |
| W7 | 10/30/2007 | | | | | 13 | | | 0.91 | | | | | | |
| W7 | 4/22/2008 | | | | | 27.6 | | | 0.8 | | | | | | |
| W7 | 4/22/2008 | | | | | 27.8 | | | 0.62 | | | | | | |
| W7 | 4/22/2008 | | | | | 27.8 | | | 0.78 | | | | | | |
| W7 | 4/22/2008 | | | | | 27.8 | | | 0.62 | | | | | | |
| W7 | 6/3/2008 | | | | | 10.4 | | | 0.38 | | | | | | |
| W7 | 6/3/2008 | | | | | 10.4 | | | 0.37 | | | | | | |
| W7 | 6/3/2008 | | | | | 10.4 | | | 0.38 | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/17/2008 | | | | | 12.9 | | | 0.42 | | | | | | |
| W7 | 8/6/2008 | | | | | 9.89 | | | 0.29 | | | | | | |
| W7 | 8/6/2008 | | | | | 9.98 | | | 0.29 | | | | | | |
| W7 | 8/6/2008 | | | | | 9.98 | | | 0.3 | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 9/18/2008 | | | | | 5.44 | | | 0.57 | | | | | | |
| W7 | 10/28/2008 | | | | | 9.43 | | | 0.34 | | | | | | |
| W7 | 10/28/2008 | | | | | 9.36 | | | 0.31 | | | | | | |
| W7 | 10/28/2008 | | | | | 9.44 | | | 0.31 | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 4/30/2009 | 7.6 | | 0.4 | | 0.65 | | | 0.38 | | | | | | |
| W7 | 6/8/2009 | 7.74 | | 3.27 | | 8.6 | | | 4.1 | | | | | | |
| W7 | 7/28/2009 | | | | | 13 | | | 0.82 | | | | | | |
| W7 | 8/6/2009 | 7.5 | | 4.4 | | 13 | | | 0.39 | | | | | | |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | 8.04 | | 3.02 | | | | | | | | | | | |
| W7 | 8/31/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | 8.24 | | -0.8 | | 9.9 | | | 0.61 | | | | | | |
| W7 | 10/25/2009 | 8.23 | | 0.2 | | | | | | | | | | | |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | 7.31 | | 1 | | 8.2 | | | 0.91 | | | | | | |
| W7 | 4/27/2010 | 7.65 | 0 | -0.07 | | 7 | | | 1.4 | <0.4 | 0.08 | | | | |
| W7 | 4/29/2010 | 7.72 | -0.4 | -0.07 | | <5 | | | 0.9 | <0.4 | 0.09 | | | | |
| W7 | 5/1/2010 | 7.15 | 6.9 | -0.06 | | <5 | | | 1.2 | <0.4 | 0.11 | | | | |
| W7 | 5/3/2010 | 7.74 | 6.3 | 0.04 | | <0.5 | | | 0.8 | <0.4 | 0.11 | | | | |
| W7 | 5/5/2010 | | | | | <0.5 | | | 0.9 | <0.4 | 0.13 | | | | |
| W7 | 5/7/2010 | 7.95 | 5.6 | 0.03 | | <0.5 | | | 0.8 | <0.4 | 0.13 | | | | |
| W7 | 5/9/2010 | 8.03 | -0.8 | 0.8 | | 9.1 | | | 1.2 | <0.4 | 0.22 | | | | |
| W7 | 5/10/2010 | 8.06 | -0.9 | 0.07 | | 3.9 | | | 0.6 | <0.4 | 0.2 | | | | |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | | | | | 5.4 | | | <0.5 | <0.4 | 0.11 | | | | |
| W7 | 5/14/2010 | 7.26 | | 1.1 | | 5.2 | | | <0.5 | <0.4 | 0.18 | | | | |
| W7 | 5/16/2010 | 7.32 | | 1.10 | | 7.6 | | | 0.6 | <0.4 | 0.2 | | | | |
| W7 | 5/17/2010 | 7.52 | | 1 | | 5.6 | | | <0.5 | <0.4 | 0.19 | | | | |
| W7 | 5/19/2010 | 7.62 | | 1 | | 9.7 | | | <0.5 | <0.4 | 0.25 | | | | |
| W7 | 5/21/2010 | 8.02 | | 1.2 | | 9.3 | | | 0.8 | <0.4 | 0.26 | | | | |
| W7 | 5/23/2010 | 7.61 | | 1 | | 9.9 | | | 1 | <0.4 | 0.28 | | | | |
| W7 | 5/25/2010 | 7.24 | | 1.2 | | 11 | | | 0.8 | <0.4 | 0.28 | | | | |
| W7 | 5/27/2010 | 7.53 | | 3 | | 12 | | | <0.5 | <0.4 | 0.3 | | | | |
| W7 | 5/29/2010 | 7.73 | | 1 | | 12 | | | 0.7 | <0.4 | 0.32 | | | | |
| W7 | 5/31/2010 | 7.83 | | 1.2 | | 12 | | | 0.7 | <0.4 | 0.32 | | | | |
| W7 | 6/2/2010 | 7.26 | | 1.4 | | 12 | | | <0.5 | <0.4 | 0.31 | | | | |
| W7 | 6/4/2010 | 7.48 | | 3.1 | | 13 | | | 0.8 | <0.4 | 0.31 | | | | |
| W7 | 6/6/2010 | | | 1.9 | | 12 | | | <0.5 | <0.4 | 0.32 | | | | |
| W7 | 6/14/2010 | | | 3.8 | | 13 | | | <0.5 | <0.4 | 0.35 | | | | |
| W7 | 6/16/2010 | 6.78 | | 2.6 | | 14 | | | <0.5 | <0.4 | 0.35 | | | | |
| W7 | 6/18/2010 | 7.03 | | 3 | | 12 | | | <0.5 | <0.4 | 0.34 | | | | |
| W7 | 6/20/2010 | 7.1 | | 3.4 | | 10 | | | 0.5 | <0.4 | 0.31 | | | | |
| W7 | 6/22/2010 | 7.92 | 135 | 3.25 | | 8.2 | | | <0.5 | <0.4 | 0.25 | | | | |
| W7 | 6/24/2010 | 7.95 | 30 | 3.55 | | 6.4 | | | <0.5 | <0.4 | 0.28 | | | | |
| W7 | 6/26/2010 | 8.03 | 9.7 | 3.12 | | 7.8 | | | <0.5 | <0.4 | 0.3 | | | | |
| W7 | 6/28/2010 | 7.89 | 2.3 | 2.94 | | 9.7 | | | <0.5 | <0.4 | 0.29 | | | | |
| W7 | 7/5/2010 | 8.02 | 35.4 | 4.48 | | 2.5 | | | <0.5 | <0.4 | 0.22 | | | | |
| W7 | 8/5/2010 | 7.91 | 3.1 | 5.57 | | | | | | | | | | | |
| W7 | 9/12/2010 | | | | | | | | | | | | | | |
| W7 | 9/12/2010 | 8.02 | 0.8 | 4.06 | | 6.4 | | | 0.7 | <0.4 | 0.22 | | | | |
| W7 | 10/8/2010 | 7.85 | -2.7 | -0.18 | | 8.8 | | | <0.5 | <0.4 | 0.23 | | | | |
| W7 | 4/27/2011 | | | | | <5 | | | 1.9 | | 0.1 | | | | |
| W7 | 5/2/2011 | | | | | <5 | | | 1.7 | | 0.08 | | | | |
| W7 | 6/1/2011 | | | | | 6.1 | | | 0.5 | | 0.24 | | | | |
| W7 | 6/16/2011 | | | | | | | | | | | | | | |
| W7 | 7/1/2011 | | | | | <0.5 | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Field pH (pH units) | Field Turbidity (NTU) | Field Temp (° C) | Sulphide (mg/L) | Dissolved SO4 (mg/L) | Total SO4 (mg/L) | TT CN (mg/L) | Chloride (mg/L) | Bromine (mg/L) | Fluoride (mg/L) | Chromium 6 (mg/L) | Chromium III (mg/L) | Cu-D-IH (mg/L) | Al-D-IH (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | | | | | | | | 1.8 | | 0.14 | | | | |
| W7 | 8/16/2011 | | | | | | | | | | | | | | |
| W7 | 8/19/2011 | | | | | | | | | | | | | | |
| W7 | 9/12/2011 | 7.92 | | 1.9 | | | | | 1.3 | | | | | | |
| W7 | 10/6/2011 | 7.65 | | 0 | | 8.9 | | | 1 | | | | | | |
| W7 | 11/22/2011 | | | | | | | | 0.8 | | | | | | |
| W7 | 1/24/2012 | | | | | 18 | | | 0.8 | | 0.43 | | | | |
| W7 | 2/25/2012 | 7.16 | | 0.00 | | 17.8 | | | 0.9 | | 0.42 | | | | |
| W7 | 3/5/2012 | 6.72 | | 0 | | 19 | | | 0.5 | | 0.42 | | | | |
| W7 | 4/24/2012 | 7.43 | | 0 | | <0.50 | | | 1.4 | | 0.1 | | | | |
| W7 | 5/6/2012 | | | | | <0.50 | | | 0.58 | | 0.12 | | | | |
| W7 | 5/6/2012 | 7.1 | | 0 | | <0.50 | | | <0.50 | | 0.12 | | | | |
| W7 | 6/19/2012 | 7.59 | | 4.1 | | <0.50 | | | 1.1 | | 0.17 | | | | |
| W7 | 7/17/2012 | 7.76 | | 5.4 | | 4.63 | | | 0.96 | | 0.23 | | | | |
| W7 | 7/30/2012 | 7.86 | | 4.4 | | 5.31 | | | 0.58 | | 0.28 | | | | |
| W7 | 8/8/2012 | 8.44 | | 4.7 | | 5.43 | | | 1.2 | | 0.29 | | | | |
| W7 | 8/23/2012 | 7.79 | | 4.6 | | 5.23 | | | 1.2 | | 0.27 | | | | |
| W7 | 9/13/2012 | 7.98 | | 1.9 | | 3.85 | | | 1.2 | | 0.18 | | | | |
| W7 | 10/16/2012 | 7.89 | | 0.4 | | 7.47 | | | 1.2 | | 0.19 | | | | |
| W7 | 11/2/2012 | | | | | 14.4 | | | 0.82 | | 0.29 | | | | |
| W7 | 12/29/2012 | 7.97 | | -0.3 | | 29.1 | | | 1.9 | | 0.43 | | | | |
| W7 | 4/30/2013 | 8.18 | | 0 | | 24.1 | | | 1.4 | | 0.53 | | | | |
| W7 | 5/14/2013 | 8.2 | | 0 | | <0.50 | | | 1.5 | | 0.064 | | | | |
| W7 | 6/19/2013 | | | | | 8.07 | | | 1.2 | | 0.25 | | | | |
| W7 | 6/19/2013 | 8.6 | | 4.6 | | 7.87 | | | 1.1 | | 0.25 | | | | |
| W7 | 7/13/2013 | 7.74 | | 3.6 | | 9.73 | | | 0.99 | | 0.26 | | | | |
| W7 | 8/21/2013 | 7.81 | | 4.2 | | 8.32 | | | 0.93 | | 0.27 | | | | |
| W7 | 9/6/2013 | 7.75 | | 4 | | 5.66 | | | 1.3 | | 0.24 | | | | |
| W7 | 10/21/2013 | 7.58 | | 0 | | 10.3 | | | 1.3 | | 0.25 | | | | |
| W7 | 11/16/2013 | 7.69 | | -0.1 | | 15.1 | | | 1 | | 0.35 | | | | |
| W7 | 12/7/2013 | 6.30 | | 0 | | 16.7 | | | 1.2 | | 0.31 | | | | |
| C4 | 5/6/2012 | 7.51 | | 0 | | <0.50 | | | 0.54 | | 0.14 | | | | |
| C4 | 8/1/2012 | 7.75 | | 9.3 | | 3.37 | | | 0.89 | | 0.2 | | | | |
| C4 | 8/8/2012 | 7.81 | | 7.8 | | <5.0 | | | <5.0 | | 0.22 | | | | |
| C4 | 8/25/2012 | 7.81 | | 6.3 | | 2.19 | | | 1.4 | | 0.22 | | | | |
| C4 | 6/22/2013 | 7.68 | | 7.3 | | 10.6 | | | 1.4 | | 0.27 | | | | |
| C4 | 7/19/2013 | 8.20 | | 9.6 | | 7.45 | | | 1.5 | | 0.27 | | | | |
| C4 | 8/22/2013 | 7.88 | | 7.7 | | 4.75 | | | 1.5 | | 0.21 | | | | |
| C4 | 9/6/2013 | 7.69 | | 5.3 | | 4.27 | | | 1.3 | | 0.19 | | | | |
| C4 | 10/18/2013 | | | | | 11.1 | | | 1.2 | | 0.19 | | | | |
| C4 | 10/18/2013 | 7.16 | | -0.1 | | 38.1 | | | 2.4 | | 0.2 | | | | |
| C4 | 11/17/2013 | 7.17 | | -0.1 | | 6.33 | | | 2.4 | | 0.29 | | | | |
| C10 | 5/12/2012 | 7.89 | | 2.4 | | <0.50 | | | 1.1 | | 0.2 | | | | |
| C10 | 7/30/2012 | | | | | <0.50 | | | 1.2 | | 0.29 | | | | |
| C10 | 7/30/2012 | 8.16 | | 11.2 | | | | | | | | | | | |
| C10 | 8/10/2012 | 8.71 | | 7.4 | | <0.50 | | | 0.75 | | 4 | | | | |
| C10 | 8/27/2012 | 8.3 | | 7.4 | | <0.50 | | | 2 | | 0.24 | | | | |
| C10 | 6/22/2013 | 8.29 | | 11.7 | | 0.97 | | | 1.3 | | 0.21 | | | | |
| C10 | 7/23/2013 | 8.31 | | 7.8 | | <0.50 | | | 1.3 | | 0.21 | | | | |
| C10 | 8/22/2013 | 8.18 | | 8.2 | | <0.50 | | | 1.6 | | 0.21 | | | | |
| C10 | 9/8/2013 | | | | | <0.50 | | | 1.6 | | 0.2 | | | | |
| C10 | 9/8/2013 | 8.16 | | 9 | | <0.50 | | | 1.3 | | 0.2 | | | | |
| C10 | 10/18/2013 | 7.78 | | 0 | | 3.24 | | | 1.5 | | 0.17 | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Cd-D-IH (mg/L) | Se-D-IH (mg/L) | Ag-D (mg/L) | Dissolved Al (mg/L) | Dissolved As (mg/L) | Dissolved Ba (mg/L) | Dissolved B (mg/L) | Dissolved Be (mg/L) | Dissolved Bi (mg/L) | Dissolved Ca (mg/L) | Dissolved Cd (mg/L) | Dissolved Co (mg/L) | Dissolved Cr (mg/L) | Dissolved Cu (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | | | <0.000020 | 0.0176 | 0.00051 | 0.049 | <0.10 | <0.0010 | | 25 | <0.000050 | <0.00030 | <0.0010 | 0.0034 |
| W1 | 6/30/2005 | | | <0.000010 | 0.0065 | 0.00048 | 0.0554 | <0.010 | <0.00050 | <0.00050 | 37.5 | <0.000050 | <0.00010 | <0.00050 | 0.00204 |
| W1 | 7/28/2005 | | | <0.000010 | 0.0072 | 0.00048 | 0.0575 | <0.010 | <0.00050 | <0.00050 | 40.4 | <0.000050 | <0.00010 | <0.00050 | 0.00211 |
| W1 | 8/29/2005 | | | <0.000020 | 0.0106 | 0.0006 | 0.058 | <0.10 | <0.0010 | | 35.9 | <0.000017 | <0.00030 | <0.0010 | 0.0024 |
| W1 | 9/28/2005 | | | <0.000020 | 0.0143 | 0.00058 | 0.055 | <0.10 | <0.0010 | | 35.3 | <0.000017 | <0.00030 | <0.0010 | 0.0026 |
| W1 | 10/15/2005 | | | <0.000010 | 0.0137 | 0.00054 | 0.0492 | <0.010 | <0.00050 | <0.00050 | 36.8 | <0.000050 | <0.00010 | <0.00050 | 0.00279 |
| W2 | 5/27/2005 | | | <0.000020 | 0.0163 | <0.00050 | 0.05 | <0.10 | <0.0010 | | 25.6 | <0.000050 | <0.00030 | <0.0010 | 0.0033 |
| W2 | 5/27/2005 | | | | 0.0108 | | 0.032 | | | | 20.3 | | | | |
| W2 | 6/30/2005 | | | <0.000010 | 0.0073 | 0.00044 | 0.0574 | <0.010 | <0.00050 | <0.00050 | 36.9 | <0.000050 | <0.00010 | <0.00050 | 0.0021 |
| W2 | 7/28/2005 | | | <0.000010 | 0.0071 | 0.00044 | 0.0604 | <0.010 | <0.00050 | <0.00050 | 39.6 | <0.000050 | <0.00010 | <0.00050 | 0.00208 |
| W2 | 8/30/2005 | | | <0.000020 | 0.0119 | 0.00058 | 0.059 | <0.10 | <0.0010 | | 35.7 | <0.000017 | <0.00030 | <0.0010 | 0.0024 |
| W2 | 9/28/2005 | | | <0.000020 | 0.0141 | 0.00059 | 0.055 | <0.10 | <0.0010 | | 35.2 | <0.000017 | <0.00030 | <0.0010 | 0.0025 |
| W2 | 10/15/2005 | | | <0.000010 | 0.0129 | 0.00053 | 0.0492 | <0.010 | <0.00050 | <0.00050 | 35.9 | <0.000050 | <0.00010 | <0.00050 | 0.00271 |
| W3 | 5/27/2005 | | | <0.000020 | 0.0267 | <0.00050 | 0.041 | <0.10 | <0.0010 | | 22 | <0.000050 | <0.00030 | <0.0010 | 0.0066 |
| W3 | 6/30/2005 | | | <0.000010 | 0.008 | 0.00034 | 0.0507 | <0.010 | <0.00050 | <0.00050 | 38.5 | <0.000050 | <0.00010 | <0.00050 | 0.00336 |
| W3 | 7/29/2005 | | | <0.000010 | 0.0113 | 0.00041 | 0.0553 | <0.010 | <0.00050 | <0.00050 | 38 | <0.000050 | 0.0001 | <0.00050 | 0.00478 |
| W3 | 8/29/2005 | | | <0.000020 | 0.0184 | <0.00050 | 0.057 | <0.10 | <0.0010 | | 31.8 | <0.000017 | <0.00030 | <0.0010 | 0.005 |
| W3 | 9/28/2005 | | | <0.000020 | 0.0257 | <0.00050 | 0.055 | <0.10 | <0.0010 | | 30.4 | <0.000017 | <0.00030 | <0.0010 | 0.0057 |
| W3 | 10/15/2005 | | | <0.000010 | 0.0223 | 0.00043 | 0.0475 | <0.010 | <0.00050 | <0.00050 | 31.6 | <0.000050 | 0.00016 | <0.00050 | 0.00608 |
| W8 | 5/27/2005 | | | <0.000020 | 0.0427 | <0.00050 | 0.039 | <0.10 | <0.0010 | | 16.6 | <0.000050 | <0.00030 | <0.0010 | 0.0141 |
| W8 | 6/30/2005 | | | <0.000010 | 0.0193 | 0.00043 | 0.0466 | <0.010 | <0.00050 | <0.00050 | 24.8 | <0.000050 | <0.00010 | 0.00061 | 0.00942 |
| W8 | 7/29/2005 | | | <0.000010 | 0.0201 | 0.00045 | 0.0538 | <0.010 | <0.00050 | <0.00050 | 30.9 | <0.000050 | 0.00014 | 0.00052 | 0.00863 |
| W8 | 8/30/2005 | | | <0.000020 | 0.0259 | <0.00050 | 0.054 | <0.10 | <0.0010 | | 26.3 | <0.000017 | <0.00030 | <0.0010 | 0.0081 |
| W8 | 9/28/2005 | | | <0.000020 | 0.0305 | <0.00050 | 0.049 | <0.10 | <0.0010 | | 25.3 | <0.000017 | <0.00030 | <0.0010 | 0.0081 |
| W8 | 10/15/2005 | | | 0.000031 | 0.0258 | 0.0005 | 0.0479 | <0.010 | <0.00050 | <0.00050 | 26.8 | <0.000050 | 0.00028 | <0.00050 | 0.00561 |
| W9 | 5/27/2005 | | | <0.000020 | 0.0718 | <0.00050 | 0.042 | <0.10 | <0.0010 | | 12.9 | <0.000050 | <0.00030 | <0.0010 | 0.0035 |
| W9 | 6/30/2005 | | | <0.000010 | 0.0345 | 0.00054 | 0.0525 | <0.010 | <0.00050 | <0.00050 | 18.9 | <0.000050 | 0.00018 | <0.00050 | 0.00184 |
| W9 | 7/29/2005 | | | <0.000010 | 0.0298 | 0.00057 | 0.056 | <0.010 | <0.00050 | <0.00050 | 25.9 | <0.000050 | 0.00018 | <0.00050 | 0.00334 |
| W9 | 8/29/2005 | | | <0.000020 | 0.0449 | 0.00058 | 0.055 | <0.10 | <0.0010 | | 19.1 | 0.000022 | <0.00030 | <0.0010 | 0.0017 |
| W9 | 9/28/2005 | | | <0.000020 | 0.0578 | <0.00050 | 0.049 | <0.10 | <0.0010 | | 17.7 | <0.000017 | <0.00030 | <0.0010 | 0.0022 |
| W9 | 10/15/2005 | | | <0.000010 | 0.056 | 0.00039 | 0.0421 | <0.010 | <0.00050 | <0.00050 | 16.6 | <0.000050 | 0.00016 | <0.00050 | 0.00209 |
| W10 | 5/27/2005 | | | <0.000020 | 0.135 | <0.00050 | 0.052 | <0.10 | <0.0010 | | 13.1 | <0.000050 | <0.00030 | <0.0010 | 0.0184 |
| W10 | 5/27/2005 | | | <0.00002 | | <0.0005 | | <0.1 | <0.001 | | | <0.00005 | <0.0003 | <0.001 | <0.001 |
| W10 | 6/30/2005 | | | <0.000010 | 0.113 | 0.00059 | 0.0396 | <0.010 | <0.00050 | <0.00050 | 13.1 | <0.000050 | 0.00046 | 0.00062 | 0.00472 |
| W10 | 7/29/2005 | | | <0.000010 | 0.0683 | 0.00037 | 0.0369 | <0.010 | <0.00050 | <0.00050 | 14.7 | <0.000050 | 0.00011 | <0.00050 | 0.00437 |
| W10 | 8/29/2005 | | | <0.000020 | 0.0433 | <0.00050 | 0.044 | <0.10 | <0.0010 | | 18.2 | <0.000017 | <0.00030 | <0.0010 | 0.004 |
| W10 | 9/28/2005 | | | <0.000020 | 0.0302 | <0.00050 | 0.057 | <0.10 | <0.0010 | | 25.8 | <0.000017 | <0.00030 | <0.0010 | 0.0033 |
| W10 | 10/15/2005 | | | <0.000010 | 0.0361 | 0.0003 | 0.0487 | <0.010 | <0.00050 | <0.00050 | 25.4 | <0.000050 | <0.00010 | <0.00050 | 0.00412 |
| W6 | 5/27/2005 | | | <0.000020 | 0.0144 | <0.00050 | 0.035 | <0.10 | <0.0010 | | 17.9 | <0.000050 | <0.00030 | <0.0010 | 0.0016 |
| W6 | 6/30/2005 | | | <0.000010 | 0.0056 | 0.00039 | 0.0429 | <0.010 | <0.00050 | <0.00050 | 25.2 | <0.000050 | <0.00010 | <0.00050 | 0.00101 |
| W6 | 7/29/2005 | | | <0.000010 | 0.007 | 0.00026 | 0.0668 | <0.010 | <0.00050 | <0.00050 | 46.9 | <0.000050 | <0.00010 | <0.00050 | 0.00247 |
| W6 | 8/30/2005 | | | <0.000020 | 0.0067 | <0.00050 | 0.053 | <0.10 | <0.0010 | | 29 | <0.000017 | <0.00030 | <0.0010 | 0.001 |
| W6 | 9/28/2005 | | | <0.000020 | 0.0067 | <0.00050 | 0.048 | <0.10 | <0.0010 | | 28.8 | <0.000017 | <0.00030 | <0.0010 | 0.0011 |
| W6 | 10/15/2005 | | | <0.000010 | 0.0769 | 0.00042 | 0.0419 | <0.010 | <0.00050 | <0.00050 | 26.7 | <0.000050 | <0.00010 | <0.00050 | 0.00108 |
| W6 | 6/2/2006 | | | <0.00001 | 0.0252 | 0.00044 | 0.0315 | <0.01 | <0.0005 | <0.0005 | 17.8 | <0.00005 | <0.0001 | <0.0005 | 0.00175 |
| W6 | 8/25/2006 | | | | | | | | | | 31.7 | | | | |
| W6 | 9/6/2006 | | | <0.0001 | 0.008 | 0.0005 | 0.051 | <0.002 | <0.0001 | <0.0005 | 30 | <0.00001 | 0.0001 | 0.0006 | 0.001 |
| W6 | 6/20/2007 | | | | | | | | | | | | | | |
| W6 | 9/18/2007 | | | | | | | | | | | | | | |
| W6 | 6/17/2008 | | | | | | | | | | | | | | |
| W6 | 9/18/2008 | | | <0.00001 | 0.012 | 0.0004 | 0.039 | <0.004 | <0.00004 | | 23.7 | <0.00001 | 0.00022 | 0.0013 | 0.002 |
| W6 | 4/14/2009 | | | <0.00001 | 0.038 | 0.0004 | 0.046 | 0.017 | <0.00004 | <0.0001 | 23.6 | 0.00002 | 0.00033 | 0.0004 | 0.043 |
| W6 | 4/30/2009 | | | <0.00001 | 0.097 | 0.0003 | 0.026 | 0.007 | <0.00004 | <0.0001 | 14.5 | 0.00023 | 0.00014 | 0.0007 | 0.008 |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/18/2009 | | | <0.00001 | 0.03 | 0.0004 | 0.101 | 0.023 | <0.00004 | <0.001 | 46.1 | <0.00001 | 0.00014 | 0.001 | 0.004 |
| W6 | 8/25/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/25/2009 | | | <0.00002 | 0.023 | 0.0003 | 0.118 | <0.05 | <0.0001 | <0.001 | 57.9 | 0.00001 | <0.0005 | <0.001 | 0.0021 |
| W6 | 4/19/2010 | | | <0.00001 | 0.024 | 0.0002 | 0.048 | 0.009 | <0.00004 | <0.001 | 32.3 | 0.00003 | 0.00016 | <0.0004 | 0.019 |
| W6 | 5/16/2010 | | | <0.00002 | <0.003 | 0.0004 | 0.025 | <0.05 | <0.0001 | <0.001 | 25.4 | <0.00001 | <0.0005 | <0.001 | 0.0015 |
| W6 | 5/17/2010 | | | <0.00002 | 0.009 | 0.0003 | 0.033 | <0.05 | <0.0001 | <0.001 | 20.8 | <0.00001 | <0.0005 | <0.001 | 0.0022 |
| W6 | 5/19/2010 | | | <0.00002 | 0.004 | 0.0003 | 0.039 | <0.05 | <0.0001 | <0.001 | 26 | <0.00001 | <0.0005 | <0.001 | 0.0027 |
| W6 | 5/21/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.04 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | 0.003 |
| W6 | 5/23/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.046 | <0.1 | <0.0002 | <0.001 | 28 | <0.0001 | <0.0005 | <0.002 | 0.003 |
| W6 | 5/25/2010 | | | <0.0001 | <0.01 | <0.001 | 0.045 | <0.1 | <0.0005 | <0.001 | 29 | <0.0001 | <0.0005 | <0.002 | 0.006 |
| W6 | 5/29/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.037 | <0.1 | <0.0002 | <0.001 | 21 | <0.0001 | <0.0005 | <0.002 | 0.003 |
| W6 | 6/2/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.074 | <0.1 | <0.0002 | <0.001 | 56 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W6 | 6/4/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.043 | <0.1 | <0.0002 | <0.001 | 23 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 6/6/2010 | | | <0.0001 | <0.01 | 0.0004 | 0.046 | <0.1 | <0.0002 | <0.001 | 27 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W6 | 6/14/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.038 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W6 | 6/16/2010 | | | <0.0001 | <0.01 | 0.0005 | 0.044 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | 0.006 |
| W6 | 6/18/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.044 | <0.1 | <0.0002 | <0.001 | 26 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W6 | 6/20/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.043 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 6/22/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.044 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 6/24/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.043 | <0.1 | <0.0002 | <0.001 | 26 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 6/26/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.045 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.044 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 7/5/2010 | | | <0.0001 | 0.015 | 0.0004 | 0.047 | <0.1 | <0.0002 | <0.001 | 22 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W6 | 8/5/2010 | | | <0.0001 | 0.012 | 0.0005 | 0.056 | <0.1 | <0.0002 | <0.001 | 31 | <0.0001 | <0.0005 | <0.002 | 0.002 |
| W6 | 9/9/2010 | | | <0.0001 | 0.011 | 0.0004 | 0.053 | <0.1 | <0.0002 | <0.001 | 30 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W6 | 10/8/2010 | | | <0.00002 | 0.008 | 0.0004 | 0.05 | <0.05 | <0.0001 | <0.001 | 28.8 | <0.00001 | <0.0005 | <0.001 | 0.0008 |
| W6 | 8/19/2011 | | | <0.00002 | 0.01 | 0.0003 | 0.077 | <0.05 | <0.0001 | <0.001 | 53.6 | <0.00001 | <0.0005 | <0.001 | 0.0025 |
| W6 | 7/17/2012 | | | <0.000020 | 0.0161 | 0.00053 | 0.0597 | <0.05 | <0.00010 | <0.0010 | 29.7 | <0.000010 | <0.00050 | <0.0010 | 0.00105 |
| W6 | 7/30/2012 | | | <0.000020 | 0.0186 | 0.00059 | 0.0601 | <0.05 | <0.00010 | <0.0010 | 28.9 | <0.000010 | <0.00050 | <0.0010 | 0.00089 |
| W6 | 8/9/2012 | | | <0.000020 | 0.0173 | 0.00081 | 0.0681 | <0.05 | <0.00010 | <0.0010 | 31.9 | <0.000010 | <0.00050 | <0.0010 | 0.00083 |
| W6 | 8/25/2012 | | | <0.000020 | 0.0138 | 0.00081 | 0.063 | <0.05 | <0.00010 | <0.0010 | 28.9 | <0.000010 | <0.00050 | <0.0010 | 0.00103 |
| W6 | 9/13/2012 | | | <0.000020 | 0.0169 | 0.00047 | 0.0451 | <0.05 | <0.00010 | <0.0010 | 24.1 | <0.000010 | <0.00050 | <0.0010 | 0.00145 |
| W6 | 10/13/2012 | | | | | | | | | | | | | | |
| W6 | 11/12/2012 | | | <0.000020 | 0.0062 | 0.00039 | 0.0697 | <0.05 | <0.00010 | <0.0010 | 41.6 | <0.000010 | <0.00050 | <0.0010 | 0.00143 |
| W6 | 5/14/2013 | | | <0.000020 | 0.0591 | 0.00037 | 0.0195 | <0.05 | <0.00010 | <0.0010 | 8.75 | 0.000012 | <0.00050 | <0.0010 | 0.0035 |
| W6 | 6/22/2013 | | | <0.000020 | 0.0095 | 0.00053 | 0.0493 | <0.05 | <0.00010 | <0.0010 | 26.4 | <0.000010 | <0.00050 | <0.0010 | 0.00096 |
| W6 | 7/12/2013 | | | <0.000020 | 0.0066 | 0.00046 | 0.0438 | <0.05 | <0.00010 | <0.0010 | 24.1 | <0.000010 | <0.00050 | <0.0010 | 0.00095 |
| W6 | 8/22/2013 | | | <0.000020 | 0.0084 | 0.00052 | 0.0495 | <0.05 | <0.00010 | <0.0010 | 28.3 | <0.000010 | <0.00050 | <0.0010 | 0.00119 |
| W6 | 9/6/2013 | | | <0.000020 | 0.0083 | 0.00056 | 0.0499 | <0.05 | <0.00010 | <0.0010 | 28.4 | <0.000010 | <0.00050 | <0.0010 | 0.00089 |
| W6 | 10/7/2013 | | | <0.000020 | 0.0132 | 0.00051 | 0.0518 | <0.05 | <0.00010 | <0.0010 | 30.7 | <0.000010 | <0.00050 | <0.0010 | 0.00097 |
| W6 | 11/16/2013 | | | <0.000020 | 0.0057 | 0.00048 | 0.0582 | <0.05 | <0.00010 | <0.0010 | 33.2 | <0.000010 | <0.00050 | <0.0010 | 0.00084 |
| W6 | 12/7/2013 | | | <0.000020 | 0.0041 | 0.00061 | 0.0725 | <0.05 | <0.00010 | <0.0010 | 44.6 | 0.000011 | <0.00050 | <0.0010 | 0.00156 |
| W7 | 5/27/2005 | | | <0.000020 | 0.0236 | <0.00050 | 0.045 | <0.10 | <0.0010 | | 19.5 | <0.000050 | <0.00030 | <0.0010 | 0.0018 |
| W7 | 6/30/2005 | | | <0.000010 | 0.0086 | 0.00042 | 0.0609 | <0.010 | <0.00050 | <0.00050 | 30 | <0.000050 | <0.00010 | <0.00050 | 0.00119 |
| W7 | 7/29/2005 | | | <0.000010 | 0.0096 | 0.00035 | 0.061 | <0.010 | <0.00050 | <0.00050 | 41.3 | <0.000050 | <0.00010 | <0.00050 | 0.00404 |
| W7 | 8/30/2005 | | | <0.000020 | 0.0156 | 0.00051 | 0.062 | <0.10 | <0.0010 | | 27.8 | <0.000017 | <0.00030 | <0.0010 | 0.0014 |
| W7 | 9/28/2005 | | | <0.000020 | 0.0186 | 0.00054 | 0.055 | <0.10 | <0.0010 | | 27.4 | <0.000017 | <0.00030 | <0.0010 | 0.0016 |
| W7 | 10/15/2005 | | | <0.000010 | 0.0155 | 0.00048 | 0.0502 | <0.010 | <0.00050 | <0.00050 | 27.1 | <0.000050 | 0.00011 | <0.00050 | 0.00127 |
| W7 | 6/2/2006 | | | <0.00001 | 0.0714 | 0.00062 | 0.0341 | <0.01 | <0.0005 | <0.0005 | 14.4 | <0.00005 | 0.00033 | 0.00055 | 0.00212 |
| W7 | 6/8/2006 | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Cd-D-IH (mg/L) | Se-D-IH (mg/L) | Ag-D (mg/L) | Dissolved Al (mg/L) | Dissolved As (mg/L) | Dissolved Ba (mg/L) | Dissolved B (mg/L) | Dissolved Be (mg/L) | Dissolved Bi (mg/L) | Dissolved Ca (mg/L) | Dissolved Cd (mg/L) | Dissolved Co (mg/L) | Dissolved Cr (mg/L) | Dissolved Cu (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | | | <0.0001 | 0.013 | 0.0004 | 0.063 | 0.003 | <0.0001 | <0.0005 | 26.9 | <0.00001 | 0.0001 | <0.0005 | 0.001 |
| W7 | 6/23/2006 | | | <0.0001 | 0.011 | 0.0005 | 0.067 | 0.002 | <0.0001 | <0.0005 | 31.8 | <0.00001 | 0.0001 | 0.0007 | <0.001 |
| W7 | 6/28/2006 | | | <0.0001 | 0.407 | 0.0008 | 0.079 | 0.002 | <0.0001 | <0.0005 | 22.8 | 0.00003 | 0.0009 | 0.0015 | 0.003 |
| W7 | 7/7/2006 | | | <0.0001 | <0.005 | 0.0006 | 0.067 | 0.005 | <0.0001 | 0.0007 | 26.5 | <0.00001 | <0.0001 | 0.0011 | 0.001 |
| W7 | 7/12/2006 | | | <0.0001 | 0.006 | 0.0005 | 0.064 | 0.005 | <0.0001 | 0.0007 | 26.9 | <0.00001 | <0.0001 | 0.001 | 0.001 |
| W7 | 7/20/2006 | | | <0.0001 | 0.006 | 0.0004 | 0.068 | 0.004 | <0.0001 | <0.0005 | 33 | <0.00001 | <0.0001 | 0.0007 | <0.001 |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | | | <0.0001 | 0.008 | 0.0004 | 0.072 | <0.002 | <0.0001 | <0.0005 | 33.4 | <0.00001 | <0.0001 | <0.0005 | 0.002 |
| W7 | 8/2/2006 | | | <0.0001 | 0.008 | <0.0002 | 0.07 | 0.004 | <0.0001 | <0.0005 | 33.3 | <0.00001 | <0.0001 | <0.0005 | 0.001 |
| W7 | 8/10/2006 | | | <0.0001 | 0.009 | 0.0005 | 0.073 | 0.005 | <0.0001 | <0.0005 | 32.9 | <0.00001 | <0.0001 | 0.0007 | 0.001 |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | | | <0.0001 | 0.012 | 0.0004 | 0.071 | 0.005 | <0.0001 | <0.0005 | 32.4 | <0.00001 | 0.0002 | 0.0006 | 0.001 |
| W7 | 8/30/2006 | | | <0.0001 | 0.013 | 0.0004 | 0.067 | 0.004 | <0.0001 | <0.0005 | 33.6 | <0.00001 | 0.0001 | 0.0008 | 0.002 |
| W7 | 9/6/2006 | | | <0.0001 | 0.005 | 0.0005 | 0.068 | 0.005 | <0.0001 | <0.0005 | 33.5 | <0.00001 | <0.0001 | 0.0008 | 0.002 |
| W7 | 9/13/2006 | | | <0.0001 | 0.008 | 0.0003 | 0.064 | 0.005 | <0.0001 | <0.0005 | 32.3 | <0.00001 | <0.0001 | 0.0009 | 0.001 |
| W7 | 9/20/2006 | | | <0.0001 | 0.007 | 0.0005 | 0.069 | 0.005 | <0.0001 | <0.0005 | 33.5 | 0.00028 | <0.0001 | 0.0007 | 0.001 |
| W7 | 9/28/2006 | | | <0.0001 | 0.011 | 0.0004 | 0.071 | 0.003 | <0.0001 | <0.0005 | 33.3 | <0.00001 | <0.0001 | 0.0008 | 0.001 |
| W7 | 10/4/2006 | | | <0.0001 | <0.005 | 0.0003 | 0.068 | 0.004 | <0.0001 | <0.0005 | 32.6 | <0.00001 | <0.0001 | <0.0005 | <0.001 |
| W7 | 10/12/2006 | | | <0.0001 | 0.007 | 0.0004 | 0.067 | 0.005 | <0.0001 | <0.0005 | 34 | <0.00001 | <0.0001 | <0.0005 | 0.001 |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/20/2007 | | | <0.0001 | 0.014 | 0.0004 | 0.06 | 0.005 | <0.0001 | <0.0005 | 29.6 | <0.00001 | <0.0001 | 0.0006 | 0.002 |
| W7 | 7/18/2007 | | | <0.0001 | 0.011 | 0.0005 | 0.066 | 0.005 | <0.0001 | <0.0005 | 32 | <0.00001 | <0.0001 | 0.001 | 0.002 |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 9/18/2007 | | | <0.0001 | 0.007 | 0.0004 | 0.059 | 0.004 | <0.0001 | <0.0005 | 26.9 | <0.00001 | <0.0001 | 0.0016 | 0.001 |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | | <0.0010 | <0.02 | <0.0002 | 0.075 | <0.005 | <0.00004 | | 40.9 | <0.00008 | 0.00008 | 0.0012 | <0.001 |
| W7 | 4/22/2008 | | | <0.0010 | <0.02 | 0.0004 | 0.08 | <0.005 | <0.00004 | | 42.2 | <0.00008 | 0.00012 | 0.0014 | 0.002 |
| W7 | 4/22/2008 | | | <0.0010 | <0.02 | 0.0003 | 0.073 | <0.005 | <0.00004 | | 39.9 | <0.00008 | 0.00023 | <0.0006 | 0.001 |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | <0.00001 | <0.01 | <0.0002 | 0.05 | <0.004 | <0.00004 | | 23.2 | <0.00008 | 0.00011 | 0.0013 | <0.001 |
| W7 | 6/17/2008 | | | <0.00001 | 0.02 | <0.0002 | 0.056 | 0.006 | <0.00004 | | | <0.00008 | 0.00014 | 0.0013 | 0.001 |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | 0.00006 | 0.014 | 0.0004 | 0.068 | 0.004 | <0.0001 | <0.0005 | 31.8 | <0.00001 | 0.0001 | 0.0006 | 0.002 |
| W7 | 9/18/2008 | | | <0.00001 | 0.07 | 0.0003 | 0.043 | <0.004 | <0.00004 | | 20 | <0.00001 | 0.00025 | 0.0016 | 0.004 |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | <0.00001 | 0.009 | 0.0005 | 0.061 | 0.006 | <0.00004 | | 30.5 | <0.00001 | 0.0001 | 0.0005 | 0.001 |
| W7 | 4/30/2009 | | | <0.00001 | 0.053 | <0.0002 | 0.01 | <0.004 | <0.00004 | <0.0001 | 5.23 | 0.00008 | 0.0001 | 0.0006 | 0.005 |
| W7 | 6/8/2009 | | | <0.00001 | 0.013 | 0.0003 | 0.052 | <0.004 | <0.00004 | <0.0001 | 23.8 | <0.00001 | 0.00013 | <0.0004 | 0.002 |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | | | | | | | | | | | | | | |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | | | <0.00001 | 0.01 | 0.0004 | 0.056 | <0.004 | <0.00004 | <0.001 | 29.1 | <0.00001 | 0.0001 | 0.0012 | 0.004 |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/25/2009 | | | <0.00002 | 0.007 | 0.0003 | 0.067 | <0.05 | <0.0001 | <0.001 | 32.6 | 0.00004 | <0.0005 | <0.001 | 0.0012 |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | | | <0.00001 | 0.019 | 0.0003 | 0.039 | <0.004 | <0.00004 | <0.001 | 19.9 | 0.00002 | 0.00017 | 0.0004 | 0.006 |
| W7 | 4/27/2010 | | | <0.00002 | 0.075 | 0.0003 | 0.022 | <0.05 | <0.0001 | <0.001 | 9.79 | <0.00001 | <0.0005 | <0.001 | 0.0041 |
| W7 | 4/29/2010 | | | <0.00002 | 0.065 | 0.0003 | 0.023 | <0.05 | <0.0001 | <0.001 | 9.79 | <0.00001 | <0.0005 | <0.001 | 0.0034 |
| W7 | 5/1/2010 | | | <0.00002 | 0.053 | 0.0004 | 0.025 | <0.05 | <0.0001 | <0.001 | 11 | 0.00002 | <0.0005 | <0.001 | 0.0032 |
| W7 | 5/3/2010 | | | <0.00002 | 0.047 | 0.0004 | 0.027 | <0.05 | <0.0001 | <0.001 | 12 | <0.00001 | <0.0005 | <0.001 | 0.0027 |
| W7 | 5/5/2010 | | | <0.00002 | 0.038 | 0.0005 | 0.03 | <0.05 | <0.0001 | <0.001 | 12.9 | <0.00001 | <0.0005 | <0.001 | 0.0025 |
| W7 | 5/7/2010 | | | <0.00002 | 0.028 | 0.0004 | 0.034 | <0.05 | <0.0001 | <0.001 | 14.7 | 0.00001 | <0.0005 | <0.001 | 0.0026 |
| W7 | 5/9/2010 | | | <0.00002 | 0.023 | 0.0004 | 0.044 | <0.05 | <0.0001 | <0.001 | 20.5 | <0.00001 | <0.0005 | <0.001 | 0.0018 |
| W7 | 5/10/2010 | | | <0.00002 | 0.021 | 0.0004 | 0.046 | <0.05 | <0.0001 | <0.001 | 20.7 | 0.00002 | <0.0005 | <0.001 | 0.0022 |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | | | <0.00002 | 0.017 | 0.0004 | 0.046 | <0.05 | <0.0001 | <0.001 | 21.1 | <0.00001 | <0.0005 | <0.001 | 0.0016 |
| W7 | 5/14/2010 | | | <0.00002 | 0.096 | 0.0004 | 0.044 | <0.05 | <0.0001 | <0.001 | 18.7 | 0.00001 | <0.0005 | <0.001 | 0.0031 |
| W7 | 5/16/2010 | | | <0.00002 | 0.012 | 0.0003 | 0.045 | <0.05 | <0.0001 | <0.001 | 22.3 | <0.00001 | <0.0005 | <0.001 | 0.0013 |
| W7 | 5/17/2010 | | | <0.00002 | 0.018 | 0.0004 | 0.043 | <0.05 | <0.0001 | <0.001 | 20.9 | <0.00001 | <0.0005 | <0.001 | 0.0012 |
| W7 | 5/19/2010 | | | <0.00002 | 0.016 | 0.0003 | 0.049 | <0.05 | <0.0001 | <0.001 | 24.4 | <0.00001 | <0.0005 | <0.001 | 0.0017 |
| W7 | 5/21/2010 | | | <0.0001 | 0.013 | <0.0004 | 0.05 | <0.1 | <0.0002 | <0.001 | 24 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 5/23/2010 | | | <0.0001 | 0.017 | <0.0004 | 0.053 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 5/25/2010 | | | <0.0001 | 0.024 | <0.001 | 0.065 | <0.1 | <0.0005 | <0.001 | 30 | <0.0001 | <0.0005 | <0.002 | 0.003 |
| W7 | 5/27/2010 | | | <0.0001 | 0.028 | <0.001 | 0.055 | <0.1 | <0.0005 | <0.001 | 27 | <0.0001 | <0.0005 | <0.002 | 0.003 |
| W7 | 5/29/2010 | | | <0.0001 | 0.017 | 0.0005 | 0.056 | <0.1 | <0.0002 | <0.001 | 29 | <0.0001 | <0.0005 | <0.002 | 0.002 |
| W7 | 5/31/2010 | | | <0.0001 | 0.02 | <0.0004 | 0.058 | <0.1 | <0.0002 | <0.001 | 27 | <0.0001 | <0.0005 | <0.002 | 0.002 |
| W7 | 6/2/2010 | | | <0.0001 | 0.012 | 0.0004 | 0.058 | <0.1 | <0.0002 | <0.001 | 29 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 6/4/2010 | | | <0.0001 | 0.013 | 0.0004 | 0.058 | <0.1 | <0.0002 | <0.001 | 29 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 6/6/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.062 | <0.1 | <0.0002 | <0.001 | 33 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 6/14/2010 | | | <0.0001 | 0.011 | <0.0004 | 0.064 | <0.1 | <0.0002 | <0.001 | 31 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W7 | 6/16/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.064 | <0.1 | <0.0002 | <0.001 | 30 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W7 | 6/18/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.064 | <0.1 | <0.0002 | <0.001 | 30 | <0.0001 | <0.0005 | <0.002 | <0.001 |
| W7 | 6/20/2010 | | | <0.0001 | 0.014 | <0.0004 | 0.06 | <0.1 | <0.0002 | <0.001 | 28 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 6/22/2010 | | | <0.0001 | 0.033 | 0.0005 | 0.055 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | 0.002 |
| W7 | 6/24/2010 | | | <0.0001 | 0.018 | <0.0004 | 0.052 | <0.1 | <0.0002 | <0.001 | 25 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 6/26/2010 | | | <0.0001 | 0.012 | 0.0004 | 0.06 | <0.1 | <0.0002 | <0.001 | 26 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 6/28/2010 | | | <0.0001 | <0.01 | <0.0004 | 0.061 | <0.1 | <0.0002 | <0.001 | 29 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 7/5/2010 | | | <0.0001 | 0.019 | <0.0004 | 0.054 | <0.1 | <0.0002 | <0.001 | 23 | <0.0001 | <0.0005 | <0.002 | 0.002 |
| W7 | 8/5/2010 | | | <0.0001 | 0.011 | 0.0004 | 0.065 | <0.1 | <0.0002 | <0.001 | 30 | <0.0001 | <0.0005 | <0.002 | 0.002 |
| W7 | 9/12/2010 | | | | | | | | | | | | | | |
| W7 | 9/12/2010 | | | <0.0001 | 0.016 | 0.0005 | 0.055 | <0.1 | <0.0002 | <0.001 | 28 | <0.0001 | <0.0005 | <0.002 | 0.001 |
| W7 | 10/8/2010 | | | <0.00002 | 0.011 | 0.0004 | 0.06 | <0.05 | <0.0001 | <0.001 | 29.2 | <0.00001 | <0.0005 | <0.001 | 0.0012 |
| W7 | 4/27/2011 | | | <0.00002 | 0.057 | 0.0003 | 0.024 | <0.05 | <0.0001 | <0.001 | 11.2 | 0.00003 | <0.0005 | <0.001 | 0.0077 |
| W7 | 5/2/2011 | | | <0.00002 | 0.076 | 0.0002 | 0.02 | <0.05 | <0.0001 | <0.001 | 8.48 | 0.00004 | <0.0005 | <0.001 | 0.007 |
| W7 | 6/1/2011 | | | <0.00002 | 0.013 | 0.0003 | 0.056 | <0.05 | <0.0001 | <0.001 | 23.5 | <0.00001 | <0.0005 | <0.001 | 0.0016 |
| W7 | 6/16/2011 | | | <0.00002 | 0.022 | 0.0004 | 0.053 | <0.05 | <0.0001 | <0.001 | 24.9 | <0.00001 | <0.0005 | <0.001 | 0.0019 |
| W7 | 7/1/2011 | | | <0.00002 | 0.034 | 0.0007 | 0.053 | <0.05 | <0.0001 | <0.001 | 20.6 | 0.00001 | <0.0005 | <0.001 | 0.0031 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Cd-D-IH (mg/L) | Se-D-IH (mg/L) | Ag-D (mg/L) | Dissolved Al (mg/L) | Dissolved As (mg/L) | Dissolved Ba (mg/L) | Dissolved B (mg/L) | Dissolved Be (mg/L) | Dissolved Bi (mg/L) | Dissolved Ca (mg/L) | Dissolved Cd (mg/L) | Dissolved Co (mg/L) | Dissolved Cr (mg/L) | Dissolved Cu (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | | | <0.00002 | 0.051 | 0.0007 | 0.048 | <0.05 | <0.0001 | <0.001 | 15.6 | 0.00002 | <0.0005 | <0.001 | 0.0041 |
| W7 | 8/16/2011 | | | <0.00002 | 0.036 | 0.0007 | 0.057 | <0.05 | <0.0001 | <0.001 | 26 | <0.00001 | <0.0005 | <0.001 | 0.0019 |
| W7 | 8/19/2011 | | | <0.00002 | 0.033 | 0.0008 | 0.053 | <0.05 | <0.0001 | <0.001 | 24.2 | 0.00001 | <0.0005 | <0.001 | 0.002 |
| W7 | 9/12/2011 | | | <0.00002 | 0.024 | 0.0007 | 0.061 | <0.05 | <0.0001 | <0.001 | 30.8 | 0.00001 | <0.0005 | <0.001 | 0.0016 |
| W7 | 10/6/2011 | | | <0.00002 | 0.013 | 0.0006 | 0.057 | <0.05 | <0.0001 | <0.001 | 27.9 | 0.00003 | <0.0005 | <0.001 | 0.0012 |
| W7 | 11/22/2011 | | | <0.000020 | 0.0076 | 0.0004 | 0.075 | <0.05 | <0.00010 | <0.0010 | 38.3 | <0.000010 | <0.00050 | <0.0010 | 0.00109 |
| W7 | 1/24/2012 | | | <0.000020 | 0.0053 | 0.00041 | 0.0882 | <0.05 | <0.00010 | <0.0010 | 43 | 0.000035 | <0.00050 | <0.0010 | 0.00114 |
| W7 | 2/25/2012 | | | <0.000020 | 0.0211 | 0.00033 | 0.0796 | <0.05 | <0.00010 | <0.0010 | 41.2 | 0.000064 | <0.00050 | <0.0010 | 0.0154 |
| W7 | 3/5/2012 | | | <0.000020 | 0.0031 | 0.00039 | 0.0803 | <0.05 | <0.00010 | <0.0010 | 41.2 | <0.000010 | <0.00050 | <0.0010 | 0.00122 |
| W7 | 4/24/2012 | | | <0.000020 | 0.0499 | 0.00048 | 0.0319 | <0.05 | <0.00010 | <0.0010 | 10.2 | 0.000023 | <0.00050 | <0.0010 | 0.00523 |
| W7 | 5/6/2012 | | | <0.000020 | 0.0298 | 0.00043 | 0.0319 | <0.05 | <0.00010 | <0.0010 | 12 | 0.000013 | <0.00050 | <0.0010 | 0.00303 |
| W7 | 5/6/2012 | | | <0.000020 | 0.0442 | 0.00044 | 0.0324 | <0.05 | <0.00010 | <0.0010 | 11.9 | 0.000016 | <0.00050 | <0.0010 | 0.00273 |
| W7 | 6/19/2012 | | | <0.000020 | 0.0265 | 0.0007 | 0.0543 | <0.05 | <0.00010 | <0.0010 | 23.5 | <0.000010 | <0.00050 | <0.0010 | 0.00163 |
| W7 | 7/17/2012 | | | <0.000020 | 0.0197 | 0.00086 | 0.0706 | <0.05 | <0.00010 | <0.0010 | 33 | 0.000012 | <0.00050 | <0.0010 | 0.00127 |
| W7 | 7/30/2012 | | | <0.000020 | 0.0171 | 0.00095 | 0.0727 | <0.05 | <0.00010 | <0.0010 | 33.9 | <0.000010 | <0.00050 | <0.0010 | 0.00123 |
| W7 | 8/8/2012 | | | <0.000020 | 0.0184 | 0.001 | 0.0769 | <0.05 | <0.00010 | <0.0010 | 35.9 | <0.000010 | <0.00050 | <0.0010 | 0.00112 |
| W7 | 8/23/2012 | | | <0.000020 | 0.0178 | 0.00088 | 0.0756 | <0.05 | <0.00010 | <0.0010 | 35.7 | <0.000010 | <0.00050 | <0.0010 | 0.0017 |
| W7 | 9/13/2012 | | | <0.000020 | 0.0239 | 0.00074 | 0.0599 | <0.05 | <0.00010 | <0.0010 | 30.1 | <0.000010 | <0.00050 | <0.0010 | 0.00244 |
| W7 | 10/16/2012 | | | <0.000020 | 0.0114 | 0.0006 | 0.0633 | <0.05 | <0.00010 | <0.0010 | 33.2 | <0.000010 | <0.00050 | <0.0010 | 0.00094 |
| W7 | 11/2/2012 | | | <0.000020 | 0.0095 | 0.00053 | 0.0862 | <0.05 | <0.00010 | <0.0010 | 39.3 | 0.000031 | <0.00050 | <0.0010 | 0.00236 |
| W7 | 12/29/2012 | | | <0.000020 | 0.0061 | 0.00051 | 0.119 | <0.05 | <0.00010 | <0.0010 | 56.1 | <0.000010 | <0.00050 | <0.0010 | 0.00232 |
| W7 | 4/30/2013 | | | <0.000020 | 0.0031 | 0.00025 | 0.101 | <0.05 | <0.00010 | <0.0010 | 46.8 | <0.000010 | <0.00050 | <0.0010 | 0.00108 |
| W7 | 5/14/2013 | | | <0.000020 | 0.0436 | 0.00029 | 0.023 | <0.05 | <0.00010 | <0.0010 | 8.81 | 0.00001 | <0.00050 | <0.0010 | 0.00365 |
| W7 | 6/19/2013 | | | <0.000020 | 0.0125 | 0.00052 | 0.0665 | <0.05 | <0.00010 | <0.0010 | 29.9 | <0.000010 | <0.00050 | <0.0010 | 0.00116 |
| W7 | 6/19/2013 | | | <0.000020 | 0.0134 | 0.00051 | 0.0664 | <0.05 | <0.00010 | <0.0010 | 30 | <0.000010 | <0.00050 | <0.0010 | 0.00124 |
| W7 | 7/13/2013 | | | <0.000020 | 0.0138 | 0.00053 | 0.072 | <0.05 | <0.00010 | <0.0010 | 34.9 | <0.000010 | <0.00050 | <0.0010 | 0.00121 |
| W7 | 8/21/2013 | | | <0.000020 | 0.0122 | 0.00056 | 0.0737 | <0.05 | <0.00010 | <0.0010 | 35.2 | <0.000010 | <0.00050 | <0.0010 | 0.00101 |
| W7 | 9/6/2013 | | | <0.000020 | 0.016 | 0.00081 | 0.0718 | <0.05 | <0.00010 | <0.0010 | 34.9 | <0.000010 | <0.00050 | <0.0010 | 0.00113 |
| W7 | 10/21/2013 | | | <0.000020 | 0.0093 | 0.00067 | 0.0715 | <0.05 | <0.00010 | <0.0010 | 38 | <0.000010 | <0.00050 | <0.0010 | 0.00111 |
| W7 | 11/16/2013 | | | <0.000020 | 0.0053 | 0.00048 | 0.08 | <0.05 | <0.00010 | <0.0010 | 39.4 | <0.000010 | <0.00050 | <0.0010 | 0.0008 |
| W7 | 12/7/2013 | | | <0.000020 | 0.0035 | 0.00053 | 0.0919 | <0.05 | <0.00010 | <0.0010 | 43.3 | <0.000010 | <0.00050 | <0.0010 | 0.00078 |
| C4 | 5/6/2012 | | | <0.000020 | 0.0622 | 0.00104 | 0.0488 | <0.05 | <0.00010 | <0.0010 | 12 | 0.000029 | 0.00071 | <0.0010 | 0.00314 |
| C4 | 8/1/2012 | | | <0.000020 | 0.059 | 0.00184 | 0.0984 | <0.05 | <0.00010 | <0.0010 | 31.9 | <0.000010 | 0.00111 | <0.0010 | 0.00181 |
| C4 | 8/8/2012 | | | <0.000020 | 0.0425 | 0.00203 | 0.0987 | <0.05 | <0.00010 | <0.0010 | 33.7 | <0.000010 | 0.00108 | <0.0010 | 0.00132 |
| C4 | 8/25/2012 | | | <0.000020 | 0.04 | 0.00197 | 0.098 | <0.05 | <0.00010 | <0.0010 | 35 | <0.000010 | 0.00113 | <0.0010 | 0.00176 |
| C4 | 6/22/2013 | | | <0.000020 | 0.0342 | 0.00225 | 0.075 | <0.05 | <0.00010 | <0.0010 | 35 | <0.000010 | 0.00063 | <0.0010 | 0.0017 |
| C4 | 7/19/2013 | | | <0.000020 | 0.0317 | 0.00207 | 0.0699 | <0.05 | <0.00010 | <0.0010 | 36 | <0.000010 | 0.00062 | <0.0010 | 0.00137 |
| C4 | 8/22/2013 | | | <0.000020 | 0.0455 | 0.00179 | 0.0794 | <0.05 | <0.00010 | <0.0010 | 33.1 | <0.000010 | 0.00073 | <0.0010 | 0.00143 |
| C4 | 9/6/2013 | | | <0.000020 | 0.0405 | 0.00196 | 0.0798 | <0.05 | <0.00010 | <0.0010 | 34.2 | <0.000010 | 0.00092 | <0.0010 | 0.00161 |
| C4 | 10/18/2013 | | | <0.000020 | 0.0221 | 0.00106 | 0.0735 | <0.05 | <0.00010 | <0.0010 | 34.2 | <0.000010 | 0.00079 | <0.0010 | 0.00112 |
| C4 | 10/18/2013 | | | <0.000020 | 0.0249 | 0.00107 | 0.0732 | <0.05 | <0.00010 | <0.0010 | 34.5 | <0.000010 | 0.00074 | <0.0010 | 0.00118 |
| C4 | 11/17/2013 | | | <0.000020 | 0.033 | 0.00559 | 0.169 | <0.05 | <0.00010 | <0.0010 | 72.1 | 0.000022 | 0.00611 | 0.0013 | 0.00095 |
| C10 | 5/12/2012 | | | <0.000020 | 0.0583 | 0.0012 | 0.0501 | <0.05 | <0.00010 | <0.0010 | 19.9 | 0.000018 | 0.00054 | <0.0010 | 0.00212 |
| C10 | 7/30/2012 | | | <0.000020 | 0.0571 | 0.00142 | 0.0795 | <0.05 | <0.00010 | <0.0010 | 38.8 | <0.000010 | <0.00050 | <0.0010 | 0.00198 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | | | <0.000020 | 0.0505 | 0.00134 | 0.0786 | <0.05 | <0.00010 | <0.0010 | 39.8 | <0.000010 | <0.00050 | <0.0010 | 0.00189 |
| C10 | 8/27/2012 | | | <0.000020 | 0.0262 | 0.00149 | 0.0804 | <0.05 | <0.00010 | <0.0010 | 41.8 | <0.000010 | <0.00050 | <0.0010 | 0.00148 |
| C10 | 6/22/2013 | | | <0.000020 | 0.0785 | 0.00123 | 0.0721 | <0.05 | <0.00010 | <0.0010 | 45.1 | 0.000019 | <0.00050 | <0.0010 | 0.00313 |
| C10 | 7/23/2013 | | | <0.000020 | 0.0252 | 0.00116 | 0.0668 | <0.05 | <0.00010 | <0.0010 | 37.4 | <0.000010 | <0.00050 | <0.0010 | 0.00135 |
| C10 | 8/22/2013 | | | <0.000020 | 0.0197 | 0.00141 | 0.0724 | <0.05 | <0.00010 | <0.0010 | 48 | <0.000010 | <0.00050 | <0.0010 | 0.00134 |
| C10 | 9/8/2013 | | | <0.000020 | 0.0254 | 0.00166 | 0.0764 | <0.05 | <0.00010 | <0.0010 | 45 | <0.000010 | 0.00058 | <0.0010 | 0.00125 |
| C10 | 9/8/2013 | | | <0.000020 | 0.0241 | 0.00158 | 0.0763 | <0.05 | <0.00010 | <0.0010 | 44.8 | 0.00001 | 0.0006 | 0.0017 | 0.00133 |
| C10 | 10/18/2013 | | | <0.000020 | 0.0108 | 0.00089 | 0.0599 | <0.05 | <0.00010 | <0.0010 | 40.1 | <0.000010 | <0.00050 | <0.0010 | 0.00091 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Dissolved Fe (mg/L) | Dissolved Hg (mg/L) | Dissolved K (mg/L) | Dissolved Li (mg/L) | Dissolved Mg (mg/L) | Dissolved Mn (mg/L) | Dissolved Mo (mg/L) | Dissolved Na (mg/L) | Dissolved Ni (mg/L) | Dissolved Pb (mg/L) | Dissolved P (mg/L) | Dissolved Sb (mg/L) | Dissolved S (mg/L) | Dissolved Se (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | 0.172 | <0.000020 | <2.0 | <0.0050 | 8.46 | 0.00579 | <0.0010 | 4.9 | 0.0015 | <0.00050 | | <0.00050 | | <0.0010 |
| W1 | 6/30/2005 | 0.046 | | <2.0 | <0.0050 | 12.6 | 0.00391 | 0.00106 | 8.8 | 0.00096 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W1 | 7/28/2005 | 0.056 | | <2.0 | <0.0050 | 13.6 | 0.0119 | 0.00131 | 9.2 | 0.0011 | 0.000073 | <0.30 | <0.00010 | | <0.0010 |
| W1 | 8/29/2005 | 0.25 | <0.000020 | <2.0 | <0.0050 | 11.7 | 0.0157 | 0.001 | 6.9 | 0.0014 | <0.00050 | | <0.00050 | | <0.0010 |
| W1 | 9/28/2005 | 0.331 | <0.000020 | <2.0 | <0.0050 | 11.2 | 0.0355 | <0.0010 | 6.2 | 0.0016 | <0.00050 | | <0.00050 | | <0.0010 |
| W1 | 10/15/2005 | 0.266 | | <2.0 | <0.0050 | 11.7 | 0.0228 | 0.000892 | 6.4 | 0.0014 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W2 | 5/27/2005 | 0.164 | <0.000020 | <2.0 | <0.0050 | 8.72 | 0.00507 | <0.0010 | 5 | 0.0015 | <0.00050 | | <0.00050 | | <0.0010 |
| W2 | 5/27/2005 | | | | | 5.19 | 0.00345 | | | | | | | | |
| W2 | 6/30/2005 | 0.039 | | <2.0 | <0.0050 | 12.3 | 0.00684 | 0.00108 | 8.6 | 0.00102 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W2 | 7/28/2005 | 0.05 | | <2.0 | <0.0050 | 13.2 | 0.014 | 0.00127 | 8.7 | 0.00112 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W2 | 8/30/2005 | 0.234 | <0.000020 | <2.0 | <0.0050 | 11.7 | 0.0152 | 0.001 | 7 | 0.0015 | <0.00050 | | <0.00050 | | <0.0010 |
| W2 | 9/28/2005 | 0.338 | <0.000020 | <2.0 | <0.0050 | 11.2 | 0.0341 | <0.0010 | 6.2 | 0.0017 | <0.00050 | | <0.00050 | | <0.0010 |
| W2 | 10/15/2005 | 0.246 | | <2.0 | <0.0050 | 11.5 | 0.0208 | 0.000859 | 6.3 | 0.00141 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W3 | 5/27/2005 | 0.116 | <0.000020 | <2.0 | <0.0050 | 9.48 | 0.0094 | <0.0010 | 5.2 | 0.0014 | <0.00050 | | <0.00050 | | <0.0010 |
| W3 | 6/30/2005 | 0.042 | | <2.0 | <0.0050 | 17.4 | 0.0052 | 0.00163 | 11.7 | 0.00078 | 0.000241 | <0.30 | <0.00010 | | <0.0010 |
| W3 | 7/29/2005 | 0.134 | | <2.0 | <0.0050 | 17.3 | 0.0311 | 0.00158 | 9.7 | 0.00115 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W3 | 8/29/2005 | 0.306 | <0.000020 | <2.0 | <0.0050 | 13.6 | 0.0657 | 0.0013 | 8 | 0.0014 | <0.00050 | | <0.00050 | | <0.0010 |
| W3 | 9/28/2005 | 0.421 | <0.000020 | <2.0 | <0.0050 | 12.8 | 0.102 | 0.0011 | 7.7 | 0.0014 | <0.00050 | | <0.00050 | | <0.0010 |
| W3 | 10/15/2005 | 0.39 | | <2.0 | <0.0050 | 13.4 | 0.112 | 0.00122 | 7.5 | 0.00121 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W8 | 5/27/2005 | 0.194 | <0.000020 | <2.0 | <0.0050 | 5.05 | 0.00284 | <0.0010 | 2.6 | 0.0018 | <0.00050 | | <0.00050 | | <0.0010 |
| W8 | 6/30/2005 | 0.249 | | <2.0 | <0.0050 | 7.68 | 0.0142 | 0.000547 | 4.5 | 0.00144 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W8 | 7/29/2005 | 0.352 | | <2.0 | <0.0050 | 9.39 | 0.0206 | 0.000589 | 3.9 | 0.00157 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W8 | 8/30/2005 | 0.544 | <0.000020 | <2.0 | <0.0050 | 8.28 | 0.0296 | <0.0010 | 3.9 | 0.0016 | <0.00050 | | <0.00050 | | <0.0010 |
| W8 | 9/28/2005 | 0.556 | <0.000020 | <2.0 | <0.0050 | 7.73 | 0.0387 | <0.0010 | 3.9 | 0.0015 | <0.00050 | | <0.00050 | | <0.0010 |
| W8 | 10/15/2005 | 0.711 | | <2.0 | <0.0050 | 7.92 | 0.223 | 0.00169 | 4.8 | 0.00096 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W9 | 5/27/2005 | 0.251 | 0.000038 | <2.0 | <0.0050 | 4.18 | 0.00696 | <0.0010 | 2.3 | 0.0013 | <0.00050 | | <0.00050 | | <0.0010 |
| W9 | 6/30/2005 | 0.53 | | <2.0 | <0.0050 | 6.05 | 0.0378 | 0.000365 | 4.1 | 0.00119 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W9 | 7/29/2005 | 0.647 | | <2.0 | <0.0050 | 7.46 | 0.057 | 0.00108 | 4 | 0.00132 | 0.000185 | <0.30 | <0.00010 | | <0.0010 |
| W9 | 8/29/2005 | 0.67 | <0.000020 | <2.0 | <0.0050 | 6.3 | 0.0606 | <0.0010 | 3.6 | 0.0012 | <0.00050 | | <0.00050 | | <0.0010 |
| W9 | 9/28/2005 | 0.602 | <0.000020 | <2.0 | <0.0050 | 5.69 | 0.0451 | <0.0010 | 3.2 | 0.0011 | <0.00050 | | <0.00050 | | <0.0010 |
| W9 | 10/15/2005 | 0.438 | | <2.0 | <0.0050 | 5.55 | 0.0335 | 0.000313 | 3.1 | 0.00096 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W10 | 5/27/2005 | 0.106 | <0.000020 | <2.0 | <0.0050 | 3.31 | 0.00042 | <0.0010 | <2.0 | 0.0016 | <0.00050 | | <0.00050 | | <0.0010 |
| W10 | 5/27/2005 | <0.03 | <0.00002 | <2.0 | <0.005 | | 0.00271 | <0.001 | <2 | <0.001 | <0.0005 | | <0.0005 | | <0.001 |
| W10 | 6/30/2005 | 0.401 | | <2.0 | <0.0050 | 3.68 | 0.0299 | 0.000144 | 3.5 | 0.00179 | 0.000082 | <0.30 | <0.00010 | | <0.0010 |
| W10 | 7/29/2005 | 0.099 | | <2.0 | <0.0050 | 4.39 | 0.00483 | 0.000137 | 4.7 | 0.00123 | 0.000112 | <0.30 | <0.00010 | | <0.0010 |
| W10 | 8/29/2005 | 0.081 | <0.000020 | <2.0 | <0.0050 | 5.95 | 0.00447 | <0.0010 | 5.4 | 0.0016 | <0.00050 | | <0.00050 | | <0.0010 |
| W10 | 9/28/2005 | 0.048 | <0.000020 | <2.0 | <0.0050 | 8.93 | 0.00069 | <0.0010 | 5.4 | <0.0010 | <0.00050 | | <0.00050 | | <0.0010 |
| W10 | 10/15/2005 | 0.055 | | <2.0 | <0.0050 | 8.98 | 0.000385 | 0.000241 | 4.7 | 0.00073 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W6 | 5/27/2005 | 0.072 | <0.000020 | <2.0 | <0.0050 | 5.01 | 0.00543 | <0.0010 | 2.8 | 0.0015 | <0.00050 | | <0.00050 | | <0.0010 |
| W6 | 6/30/2005 | <0.030 | | <2.0 | <0.0050 | 6.72 | 0.00324 | 0.000448 | 4.8 | 0.00099 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W6 | 7/29/2005 | 0.062 | | <2.0 | <0.0050 | 13.2 | 0.0145 | 0.000818 | 7.3 | 0.0006 | 0.000083 | <0.30 | <0.00010 | | <0.0010 |
| W6 | 8/30/2005 | 0.064 | <0.000020 | <2.0 | <0.0050 | 8.1 | 0.0211 | <0.0010 | 4.6 | 0.0011 | <0.00050 | | <0.00050 | | <0.0010 |
| W6 | 9/28/2005 | 0.1 | <0.000020 | <2.0 | <0.0050 | 8.25 | 0.0245 | <0.0010 | 4.4 | 0.0012 | <0.00050 | | <0.00050 | | <0.0010 |
| W6 | 10/15/2005 | 0.088 | | <2.0 | <0.0050 | 7.66 | 0.0162 | 0.000395 | 4.5 | 0.00118 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W6 | 6/2/2006 | 0.096 | | <2 | <0.005 | 4.95 | 0.00673 | 0.000305 | 3.3 | 0.00182 | <0.00005 | <0.3 | <0.0001 | | <0.001 |
| W6 | 8/25/2006 | | | | | 8.7 | | | | | | | | | |
| W6 | 9/6/2006 | 0.11 | | 0.6 | 0.001 | 7.7 | 0.046 | <0.001 | 4.8 | 0.0006 | <0.0001 | | <0.0002 | 0.9 | <0.0002 |
| W6 | 6/20/2007 | | | | | | | | | | | | | | |
| W6 | 9/18/2007 | | | | | | | | | | | | | | |
| W6 | 6/17/2008 | | | | | | | | | | | | | | |
| W6 | 9/18/2008 | 0.09 | <0.00001 | 0.4 | <0.001 | 6.33 | 0.0099 | 0.00027 | 4.27 | 0.002 | <0.0001 | 0.02 | 0.0008 | | 0.0012 |
| W6 | 4/14/2009 | 0.06 | <0.00001 | 7.4 | 0.004 | 45.8 | 0.0307 | 0.00312 | 35.1 | <0.001 | 0.0002 | 0.13 | 0.003 | 34.5 | 0.0011 |
| W6 | 4/30/2009 | 0.12 | 0.00001 | 1.9 | <0.001 | 4.9 | 0.0147 | 0.00042 | 3 | 0.001 | 0.0003 | 0.05 | 0.0006 | 2.5 | <0.0006 |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/18/2009 | 0.02 | <0.00001 | 3.5 | 0.002 | 14.2 | 0.0808 | 0.0098 | 14.9 | 0.001 | 0.0005 | 0.01 | 0.0013 | 16.6 | 0.0012 |
| W6 | 8/25/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/25/2009 | 0.01 | <0.00002 | 3.34 | <0.005 | 15.2 | 0.215 | 0.015 | 17.3 | <0.001 | <0.0002 | | 0.0006 | 24 | 0.002 |
| W6 | 4/19/2010 | 0.06 | <0.00001 | 2.3 | 0.002 | 13.2 | 0.0461 | 0.0017 | 8.6 | <0.001 | 0.0002 | 0.02 | 0.0011 | 10.1 | <0.0006 |
| W6 | 5/16/2010 | 0.01 | <0.0002 | 1.39 | <0.005 | 8.38 | <0.001 | <0.001 | 4.49 | <0.001 | <0.0002 | <0.01 | <0.0005 | <3 | 0.0002 |
| W6 | 5/17/2010 | 0.016 | <0.0002 | 1 | <0.005 | 5.28 | <0.001 | <0.001 | 3.32 | <0.001 | <0.0002 | 0.016 | <0.0005 | <3 | <0.0001 |
| W6 | 5/19/2010 | 0.021 | <0.00002 | 1.19 | <0.005 | 7.41 | <0.001 | <0.001 | 5.01 | <0.001 | <0.0002 | 0.013 | <0.0005 | 5 | 0.0001 |
| W6 | 5/21/2010 | <0.02 | <0.0002 | <1 | <0.01 | 5 | <0.001 | <0.001 | 3 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 5/23/2010 | 0.029 | <0.0002 | 1 | <0.01 | 8 | <0.001 | <0.001 | 6 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 5/25/2010 | 0.024 | <0.00002 | 1 | <0.01 | 9 | <0.001 | <0.001 | 8 | <0.003 | <0.0002 | | <0.0005 | <60 | <0.001 |
| W6 | 5/29/2010 | 0.03 | <0.00002 | <1 | <0.01 | 4 | <0.001 | <0.001 | 2 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/2/2010 | <0.02 | <0.0002 | 2 | <0.01 | 20 | 0.01 | 0.003 | 13 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/4/2010 | 0.027 | <0.0002 | <1 | <0.01 | 6 | <0.001 | <0.001 | 3 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/6/2010 | 0.027 | | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/14/2010 | 0.021 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 5 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/16/2010 | 0.021 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/18/2010 | 0.021 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/20/2010 | 0.027 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/22/2010 | 0.025 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/24/2010 | 0.025 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/26/2010 | 0.025 | <0.0002 | <1 | <0.01 | 7 | 0.001 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | 0.025 | <0.0002 | <1 | <0.01 | 7 | <0.001 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 7/5/2010 | 0.092 | <0.0002 | <1 | <0.01 | 6 | 0.005 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 8/5/2010 | 0.069 | <0.0002 | <1 | <0.01 | 8 | 0.018 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 9/9/2010 | 0.061 | <0.0002 | <1 | <0.01 | 8 | 0.02 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W6 | 10/8/2010 | 0.054 | <0.00002 | 0.42 | <0.005 | 7.52 | 0.019 | <0.001 | 3.79 | 0.001 | <0.0002 | | <0.0005 | <3 | <0.0001 |
| W6 | 8/19/2011 | 0.025 | <0.00002 | 1.66 | <0.005 | 22.2 | 0.019 | 0.003 | 15.2 | <0.001 | <0.0002 | <0.01 | <0.0005 | 18 | 0.0004 |
| W6 | 7/17/2012 | 0.0679 | <0.000010 | 0.52 | <0.0050 | 7.16 | 0.0542 | <0.0010 | 4.31 | 0.001 | <0.00020 | <0.01 | <0.00050 | <3.0 | 0.00012 |
| W6 | 7/30/2012 | 0.0814 | <0.000010 | 0.542 | <0.0050 | 7.02 | 0.102 | <0.0010 | 4.2 | <0.0010 | <0.00020 | <0.01 | <0.00050 | <3.0 | <0.00010 |
| W6 | 8/9/2012 | 0.0845 | <0.000010 | 0.578 | <0.0050 | 7.95 | 0.134 | <0.0010 | 4.56 | 0.001 | <0.00020 | 0.011 | <0.00050 | <3.0 | 0.0001 |
| W6 | 8/25/2012 | 0.0799 | <0.000010 | 0.648 | <0.0050 | 7.34 | 0.134 | <0.0010 | 4.21 | 0.001 | <0.00020 | 0.012 | <0.00050 | <3.0 | <0.00010 |
| W6 | 9/13/2012 | 0.108 | <0.000010 | 0.411 | <0.0050 | 6.66 | 0.0408 | <0.0010 | 3.89 | 0.0014 | <0.00020 | <0.01 | <0.00050 | <3.0 | <0.00010 |
| W6 | 10/13/2012 | | <0.000010 | | | | | | | | | | | | |
| W6 | 11/12/2012 | 0.0235 | <0.000010 | 0.562 | <0.0050 | 11.8 | 0.0013 | <0.0010 | 6.34 | 0.0014 | <0.00020 | <0.01 | <0.00050 | <3.0 | 0.0001 |
| W6 | 5/14/2013 | 0.183 | <0.000010 | 1.73 | <0.0050 | 2.31 | 0.0433 | <0.0010 | 0.999 | 0.0013 | <0.00020 | 0.044 | <0.00050 | <3.0 | <0.00010 |
| W6 | 6/22/2013 | 0.0718 | <0.000010 | 0.724 | <0.0050 | 7.04 | 0.0293 | <0.0010 | 3.95 | 0.0012 | <0.00020 | <0.01 | <0.00050 | <3.0 | <0.00010 |
| W6 | 7/12/2013 | 0.105 | <0.000010 | 0.482 | <0.0050 | 6.83 | 0.022 | <0.0010 | 4.07 | 0.0011 | <0.00020 | <0.01 | <0.00050 | <3.0 | <0.00010 |
| W6 | 8/22/2013 | 0.103 | <0.000010 | 0.489 | <0.0050 | 7.54 | 0.0286 | <0.0010 | 4.33 | 0.0011 | <0.00020 | <0.01 | <0.00050 | <3.0 | <0.00010 |
| W6 | 9/6/2013 | 0.111 | <0.000010 | 0.554 | <0.0050 | 7.18 | 0.0323 | <0.0010 | 4.02 | 0.0011 | <0.00020 | 0.013 | <0.00050 | <3.0 | <0.00010 |
| W6 | 10/7/2013 | 0.145 | <0.000010 | 0.581 | <0.0050 | 7.36 | 0.048 | <0.0010 | 4.6 | 0.0013 | <0.00020 | 0.011 | <0.00050 | <3.0 | <0.00010 |
| W6 | 11/16/2013 | 0.124 | <0.000010 | 0.589 | <0.0050 | 8.66 | 0.0399 | <0.0010 | 4.77 | 0.001 | <0.00020 | 0.015 | <0.00050 | <3.0 | <0.00010 |
| W6 | 12/7/2013 | 0.0144 | <0.000010 | 0.562 | <0.0050 | 11.7 | 0.0017 | <0.0010 | 6.36 | 0.0011 | <0.00020 | 0.015 | <0.00050 | <3.0 | <0.00010 |
| W7 | 5/27/2005 | 0.136 | <0.000020 | <2.0 | <0.0050 | 6.77 | 0.0193 | <0.0010 | 3.9 | 0.0016 | <0.00050 | | <0.00050 | | <0.0010 |
| W7 | 6/30/2005 | 0.07 | | <2.0 | <0.0050 | 10.2 | 0.0415 | 0.00124 | 6.9 | 0.00093 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W7 | 7/29/2005 | 0.105 | | <2.0 | <0.0050 | 15.6 | 0.0244 | 0.00127 | 8.8 | 0.00095 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W7 | 8/30/2005 | 0.292 | <0.000020 | <2.0 | <0.0050 | 9.7 | 0.0315 | 0.001 | 5.9 | 0.0015 | <0.00050 | | <0.00050 | | <0.0010 |
| W7 | 9/28/2005 | 0.32 | <0.000020 | <2.0 | <0.0050 | 9.32 | 0.0414 | <0.0010 | 5.3 | 0.0018 | <0.00050 | | <0.00050 | | <0.0010 |
| W7 | 10/15/2005 | 0.253 | | <2.0 | <0.0050 | 9.35 | 0.0383 | 0.000925 | 5.5 | 0.00146 | <0.000050 | <0.30 | <0.00010 | | <0.0010 |
| W7 | 6/2/2006 | 0.546 | | <2 | <0.005 | 4.85 | 0.0882 | 0.000697 | 3.8 | 0.0022 | 0.000054 | <0.3 | <0.0001 | | <0.001 |
| W7 | 6/8/2006 | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Dissolved Fe (mg/L) | Dissolved Hg (mg/L) | Dissolved K (mg/L) | Dissolved Li (mg/L) | Dissolved Mg (mg/L) | Dissolved Mn (mg/L) | Dissolved Mo (mg/L) | Dissolved Na (mg/L) | Dissolved Ni (mg/L) | Dissolved Pb (mg/L) | Dissolved P (mg/L) | Dissolved Sb (mg/L) | Dissolved S (mg/L) | Dissolved Se (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | 0.09 | | <0.4 | <0.001 | 8.9 | 0.044 | 0.001 | 5.9 | 0.001 | <0.0001 | | <0.0002 | 3.5 | 0.0002 |
| W7 | 6/23/2006 | 0.09 | | 1.1 | <0.001 | 10.4 | 0.043 | 0.001 | 5.9 | 0.0013 | <0.0001 | | <0.0002 | 4.3 | 0.0003 |
| W7 | 6/28/2006 | 0.06 | | 0.8 | <0.001 | 9.2 | 0.011 | <0.001 | 6.2 | 0.0036 | 0.0005 | | <0.0002 | 3.4 | <0.0002 |
| W7 | 7/7/2006 | 0.06 | | 0.8 | 0.001 | 10.7 | 0.023 | 0.002 | 6.7 | 0.0015 | <0.0001 | | <0.0002 | 4 | <0.0002 |
| W7 | 7/12/2006 | 0.06 | | 0.9 | 0.001 | 10.5 | 0.022 | 0.001 | 6.6 | 0.0007 | <0.0001 | | <0.0002 | 4 | 0.0002 |
| W7 | 7/20/2006 | 0.11 | | 1 | 0.001 | 11.7 | 0.042 | 0.001 | 6.7 | 0.0006 | 0.0002 | | <0.0002 | 4.1 | <0.0002 |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | 0.1 | | 1 | <0.001 | 10.9 | 0.044 | <0.001 | 7 | 0.0021 | <0.0001 | | <0.0002 | 4.2 | <0.0002 |
| W7 | 8/2/2006 | 0.07 | | 1.1 | <0.001 | 11 | 0.033 | <0.001 | 7.2 | 0.0006 | <0.0001 | | <0.0002 | 4 | <0.0002 |
| W7 | 8/10/2006 | 0.08 | | 1 | 0.001 | 10.8 | 0.039 | 0.001 | 7.2 | 0.0006 | <0.0001 | | <0.0002 | 4 | <0.0002 |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | 0.08 | | 0.9 | 0.001 | 11.7 | 0.037 | 0.001 | 6.7 | 0.0009 | <0.0001 | | <0.0002 | 3.8 | <0.0002 |
| W7 | 8/30/2006 | 0.1 | | 1.2 | 0.002 | 11.7 | 0.038 | 0.001 | 7.7 | 0.0012 | <0.0001 | | <0.0002 | 3.7 | <0.0002 |
| W7 | 9/6/2006 | 0.1 | | 0.8 | 0.002 | 11.2 | 0.036 | 0.001 | 7.5 | 0.001 | <0.0001 | | <0.0002 | 3.7 | <0.0002 |
| W7 | 9/13/2006 | 0.11 | | 0.9 | 0.002 | 11.4 | 0.03 | 0.001 | 7.4 | 0.0009 | <0.0001 | | <0.0002 | 3.5 | <0.0002 |
| W7 | 9/20/2006 | 0.09 | | 1 | 0.002 | 11.6 | 0.04 | 0.001 | 6.6 | <0.0005 | <0.0001 | | <0.0002 | 3.9 | 0.0002 |
| W7 | 9/28/2006 | 0.08 | | 1.1 | 0.001 | 11.1 | 0.035 | 0.001 | 7.4 | 0.0008 | <0.0001 | | <0.0002 | 3.7 | <0.0002 |
| W7 | 10/4/2006 | 0.11 | | 1.1 | 0.001 | 10.9 | 0.035 | 0.001 | 7.3 | 0.0007 | <0.0001 | | <0.0002 | 3.7 | <0.0002 |
| W7 | 10/12/2006 | 0.09 | | 1.1 | 0.001 | 11.4 | 0.043 | 0.001 | 7.4 | 0.0006 | <0.0001 | | <0.0002 | 3.9 | 0.0003 |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/5/2007 | | | | | | | | | | | | | | |
| W7 | 6/20/2007 | 0.05 | <0.0001 | 1 | 0.001 | 9.8 | 0.031 | 0.001 | 7.4 | <0.0005 | <0.0001 | | <0.0002 | 4.2 | <0.0002 |
| W7 | 7/18/2007 | 0.04 | <0.0001 | 0.9 | 0.001 | 11.6 | 0.019 | 0.001 | 7.6 | 0.0007 | <0.0001 | | <0.0002 | 3.9 | <0.0002 |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 7/18/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 9/18/2007 | 0.08 | <0.0001 | 0.9 | 0.001 | 9.8 | 0.018 | 0.002 | 7.2 | 0.0008 | <0.0001 | | <0.0002 | 2.9 | <0.0002 |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | <0.02 | <0.00001 | 2.68 | 0.002 | 20.4 | 0.025 | 0.00161 | 12.6 | <0.001 | <0.0001 | <0.01 | 0.006 | | <0.0006 |
| W7 | 4/22/2008 | 0.07 | <0.00001 | 2.78 | 0.002 | 21.2 | 0.027 | 0.0017 | 12.7 | 0.002 | 0.0001 | 0.02 | 0.0084 | | <0.0006 |
| W7 | 4/22/2008 | <0.02 | <0.00001 | 2.63 | 0.002 | 19.9 | 0.0242 | 0.00166 | 12.4 | <0.001 | <0.0001 | <0.01 | 0.0016 | | <0.0006 |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | 0.05 | <0.00001 | 0.84 | <0.001 | 8.39 | 0.0418 | 0.00124 | 6.82 | 0.001 | <0.0001 | | 0.0006 | | <0.0006 |
| W7 | 6/17/2008 | 0.07 | | | <0.001 | | 0.0682 | 0.00149 | | 0.001 | <0.0001 | | 0.001 | | 0.0022 |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 8/6/2008 | 0.07 | <0.0001 | 1 | 0.001 | 10.6 | 0.02 | 0.001 | 7.4 | 0.001 | <0.0001 | <0.05 | 0.0014 | 3.5 | <0.0002 |
| W7 | 9/18/2008 | 0.2 | <0.00001 | 0.53 | <0.001 | 6.63 | 0.0198 | 0.00072 | 4.92 | 0.001 | 0.0017 | 0.02 | 0.0008 | | <0.0006 |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 10/28/2008 | 0.078 | <0.00001 | 0.8 | <0.001 | 11.4 | 0.0338 | 0.00108 | 6.4 | 0.001 | <0.0001 | <0.01 | 0.0009 | | <0.0006 |
| W7 | 4/30/2009 | 0.07 | 0.00001 | 1.5 | <0.001 | 1.68 | 0.0114 | 0.00013 | 1.2 | <0.001 | 0.0001 | 0.06 | 0.0007 | 0.4 | <0.0006 |
| W7 | 6/8/2009 | 0.05 | <0.00001 | 0.7 | <0.001 | 8.18 | 0.0129 | 0.00127 | 5.3 | 0.001 | <0.0001 | 0.01 | 0.0011 | 2.8 | <0.0006 |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | | | | | | | | | | | | | | |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | 0.1 | <0.00001 | 0.9 | <0.001 | 9.9 | 0.0128 | 0.0011 | 6.8 | 0.001 | 0.0004 | 0.03 | 0.0009 | 3 | <0.0006 |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/25/2009 | 0.046 | <0.00002 | 0.95 | <0.005 | 10.8 | 0.024 | 0.001 | 6.68 | <0.001 | <0.0002 | | <0.0005 | 4 | 0.0002 |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | 0.09 | <0.00001 | 2.1 | <0.001 | 7.3 | 0.0188 | 0.0008 | 5 | <0.001 | 0.0003 | 0.02 | 0.001 | 2.7 | <0.0006 |
| W7 | 4/27/2010 | 0.15 | <0.00002 | 1.04 | <0.005 | 2.87 | <0.001 | <0.001 | 1.86 | 0.001 | <0.0002 | | <0.0005 | <3 | <0.0001 |
| W7 | 4/29/2010 | 0.18 | <0.00002 | 0.9 | <0.005 | 2.86 | <0.001 | <0.001 | 1.92 | 0.001 | <0.0002 | | <0.0005 | <3 | <0.0001 |
| W7 | 5/1/2010 | 0.26 | <0.00002 | 0.71 | <0.005 | 3.26 | <0.001 | <0.001 | 2.22 | 0.001 | <0.0002 | 0.023 | <0.0005 | <3 | <0.0001 |
| W7 | 5/3/2010 | 0.378 | <0.00002 | 0.64 | <0.005 | 3.67 | <0.001 | <0.001 | 2.6 | 0.001 | <0.0002 | | <0.0005 | <3 | <0.0001 |
| W7 | 5/5/2010 | 0.574 | <0.00002 | 0.57 | <0.005 | 4.09 | <0.001 | <0.001 | 2.85 | 0.001 | <0.0002 | 0.021 | <0.0005 | <3 | <0.0001 |
| W7 | 5/7/2010 | 0.359 | <0.00002 | 0.68 | <0.005 | 4.9 | <0.001 | <0.001 | 3.35 | 0.002 | <0.0002 | 0.017 | <0.0005 | <3 | <0.0001 |
| W7 | 5/9/2010 | 0.297 | <0.00002 | 0.78 | <0.005 | 6.97 | <0.001 | <0.001 | 4.54 | 0.001 | <0.0002 | 0.014 | <0.0005 | <3 | 0.0001 |
| W7 | 5/10/2010 | 0.276 | <0.00002 | 0.8 | <0.005 | 7.08 | <0.001 | <0.001 | 4.69 | 0.001 | <0.0002 | 0.013 | <0.0005 | 3 | 0.0001 |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | 0.173 | 0.00002 | 0.77 | <0.005 | 7.06 | <0.001 | 0.001 | 4.6 | 0.001 | <0.0002 | <0.01 | <0.0005 | <3 | 0.0001 |
| W7 | 5/14/2010 | 0.339 | <0.00002 | 0.71 | <0.005 | 6.27 | 0.039 | <0.001 | 4.05 | 0.002 | <0.0002 | | <0.0005 | <3 | 0.0001 |
| W7 | 5/16/2010 | 0.08 | <0.0002 | 0.8 | <0.005 | 7.28 | <0.001 | 0.001 | 4.75 | <0.001 | <0.0002 | <0.01 | <0.0005 | <3 | 0.0001 |
| W7 | 5/17/2010 | 0.068 | <0.0002 | 0.78 | <0.005 | 6.82 | <0.001 | 0.001 | 4.36 | <0.001 | <0.0002 | <0.01 | <0.0005 | <3 | 0.0001 |
| W7 | 5/19/2010 | 0.069 | <0.00002 | 0.85 | <0.005 | 9.16 | <0.001 | 0.001 | 6.6 | <0.001 | <0.0002 | <0.01 | <0.0005 | 3 | 0.0003 |
| W7 | 5/21/2010 | 0.057 | <0.0002 | <1 | <0.01 | 8 | <0.001 | 0.001 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 5/23/2010 | 0.069 | <0.0002 | <1 | <0.01 | 9 | <0.001 | 0.001 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 5/25/2010 | 0.062 | <0.00002 | 1 | <0.01 | 12 | 0.001 | 0.002 | 8 | <0.003 | <0.0002 | | <0.0005 | <60 | <0.001 |
| W7 | 5/27/2010 | 0.069 | <0.00002 | 1 | <0.01 | 11 | 0.014 | 0.002 | 8 | <0.003 | <0.0002 | | <0.0005 | <60 | <0.001 |
| W7 | 5/29/2010 | 0.051 | <0.00002 | 1 | <0.01 | 10 | 0.015 | 0.002 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 5/31/2010 | 0.05 | <0.00002 | <1 | <0.01 | 10 | 0.012 | 0.002 | 7 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/2/2010 | 0.03 | <0.0002 | <1 | <0.01 | 10 | <0.001 | 0.002 | 6 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/4/2010 | 0.03 | <0.0002 | <1 | <0.01 | 10 | 0.001 | 0.002 | 6 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/6/2010 | 0.024 | | 1 | <0.01 | 11 | 0.004 | 0.002 | 7 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/14/2010 | 0.025 | <0.0002 | 1 | <0.01 | 11 | 0.002 | 0.002 | 8 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/16/2010 | 0.026 | <0.0002 | 1 | <0.01 | 11 | 0.004 | 0.002 | 7 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/18/2010 | 0.023 | <0.0002 | 1 | <0.01 | 11 | <0.001 | 0.002 | 7 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/20/2010 | 0.028 | <0.0002 | <1 | <0.01 | 10 | 0.003 | 0.002 | 7 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/22/2010 | 0.082 | <0.0002 | <1 | <0.01 | 9 | 0.001 | 0.001 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/24/2010 | 0.056 | <0.0002 | <1 | <0.01 | 9 | 0.001 | 0.001 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/26/2010 | 0.038 | <0.0002 | <1 | <0.01 | 10 | 0.003 | 0.001 | 7 | 0.004 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 6/28/2010 | 0.028 | <0.0002 | <1 | <0.01 | 10 | 0.002 | 0.001 | 7 | <0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 7/5/2010 | 0.104 | <0.0002 | <1 | <0.01 | 8 | 0.003 | 0.001 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 8/5/2010 | 0.112 | <0.0002 | <1 | <0.01 | 10 | 0.023 | 0.001 | 6 | 0.001 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 9/12/2010 | | | | | | | | | | | | | | |
| W7 | 9/12/2010 | 0.231 | <0.0002 | <1 | <0.01 | 9 | 0.017 | 0.001 | 5 | 0.002 | <0.0002 | | <0.0005 | <60 | <0.0008 |
| W7 | 10/8/2010 | 0.127 | <0.00002 | 0.71 | <0.005 | 9.34 | 0.027 | 0.001 | 5.34 | 0.001 | <0.0002 | | <0.0005 | 3 | 0.0001 |
| W7 | 4/27/2011 | 0.148 | <0.00002 | 1.75 | <0.005 | 3.57 | 0.027 | <0.001 | 2.12 | 0.001 | <0.0002 | 0.048 | <0.0005 | <3 | <0.0001 |
| W7 | 5/2/2011 | 0.169 | <0.00002 | 1.39 | <0.005 | 2.57 | 0.021 | <0.001 | 1.43 | 0.001 | <0.0002 | | <0.0005 | <3 | <0.0001 |
| W7 | 6/1/2011 | 0.099 | <0.00002 | 0.85 | <0.005 | 8.19 | 0.011 | 0.001 | 5.09 | 0.001 | <0.0002 | 0.011 | <0.0005 | 4 | 0.0001 |
| W7 | 6/16/2011 | 0.207 | <0.00002 | 0.67 | <0.005 | 8.56 | 0.011 | 0.001 | 5.67 | 0.002 | <0.0002 | 0.014 | <0.0005 | <3 | 0.0001 |
| W7 | 7/1/2011 | 0.441 | 0.00005 | 0.39 | <0.005 | 6.25 | 0.037 | <0.001 | 4.4 | 0.002 | <0.0002 | 0.017 | <0.0005 | <3 | 0.0001 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Dissolved Fe (mg/L) | Dissolved Hg (mg/L) | Dissolved K (mg/L) | Dissolved Li (mg/L) | Dissolved Mg (mg/L) | Dissolved Mn (mg/L) | Dissolved Mo (mg/L) | Dissolved Na (mg/L) | Dissolved Ni (mg/L) | Dissolved Pb (mg/L) | Dissolved P (mg/L) | Dissolved Sb (mg/L) | Dissolved S (mg/L) | Dissolved Se (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | 0.614 | <0.00002 | 0.29 | <0.005 | 4.85 | 0.064 | <0.001 | 3.69 | 0.003 | <0.0002 | 0.02 | <0.0005 | <3 | 0.0001 |
| W7 | 8/16/2011 | 0.593 | <0.00002 | 0.46 | <0.005 | 7.96 | 0.054 | <0.001 | 4.81 | 0.002 | <0.0002 | 0.023 | <0.0005 | <3 | 0.0001 |
| W7 | 8/19/2011 | 0.556 | <0.00002 | 0.41 | <0.005 | 7.89 | 0.06 | <0.001 | 4.58 | 0.002 | <0.0002 | 0.032 | <0.0005 | <3 | 0.0001 |
| W7 | 9/12/2011 | 0.616 | <0.00002 | 0.62 | <0.005 | 10.1 | 0.079 | <0.001 | 5.73 | 0.002 | <0.0002 | 0.023 | <0.0005 | <3 | 0.0001 |
| W7 | 10/6/2011 | 0.346 | <0.00002 | 0.62 | <0.005 | 9.89 | 0.07 | 0.001 | 5.68 | 0.001 | <0.0002 | 0.015 | <0.0005 | <3 | 0.0001 |
| W7 | 11/22/2011 | 0.167 | <0.000020 | 0.864 | <0.0050 | 12.8 | 0.0626 | 0.0013 | 6.99 | 0.0012 | <0.00020 | 0.014 | <0.00050 | 4.6 | 0.00016 |
| W7 | 1/24/2012 | 0.0944 | <0.000010 | 1.6 | <0.0050 | 14.9 | 0.0614 | 0.0015 | 8.72 | <0.0010 | <0.00020 | 0.012 | <0.00050 | 7.3 | 0.00043 |
| W7 | 2/25/2012 | 0.0488 | <0.000010 | 1.63 | <0.0050 | 15.1 | 0.007 | 0.0014 | 8.86 | <0.0010 | 0.00024 | 0.031 | <0.00050 | 7.3 | 0.00034 |
| W7 | 3/5/2012 | 0.0124 | <0.000010 | 1.5 | <0.0050 | 14.2 | 0.0015 | 0.0011 | 8.03 | <0.0010 | <0.00020 | <0.01 | <0.00050 | 6.1 | 0.00031 |
| W7 | 4/24/2012 | 0.475 | <0.000010 | 1.18 | <0.0050 | 3.2 | 0.0486 | <0.0010 | 1.9 | 0.0012 | <0.00020 | 0.027 | <0.00050 | <3.0 | <0.00010 |
| W7 | 5/6/2012 | 0.427 | <0.000010 | 0.932 | <0.0050 | 3.95 | 0.0108 | <0.0010 | 2.4 | 0.0011 | <0.00020 | 0.021 | <0.00050 | <3.0 | <0.00010 |
| W7 | 5/6/2012 | 0.462 | <0.000010 | 0.948 | <0.0050 | 4.04 | 0.0113 | <0.0010 | 2.44 | 0.0012 | <0.00020 | 0.021 | <0.00050 | <3.0 | <0.00010 |
| W7 | 6/19/2012 | 0.56 | <0.000010 | 0.583 | <0.0050 | 8.07 | 0.0433 | 0.0013 | 5.29 | 0.002 | <0.00020 | 0.02 | <0.00050 | <3.0 | 0.00015 |
| W7 | 7/17/2012 | 0.965 | <0.000010 | 0.791 | <0.0050 | 11 | 0.0366 | 0.0015 | 6.55 | 0.0016 | <0.00020 | 0.035 | <0.00050 | <3.0 | 0.00013 |
| W7 | 7/30/2012 | 0.964 | <0.000010 | 0.833 | <0.0050 | 12.1 | 0.0534 | 0.0015 | 6.98 | 0.0015 | <0.00020 | 0.032 | <0.00050 | <3.0 | 0.00016 |
| W7 | 8/8/2012 | 1.06 | <0.000010 | 0.882 | <0.0050 | 12.6 | 0.0554 | 0.0016 | 7.09 | 0.0017 | <0.00020 | 0.033 | <0.00050 | <3.0 | 0.00014 |
| W7 | 8/23/2012 | 0.978 | <0.000010 | 0.942 | <0.0050 | 13 | 0.057 | 0.0016 | 7.35 | 0.0016 | <0.00020 | 0.031 | <0.00050 | 3.1 | 0.00015 |
| W7 | 9/13/2012 | 0.734 | <0.000010 | 0.567 | <0.0050 | 9.91 | 0.0956 | <0.0010 | 5.77 | 0.0036 | <0.00020 | 0.023 | <0.00050 | <3.0 | 0.00014 |
| W7 | 10/16/2012 | 0.603 | <0.000010 | 0.675 | <0.0050 | 11.2 | 0.073 | 0.0011 | 6.34 | 0.0015 | <0.00020 | 0.021 | <0.00050 | 3.4 | 0.00014 |
| W7 | 11/2/2012 | 0.183 | <0.000010 | 1.34 | <0.0050 | 14.6 | 0.101 | 0.0013 | 8.07 | 0.0012 | 0.00021 | 0.031 | <0.00050 | 5.2 | 0.00018 |
| W7 | 12/29/2012 | 0.0301 | <0.000010 | 2.54 | <0.0050 | 20.2 | 0.0374 | 0.0012 | 12.2 | 0.0011 | <0.00020 | <0.01 | <0.00050 | 10.9 | 0.00045 |
| W7 | 4/30/2013 | 0.0143 | <0.000010 | 1.92 | <0.0050 | 18.3 | 0.0528 | 0.0013 | 10.1 | <0.0010 | <0.00020 | <0.01 | <0.00050 | 8 | 0.00043 |
| W7 | 5/14/2013 | 0.306 | <0.000010 | 1.03 | <0.0050 | 2.75 | 0.103 | <0.0010 | 1.52 | 0.001 | <0.00020 | 0.027 | <0.00050 | <3.0 | <0.00010 |
| W7 | 6/19/2013 | 0.285 | <0.000010 | 0.94 | <0.0050 | 9.4 | 0.0317 | 0.0015 | 5.9 | 0.0013 | <0.00020 | 0.019 | <0.00050 | 3.2 | 0.00011 |
| W7 | 6/19/2013 | 0.291 | <0.000010 | 0.955 | <0.0050 | 9.47 | 0.0339 | 0.0016 | 5.88 | 0.0012 | <0.00020 | 0.019 | <0.00050 | 3.5 | 0.00019 |
| W7 | 7/13/2013 | 0.416 | <0.000010 | 0.91 | <0.0050 | 11 | 0.026 | 0.0015 | 6.52 | 0.0013 | <0.00020 | 0.016 | <0.00050 | 3.2 | 0.00015 |
| W7 | 8/21/2013 | 0.3 | <0.000010 | 0.934 | <0.0050 | 12.7 | 0.0355 | 0.0015 | 7.34 | 0.0012 | <0.00020 | 0.017 | <0.00050 | 3.2 | 0.00015 |
| W7 | 9/6/2013 | 0.663 | <0.000010 | 0.887 | <0.0050 | 12.3 | 0.081 | 0.0013 | 7.31 | 0.0016 | <0.00020 | 0.026 | <0.00050 | <3.0 | 0.00017 |
| W7 | 10/21/2013 | 0.549 | <0.000010 | 0.878 | <0.0050 | 12.6 | 0.1 | 0.0012 | 7.03 | 0.0012 | <0.00020 | 0.025 | <0.00050 | 4.2 | 0.00017 |
| W7 | 11/16/2013 | 0.169 | <0.000010 | 1.15 | <0.0050 | 13.3 | 0.0809 | 0.0016 | 7.71 | <0.0010 | <0.00020 | 0.017 | <0.00050 | 5.4 | 0.00024 |
| W7 | 12/7/2013 | 0.109 | <0.000010 | 1.38 | <0.0050 | 14.5 | 0.143 | 0.0011 | 8.17 | <0.0010 | <0.00020 | <0.01 | <0.00050 | 5.3 | 0.00024 |
| C4 | 5/6/2012 | 1.11 | <0.000010 | 0.895 | <0.0050 | 3.4 | 0.243 | <0.0010 | 2.4 | 0.0023 | <0.00020 | 0.037 | <0.00050 | <3.0 | <0.00010 |
| C4 | 8/1/2012 | 1.5 | <0.000010 | 0.754 | <0.0050 | 9.12 | 0.622 | 0.0011 | 4.95 | 0.0031 | <0.00020 | 0.049 | <0.00050 | 3 | 0.00011 |
| C4 | 8/8/2012 | 1.6 | <0.000010 | 0.759 | <0.0050 | 9.81 | 0.683 | 0.0011 | 5.16 | 0.0027 | <0.00020 | 0.047 | <0.00050 | <3.0 | 0.00011 |
| C4 | 8/25/2012 | 1.68 | <0.000010 | 0.989 | <0.0050 | 10.3 | 0.682 | 0.0012 | 5.21 | 0.0029 | <0.00020 | 0.06 | <0.00050 | <3.0 | <0.00010 |
| C4 | 6/22/2013 | 1.2 | <0.000010 | 0.983 | <0.0050 | 9.29 | 0.405 | 0.0018 | 5.62 | 0.0027 | <0.00020 | 0.041 | <0.00050 | 3.2 | 0.00013 |
| C4 | 7/19/2013 | 1.56 | <0.000010 | 0.845 | <0.0050 | 9.31 | 0.385 | 0.0017 | 5.66 | 0.0025 | <0.00020 | 0.04 | <0.00050 | <3.0 | 0.00012 |
| C4 | 8/22/2013 | 1.44 | <0.000010 | 0.776 | <0.0050 | 9.87 | 0.448 | 0.0013 | 5.49 | 0.0027 | <0.00020 | 0.043 | <0.00050 | <3.0 | 0.00012 |
| C4 | 9/6/2013 | 1.78 | <0.000010 | 0.777 | <0.0050 | 9.52 | 0.495 | 0.001 | 5.28 | 0.0028 | <0.00020 | 0.048 | <0.00050 | 3.1 | <0.00010 |
| C4 | 10/18/2013 | 1.15 | <0.000010 | 0.754 | <0.0050 | 10.5 | 0.417 | <0.0010 | 5.46 | 0.0023 | <0.00020 | 0.033 | <0.00050 | 4.5 | <0.00010 |
| C4 | 10/18/2013 | 1.16 | <0.000010 | 0.762 | <0.0050 | 10.4 | 0.408 | 0.0012 | 5.38 | 0.0025 | <0.00020 | 0.036 | <0.00050 | 4.4 | <0.00010 |
| C4 | 11/17/2013 | 14.2 | <0.000010 | 0.985 | <0.0050 | 18.8 | 3.09 | 0.0011 | 8.06 | 0.0061 | <0.00020 | 0.117 | <0.00050 | 4.5 | 0.00024 |
| C10 | 5/12/2012 | 1.55 | <0.000010 | 1.08 | <0.0050 | 4.24 | 0.305 | <0.0010 | 2.95 | 0.0019 | 0.00025 | 0.035 | <0.00050 | <3.0 | 0.0001 |
| C10 | 7/30/2012 | 1.15 | <0.000010 | 0.921 | <0.0050 | 8.1 | 0.189 | 0.0014 | 5.64 | 0.0023 | 0.00067 | 0.039 | <0.00050 | <3.0 | 0.00014 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | 0.883 | <0.000010 | 0.824 | <0.0050 | 8.59 | 0.252 | 0.0019 | 5.34 | 0.0022 | <0.00020 | 0.034 | <0.00050 | <3.0 | 0.0001 |
| C10 | 8/27/2012 | 1 | <0.000010 | 1.02 | <0.0050 | 8.82 | 0.27 | 0.0011 | 5.26 | 0.0023 | <0.00020 | 0.038 | <0.00050 | <3.0 | 0.00012 |
| C10 | 6/22/2013 | 0.802 | <0.000010 | 1.45 | <0.0050 | 8.63 | 0.0628 | 0.0012 | 6.07 | 0.0025 | <0.00020 | 0.053 | <0.00050 | <3.0 | 0.00011 |
| C10 | 7/23/2013 | 0.54 | <0.000010 | 0.848 | <0.0050 | 7.65 | 0.154 | 0.001 | 5.75 | 0.0022 | <0.00020 | 0.025 | <0.00050 | <3.0 | <0.00010 |
| C10 | 8/22/2013 | 0.992 | <0.000010 | 0.979 | <0.0050 | 9.84 | 0.063 | 0.0015 | 6.05 | 0.0023 | <0.00020 | 0.032 | <0.00050 | <3.0 | <0.00010 |
| C10 | 9/8/2013 | 1.26 | <0.000010 | 1.03 | <0.0050 | 9.12 | 0.137 | <0.0010 | 5.65 | 0.0025 | <0.00020 | 0.04 | <0.00050 | <3.0 | <0.00010 |
| C10 | 9/8/2013 | 1.28 | <0.000010 | 1.03 | <0.0050 | 9.37 | 0.139 | <0.0010 | 5.79 | 0.0025 | <0.00020 | 0.043 | <0.00050 | <3.0 | <0.00010 |
| C10 | 10/18/2013 | 0.761 | <0.000010 | 0.844 | <0.0050 | 8.73 | 0.187 | <0.0010 | 5.44 | 0.0019 | <0.00020 | 0.027 | <0.00050 | <3.0 | <0.00010 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Dissolved Si (mg/L) | Dissolved Sn (mg/L) | Dissolved Sr (mg/L) | Dissolved Te (mg/L) | Dissolved Th (mg/L) | Dissolved Ti (mg/L) | Dissolved Tl (mg/L) | Dissolved U (mg/L) | Dissolved V (mg/L) | Dissolved Zn (mg/L) | Dissolved Zr (mg/L) | P-E (mg/L) | TT Ag (mg/L) | TT Al (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00049 | <0.030 | <0.0050 | | | 0.000036 | 0.613 |
| W1 | 6/30/2005 | 5.53 | <0.00010 | 0.3 | | | <0.010 | <0.00010 | 0.00113 | <0.0010 | <0.0010 | | | <0.000010 | 0.0218 |
| W1 | 7/28/2005 | 5.55 | <0.00010 | 0.331 | | | <0.010 | <0.00010 | 0.00133 | <0.0010 | 0.0025 | | | <0.000010 | 0.0174 |
| W1 | 8/29/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00077 | <0.030 | <0.0050 | | | <0.000020 | 0.0524 |
| W1 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00055 | <0.030 | <0.0050 | | | <0.000020 | 0.127 |
| W1 | 10/15/2005 | 6.25 | <0.00010 | 0.257 | | | <0.010 | <0.00010 | 0.000727 | <0.0010 | 0.0014 | | | <0.000010 | 0.15 |
| W2 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | | | | | | <0.000020 | 0.362 |
| W2 | 5/27/2005 | | | | | | <0.01 | | 0.00081 | <0.03 | <0.005 | | | | 1.14 |
| W2 | 6/30/2005 | 5.4 | <0.00010 | 0.307 | | | <0.010 | <0.00010 | 0.0011 | <0.0010 | 0.0015 | | | <0.000010 | 0.0111 |
| W2 | 7/28/2005 | 5.31 | <0.00010 | 0.341 | | | <0.010 | <0.00010 | 0.00127 | <0.0010 | 0.0011 | | | <0.000010 | 0.0127 |
| W2 | 8/30/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00077 | <0.030 | <0.0050 | | | <0.000020 | 0.0475 |
| W2 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00055 | <0.030 | <0.0050 | | | <0.000020 | 0.133 |
| W2 | 10/15/2005 | 6.19 | <0.00010 | 0.256 | | | <0.010 | <0.00010 | 0.000713 | <0.0010 | <0.0010 | | | <0.000010 | 0.0972 |
| W3 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00031 | <0.030 | <0.0050 | | | <0.000020 | 0.152 |
| W3 | 6/30/2005 | 5.89 | <0.00010 | 0.297 | | | <0.010 | <0.00010 | 0.000903 | <0.0010 | 0.0116 | | | <0.000010 | 0.0313 |
| W3 | 7/29/2005 | 5.56 | <0.00010 | 0.279 | | | <0.010 | <0.00010 | 0.000717 | <0.0010 | 0.0015 | | | <0.000030 | 0.732 |
| W3 | 8/29/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00045 | <0.030 | <0.0050 | | | 0.000027 | 0.267 |
| W3 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00034 | <0.030 | <0.0050 | | | 0.000029 | 0.236 |
| W3 | 10/15/2005 | 6.16 | <0.00010 | 0.225 | | | <0.010 | <0.00010 | 0.00042 | <0.0010 | 0.0018 | | | <0.000010 | 0.09 |
| W8 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0506 |
| W8 | 6/30/2005 | 5.25 | <0.00010 | 0.113 | | | <0.010 | <0.00010 | 0.000059 | <0.0010 | 0.0012 | | | <0.000010 | 0.0807 |
| W8 | 7/29/2005 | 4.95 | <0.00010 | 0.132 | | | <0.010 | <0.00010 | 0.000074 | <0.0010 | 0.0019 | | | <0.000010 | 0.033 |
| W8 | 8/30/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0688 |
| W8 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0509 |
| W8 | 10/15/2005 | 6.54 | <0.00010 | 0.171 | | | <0.010 | <0.00010 | 0.000093 | <0.0010 | <0.0010 | | | <0.000010 | 0.116 |
| W9 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0732 |
| W9 | 6/30/2005 | 5.35 | <0.00010 | 0.0957 | | | <0.010 | <0.00010 | 0.000024 | <0.0010 | <0.0010 | | | <0.000010 | 0.0401 |
| W9 | 7/29/2005 | 5.69 | <0.00010 | 0.14 | | | <0.010 | <0.00010 | 0.00005 | <0.0010 | 0.004 | | | <0.000010 | 0.0478 |
| W9 | 8/29/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0564 |
| W9 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0642 |
| W9 | 10/15/2005 | 6.13 | <0.00010 | 0.0806 | | | <0.010 | <0.00010 | 0.000023 | <0.0010 | 0.0017 | | | <0.000010 | 0.0622 |
| W10 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | 0.0085 | | | <0.000020 | 0.151 |
| W10 | 5/27/2005 | | <0.0005 | | | | <0.01 | <0.0002 | 0.00079 | <0.03 | <0.005 | | | <0.00002 | |
| W10 | 6/30/2005 | 5.43 | <0.00010 | 0.0772 | | | <0.010 | <0.00010 | 0.000028 | <0.0010 | 0.0223 | | | <0.000010 | 0.142 |
| W10 | 7/29/2005 | 5.64 | <0.00010 | 0.0921 | | | <0.010 | <0.00010 | <0.000010 | <0.0010 | 0.0074 | | | <0.000030 | 2.59 |
| W10 | 8/29/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | 0.0052 | | | <0.000020 | 0.587 |
| W10 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0818 |
| W10 | 10/15/2005 | 5.82 | <0.00010 | 0.147 | | | <0.010 | <0.00010 | 0.000013 | <0.0010 | 0.0015 | | | <0.000010 | 0.089 |
| W6 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.229 |
| W6 | 6/30/2005 | 7.18 | <0.00010 | 0.102 | | | <0.010 | <0.00010 | 0.000134 | <0.0010 | 0.021 | | | <0.000010 | 0.17 |
| W6 | 7/29/2005 | 5.51 | <0.00010 | 0.274 | | | <0.010 | <0.00010 | 0.0014 | <0.0010 | 0.0025 | | | <0.000020 | 0.598 |
| W6 | 8/30/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0181 |
| W6 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | <0.00020 | <0.030 | <0.0050 | | | <0.000020 | 0.0321 |
| W6 | 10/15/2005 | 6.93 | <0.00010 | 0.108 | | | <0.010 | <0.00010 | 0.000122 | <0.0010 | 0.0015 | | | <0.000010 | 0.0251 |
| W6 | 6/2/2006 | 4.84 | <0.0001 | 0.0682 | | | <0.01 | <0.0001 | 0.000081 | <0.001 | 0.003 | | | 0.000021 | 1.95 |
| W6 | 8/25/2006 | | | | | | | | | | | | | <0.0002 | 0.024 |
| W6 | 9/6/2006 | 7.54 | <0.001 | 0.136 | | | 0.0005 | <0.00005 | <0.0005 | 0.0016 | 0.002 | | | <0.0001 | 0.035 |
| W6 | 6/20/2007 | | | | | | | | | | | | | <0.0001 | 0.042 |
| W6 | 9/18/2007 | | | | | | | | | | | | | <0.0001 | 0.023 |
| W6 | 6/17/2008 | | | | | | | | | | | | | <0.00001 | 0.14 |
| W6 | 9/18/2008 | 6.29 | <0.0001 | 0.098 | <0.0001 | <0.0001 | 0.001 | <0.00001 | <0.0004 | 0.00073 | 0.003 | 0.0002 | | 0.00008 | 0.022 |
| W6 | 4/14/2009 | 3.63 | <0.0001 | 0.419 | <0.0001 | <0.0001 | 0.0032 | <0.00001 | 0.004 | 0.00029 | 0.049 | <0.0001 | | 0.00021 | 1.3 |
| W6 | 4/30/2009 | 2.3 | <0.0001 | 0.099 | <0.0001 | <0.0001 | 0.0044 | <0.00001 | <0.0004 | 0.00047 | 0.006 | 0.0004 | | <0.00001 | 5.31 |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | <0.00001 | 0.085 |
| W6 | 8/6/2009 | | | | | | | | | | | | | <0.00001 | 0.07 |
| W6 | 8/18/2009 | 4.06 | <0.0001 | 0.584 | <0.0001 | <0.0004 | 0.0004 | <0.00001 | 0.0008 | 0.0006 | 0.002 | <0.0001 | | | |
| W6 | 8/25/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | <0.00001 | 0.171 |
| W6 | 10/25/2009 | 4.2 | <0.005 | 0.817 | | | <0.005 | <0.00005 | 0.0009 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.065 |
| W6 | 4/19/2010 | 3.81 | <0.0001 | 0.372 | <0.0001 | <0.0004 | <0.01 | <0.00001 | 0.0013 | 0.0006 | 0.005 | <0.0001 | | 0.00002 | 1.25 |
| W6 | 5/16/2010 | 5.52 | <0.005 | 0.199 | | | <0.005 | <0.00005 | <0.0001 | <0.005 | <0.005 | <0.0005 | | 0.00002 | 0.041 |
| W6 | 5/17/2010 | 2.22 | <0.005 | 0.219 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.025 |
| W6 | 5/19/2010 | 2.79 | <0.005 | 0.245 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.03 |
| W6 | 5/21/2010 | 2.14 | <0.005 | 0.243 | | | <0.01 | <0.00005 | 0.0006 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.162 |
| W6 | 5/23/2010 | 2.58 | <0.005 | 0.285 | | | <0.01 | <0.00005 | 0.0006 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.027 |
| W6 | 5/25/2010 | 2.6 | <0.005 | 0.306 | | | <0.01 | <0.00005 | 0.0005 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.061 |
| W6 | 5/29/2010 | <2 | <0.005 | 0.221 | | | <0.01 | <0.00005 | 0.0005 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.09 |
| W6 | 6/2/2010 | 5.16 | <0.005 | 0.623 | | | <0.01 | <0.00005 | 0.0028 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.036 |
| W6 | 6/4/2010 | 5.66 | <0.005 | 0.099 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.049 |
| W6 | 6/6/2010 | 6.95 | <0.005 | 0.115 | | | <0.01 | <0.00005 | 0.0004 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.142 |
| W6 | 6/14/2010 | 7.21 | <0.005 | 0.099 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.274 |
| W6 | 6/16/2010 | 6.57 | <0.005 | 0.117 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.274 |
| W6 | 6/18/2010 | 7.25 | <0.005 | 0.111 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.154 |
| W6 | 6/20/2010 | 6.72 | <0.005 | 0.109 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.138 |
| W6 | 6/22/2010 | 6.78 | <0.005 | 0.109 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.208 |
| W6 | 6/24/2010 | 6.84 | <0.005 | 0.109 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.118 |
| W6 | 6/26/2010 | 6.94 | <0.005 | 0.118 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.143 |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | 7.64 | <0.005 | 0.115 | | | <0.01 | <0.00005 | 0.0002 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.612 |
| W6 | 7/5/2010 | 6.24 | <0.005 | 0.112 | | | <0.01 | <0.00005 | 0.0002 | <0.005 | <0.01 | <0.002 | | <0.0001 | 1.41 |
| W6 | 8/5/2010 | 7.84 | <0.005 | 0.13 | | | <0.01 | <0.00005 | 0.0002 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.157 |
| W6 | 9/9/2010 | 7.77 | <0.005 | 0.13 | | | <0.01 | <0.00005 | 0.0002 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.655 |
| W6 | 10/8/2010 | 6.98 | <0.005 | 0.125 | | | <0.005 | <0.00005 | 0.0002 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.429 |
| W6 | 8/19/2011 | 5.54 | <0.005 | 0.617 | | | <0.005 | <0.00005 | 0.0025 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.033 |
| W6 | 7/17/2012 | 7.25 | <0.0050 | 0.131 | | | <0.0050 | <0.000050 | 0.00034 | <0.0050 | <0.0050 | <0.00050 | | 0.000172 | 20.8 |
| W6 | 7/30/2012 | 6.95 | <0.0050 | 0.135 | | | <0.0050 | <0.000050 | 0.00039 | <0.0050 | <0.0050 | <0.00050 | | 0.000122 | 15.1 |
| W6 | 8/9/2012 | 8.13 | <0.0050 | 0.151 | | | <0.0050 | <0.000050 | 0.00038 | <0.0050 | <0.0050 | <0.00050 | | 0.000054 | 8.03 |
| W6 | 8/25/2012 | 6.56 | <0.0050 | 0.143 | | | <0.0050 | <0.000050 | 0.0004 | <0.0050 | <0.0050 | <0.00050 | | 0.000021 | 5.23 |
| W6 | 9/13/2012 | 6.42 | <0.0050 | 0.11 | | | <0.0050 | <0.000050 | 0.00013 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.271 |
| W6 | 10/13/2012 | | | | | | | | | | | | | <0.000020 | 0.241 |
| W6 | 11/12/2012 | 8.72 | <0.0050 | 0.189 | | | <0.0050 | <0.000050 | 0.00032 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0243 |
| W6 | 5/14/2013 | 2.67 | <0.0050 | 0.0363 | | | <0.0050 | <0.000050 | <0.00010 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.65 |
| W6 | 6/22/2013 | 6.57 | <0.0050 | 0.115 | | | <0.0050 | <0.000050 | 0.00028 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 4.63 |
| W6 | 7/12/2013 | 7.05 | <0.0050 | 0.112 | | | <0.0050 | <0.000050 | 0.00017 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.506 |
| W6 | 8/22/2013 | 7.24 | <0.0050 | 0.132 | | | <0.0050 | <0.000050 | 0.00017 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0846 |
| W6 | 9/6/2013 | 7.48 | <0.0050 | 0.132 | | | <0.0050 | <0.000050 | 0.00016 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.165 |
| W6 | 10/7/2013 | 7.39 | <0.0050 | 0.126 | | | <0.0050 | <0.000050 | 0.00018 | <0.0050 | <0.0050 | <0.00050 | | 0.000045 | 2.18 |
| W6 | 11/16/2013 | 8.28 | <0.0050 | 0.144 | | | <0.0050 | <0.000050 | 0.00019 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.283 |
| W6 | 12/7/2013 | 9.38 | <0.0050 | 0.2 | | | <0.0050 | <0.000050 | 0.00039 | <0.0050 | <0.0050 | <0.00050 | | 0.000049 | 0.0734 |
| W7 | 5/27/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00036 | <0.030 | <0.0050 | | | <0.000020 | 0.489 |
| W7 | 6/30/2005 | 5.72 | <0.00010 | 0.284 | | | <0.010 | <0.00010 | 0.000759 | <0.0010 | 0.0064 | | | <0.000010 | 0.153 |
| W7 | 7/29/2005 | 5.47 | <0.00010 | 0.277 | | | <0.010 | <0.00010 | 0.000994 | <0.0010 | 0.002 | | | <0.000020 | 0.506 |
| W7 | 8/30/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00055 | <0.030 | <0.0050 | | | <0.000020 | 0.0436 |
| W7 | 9/28/2005 | | <0.00050 | | | | <0.010 | <0.00020 | 0.00038 | <0.030 | <0.0050 | | | <0.000020 | 1.65 |
| W7 | 10/15/2005 | 6.44 | <0.00010 | 0.23 | | | <0.010 | <0.00010 | 0.000515 | <0.0010 | <0.0010 | | | <0.000010 | 0.0738 |
| W7 | 6/2/2006 | 4.19 | <0.0001 | 0.11 | | | <0.01 | <0.0001 | 0.000216 | 0.0017 | <0.001 | | | 0.000069 | 11.4 |
| W7 | 6/8/2006 | | | | | | | | | | | | | <0.00001 | 0.648 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Dissolved Si (mg/L) | Dissolved Sn (mg/L) | Dissolved Sr (mg/L) | Dissolved Te (mg/L) | Dissolved Th (mg/L) | Dissolved Ti (mg/L) | Dissolved Tl (mg/L) | Dissolved U (mg/L) | Dissolved V (mg/L) | Dissolved Zn (mg/L) | Dissolved Zr (mg/L) | P-E (mg/L) | TT Ag (mg/L) | TT Al (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | 5.35 | <0.001 | 0.236 | | | 0.0007 | <0.00005 | 0.0007 | 0.0011 | <0.001 | | | <0.0001 | 1.48 |
| W7 | 6/23/2006 | 5.5 | <0.001 | 0.321 | | | 0.0006 | <0.00005 | 0.001 | 0.001 | 0.002 | | | 0.0003 | 5.09 |
| W7 | 6/28/2006 | 6.48 | <0.001 | 0.284 | | | 0.0117 | <0.00005 | 0.0009 | 0.0029 | 0.005 | | | <0.0001 | 1.69 |
| W7 | 7/7/2006 | 6.8 | <0.001 | 0.322 | | | 0.0007 | <0.00005 | 0.0005 | 0.0013 | 0.001 | | | <0.0001 | 0.096 |
| W7 | 7/12/2006 | 5.36 | <0.001 | 0.322 | | | 0.0005 | <0.00005 | 0.0007 | 0.0018 | <0.001 | | | <0.0001 | 0.078 |
| W7 | 7/20/2006 | 6.34 | <0.001 | 0.284 | | | <0.0005 | <0.00005 | 0.001 | 0.0016 | <0.001 | | | <0.0001 | 0.058 |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | 5.35 | <0.001 | 0.274 | | | <0.0005 | <0.00005 | 0.001 | 0.0007 | <0.001 | | | <0.0001 | 0.099 |
| W7 | 8/2/2006 | 5.87 | <0.001 | 0.247 | | | 0.0005 | <0.00005 | 0.001 | 0.0013 | <0.001 | | | 0.0002 | 0.06 |
| W7 | 8/10/2006 | 5.9 | <0.001 | 0.343 | | | 0.0006 | <0.00005 | 0.001 | 0.0015 | 0.001 | | | <0.0001 | 0.034 |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | 6.32 | <0.001 | 0.344 | | | 0.0005 | <0.00005 | 0.0011 | 0.0017 | 0.003 | | | <0.0002 | 0.048 |
| W7 | 8/30/2006 | 5.84 | <0.001 | 0.333 | | | 0.0008 | <0.00005 | 0.001 | 0.0008 | 0.005 | | | <0.0001 | 0.054 |
| W7 | 9/6/2006 | 6.02 | <0.001 | 0.355 | | | 0.0005 | <0.00005 | 0.001 | 0.0018 | 0.002 | | | <0.0001 | 0.049 |
| W7 | 9/13/2006 | 5.56 | <0.001 | 0.321 | | | 0.0006 | <0.00005 | 0.001 | 0.0014 | 0.001 | | | <0.0001 | 0.025 |
| W7 | 9/20/2006 | 5.74 | <0.001 | 0.319 | | | <0.0005 | <0.00005 | 0.001 | 0.0015 | <0.001 | | | <0.0001 | 0.074 |
| W7 | 9/28/2006 | 5.97 | <0.001 | 0.34 | | | <0.0005 | <0.00005 | 0.001 | 0.0015 | 0.002 | | | <0.0002 | 0.042 |
| W7 | 10/4/2006 | 5.93 | <0.001 | 0.326 | | | 0.0007 | <0.00005 | 0.001 | 0.0011 | 0.001 | | | <0.0002 | 0.082 |
| W7 | 10/12/2006 | 6.08 | <0.001 | 0.344 | | | 0.0006 | <0.00005 | 0.0011 | 0.0009 | 0.002 | | | <0.0001 | 0.264 |
| W7 | 6/5/2007 | | | | | | | | | | | | | <0.0001 | 1.56 |
| W7 | 6/5/2007 | | | | | | | | | | | | | <0.0002 | 1.77 |
| W7 | 6/5/2007 | | | | | | | | | | | | | <0.0001 | 1.85 |
| W7 | 6/20/2007 | 5.02 | <0.001 | 0.307 | | | 0.0009 | <0.00005 | 0.0012 | 0.0016 | 0.004 | | | <0.0001 | 0.172 |
| W7 | 7/18/2007 | 6.1 | <0.001 | 0.34 | | | 0.0006 | <0.00005 | 0.0012 | 0.0024 | 0.006 | | | <0.0001 | 0.231 |
| W7 | 7/18/2007 | | | | | | | | | | | | | <0.0001 | 0.216 |
| W7 | 7/18/2007 | | | | | | | | | | | | | <0.0001 | 0.211 |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | <0.0001 | 0.205 |
| W7 | 8/24/2007 | | | | | | | | | | | | | <0.0001 | 0.098 |
| W7 | 8/24/2007 | | | | | | | | | | | | | <0.0001 | 0.092 |
| W7 | 8/24/2007 | | | | | | | | | | | | | <0.0001 | 0.092 |
| W7 | 9/18/2007 | 6.17 | <0.001 | 0.31 | | | 0.0006 | <0.00005 | 0.0006 | 0.0044 | 0.002 | | | <0.0001 | 0.33 |
| W7 | 10/30/2007 | | | | | | | | | | | | | <0.0001 | 0.121 |
| W7 | 10/30/2007 | | | | | | | | | | | | | <0.0001 | 0.071 |
| W7 | 10/30/2007 | | | | | | | | | | | | | <0.0001 | 0.076 |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | 3.97 | <0.004 | 0.497 | <0.0001 | <0.0001 | 0.0011 | <0.00001 | 0.0021 | 0.00059 | 0.001 | <0.0001 | | <0.0001 | <0.02 |
| W7 | 4/22/2008 | 4.03 | <0.004 | 0.51 | <0.0001 | <0.0001 | 0.0009 | <0.00001 | 0.0024 | 0.00077 | 0.003 | 0.0001 | | <0.0001 | 0.02 |
| W7 | 4/22/2008 | 3.95 | <0.004 | 0.491 | <0.0001 | <0.0001 | 0.0014 | <0.00001 | 0.0022 | 0.0003 | 0.001 | <0.0001 | | <0.0001 | 0.02 |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | | | | | | | | | | | | | <0.0001 | 0.4 |
| W7 | 6/3/2008 | | | | | | | | | | | | | <0.0001 | 0.38 |
| W7 | 6/3/2008 | | | | | | | | | | | | | <0.0001 | 0.42 |
| W7 | 6/3/2008 | 2.27 | <0.0001 | 0.226 | <0.0001 | <0.0001 | 0.0005 | <0.00001 | 0.001 | 0.00062 | 0.002 | 0.0004 | | | |
| W7 | 6/17/2008 | | <0.0001 | 0.289 | 0.0002 | <0.0001 | 0.0015 | <0.00001 | 0.0014 | 0.00091 | 0.002 | 0.0003 | | <0.00001 | 0.21 |
| W7 | 8/6/2008 | | | | | | | | | | | | | 0.00001 | 0.817 |
| W7 | 8/6/2008 | | | | | | | | | | | | | 0.00001 | 1.27 |
| W7 | 8/6/2008 | | | | | | | | | | | | | 0.00001 | 1.36 |
| W7 | 8/6/2008 | 5.81 | <0.001 | 0.336 | | | <0.0005 | <0.00005 | 0.0011 | 0.001 | 0.006 | | | | |
| W7 | 9/18/2008 | 5.8 | <0.0001 | 0.173 | <0.0001 | <0.0001 | 0.0055 | <0.00001 | <0.0004 | 0.00094 | 0.003 | 0.0004 | | 0.00006 | 0.469 |
| W7 | 10/28/2008 | | | | | | | | | | | | | <0.00001 | 0.084 |
| W7 | 10/28/2008 | | | | | | | | | | | | | <0.00001 | 0.038 |
| W7 | 10/28/2008 | | | | | | | | | | | | | <0.00001 | 0.031 |
| W7 | 10/28/2008 | 6.6 | <0.0001 | 0.276 | <0.0001 | <0.0001 | 0.0011 | <0.00001 | 0.0007 | 0.00067 | 0.001 | 0.0002 | | | |
| W7 | 4/30/2009 | 1.48 | <0.0001 | 0.029 | <0.0001 | <0.0001 | 0.0015 | <0.00001 | <0.0004 | 0.00024 | 0.009 | 0.0002 | | <0.00001 | 0.138 |
| W7 | 6/8/2009 | 4.13 | <0.0001 | 0.24 | <0.0001 | <0.0001 | 0.0011 | <0.00001 | 0.0008 | 0.0008 | 0.002 | 0.0003 | | 0.00002 | 0.595 |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | | | | | | | | | | | | | 0.00002 | 0.071 |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | 6.04 | <0.0001 | 0.256 | <0.0001 | <0.0004 | 0.0004 | <0.00001 | 0.0007 | 0.0007 | 0.001 | 0.0002 | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | <0.00001 | 0.189 |
| W7 | 10/25/2009 | 6.3 | <0.005 | 0.334 | | | <0.005 | <0.00005 | 0.0012 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.052 |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | 4.15 | <0.0001 | 0.212 | <0.0001 | <0.0004 | <0.01 | <0.00001 | 0.0005 | 0.0005 | 0.005 | <0.0001 | | <0.00001 | 0.033 |
| W7 | 4/27/2010 | 2.94 | <0.005 | 0.071 | | | <0.005 | <0.00005 | 0.0001 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.113 |
| W7 | 4/29/2010 | 2.89 | <0.005 | 0.076 | | | <0.005 | <0.00005 | 0.0001 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.11 |
| W7 | 5/1/2010 | 3.27 | <0.005 | 0.088 | | | <0.005 | <0.00005 | 0.0002 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.502 |
| W7 | 5/3/2010 | 3.63 | <0.005 | 0.097 | | | <0.005 | <0.00005 | 0.0002 | <0.005 | <0.005 | <0.0005 | | 0.00003 | 0.406 |
| W7 | 5/5/2010 | 3.84 | <0.005 | 0.116 | | | <0.005 | <0.00005 | 0.0003 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.394 |
| W7 | 5/7/2010 | 3.77 | <0.005 | 0.129 | | | <0.005 | <0.00005 | 0.0003 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.407 |
| W7 | 5/9/2010 | 4.61 | <0.005 | 0.192 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.183 |
| W7 | 5/10/2010 | 4.62 | <0.005 | 0.195 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.125 |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | 5 | <0.005 | 0.201 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.123 |
| W7 | 5/14/2010 | 4.35 | <0.005 | 0.178 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.286 |
| W7 | 5/16/2010 | 4.68 | <0.005 | 0.207 | | | <0.005 | <0.00005 | 0.0007 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.207 |
| W7 | 5/17/2010 | 4.22 | <0.005 | 0.191 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.219 |
| W7 | 5/19/2010 | 5.24 | <0.005 | 0.21 | | | <0.005 | <0.00005 | 0.0008 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.105 |
| W7 | 5/21/2010 | 4.98 | <0.005 | 0.22 | | | <0.01 | <0.00005 | 0.0008 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.457 |
| W7 | 5/23/2010 | 5.24 | <0.005 | 0.235 | | | <0.01 | <0.00005 | 0.0009 | <0.005 | <0.01 | <0.002 | | <0.0001 | 2.14 |
| W7 | 5/25/2010 | 6.05 | <0.005 | 0.306 | | | <0.01 | <0.00005 | 0.0011 | <0.005 | <0.01 | <0.002 | | <0.0001 | 4.2 |
| W7 | 5/27/2010 | 5.4 | <0.005 | 0.277 | | | <0.01 | <0.00005 | 0.0011 | <0.005 | <0.01 | <0.002 | | <0.0001 | 10.3 |
| W7 | 5/29/2010 | 5.26 | <0.005 | 0.289 | | | <0.01 | <0.00005 | 0.0014 | <0.005 | <0.01 | <0.002 | | <0.0001 | 3.93 |
| W7 | 5/31/2010 | | <0.005 | 0.286 | | | <0.01 | <0.00005 | 0.0014 | <0.005 | <0.01 | <0.002 | | <0.0001 | 4.54 |
| W7 | 6/2/2010 | 5.16 | <0.005 | 0.293 | | | <0.01 | <0.00005 | 0.0015 | <0.005 | <0.01 | <0.002 | | <0.0001 | 2.91 |
| W7 | 6/4/2010 | 4.96 | <0.005 | 0.275 | | | <0.01 | <0.00005 | 0.0014 | <0.005 | <0.01 | <0.002 | | <0.0001 | 1.64 |
| W7 | 6/6/2010 | 5.46 | <0.005 | 0.313 | | | <0.01 | <0.00005 | 0.0015 | <0.005 | <0.01 | <0.002 | | <0.0001 | 2.05 |
| W7 | 6/14/2010 | 5.87 | <0.005 | 0.314 | | | <0.01 | <0.00005 | 0.0015 | <0.005 | <0.01 | <0.002 | | <0.0001 | 1.1 |
| W7 | 6/16/2010 | 5.32 | <0.005 | 0.338 | | | <0.01 | <0.00005 | 0.0015 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.43 |
| W7 | 6/18/2010 | 5.82 | <0.005 | 0.318 | | | <0.01 | <0.00005 | 0.0015 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.504 |
| W7 | 6/20/2010 | 5.69 | <0.005 | 0.3 | | | <0.01 | <0.00005 | 0.0012 | <0.005 | <0.01 | <0.002 | | <0.0001 | 1.17 |
| W7 | 6/22/2010 | 5.86 | <0.005 | 0.249 | | | <0.01 | <0.00005 | 0.0008 | <0.005 | <0.01 | <0.002 | | <0.0001 | 5.52 |
| W7 | 6/24/2010 | 5.79 | <0.005 | 0.259 | | | <0.01 | <0.00005 | 0.0008 | <0.005 | <0.01 | <0.002 | | <0.0001 | 1.21 |
| W7 | 6/26/2010 | 6.05 | <0.005 | 0.305 | | | <0.01 | <0.00005 | 0.001 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.503 |
| W7 | 6/28/2010 | 6.64 | <0.005 | 0.314 | | | <0.01 | <0.00005 | 0.001 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.298 |
| W7 | 7/5/2010 | 6.08 | <0.005 | 0.255 | | | <0.01 | <0.00005 | 0.0006 | <0.005 | <0.01 | <0.002 | | <0.0001 | 1.59 |
| W7 | 8/5/2010 | 6.47 | <0.005 | 0.303 | | | <0.01 | <0.00005 | 0.0007 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.22 |
| W7 | 9/12/2010 | | | | | | | | | | | | | <0.0001 | 0.256 |
| W7 | 9/12/2010 | 7.17 | <0.005 | 0.253 | | | <0.01 | <0.00005 | 0.0005 | <0.005 | <0.01 | <0.002 | | <0.0001 | 0.273 |
| W7 | 10/8/2010 | 6.54 | <0.005 | 0.277 | | | <0.005 | <0.00005 | 0.0007 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.064 |
| W7 | 4/27/2011 | 3.09 | <0.005 | 0.084 | | | <0.005 | <0.00005 | 0.0001 | <0.005 | 0.005 | <0.0005 | | <0.00002 | 0.101 |
| W7 | 5/2/2011 | 2.52 | <0.005 | 0.062 | | | <0.005 | <0.00005 | <0.0001 | <0.005 | 0.01 | <0.0005 | | <0.00002 | 0.25 |
| W7 | 6/1/2011 | 5.26 | <0.005 | 0.25 | | | <0.005 | <0.00005 | 0.0007 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.454 |
| W7 | 6/16/2011 | 6.52 | <0.005 | 0.213 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 2.48 |
| W7 | 7/1/2011 | 6.61 | <0.005 | 0.154 | | | <0.005 | <0.00005 | 0.0003 | <0.005 | <0.005 | <0.0005 | | 0.00004 | 3.4 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Dissolved Si (mg/L) | Dissolved Sn (mg/L) | Dissolved Sr (mg/L) | Dissolved Te (mg/L) | Dissolved Th (mg/L) | Dissolved Ti (mg/L) | Dissolved Tl (mg/L) | Dissolved U (mg/L) | Dissolved V (mg/L) | Dissolved Zn (mg/L) | Dissolved Zr (mg/L) | P-E (mg/L) | TT Ag (mg/L) | TT Al (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | 5.78 | <0.005 | 0.12 | | | <0.005 | <0.00005 | 0.0002 | <0.005 | <0.005 | <0.0005 | | 0.00008 | 9.23 |
| W7 | 8/16/2011 | 6.96 | <0.005 | 0.21 | | | <0.005 | <0.00005 | 0.0004 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.403 |
| W7 | 8/19/2011 | 6.9 | <0.005 | 0.197 | | | <0.005 | <0.00005 | 0.0003 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.444 |
| W7 | 9/12/2011 | 7.71 | <0.005 | 0.266 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.08 |
| W7 | 10/6/2011 | 6.17 | <0.005 | 0.266 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | <0.005 | <0.0005 | | <0.00002 | 0.065 |
| W7 | 11/22/2011 | 8.07 | <0.0050 | 0.366 | | | <0.0050 | <0.000050 | 0.00106 | <0.0050 | <0.0050 | <0.00050 | | <0.00002 | 0.407 |
| W7 | 1/24/2012 | 7.24 | <0.0050 | 0.456 | | | <0.0050 | <0.000050 | 0.00163 | <0.0050 | <0.0050 | <0.00050 | | <0.00002 | 0.01 |
| W7 | 2/25/2012 | 6.43 | <0.0050 | 0.448 | | | <0.0050 | <0.000050 | 0.0015 | <0.0050 | 0.0083 | <0.00050 | | <0.00002 | 0.018 |
| W7 | 3/5/2012 | 5.99 | <0.0050 | 0.468 | | | <0.0050 | <0.000050 | 0.00145 | <0.0050 | <0.0050 | <0.00050 | | <0.00002 | 0.043 |
| W7 | 4/24/2012 | 2.94 | <0.0050 | 0.0774 | | | <0.0050 | <0.000050 | 0.00014 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.766 |
| W7 | 5/6/2012 | 3.66 | <0.0050 | 0.106 | | | <0.0050 | <0.000050 | <0.00010 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.11 |
| W7 | 5/6/2012 | 3.7 | <0.0050 | 0.105 | | | <0.0050 | <0.000050 | <0.00010 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.131 |
| W7 | 6/19/2012 | 6.21 | <0.0050 | 0.191 | | | <0.0050 | <0.000050 | 0.00043 | <0.0050 | <0.0050 | <0.00050 | | 0.00003 | 5.38 |
| W7 | 7/17/2012 | 6.79 | <0.0050 | 0.306 | | | <0.0050 | <0.000050 | 0.00074 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.93 |
| W7 | 7/30/2012 | 6.86 | <0.0050 | 0.329 | | | <0.0050 | <0.000050 | 0.00091 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.2 |
| W7 | 8/8/2012 | 7 | <0.0050 | 0.357 | | | <0.0050 | <0.000050 | 0.00096 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0828 |
| W7 | 8/23/2012 | 7.06 | <0.0050 | 0.35 | | | <0.0050 | <0.000050 | 0.00097 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0342 |
| W7 | 9/13/2012 | 6.7 | <0.0050 | 0.247 | | | <0.0050 | <0.000050 | 0.00052 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.139 |
| W7 | 10/16/2012 | 6.8 | <0.0050 | 0.303 | | | <0.0050 | <0.000050 | 0.00077 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.127 |
| W7 | 11/2/2012 | 6.94 | <0.0050 | 0.407 | | | <0.0050 | <0.000050 | 0.00135 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0576 |
| W7 | 12/29/2012 | 9.63 | <0.0050 | 0.535 | | | <0.0050 | <0.000050 | 0.00133 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0127 |
| W7 | 4/30/2013 | 6.83 | <0.0050 | 0.607 | | | <0.0050 | <0.000050 | 0.00213 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0111 |
| W7 | 5/14/2013 | 2.15 | <0.0050 | 0.063 | | | <0.0050 | <0.000050 | <0.00010 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 1.34 |
| W7 | 6/19/2013 | 5.93 | <0.0050 | 0.276 | | | <0.0050 | <0.000050 | 0.00097 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.256 |
| W7 | 6/19/2013 | 5.92 | <0.0050 | 0.277 | | | <0.0050 | <0.000050 | 0.00098 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.213 |
| W7 | 7/13/2013 | 7.01 | <0.0050 | 0.327 | | | <0.0050 | <0.000050 | 0.00105 | <0.0050 | <0.0050 | <0.00050 | | 0.000024 | 0.127 |
| W7 | 8/21/2013 | 6.79 | <0.0050 | 0.364 | | | <0.0050 | <0.000050 | 0.00107 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.137 |
| W7 | 9/6/2013 | 7.12 | <0.0050 | 0.339 | | | <0.0050 | <0.000050 | 0.00088 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.37 |
| W7 | 10/21/2013 | 7.18 | <0.0050 | 0.353 | | | <0.0050 | <0.000050 | 0.00093 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0931 |
| W7 | 11/16/2013 | 6.47 | <0.0050 | 0.418 | | | <0.0050 | <0.000050 | 0.0015 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.0389 |
| W7 | 12/7/2013 | 7.02 | <0.0050 | 0.439 | | | <0.0050 | <0.000050 | 0.00126 | <0.0050 | <0.0050 | <0.00050 | | 0.000046 | 0.0098 |
| C4 | 5/6/2012 | 4.02 | <0.0050 | 0.0653 | | | <0.0050 | <0.000050 | 0.00015 | <0.0050 | <0.0050 | 0.00054 | | 0.00021 | 29.7 |
| C4 | 8/1/2012 | 8.03 | <0.0050 | 0.206 | | | <0.0050 | <0.000050 | 0.00065 | <0.0050 | <0.0050 | 0.00061 | | 0.000056 | 7.06 |
| C4 | 8/8/2012 | 7.91 | <0.0050 | 0.225 | | | <0.0050 | <0.000050 | 0.00075 | <0.0050 | <0.0050 | 0.00053 | | 0.000051 | 7.01 |
| C4 | 8/25/2012 | 7.53 | <0.0050 | 0.231 | | | <0.0050 | <0.000050 | 0.00076 | <0.0050 | <0.0050 | 0.00058 | | 0.00002 | 4.45 |
| C4 | 6/22/2013 | 6.82 | <0.0050 | 0.184 | | | <0.0050 | <0.000050 | 0.00115 | <0.0050 | <0.0050 | 0.00052 | | 0.000074 | 20.4 |
| C4 | 7/19/2013 | 7.14 | <0.0050 | 0.193 | | | <0.0050 | <0.000050 | 0.001 | <0.0050 | <0.0050 | <0.00050 | | 0.000087 | 13.5 |
| C4 | 8/22/2013 | 7.18 | <0.0050 | 0.209 | | | <0.0050 | <0.000050 | 0.00095 | <0.0050 | <0.0050 | 0.00058 | | 0.000063 | 13.8 |
| C4 | 9/6/2013 | 7.73 | <0.0050 | 0.214 | | | <0.0050 | <0.000050 | 0.00075 | <0.0050 | <0.0050 | 0.00055 | | 0.000021 | 5.43 |
| C4 | 10/18/2013 | 7.06 | <0.0050 | 0.217 | | | <0.0050 | <0.000050 | 0.00068 | <0.0050 | <0.0050 | <0.00050 | | 0.000052 | 0.349 |
| C4 | 10/18/2013 | 7.12 | <0.0050 | 0.218 | | | <0.0050 | <0.000050 | 0.0007 | <0.0050 | <0.0050 | <0.00050 | | 0.000124 | 0.358 |
| C4 | 11/17/2013 | 8.74 | <0.0050 | 0.405 | | | <0.0050 | <0.000050 | 0.00063 | <0.0050 | <0.0050 | 0.00111 | | <0.000020 | 0.0856 |
| C10 | 5/12/2012 | 3.83 | <0.0050 | 0.0919 | | | <0.0050 | <0.000050 | 0.00057 | <0.0050 | <0.0050 | <0.00050 | | 0.000337 | 39.6 |
| C10 | 7/30/2012 | 6.28 | <0.0050 | 0.189 | | | <0.0050 | <0.000050 | 0.00243 | <0.0050 | <0.0050 | <0.00050 | | 0.0002 | 21.3 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | 6.7 | <0.0050 | 0.2 | | | <0.0050 | <0.000050 | 0.00182 | <0.0050 | <0.0050 | <0.00050 | | 0.000187 | 21.1 |
| C10 | 8/27/2012 | 6.39 | <0.0050 | 0.214 | | | <0.0050 | <0.000050 | 0.00149 | <0.0050 | <0.0050 | <0.00050 | | 0.000217 | 24.8 |
| C10 | 6/22/2013 | 6.15 | <0.0050 | 0.195 | | | <0.0050 | <0.000050 | 0.0011 | <0.0050 | 0.0104 | <0.00050 | | <0.000020 | 1.31 |
| C10 | 7/23/2013 | 6.42 | <0.0050 | 0.177 | | | <0.0050 | <0.000050 | 0.00075 | <0.0050 | <0.0050 | <0.00050 | | 0.000021 | 4.86 |
| C10 | 8/22/2013 | 7.14 | <0.0050 | 0.242 | | | <0.0050 | <0.000050 | 0.00117 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.947 |
| C10 | 9/8/2013 | 7.12 | <0.0050 | 0.255 | | | <0.0050 | <0.000050 | 0.00094 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.509 |
| C10 | 9/8/2013 | 7.01 | <0.0050 | 0.254 | | | <0.0050 | <0.000050 | 0.0009 | <0.0050 | <0.0050 | <0.00050 | | <0.000020 | 0.483 |
| C10 | 10/18/2013 | 5.99 | <0.0050 | 0.201 | | | <0.0050 | <0.000050 | 0.0007 | <0.0050 | <0.0050 | <0.00050 | | 0.000068 | 1.14 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | TT As (mg/L) | Ba (mg/L) | Total Be (mg/L) | Total Bi (mg/L) | Total B (mg/L) | Total Ca (mg/L) | Total Cd (mg/L) | Total Co (mg/L) | Total Cr (mg/L) | Total Cu (mg/L) | Total Fe (mg/L) | Total Hg (mg/L) | Total K (mg/L) | Total La (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | 0.0009 | 0.062 | <0.0010 | | <0.10 | 25.9 | <0.000050 | 0.00058 | 0.002 | 0.0059 | 1.05 | <0.000020 | <2.0 | |
| W1 | 6/30/2005 | 0.00047 | 0.0545 | <0.00050 | <0.00050 | <0.010 | 36.7 | <0.000050 | <0.00010 | <0.00050 | 0.00204 | 0.088 | | <2.0 | |
| W1 | 7/28/2005 | 0.00045 | 0.0597 | <0.00050 | <0.00050 | <0.010 | 38.5 | <0.000050 | <0.00010 | <0.00050 | 0.00229 | 0.079 | | <2.0 | |
| W1 | 8/29/2005 | 0.00062 | 0.059 | <0.0010 | | <0.10 | 35 | <0.000017 | <0.00030 | <0.0010 | 0.0026 | 0.387 | <0.000020 | <2.0 | |
| W1 | 9/28/2005 | 0.00068 | 0.059 | <0.0010 | | <0.10 | 35.5 | <0.000017 | <0.00030 | <0.0010 | 0.0039 | 0.691 | <0.000020 | <2.0 | |
| W1 | 10/15/2005 | 0.00062 | 0.054 | <0.00050 | <0.00050 | <0.010 | 34.2 | <0.000050 | 0.00026 | 0.00068 | 0.00458 | 0.526 | | <2.0 | |
| W2 | 5/27/2005 | 0.00075 | 0.058 | <0.0010 | | <0.10 | 24.8 | <0.000050 | 0.00043 | 0.0012 | 0.0049 | 0.778 | <0.000020 | <2.0 | |
| W2 | 5/27/2005 | 0.00104 | 0.053 | <0.001 | | <0.1 | 19.9 | <0.00005 | 0.00087 | 0.0027 | 0.0037 | 1.49 | | | |
| W2 | 6/30/2005 | 0.00045 | 0.0569 | <0.00050 | <0.00050 | <0.010 | 37.5 | <0.000050 | <0.00010 | <0.00050 | 0.00207 | 0.052 | | <2.0 | |
| W2 | 7/28/2005 | 0.00046 | 0.0576 | <0.00050 | <0.00050 | <0.010 | 39.1 | <0.000050 | <0.00010 | <0.00050 | 0.00245 | 0.079 | | <2.0 | |
| W2 | 8/30/2005 | 0.00063 | 0.06 | <0.0010 | | <0.10 | 35.4 | <0.000017 | <0.00030 | <0.0010 | 0.0026 | 0.373 | <0.000020 | <2.0 | |
| W2 | 9/28/2005 | 0.00069 | 0.057 | <0.0010 | | <0.10 | 34.3 | <0.000017 | <0.00030 | <0.0010 | 0.0039 | 0.674 | <0.000020 | <2.0 | |
| W2 | 10/15/2005 | 0.00061 | 0.0528 | <0.00050 | <0.00050 | <0.010 | 34.1 | <0.000050 | 0.00018 | 0.00059 | 0.00404 | 0.436 | | <2.0 | |
| W3 | 5/27/2005 | <0.00050 | 0.042 | <0.0010 | | <0.10 | 20.9 | <0.000050 | <0.00030 | <0.0010 | 0.0078 | 0.32 | <0.000020 | <2.0 | |
| W3 | 6/30/2005 | 0.00037 | 0.0518 | <0.00050 | <0.00050 | <0.010 | 39.1 | <0.000050 | <0.00010 | 0.0005 | 0.00374 | 0.081 | | <2.0 | |
| W3 | 7/29/2005 | 0.00081 | 0.0667 | <0.00050 | <0.00050 | <0.010 | 37.3 | <0.000050 | 0.00062 | 0.002 | 0.0149 | 1.32 | | <2.0 | |
| W3 | 8/29/2005 | 0.00054 | 0.06 | <0.0010 | | <0.10 | 30.8 | <0.000017 | <0.00030 | <0.0010 | 0.0086 | 0.698 | <0.000020 | <2.0 | |
| W3 | 9/28/2005 | 0.00055 | 0.055 | <0.0010 | | <0.10 | 28.7 | <0.000017 | 0.0003 | <0.0010 | 0.01 | 0.794 | <0.000020 | <2.0 | |
| W3 | 10/15/2005 | 0.00045 | 0.0489 | <0.00050 | <0.00050 | <0.010 | 29.4 | <0.000050 | 0.00023 | <0.00050 | 0.00855 | 0.497 | | <2.0 | |
| W8 | 5/27/2005 | <0.00050 | 0.04 | <0.0010 | | <0.10 | 16.9 | <0.000050 | <0.00030 | <0.0010 | 0.0143 | 0.23 | <0.000020 | <2.0 | |
| W8 | 6/30/2005 | 0.00048 | 0.0503 | <0.00050 | <0.00050 | <0.010 | 24.3 | <0.000050 | 0.00021 | 0.00073 | 0.0103 | 0.503 | | <2.0 | |
| W8 | 7/29/2005 | 0.00047 | 0.0546 | <0.00050 | <0.00050 | <0.010 | 30.9 | <0.000050 | 0.00017 | 0.00056 | 0.00891 | 0.435 | | <2.0 | |
| W8 | 8/30/2005 | 0.00052 | 0.055 | <0.0010 | | <0.10 | 25.6 | <0.000017 | <0.00030 | <0.0010 | 0.0094 | 0.722 | <0.000020 | <2.0 | |
| W8 | 9/28/2005 | <0.00050 | 0.049 | <0.0010 | | <0.10 | 24.7 | <0.000017 | <0.00030 | <0.0010 | 0.0088 | 0.706 | <0.000020 | <2.0 | |
| W8 | 10/15/2005 | 0.00054 | 0.0504 | <0.00050 | <0.00050 | <0.010 | 25.1 | <0.000050 | 0.00037 | <0.00050 | 0.0104 | 0.887 | | <2.0 | |
| W9 | 5/27/2005 | <0.00050 | 0.042 | <0.0010 | | <0.10 | 12.9 | <0.000050 | <0.00030 | <0.0010 | 0.0035 | 0.277 | 0.000023 | <2.0 | |
| W9 | 6/30/2005 | 0.00058 | 0.0532 | <0.00050 | <0.00050 | <0.010 | 18.9 | <0.000050 | 0.00019 | <0.00050 | 0.0021 | 0.799 | | <2.0 | |
| W9 | 7/29/2005 | 0.00061 | 0.058 | <0.00050 | <0.00050 | <0.010 | 25.1 | <0.000050 | 0.0002 | 0.0006 | 0.00345 | 0.894 | | <2.0 | |
| W9 | 8/29/2005 | 0.00064 | 0.054 | <0.0010 | | <0.10 | 18.3 | <0.000017 | 0.00031 | <0.0010 | 0.002 | 1.01 | <0.000020 | <2.0 | |
| W9 | 9/28/2005 | 0.00051 | 0.048 | <0.0010 | | <0.10 | 17.2 | <0.000017 | <0.00030 | <0.0010 | 0.0024 | 0.783 | <0.000020 | <2.0 | |
| W9 | 10/15/2005 | 0.00042 | 0.0424 | <0.00050 | <0.00050 | <0.010 | 15.6 | <0.000050 | 0.00016 | 0.00051 | 0.00214 | 0.543 | | <2.0 | |
| W10 | 5/27/2005 | <0.00050 | 0.053 | <0.0010 | | <0.10 | 12.9 | <0.000050 | <0.00030 | <0.0010 | 0.02 | 0.113 | <0.000020 | <2.0 | |
| W10 | 5/27/2005 | <0.0005 | | <0.001 | | <0.1 | | | 0.00088 | <0.001 | | | <0.00002 | <2.0 | |
| W10 | 6/30/2005 | 0.00076 | 0.0459 | <0.00050 | <0.00050 | <0.010 | 13.1 | <0.000050 | 0.00063 | 0.00069 | 0.00534 | 1.01 | | <2.0 | |
| W10 | 7/29/2005 | 0.00095 | 0.0868 | <0.00050 | <0.00050 | <0.010 | 15.5 | 0.000097 | 0.00241 | 0.00499 | 0.0138 | 2.84 | | <2.0 | |
| W10 | 8/29/2005 | <0.00050 | 0.059 | <0.0010 | | <0.10 | 18.5 | 0.000038 | 0.00053 | 0.0012 | 0.0056 | 0.681 | <0.000020 | <2.0 | |
| W10 | 9/28/2005 | <0.00050 | 0.057 | <0.0010 | | <0.10 | 25.4 | <0.000017 | <0.00030 | <0.0010 | 0.0035 | 0.097 | <0.000020 | <2.0 | |
| W10 | 10/15/2005 | 0.0003 | 0.051 | <0.00050 | <0.00050 | <0.010 | 24 | <0.000050 | 0.00011 | <0.00050 | 0.0045 | 0.121 | | <2.0 | |
| W6 | 5/27/2005 | 0.00052 | 0.038 | <0.0010 | | <0.10 | 17.4 | <0.000050 | <0.00030 | <0.0010 | 0.0021 | 0.363 | <0.000020 | <2.0 | |
| W6 | 6/30/2005 | 0.00045 | 0.0462 | <0.00050 | <0.00050 | <0.010 | 24.7 | <0.000050 | 0.00017 | 0.00057 | 0.00148 | 0.266 | | <2.0 | |
| W6 | 7/29/2005 | 0.00063 | 0.0683 | <0.00050 | <0.00050 | <0.010 | 41.1 | <0.000050 | 0.00049 | 0.00145 | 0.0118 | 1.08 | | <2.0 | |
| W6 | 8/30/2005 | <0.00050 | 0.053 | <0.0010 | | <0.10 | 28.6 | <0.000017 | <0.00030 | <0.0010 | 0.0012 | 0.088 | <0.000020 | <2.0 | |
| W6 | 9/28/2005 | <0.00050 | 0.048 | <0.0010 | | <0.10 | 28.2 | <0.000017 | <0.00030 | <0.0010 | 0.0012 | 0.148 | <0.000020 | <2.0 | |
| W6 | 10/15/2005 | 0.00043 | 0.0424 | <0.00050 | <0.00050 | <0.010 | 25.1 | <0.000050 | 0.00011 | <0.00050 | 0.00107 | 0.116 | | <2.0 | |
| W6 | 6/2/2006 | 0.00131 | 0.0679 | <0.0005 | <0.0005 | <0.01 | 18.9 | <0.00005 | 0.00127 | 0.00384 | 0.00531 | 2.74 | | <2 | |
| W6 | 8/25/2006 | 0.0006 | 0.056 | <0.0002 | <0.001 | 0.004 | 31.5 | <0.00002 | <0.0002 | <0.001 | <0.002 | <0.2 | | <0.8 | |
| W6 | 9/6/2006 | 0.0005 | 0.052 | <0.0001 | <0.0005 | 0.003 | 29 | <0.00001 | 0.0001 | 0.0005 | 0.001 | 0.1 | | 0.5 | |
| W6 | 6/20/2007 | 0.0004 | 0.042 | <0.0001 | <0.0005 | 0.004 | 23.2 | <0.00001 | 0.0001 | <0.0005 | 0.002 | 0.1 | <0.0001 | 0.4 | |
| W6 | 9/18/2007 | 0.0004 | 0.046 | <0.0001 | <0.0005 | 0.002 | 25.8 | <0.00001 | 0.0001 | <0.0005 | 0.001 | <0.1 | <0.0001 | 0.4 | |
| W6 | 6/17/2008 | 0.0004 | 0.042 | <0.00004 | | <0.005 | 23.8 | <0.00008 | 0.00018 | 0.0011 | 0.001 | 0.35 | | 0.46 | |
| W6 | 9/18/2008 | <0.0002 | 0.039 | <0.00004 | <0.0001 | <0.005 | 24.6 | <0.00001 | 0.00008 | 0.001 | 0.001 | 0.09 | <0.00001 | 0.4 | |
| W6 | 4/14/2009 | 0.0006 | 0.08 | 0.00006 | <0.0001 | 0.017 | 36 | 0.00024 | 0.00079 | 0.0029 | 0.454 | 2.19 | 0.00002 | 9.2 | |
| W6 | 4/30/2009 | 0.0023 | 0.111 | 0.00014 | <0.0001 | 0.006 | 18.6 | 0.00008 | 0.00275 | 0.0096 | 0.068 | 8 | 0.00002 | 2.6 | |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | 0.0008 | 0.098 | <0.00004 | <0.001 | 0.025 | 49.4 | 0.00002 | 0.00016 | 0.0008 | 0.011 | 0.053 | | 3.4 | |
| W6 | 8/6/2009 | 0.0008 | 0.09 | <0.00004 | <0.001 | 0.018 | 49.7 | 0.00003 | 0.00015 | 0.0008 | 0.011 | 0.055 | | 3.4 | |
| W6 | 8/18/2009 | | | | | | | | | | | | | | |
| W6 | 8/25/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | 0.0002 | 0.132 | <0.00004 | <0.001 | 0.039 | 58 | <0.00001 | 0.00025 | 0.001 | 0.004 | 0.059 | <0.00001 | 3.2 | |
| W6 | 10/25/2009 | 0.0003 | 0.129 | <0.0001 | <0.001 | <0.05 | 59.9 | 0.00002 | <0.0005 | <0.001 | 0.0066 | 0.076 | <0.00002 | 3.41 | |
| W6 | 4/19/2010 | 0.0006 | 0.068 | <0.00004 | <0.001 | 0.013 | 35.2 | 0.00003 | 0.00075 | 0.0012 | 0.051 | 1.73 | <0.00001 | 2.7 | |
| W6 | 5/16/2010 | 0.0004 | 0.024 | <0.0001 | <0.001 | <0.05 | 25.1 | <0.00001 | <0.0005 | <0.001 | 0.0051 | 0.08 | <0.0002 | 1.34 | |
| W6 | 5/17/2010 | 0.0002 | 0.028 | <0.0001 | <0.001 | <0.05 | 19.6 | 0.00002 | <0.0005 | <0.001 | 0.0064 | 0.073 | <0.0002 | 0.89 | |
| W6 | 5/19/2010 | <0.001 | 0.045 | <0.0005 | <0.001 | <0.05 | 27.2 | 0.00003 | <0.0005 | 0.001 | 0.007 | 0.069 | <0.00002 | 1.32 | |
| W6 | 5/21/2010 | <0.0004 | 0.046 | <0.0002 | <0.001 | <0.1 | 25 | <0.0001 | <0.0005 | <0.002 | 0.033 | 0.263 | <0.0002 | 1 | |
| W6 | 5/23/2010 | <0.0004 | 0.047 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | <0.0005 | <0.002 | 0.007 | 0.083 | <0.0002 | 1 | |
| W6 | 5/25/2010 | <0.001 | 0.049 | <0.0005 | <0.001 | <0.1 | 32 | <0.0001 | <0.0005 | <0.002 | 0.028 | 0.133 | <0.00002 | 1 | |
| W6 | 5/29/2010 | <0.0004 | 0.04 | <0.0002 | <0.001 | <0.1 | 21 | <0.0001 | <0.0005 | <0.002 | 0.022 | 0.21 | <0.00002 | <1 | |
| W6 | 6/2/2010 | <0.0004 | 0.077 | <0.0002 | <0.001 | <0.1 | 61 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.081 | <0.0002 | 2 | |
| W6 | 6/4/2010 | 0.0004 | 0.047 | <0.0002 | <0.001 | <0.1 | 26 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.12 | <0.0002 | <1 | |
| W6 | 6/6/2010 | 0.0005 | 0.053 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | <0.0005 | <0.002 | 0.001 | 0.218 | | <1 | |
| W6 | 6/14/2010 | 0.0005 | 0.054 | <0.0002 | <0.001 | <0.1 | 26 | <0.0001 | <0.0005 | <0.002 | 0.004 | 0.378 | <0.0002 | <1 | |
| W6 | 6/16/2010 | 0.0005 | 0.05 | <0.0002 | <0.001 | <0.1 | 25 | <0.0001 | <0.0005 | <0.002 | 0.005 | 0.364 | <0.0002 | <1 | |
| W6 | 6/18/2010 | 0.0005 | 0.048 | <0.0002 | <0.001 | <0.1 | 24 | <0.0001 | <0.0005 | <0.002 | 0.003 | 0.226 | <0.0002 | <1 | |
| W6 | 6/20/2010 | 0.0004 | 0.049 | <0.0002 | <0.001 | <0.1 | 25 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.208 | <0.0002 | <1 | |
| W6 | 6/22/2010 | 0.0006 | 0.051 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.326 | <0.0002 | <1 | |
| W6 | 6/24/2010 | 0.0004 | 0.04 | <0.0002 | <0.001 | <0.1 | 21 | <0.0001 | <0.0005 | <0.002 | 0.001 | 0.164 | <0.0002 | <1 | |
| W6 | 6/26/2010 | <0.0004 | 0.047 | <0.0002 | <0.001 | <0.1 | 25 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.215 | <0.0002 | <1 | |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | 0.0006 | 0.056 | <0.0002 | <0.001 | <0.1 | 26 | <0.0001 | <0.0005 | <0.002 | 0.003 | 0.8 | <0.0002 | <1 | |
| W6 | 7/5/2010 | 0.001 | 0.072 | <0.0002 | <0.001 | <0.1 | 24 | <0.0001 | 0.0009 | 0.003 | 0.005 | 1.93 | <0.0002 | <1 | |
| W6 | 8/5/2010 | 0.0005 | 0.056 | <0.0002 | <0.001 | <0.1 | 28 | <0.0001 | <0.0005 | <0.002 | 0.003 | 0.294 | <0.0002 | <1 | |
| W6 | 9/9/2010 | 0.0005 | 0.07 | <0.0002 | <0.001 | <0.1 | 29 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.949 | <0.0002 | <1 | |
| W6 | 10/8/2010 | 0.0003 | 0.065 | <0.0001 | <0.001 | <0.05 | 25.5 | 0.00002 | <0.0005 | 0.001 | 0.0021 | 0.615 | <0.00002 | 0.5 | |
| W6 | 8/19/2011 | 0.0003 | 0.077 | <0.0001 | <0.001 | <0.05 | 51.2 | 0.00001 | <0.0005 | <0.001 | 0.003 | 0.059 | <0.00002 | 2.02 | |
| W6 | 7/17/2012 | 0.00898 | 0.471 | 0.00066 | <0.0010 | <0.05 | 41.2 | 0.000468 | 0.014 | 0.0388 | 0.0402 | 29.8 | <0.000010 | 2.03 | |
| W6 | 7/30/2012 | 0.0066 | 0.348 | 0.00043 | <0.0010 | <0.05 | 38.1 | 0.000195 | 0.00922 | 0.0276 | 0.0286 | 21.6 | 0.000033 | 1.62 | |
| W6 | 8/9/2012 | 0.00362 | 0.223 | 0.00031 | <0.0010 | <0.05 | 36.7 | 0.000109 | 0.00511 | 0.0137 | 0.0147 | 11.2 | <0.000010 | 1.2 | |
| W6 | 8/25/2012 | 0.00395 | 0.372 | 0.00044 | <0.0010 | <0.05 | 45 | 0.000219 | 0.00749 | 0.0085 | 0.0247 | 9.68 | <0.000010 | 0.849 | |
| W6 | 9/13/2012 | 0.00051 | 0.0533 | <0.00010 | <0.0010 | <0.05 | 25.9 | 0.000011 | <0.00050 | <0.0010 | 0.00225 | 0.591 | <0.000010 | 0.42 | |
| W6 | 10/13/2012 | 0.00066 | 0.0631 | <0.00010 | <0.0010 | <0.05 | 30.8 | <0.000010 | <0.00050 | <0.0010 | 0.00189 | 0.517 | <0.000010 | 0.594 | |
| W6 | 11/12/2012 | 0.00042 | 0.0656 | <0.00010 | <0.0010 | <0.05 | 43.3 | <0.000010 | <0.00050 | <0.0010 | 0.00345 | 0.0646 | <0.000010 | 0.507 | |
| W6 | 5/14/2013 | 0.00068 | 0.0286 | <0.00010 | <0.0010 | <0.05 | 9.4 | 0.000029 | 0.0006 | 0.0014 | 0.00697 | 1.06 | <0.000010 | 1.86 | |
| W6 | 6/22/2013 | 0.00264 | 0.127 | 0.00017 | <0.0010 | <0.05 | 30.4 | 0.000048 | 0.00283 | 0.0094 | 0.00985 | 6.84 | <0.000010 | 1.45 | |
| W6 | 7/12/2013 | 0.00066 | 0.0579 | <0.00010 | <0.0010 | <0.05 | 26.7 | <0.000010 | <0.00050 | 0.0011 | 0.00171 | 0.812 | <0.000010 | 0.55 | |
| W6 | 8/22/2013 | 0.00064 | 0.0507 | <0.00010 | <0.0010 | <0.05 | 29.6 | <0.000010 | <0.00050 | <0.0010 | 0.00123 | 0.283 | <0.000010 | 0.52 | |
| W6 | 9/6/2013 | 0.00067 | 0.0563 | <0.00010 | <0.0010 | <0.05 | 31.7 | <0.000010 | <0.00050 | <0.0010 | 0.00119 | 0.404 | <0.000010 | 0.605 | |
| W6 | 10/7/2013 | 0.00138 | 0.0866 | <0.00010 | <0.0010 | <0.05 | 29.2 | 0.000023 | 0.00119 | 0.0043 | 0.0071 | 3.02 | <0.000010 | 0.789 | |
| W6 | 11/16/2013 | 0.00063 | 0.0637 | <0.00010 | <0.0010 | <0.05 | 33.4 | <0.000010 | <0.00050 | <0.0010 | 0.00186 | 0.523 | <0.000010 | 0.652 | |
| W6 | 12/7/2013 | 0.00074 | 0.0801 | <0.00010 | <0.0010 | <0.05 | 49.1 | 0.00002 | <0.00050 | <0.0010 | 0.00602 | 0.12 | <0.000010 | 0.661 | |
| W7 | 5/27/2005 | 0.00063 | 0.054 | <0.0010 | | <0.10 | 19.3 | <0.000050 | 0.00049 | 0.0016 | 0.0031 | 0.776 | <0.000020 | <2.0 | |
| W7 | 6/30/2005 | 0.00049 | 0.0641 | <0.00050 | <0.00050 | <0.010 | 29.7 | <0.000050 | 0.00024 | 0.00065 | 0.00162 | 0.358 | | <2.0 | |
| W7 | 7/29/2005 | 0.00055 | 0.07 | <0.00050 | <0.00050 | <0.010 | 42.4 | <0.000050 | 0.00042 | 0.00127 | 0.0101 | 0.894 | | <2.0 | |
| W7 | 8/30/2005 | 0.00053 | 0.064 | <0.0010 | | <0.10 | 27.8 | <0.000017 | <0.00030 | <0.0010 | 0.0015 | 0.363 | <0.000020 | <2.0 | |
| W7 | 9/28/2005 | 0.00149 | 0.113 | <0.0010 | | <0.10 | 27.8 | 0.000061 | 0.00233 | 0.0037 | 0.0061 | 3.42 | <0.000020 | <2.0 | |
| W7 | 10/15/2005 | 0.00052 | 0.053 | <0.00050 | <0.00050 | <0.010 | 25.5 | <0.000050 | 0.00018 | 0.00062 | 0.00147 | 0.37 | | <2.0 | |
| W7 | 6/2/2006 | 0.00496 | 0.264 | <0.0005 | <0.0005 | <0.01 | 23.9 | 0.000237 | 0.00916 | 0.0234 | 0.0225 | 17.2 | | <2 | |
| W7 | 6/8/2006 | 0.00078 | 0.0586 | <0.0005 | <0.0005 | <0.01 | 20.4 | <0.00005 | 0.00078 | 0.0016 | 0.00403 | 1.09 | | <2 | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | TT As (mg/L) | Ba (mg/L) | Total Be (mg/L) | Total Bi (mg/L) | Total B (mg/L) | Total Ca (mg/L) | Total Cd (mg/L) | Total Co (mg/L) | Total Cr (mg/L) | Total Cu (mg/L) | Total Fe (mg/L) | Total Hg (mg/L) | Total K (mg/L) | Total La (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | 0.0008 | 0.082 | <0.0001 | <0.0005 | 0.006 | 25.4 | 0.00002 | 0.0011 | 0.0032 | 0.004 | 1.7 | | 1.1 | |
| W7 | 6/23/2006 | 0.0022 | 0.167 | 0.0002 | <0.0005 | 0.005 | 34.5 | 0.00008 | 0.0037 | 0.0091 | 0.01 | 7.2 | | 1.6 | |
| W7 | 6/28/2006 | 0.001 | 0.09 | <0.0001 | <0.0005 | 0.006 | 27.4 | 0.00003 | 0.001 | 0.0031 | 0.004 | 2.5 | | 1.1 | |
| W7 | 7/7/2006 | 0.0004 | 0.07 | <0.0001 | <0.0005 | 0.005 | 31.2 | <0.00001 | <0.0001 | <0.0005 | 0.001 | 0.2 | | 1 | |
| W7 | 7/12/2006 | 0.0004 | 0.067 | <0.0001 | <0.0005 | 0.005 | 31 | <0.00001 | <0.0001 | <0.0005 | 0.001 | 0.2 | | 1 | |
| W7 | 7/20/2006 | 0.0005 | 0.065 | <0.0001 | <0.0005 | 0.029 | 31.8 | <0.00001 | <0.0001 | <0.0005 | 0.001 | 0.2 | | 0.9 | |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | 0.0005 | 0.072 | <0.0001 | <0.0005 | 0.004 | 33.9 | <0.00001 | 0.0001 | <0.0005 | 0.001 | 0.3 | | 1.1 | |
| W7 | 8/2/2006 | 0.0006 | 0.07 | <0.0001 | <0.0005 | 0.006 | 32.9 | <0.00001 | <0.0001 | <0.0005 | 0.001 | 0.1 | | 1 | |
| W7 | 8/10/2006 | 0.0005 | 0.072 | <0.0001 | <0.0005 | 0.005 | 34.6 | <0.00001 | 0.0004 | <0.0005 | <0.001 | 0.1 | | 1.1 | |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | 0.0004 | 0.069 | <0.0002 | <0.001 | 0.007 | 31.8 | <0.00002 | <0.0002 | <0.001 | <0.002 | <0.2 | | 1.2 | |
| W7 | 8/30/2006 | 0.0005 | 0.07 | <0.0001 | <0.0005 | 0.005 | 30.8 | <0.00001 | <0.0001 | 0.0008 | <0.001 | 0.1 | | 1 | |
| W7 | 9/6/2006 | 0.0004 | 0.07 | <0.0001 | <0.0005 | 0.006 | 31.1 | <0.00001 | 0.0001 | 0.0008 | 0.001 | 0.1 | | 1 | |
| W7 | 9/13/2006 | <0.0002 | 0.037 | <0.0001 | <0.0005 | 0.004 | 32.2 | <0.00001 | <0.0001 | <0.0005 | <0.001 | <0.2 | | 0.9 | |
| W7 | 9/20/2006 | 0.0005 | 0.07 | <0.0001 | <0.0005 | 0.006 | 32.4 | <0.00001 | 0.0001 | <0.0005 | 0.001 | 0.2 | | 0.9 | |
| W7 | 9/28/2006 | <0.0004 | 0.073 | <0.0002 | <0.001 | 0.007 | 32.5 | <0.00002 | <0.0002 | <0.001 | <0.002 | <0.2 | | 1.1 | |
| W7 | 10/4/2006 | 0.0004 | 0.074 | <0.0002 | <0.001 | 0.005 | 31.6 | <0.00002 | <0.0002 | <0.001 | <0.002 | <0.2 | | 0.9 | |
| W7 | 10/12/2006 | 0.0004 | 0.076 | <0.0001 | <0.0005 | 0.006 | 33.5 | <0.00001 | 0.0002 | 0.0007 | 0.002 | 0.5 | | 1 | |
| W7 | 6/5/2007 | 0.0008 | 0.084 | <0.0001 | <0.0005 | 0.009 | 26.4 | 0.00003 | 0.0012 | 0.0031 | 0.003 | 2 | <0.0001 | 1.1 | |
| W7 | 6/5/2007 | 0.0007 | 0.095 | <0.0002 | <0.001 | 0.01 | 28.1 | 0.00003 | 0.001 | 0.0037 | 0.003 | 2.3 | <0.0001 | 1 | |
| W7 | 6/5/2007 | 0.001 | 0.09 | <0.0001 | <0.0005 | 0.008 | 27.2 | 0.00003 | 0.0013 | 0.0036 | 0.004 | 2.5 | <0.0001 | 1.3 | |
| W7 | 6/20/2007 | 0.0004 | 0.066 | <0.0001 | <0.0005 | 0.007 | 30.2 | <0.00001 | 0.0002 | 0.0005 | 0.002 | 0.2 | <0.0001 | 1 | |
| W7 | 7/18/2007 | 0.0005 | 0.071 | <0.0001 | <0.0005 | 0.006 | 32.2 | 0.00002 | 0.0002 | 0.0008 | 0.002 | 0.3 | <0.0001 | 1 | |
| W7 | 7/18/2007 | 0.0003 | 0.073 | <0.0001 | <0.0005 | 0.006 | 31.9 | 0.00001 | 0.0002 | 0.0007 | 0.001 | 0.3 | <0.0001 | 0.9 | |
| W7 | 7/18/2007 | <0.0002 | 0.072 | <0.0001 | <0.0005 | 0.006 | 31.8 | <0.00001 | 0.0001 | 0.0007 | 0.001 | 0.3 | <0.0001 | 0.9 | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | 0.0003 | 0.075 | <0.0001 | <0.0005 | 0.006 | 31.2 | <0.00001 | 0.0002 | 0.0008 | 0.002 | 0.2 | <0.0001 | 1 | |
| W7 | 8/24/2007 | 0.0004 | 0.074 | <0.0001 | <0.0005 | 0.006 | 31.5 | <0.00001 | 0.0001 | 0.0005 | 0.001 | 0.2 | <0.0001 | 1 | |
| W7 | 8/24/2007 | 0.0004 | 0.077 | <0.0001 | <0.0005 | 0.006 | 32.9 | <0.00001 | 0.0001 | 0.0005 | 0.001 | 0.2 | <0.0001 | 1.1 | |
| W7 | 9/18/2007 | 0.0005 | 0.067 | <0.0001 | <0.0005 | 0.005 | 27 | <0.00001 | 0.0003 | 0.0011 | 0.003 | 0.5 | <0.0001 | 0.9 | |
| W7 | 10/30/2007 | 0.0004 | 0.076 | <0.0001 | <0.0005 | 0.007 | 33.5 | 0.00004 | 0.0003 | 0.0007 | 0.012 | 0.3 | <0.0001 | 1.6 | |
| W7 | 10/30/2007 | 0.0002 | 0.075 | <0.0001 | <0.0005 | 0.006 | 33 | 0.00002 | 0.0001 | 0.0008 | 0.005 | 0.2 | <0.0001 | 1.1 | |
| W7 | 10/30/2007 | <0.0002 | 0.074 | <0.0001 | <0.0005 | 0.006 | 33.6 | 0.00002 | 0.0001 | 0.0007 | 0.003 | 0.2 | <0.0001 | 1.1 | |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | 0.0005 | 0.073 | <0.00004 | | 0.006 | 40.2 | <0.00007 | 0.00007 | <0.0005 | 0.004 | 0.05 | <0.00001 | 2.56 | |
| W7 | 4/22/2008 | 0.0012 | 0.077 | <0.00004 | | 0.006 | 43.2 | <0.00007 | 0.00009 | <0.0005 | 0.004 | 0.05 | <0.00001 | 2.77 | |
| W7 | 4/22/2008 | 0.0006 | 0.078 | <0.00004 | | 0.006 | 42.4 | <0.00007 | 0.0001 | <0.0005 | 0.004 | 0.06 | <0.00001 | 2.7 | |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | 0.0007 | 0.061 | <0.00004 | | <0.005 | 24.4 | <0.00007 | 0.0004 | 0.0028 | 0.002 | 0.78 | <0.00001 | 0.94 | |
| W7 | 6/3/2008 | 0.0013 | 0.06 | <0.00004 | | <0.005 | 24.2 | <0.00007 | 0.00041 | 0.0028 | 0.001 | 0.71 | <0.00001 | 0.93 | |
| W7 | 6/3/2008 | 0.0008 | 0.062 | 0.00004 | | <0.005 | 25.2 | <0.00007 | 0.00042 | 0.003 | 0.002 | 0.79 | <0.00001 | 0.94 | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/17/2008 | 0.0006 | 0.064 | <0.00004 | | <0.005 | 29.2 | <0.00008 | 0.00028 | 0.0012 | 0.001 | 0.4 | | 1.01 | |
| W7 | 8/6/2008 | 0.0006 | 0.083 | <0.0001 | <0.0005 | 0.008 | 31.5 | 0.00002 | 0.0006 | 0.002 | 0.002 | 1.02 | <0.0001 | 1 | |
| W7 | 8/6/2008 | 0.0007 | 0.088 | <0.0001 | <0.0005 | 0.007 | 31.4 | 0.00002 | 0.0007 | 0.0026 | 0.003 | 1.36 | <0.0001 | 1.1 | |
| W7 | 8/6/2008 | 0.0008 | 0.093 | <0.0001 | <0.0005 | 0.008 | 31.8 | 0.00002 | 0.0008 | 0.0025 | 0.003 | 1.46 | <0.0001 | 1.1 | |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 9/18/2008 | 0.0005 | 0.06 | <0.00004 | <0.0001 | <0.005 | 23 | 0.00002 | 0.00046 | 0.0022 | 0.003 | 0.91 | <0.00001 | 0.68 | |
| W7 | 10/28/2008 | 0.0004 | 0.057 | <0.00004 | <0.0001 | <0.005 | 32.4 | <0.00001 | 0.00015 | 0.0013 | 0.004 | 0.34 | <0.00001 | 0.9 | |
| W7 | 10/28/2008 | 0.0005 | 0.06 | <0.00004 | <0.0001 | <0.005 | 32.3 | 0.00002 | 0.00011 | 0.0008 | 0.004 | 0.24 | <0.00001 | 0.9 | |
| W7 | 10/28/2008 | 0.0004 | 0.057 | <0.00004 | <0.0001 | <0.005 | 32.4 | <0.00001 | 0.0001 | 0.0005 | 0.003 | 0.17 | <0.00001 | 0.8 | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 4/30/2009 | <0.0002 | 0.012 | <0.00004 | <0.0001 | <0.005 | 5.54 | 0.00008 | 0.0001 | 0.0012 | 0.013 | 0.19 | 0.00002 | 1.5 | |
| W7 | 6/8/2009 | 0.0005 | 0.069 | 0.00004 | <0.0001 | 0.005 | 27 | 0.00001 | 0.00052 | 0.0014 | 0.003 | 0.92 | <0.00001 | 0.9 | |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | 0.0007 | 0.081 | <0.00004 | <0.001 | <0.005 | 35.1 | <0.00001 | 0.00013 | 0.0009 | 0.001 | 0.126 | | 1.1 | |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | 0.0004 | 0.067 | <0.00004 | <0.001 | 0.008 | 34.2 | 0.00091 | 0.00022 | 0.0014 | 0.006 | 0.357 | <0.00001 | 0.7 | |
| W7 | 10/25/2009 | 0.0004 | 0.077 | <0.0001 | <0.001 | <0.05 | 35.7 | 0.00001 | <0.0005 | <0.001 | 0.0021 | 0.141 | <0.00002 | 1.02 | |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | 0.0004 | 0.04 | <0.00004 | <0.001 | 0.006 | 20.5 | 0.00001 | 0.0001 | 0.0004 | 0.006 | 0.104 | <0.00001 | 2.1 | |
| W7 | 4/27/2010 | 0.0003 | 0.023 | <0.0001 | <0.001 | <0.05 | 9.35 | 0.00003 | <0.0005 | <0.001 | 0.0055 | 0.211 | <0.00002 | 1.01 | |
| W7 | 4/29/2010 | 0.0004 | 0.025 | <0.0001 | <0.001 | <0.05 | 9.54 | 0.00002 | <0.0005 | <0.001 | 0.0037 | 0.259 | <0.00002 | 0.9 | |
| W7 | 5/1/2010 | 0.0006 | 0.035 | <0.0001 | <0.001 | <0.05 | 11.5 | 0.00002 | <0.0005 | 0.002 | 0.0074 | 0.902 | <0.00002 | 0.81 | |
| W7 | 5/3/2010 | 0.0007 | 0.035 | <0.0001 | <0.001 | <0.05 | 12.3 | 0.00003 | <0.0005 | 0.001 | 0.0045 | 0.983 | <0.00002 | 0.72 | |
| W7 | 5/5/2010 | 0.0007 | 0.039 | <0.0001 | <0.001 | <0.05 | 14.3 | 0.00004 | <0.0005 | 0.001 | 0.0058 | 1.14 | <0.00002 | 0.72 | |
| W7 | 5/7/2010 | 0.0005 | 0.041 | <0.0001 | <0.001 | <0.05 | 14.7 | 0.00003 | <0.0005 | <0.001 | 0.0045 | 0.92 | <0.00002 | 0.68 | |
| W7 | 5/9/2010 | 0.0004 | 0.043 | <0.0001 | <0.001 | <0.05 | 18.2 | 0.00005 | <0.0005 | 0.001 | 0.0147 | 0.468 | <0.00002 | 0.74 | |
| W7 | 5/10/2010 | 0.0005 | 0.055 | <0.0001 | <0.001 | <0.05 | 23.3 | 0.00011 | <0.0005 | <0.001 | 0.0059 | 0.452 | <0.00002 | 0.91 | |
| W7 | 5/12/2010 | | | | | | | | | | <.03 | 0.19 | | | |
| W7 | 5/12/2010 | 0.0004 | 0.048 | <0.0001 | <0.001 | <0.05 | 22.1 | 0.00009 | <0.0005 | <0.001 | 0.0075 | 0.378 | <0.00002 | 0.98 | |
| W7 | 5/14/2010 | 0.0004 | 0.046 | <0.0001 | <0.001 | <0.05 | 18.2 | 0.00005 | <0.0005 | <0.001 | 0.0055 | 0.556 | <0.00002 | 0.71 | |
| W7 | 5/16/2010 | 0.0004 | 0.044 | <0.0001 | <0.001 | <0.05 | 19.8 | 0.00005 | <0.0005 | 0.001 | 0.0031 | 0.369 | <0.0002 | 0.72 | |
| W7 | 5/17/2010 | 0.0005 | 0.046 | <0.0001 | <0.001 | <0.05 | 19.6 | 0.00001 | <0.0005 | <0.001 | 0.0035 | 0.405 | <0.0002 | 0.77 | |
| W7 | 5/19/2010 | <0.001 | 0.057 | <0.0005 | <0.001 | <0.05 | 25.6 | 0.00001 | <0.0005 | 0.001 | 0.0049 | 0.248 | <0.00002 | 0.96 | |
| W7 | 5/21/2010 | 0.0005 | 0.06 | <0.0002 | <0.001 | <0.1 | 24 | <0.0001 | <0.0005 | <0.002 | 0.003 | 0.628 | <0.0002 | <1 | |
| W7 | 5/23/2010 | 0.0014 | 0.102 | <0.0002 | <0.001 | <0.1 | 25 | <0.0001 | 0.0019 | 0.004 | 0.008 | 3.49 | <0.0002 | 1 | |
| W7 | 5/25/2010 | 0.002 | 0.121 | <0.0005 | <0.001 | <0.1 | 28 | <0.0001 | 0.0028 | 0.01 | 0.013 | 5.54 | <0.00002 | 2 | |
| W7 | 5/27/2010 | 0.006 | 0.196 | <0.0005 | <0.001 | <0.1 | 31 | 0.0002 | 0.0077 | 0.025 | 0.027 | 15.6 | <0.00002 | 3 | |
| W7 | 5/29/2010 | 0.0025 | 0.131 | 0.0002 | <0.001 | <0.1 | 31 | <0.0001 | 0.0038 | 0.01 | 0.013 | 6.13 | <0.00002 | 2 | |
| W7 | 5/31/2010 | 0.0027 | 0.149 | 0.0002 | <0.001 | <0.1 | 31 | 0.0001 | 0.004 | 0.011 | 0.013 | 6.96 | <0.00002 | 2 | |
| W7 | 6/2/2010 | 0.0016 | 0.098 | <0.0002 | <0.001 | <0.1 | 33 | <0.0001 | 0.0024 | 0.008 | 0.008 | 4.39 | <0.0002 | 2 | |
| W7 | 6/4/2010 | 0.0012 | 0.09 | <0.0002 | <0.001 | <0.1 | 31 | <0.0001 | 0.0013 | 0.004 | 0.009 | 2.42 | <0.0002 | 1 | |
| W7 | 6/6/2010 | 0.0013 | 0.109 | <0.0002 | <0.001 | <0.1 | 33 | <0.0001 | 0.0015 | 0.006 | 0.006 | 3.12 | | 2 | |
| W7 | 6/14/2010 | 0.0009 | 0.099 | <0.0002 | <0.001 | <0.1 | 31 | <0.0001 | 0.001 | 0.002 | 0.004 | 1.62 | <0.0002 | 1 | |
| W7 | 6/16/2010 | 0.0005 | 0.078 | <0.0002 | <0.001 | <0.1 | 31 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.573 | <0.0002 | 1 | |
| W7 | 6/18/2010 | 0.0006 | 0.078 | <0.0002 | <0.001 | <0.1 | 30 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.768 | <0.0002 | 1 | |
| W7 | 6/20/2010 | 0.0009 | 0.085 | <0.0002 | <0.001 | <0.1 | 29 | <0.0001 | 0.0009 | 0.003 | 0.006 | 1.74 | <0.0002 | 1 | |
| W7 | 6/22/2010 | 0.0029 | 0.164 | 0.0003 | <0.001 | <0.1 | 28 | 0.0001 | 0.0048 | 0.012 | 0.014 | 8.61 | <0.0002 | 2 | |
| W7 | 6/24/2010 | 0.0013 | 0.078 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | 0.0014 | 0.003 | 0.005 | 2.05 | <0.0002 | 1 | |
| W7 | 6/26/2010 | 0.0005 | 0.066 | <0.0002 | <0.001 | <0.1 | 26 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.761 | <0.0002 | <1 | |
| W7 | 6/28/2010 | 0.0005 | 0.064 | <0.0002 | <0.001 | <0.1 | 28 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.491 | <0.0002 | <1 | |
| W7 | 7/5/2010 | 0.0011 | 0.086 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | 0.0012 | 0.003 | 0.01 | 2.4 | <0.0002 | <1 | |
| W7 | 8/5/2010 | 0.0005 | 0.07 | <0.0002 | <0.001 | <0.1 | 29 | <0.0001 | <0.0005 | <0.002 | 0.003 | 0.428 | <0.0002 | <1 | |
| W7 | 9/12/2010 | 0.0005 | 0.061 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | <0.0005 | <0.002 | 0.002 | 0.682 | <0.0002 | <1 | |
| W7 | 9/12/2010 | 0.0005 | 0.061 | <0.0002 | <0.001 | <0.1 | 27 | <0.0001 | <0.0005 | <0.002 | 0.003 | 0.594 | <0.0002 | <1 | |
| W7 | 10/8/2010 | 0.0002 | 0.068 | <0.0001 | <0.001 | <0.05 | 32.2 | 0.00003 | <0.0005 | <0.001 | 0.0017 | 0.26 | <0.00002 | 0.77 | |
| W7 | 4/27/2011 | 0.0003 | 0.024 | <0.0001 | <0.001 | <0.05 | 10.9 | 0.00005 | <0.0005 | <0.001 | 0.0119 | 0.187 | <0.00002 | 1.88 | |
| W7 | 5/2/2011 | 0.0003 | 0.024 | <0.0001 | <0.001 | <0.05 | 8.66 | 0.00005 | <0.0005 | <0.001 | 0.0285 | 0.452 | <0.00002 | 1.46 | |
| W7 | 6/1/2011 | 0.0005 | 0.061 | <0.0001 | <0.001 | <0.05 | 22.9 | 0.00002 | <0.0005 | 0.001 | 0.0027 | 0.775 | <0.00002 | 0.86 | |
| W7 | 6/16/2011 | 0.0014 | 0.096 | <0.0001 | <0.001 | <0.05 | 26.4 | 0.00008 | 0.0021 | 0.005 | 0.0075 | 4.02 | <0.00002 | 1.04 | |
| W7 | 7/1/2011 | 0.0025 | 0.135 | 0.0002 | <0.001 | <0.05 | 22.2 | 0.00022 | 0.0035 | 0.009 | 0.0127 | 6.28 | <0.00002 | 0.76 | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | TT As (mg/L) | Ba (mg/L) | Total Be (mg/L) | Total Bi (mg/L) | Total B (mg/L) | Total Ca (mg/L) | Total Cd (mg/L) | Total Co (mg/L) | Total Cr (mg/L) | Total Cu (mg/L) | Total Fe (mg/L) | Total Hg (mg/L) | Total K (mg/L) | Total La (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | 0.0037 | 0.211 | 0.0003 | <0.001 | <0.05 | 20.7 | 0.00017 | 0.0064 | 0.021 | 0.0197 | 13.8 | <0.00002 | 1.11 | |
| W7 | 8/16/2011 | 0.001 | 0.069 | <0.0001 | <0.001 | <0.05 | 25.4 | 0.00004 | 0.0006 | 0.001 | 0.0143 | 1.25 | <0.00002 | 0.53 | |
| W7 | 8/19/2011 | 0.0009 | 0.061 | <0.0001 | <0.001 | <0.05 | 24.1 | 0.00002 | 0.0006 | 0.001 | 0.0028 | 1.21 | <0.00002 | 0.47 | |
| W7 | 9/12/2011 | 0.0008 | 0.061 | <0.0001 | <0.001 | <0.05 | 30.1 | 0.00005 | <0.0005 | <0.001 | 0.0024 | 0.738 | <0.00002 | 0.6 | |
| W7 | 10/6/2011 | 0.0005 | 0.058 | <0.0001 | <0.001 | <0.05 | 28.4 | 0.00001 | <0.0005 | <0.001 | 0.0012 | 0.49 | <0.00002 | 0.62 | |
| W7 | 11/22/2011 | 0.0006 | 0.085 | <0.0001 | <0.001 | <0.05 | 36.4 | 0.00025 | <0.0005 | 0.001 | 0.0108 | 0.865 | <0.000020 | 1.09 | |
| W7 | 1/24/2012 | 0.0004 | 0.087 | <0.0001 | <0.001 | <0.05 | 39.5 | 0.00001 | <0.0005 | <0.001 | 0.0013 | 0.113 | <0.000010 | 1.57 | |
| W7 | 2/25/2012 | 0.0003 | 0.082 | <0.0001 | <0.001 | <0.05 | 41 | 0.00003 | <0.0005 | <0.001 | 0.0055 | 0.043 | <0.000010 | 1.51 | |
| W7 | 3/5/2012 | 0.0004 | 0.083 | <0.0001 | <0.001 | <0.05 | 39.7 | 0.00001 | <0.0005 | <0.001 | 0.0068 | 0.108 | <0.000010 | 1.46 | |
| W7 | 4/24/2012 | 0.00074 | 0.0404 | <0.00010 | <0.0010 | <0.05 | 9.61 | 0.000029 | 0.00056 | 0.0015 | 0.00635 | 1.32 | <0.000010 | 1.2 | |
| W7 | 5/6/2012 | 0.00045 | 0.0317 | <0.00010 | <0.0010 | <0.05 | 11.2 | 0.000015 | <0.00050 | <0.0010 | 0.00299 | 0.551 | <0.000010 | 0.881 | |
| W7 | 5/6/2012 | 0.00049 | 0.0316 | <0.00010 | <0.0010 | <0.05 | 11.1 | 0.000016 | <0.00050 | <0.0010 | 0.00373 | 0.572 | <0.000010 | 0.912 | |
| W7 | 6/19/2012 | 0.00232 | 0.154 | 0.00016 | <0.0010 | <0.05 | 26.4 | 0.000119 | 0.00326 | 0.0112 | 0.0102 | 7.88 | <0.000010 | 1.09 | |
| W7 | 7/17/2012 | 0.00118 | 0.0843 | <0.00010 | <0.0010 | <0.05 | 31.7 | 0.000034 | 0.00075 | 0.0024 | 0.0035 | 2.28 | <0.000010 | 0.824 | |
| W7 | 7/30/2012 | 0.00095 | 0.0737 | <0.00010 | <0.0010 | <0.05 | 32.1 | 0.000014 | <0.00050 | <0.0010 | 0.0045 | 1.32 | <0.000010 | 1.14 | |
| W7 | 8/8/2012 | 0.00085 | 0.0731 | <0.00010 | <0.0010 | <0.05 | 35.7 | <0.000010 | <0.00050 | <0.0010 | 0.00108 | 1.13 | <0.000010 | 0.894 | |
| W7 | 8/23/2012 | 0.00093 | 0.0778 | <0.00010 | <0.0010 | <0.05 | 39.1 | <0.000010 | <0.00050 | <0.0010 | 0.00134 | 1.12 | <0.000010 | 0.929 | |
| W7 | 9/13/2012 | 0.0007 | 0.0629 | <0.00010 | <0.0010 | <0.05 | 31.2 | <0.000010 | <0.00050 | <0.0010 | 0.00208 | 1.15 | <0.000010 | 0.589 | |
| W7 | 10/16/2012 | 0.00065 | 0.0693 | <0.00010 | <0.0010 | <0.05 | 36 | <0.000010 | <0.00050 | <0.0010 | 0.00144 | 0.995 | <0.000010 | 0.748 | |
| W7 | 11/2/2012 | 0.00058 | 0.0848 | <0.00010 | <0.0010 | <0.05 | 37.3 | 0.000015 | <0.00050 | <0.0010 | 0.00231 | 0.289 | <0.000010 | 1.16 | |
| W7 | 12/29/2012 | 0.00042 | 0.104 | <0.00010 | <0.0010 | <0.05 | 49.6 | 0.000015 | <0.00050 | <0.0010 | 0.0028 | 0.0724 | <0.000010 | 2.29 | |
| W7 | 4/30/2013 | 0.00019 | 0.0996 | <0.00010 | <0.0010 | <0.05 | 47.8 | <0.000010 | <0.00050 | <0.0010 | 0.0021 | 0.0288 | <0.000010 | 1.95 | |
| W7 | 5/14/2013 | 0.00072 | 0.0462 | <0.00010 | <0.0010 | <0.05 | 9.61 | 0.000025 | 0.00107 | 0.0027 | 0.0084 | 2.2 | <0.000010 | 1.18 | |
| W7 | 6/19/2013 | 0.00064 | 0.0691 | <0.00010 | <0.0010 | <0.05 | 29.1 | 0.000011 | <0.00050 | <0.0010 | 0.00222 | 0.702 | <0.000010 | 0.847 | |
| W7 | 6/19/2013 | 0.00058 | 0.0683 | <0.00010 | <0.0010 | <0.05 | 29.7 | <0.000010 | <0.00050 | <0.0010 | 0.00191 | 0.657 | <0.000010 | 0.872 | |
| W7 | 7/13/2013 | 0.00063 | 0.0712 | <0.00010 | <0.0010 | <0.05 | 35.1 | <0.000010 | <0.00050 | <0.0010 | 0.00143 | 0.631 | <0.000010 | 0.856 | |
| W7 | 8/21/2013 | 0.0007 | 0.0755 | <0.00010 | <0.0010 | <0.05 | 35.8 | <0.000010 | <0.00050 | <0.0010 | 0.00138 | 0.619 | <0.000010 | 0.951 | |
| W7 | 9/6/2013 | 0.00099 | 0.0815 | <0.00010 | <0.0010 | <0.05 | 38.7 | <0.000010 | <0.00050 | 0.0014 | 0.0017 | 1.48 | <0.000010 | 0.968 | |
| W7 | 10/21/2013 | 0.00061 | 0.0642 | <0.00010 | <0.0010 | <0.05 | 31.8 | <0.000010 | <0.00050 | <0.0010 | 0.00119 | 0.683 | <0.000010 | 0.754 | |
| W7 | 11/16/2013 | 0.00052 | 0.0832 | <0.00010 | <0.0010 | <0.05 | 39.8 | <0.000010 | <0.00050 | <0.0010 | 0.00124 | 0.296 | <0.000010 | 1.14 | |
| W7 | 12/7/2013 | 0.00059 | 0.0967 | <0.00010 | <0.0010 | <0.05 | 46.7 | 0.000013 | <0.00050 | <0.0010 | 0.00141 | 0.227 | <0.000010 | 1.52 | |
| C4 | 5/6/2012 | 0.0125 | 0.56 | 0.00088 | <0.0010 | <0.05 | 23.9 | 0.000416 | 0.0178 | 0.06 | 0.0585 | 45.8 | <0.000010 | 3.02 | |
| C4 | 8/1/2012 | 0.00497 | 0.24 | 0.00031 | <0.0010 | <0.05 | 34.3 | 0.000114 | 0.00591 | 0.0135 | 0.0167 | 13.9 | <0.000010 | 1.34 | |
| C4 | 8/8/2012 | 0.00635 | 0.261 | 0.00033 | <0.0010 | <0.05 | 36.5 | 0.000107 | 0.00701 | 0.0148 | 0.015 | 16.1 | <0.000010 | 1.45 | |
| C4 | 8/25/2012 | 0.00759 | 0.373 | 0.00042 | <0.0010 | <0.05 | 45.6 | 0.000202 | 0.00894 | 0.0079 | 0.0218 | 18.2 | <0.000010 | 1.19 | |
| C4 | 6/22/2013 | 0.0123 | 0.539 | 0.00075 | <0.0010 | <0.05 | 55.7 | 0.000317 | 0.0172 | 0.0426 | 0.0479 | 36.2 | 0.000018 | 2.77 | |
| C4 | 7/19/2013 | 0.00864 | 0.373 | 0.00048 | <0.0010 | <0.05 | 54 | 0.000209 | 0.0113 | 0.0287 | 0.0323 | 24.4 | 0.000015 | 2.21 | |
| C4 | 8/22/2013 | 0.00939 | 0.438 | 0.00055 | <0.0010 | <0.05 | 51 | 0.000308 | 0.0133 | 0.0268 | 0.0347 | 26.2 | 0.000033 | 2.02 | |
| C4 | 9/6/2013 | 0.00462 | 0.189 | 0.00019 | <0.0010 | <0.05 | 43.1 | 0.000066 | 0.00447 | 0.0107 | 0.0103 | 11 | <0.000010 | 1.5 | |
| C4 | 10/18/2013 | 0.00153 | 0.0845 | <0.00010 | <0.0010 | <0.05 | 37.3 | 0.000017 | 0.00102 | 0.0012 | 0.0019 | 2.12 | <0.000010 | 0.858 | |
| C4 | 10/18/2013 | 0.00151 | 0.0837 | <0.00010 | <0.0010 | <0.05 | 36.9 | 0.000012 | 0.00101 | 0.0013 | 0.00263 | 2.1 | <0.000010 | 0.833 | |
| C4 | 11/17/2013 | 0.00545 | 0.17 | <0.00010 | <0.0010 | <0.05 | 70.5 | 0.000022 | 0.00621 | 0.0015 | 0.00357 | 14.7 | <0.000010 | 1.05 | |
| C10 | 5/12/2012 | 0.0208 | 0.942 | 0.00176 | <0.0010 | <0.05 | 51.2 | 0.000982 | 0.0315 | 0.0779 | 0.1 | 73.2 | <0.000010 | 4.64 | |
| C10 | 7/30/2012 | 0.0123 | 0.549 | 0.0008 | <0.0010 | <0.05 | 56.3 | 0.000365 | 0.0151 | 0.0385 | 0.0527 | 37.5 | 0.000062 | 3.36 | |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | 0.0124 | 0.666 | 0.00102 | <0.0010 | <0.05 | 67.1 | 0.000486 | 0.0185 | 0.0378 | 0.0597 | 38.9 | <0.000010 | 3.11 | |
| C10 | 8/27/2012 | 0.0156 | 0.754 | 0.00117 | <0.0010 | <0.05 | 72.2 | 0.000526 | 0.0213 | 0.0455 | 0.0624 | 45.6 | <0.000010 | 3.37 | |
| C10 | 6/22/2013 | 0.00203 | 0.0981 | <0.00010 | <0.0010 | <0.05 | 44.4 | 0.000019 | 0.00109 | 0.0022 | 0.00492 | 3.18 | <0.000010 | 1.46 | |
| C10 | 7/23/2013 | 0.00386 | 0.174 | 0.00022 | <0.0010 | <0.05 | 45.1 | 0.000071 | 0.00371 | 0.0095 | 0.0114 | 9.35 | <0.000010 | 1.71 | |
| C10 | 8/22/2013 | 0.00213 | 0.1 | <0.00010 | <0.0010 | <0.05 | 49.5 | 0.000016 | 0.00099 | 0.0019 | 0.00344 | 2.95 | <0.000010 | 1.18 | |
| C10 | 9/8/2013 | 0.00188 | 0.0869 | <0.00010 | <0.0010 | <0.05 | 48.6 | 0.000019 | 0.00094 | 0.0013 | 0.00241 | 2.71 | <0.000010 | 1.17 | |
| C10 | 9/8/2013 | 0.00194 | 0.0852 | <0.00010 | <0.0010 | <0.05 | 48 | 0.000093 | 0.00086 | 0.0012 | 0.00237 | 2.64 | <0.000010 | 1.17 | |
| C10 | 10/18/2013 | 0.00177 | 0.091 | <0.00010 | <0.0010 | <0.05 | 46.8 | 0.00002 | 0.00139 | 0.0024 | 0.00355 | 3.33 | <0.000010 | 1.1 | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Li (mg/L) | Total Mg (mg/L) | Total Mn (mg/L) | Total Mo (mg/L) | Total Na (mg/L) | Total Ni (mg/L) | Total Pb (mg/L) | Total P (mg/L) | Total Sb (mg/L) | Total Se (mg/L) | Total Si (mg/L) | Total Sn (mg/L) | Total Sr (mg/L) | Total S (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | <0.0050 | 8.65 | 0.0612 | 0.0011 | 4.9 | 0.0032 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W1 | 6/30/2005 | <0.0050 | 12.3 | 0.00663 | 0.00107 | 8.6 | 0.00101 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.43 | <0.00010 | 0.293 | |
| W1 | 7/28/2005 | <0.0050 | 12.7 | 0.0164 | 0.00153 | 8.5 | 0.00113 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.21 | <0.00010 | 0.333 | |
| W1 | 8/29/2005 | <0.0050 | 11.5 | 0.0258 | 0.001 | 6.8 | 0.0016 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W1 | 9/28/2005 | <0.0050 | 11.3 | 0.0559 | <0.0010 | 6.3 | 0.0019 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W1 | 10/15/2005 | <0.0050 | 10.9 | 0.0483 | 0.000867 | 5.9 | 0.0024 | 0.00012 | <0.30 | <0.00010 | <0.0010 | 5.99 | <0.00010 | 0.269 | |
| W2 | 5/27/2005 | <0.0050 | 8.37 | 0.0505 | <0.0010 | 4.8 | 0.0026 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W2 | 5/27/2005 | <0.005 | 5.78 | 0.0536 | | | 0.0033 | 0.00066 | | <0.0005 | | | | | |
| W2 | 6/30/2005 | <0.0050 | 12.5 | 0.00785 | 0.00103 | 8.7 | 0.00105 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.48 | <0.00010 | 0.304 | |
| W2 | 7/28/2005 | <0.0050 | 13.1 | 0.014 | 0.00134 | 8.7 | 0.00107 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.32 | <0.00010 | 0.338 | |
| W2 | 8/30/2005 | <0.0050 | 11.6 | 0.025 | 0.0011 | 6.9 | 0.0016 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W2 | 9/28/2005 | <0.0050 | 11 | 0.0543 | <0.0010 | 6 | 0.002 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W2 | 10/15/2005 | <0.0050 | 10.8 | 0.0368 | 0.000916 | 6 | 0.00164 | 0.000078 | <0.30 | <0.00010 | <0.0010 | 5.95 | <0.00010 | 0.267 | |
| W3 | 5/27/2005 | <0.0050 | 9.03 | 0.023 | 0.0011 | 4.9 | 0.0017 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W3 | 6/30/2005 | <0.0050 | 17.6 | 0.0084 | 0.00163 | 12.1 | 0.00087 | 0.000292 | <0.30 | <0.00010 | <0.0010 | 6.04 | <0.00010 | 0.299 | |
| W3 | 7/29/2005 | <0.0050 | 17.2 | 0.0641 | 0.0019 | 9.4 | 0.00257 | 0.000359 | <0.30 | 0.0001 | <0.0010 | 7.03 | 0.00011 | 0.295 | |
| W3 | 8/29/2005 | <0.0050 | 13.2 | 0.0806 | 0.0014 | 7.8 | 0.0017 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W3 | 9/28/2005 | <0.0050 | 12 | 0.12 | 0.0012 | 7.1 | 0.0018 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W3 | 10/15/2005 | <0.0050 | 12.5 | 0.124 | 0.00126 | 7 | 0.00136 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.86 | <0.00010 | 0.233 | |
| W8 | 5/27/2005 | <0.0050 | 5.03 | 0.00512 | <0.0010 | 2.6 | 0.0018 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W8 | 6/30/2005 | <0.0050 | 7.57 | 0.0445 | 0.000512 | 4.5 | 0.00172 | 0.000066 | <0.30 | <0.00010 | <0.0010 | 5.21 | <0.00010 | 0.112 | |
| W8 | 7/29/2005 | <0.0050 | 9.43 | 0.0268 | 0.000565 | 3.9 | 0.00146 | 0.000059 | <0.30 | <0.00010 | <0.0010 | 5.04 | <0.00010 | 0.133 | |
| W8 | 8/30/2005 | <0.0050 | 8.04 | 0.0447 | <0.0010 | 3.8 | 0.0018 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W8 | 9/28/2005 | <0.0050 | 7.45 | 0.0487 | <0.0010 | 3.7 | 0.0017 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W8 | 10/15/2005 | <0.0050 | 7.41 | 0.24 | 0.00171 | 4.5 | 0.00109 | 0.000064 | <0.30 | <0.00010 | <0.0010 | 6.29 | <0.00010 | 0.176 | |
| W9 | 5/27/2005 | <0.0050 | 4.1 | 0.00703 | <0.0010 | 2.3 | 0.0013 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W9 | 6/30/2005 | <0.0050 | 6.04 | 0.0432 | 0.000356 | 4.2 | 0.00125 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.32 | <0.00010 | 0.0956 | |
| W9 | 7/29/2005 | <0.0050 | 7.18 | 0.0638 | 0.00112 | 3.8 | 0.00152 | 0.000099 | <0.30 | <0.00010 | <0.0010 | 5.5 | <0.00010 | 0.146 | |
| W9 | 8/29/2005 | <0.0050 | 6 | 0.0669 | <0.0010 | 3.5 | 0.0013 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W9 | 9/28/2005 | <0.0050 | 5.52 | 0.0485 | <0.0010 | 3.1 | 0.0012 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W9 | 10/15/2005 | <0.0050 | 5.17 | 0.0363 | 0.000349 | 2.9 | 0.00105 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.67 | <0.00010 | 0.0837 | |
| W10 | 5/27/2005 | <0.0050 | 3.25 | 0.00326 | <0.0010 | <2.0 | 0.0018 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W10 | 5/27/2005 | <0.005 | | | <0.001 | <2 | 0.0033 | <0.0005 | | | <0.001 | | <0.0005 | | |
| W10 | 6/30/2005 | <0.0050 | 3.71 | 0.0457 | 0.000177 | 3.6 | 0.00191 | 0.000388 | <0.30 | <0.00010 | <0.0010 | 5.43 | <0.00010 | 0.0778 | |
| W10 | 7/29/2005 | <0.0050 | 5 | 0.174 | 0.000273 | 4.7 | 0.00411 | 0.00178 | <0.30 | 0.00015 | <0.0010 | 9.73 | 0.00026 | 0.108 | |
| W10 | 8/29/2005 | <0.0050 | 6.02 | 0.0422 | <0.0010 | 5.3 | 0.0016 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W10 | 9/28/2005 | <0.0050 | 8.84 | 0.00236 | <0.0010 | 5.4 | <0.0010 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W10 | 10/15/2005 | <0.0050 | 8.41 | 0.00586 | 0.000277 | 4.4 | 0.00086 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 5.52 | <0.00010 | 0.153 | |
| W6 | 5/27/2005 | <0.0050 | 4.88 | 0.0169 | <0.0010 | 2.7 | 0.0021 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W6 | 6/30/2005 | <0.0050 | 6.65 | 0.0113 | 0.000448 | 4.6 | 0.00135 | 0.000134 | <0.30 | <0.00010 | <0.0010 | 7.27 | <0.00010 | 0.1 | |
| W6 | 7/29/2005 | <0.0050 | 15.4 | 0.0536 | 0.00133 | 8.4 | 0.00204 | 0.00035 | <0.30 | <0.00010 | <0.0010 | 6.69 | 0.00013 | 0.286 | |
| W6 | 8/30/2005 | <0.0050 | 7.97 | 0.0224 | <0.0010 | 4.5 | 0.0011 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W6 | 9/28/2005 | <0.0050 | 8.02 | 0.0267 | <0.0010 | 4.2 | 0.0013 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W6 | 10/15/2005 | <0.0050 | 7.18 | 0.0188 | 0.000392 | 4 | 0.00131 | <0.000050 | <0.30 | <0.00010 | <0.0010 | 6.54 | <0.00010 | 0.112 | |
| W6 | 6/2/2006 | <0.005 | 5.63 | 0.0835 | 0.000411 | 3.4 | 0.00535 | 0.000851 | <0.3 | 0.00017 | <0.001 | 7.95 | 0.0001 | 0.0816 | |
| W6 | 8/25/2006 | <0.002 | 7.8 | 0.04 | <0.002 | 4.8 | 0.001 | <0.0002 | | <0.0004 | <0.0004 | 7.39 | <0.002 | 0.14 | 0.9 |
| W6 | 9/6/2006 | 0.001 | 7.3 | 0.042 | <0.001 | 4.6 | 0.0015 | 0.0001 | | <0.0002 | 0.0003 | 7.42 | <0.001 | 0.135 | 1 |
| W6 | 6/20/2007 | <0.001 | 5.6 | 0.011 | <0.001 | 4.3 | 0.0017 | <0.0001 | 0.18 | <0.0002 | 0.0002 | 6.4 | <0.001 | 0.104 | 0.9 |
| W6 | 9/18/2007 | 0.001 | 6.9 | 0.023 | <0.001 | 5 | 0.0012 | <0.0001 | <0.05 | <0.0002 | <0.0002 | 7.2 | <0.001 | 0.125 | 1 |
| W6 | 6/17/2008 | <0.001 | 6.44 | 0.0215 | 0.00045 | 4.8 | 0.001 | <0.0001 | 0.11 | <0.0002 | <0.0006 | 5.34 | <0.0001 | 0.103 | |
| W6 | 9/18/2008 | <0.001 | 6.61 | 0.0098 | 0.00031 | 4.1 | 0.001 | <0.0001 | 0.02 | <0.0002 | <0.0006 | 6.22 | <0.0001 | 0.104 | |
| W6 | 4/14/2009 | 0.005 | 50 | 0.083 | 0.00334 | 33.3 | 0.001 | 0.0011 | 0.34 | 0.0003 | 0.0017 | 6.62 | <0.0001 | 0.524 | 42.4 |
| W6 | 4/30/2009 | 0.004 | 7.92 | 0.167 | 0.00043 | 3.38 | 0.009 | 0.0024 | 0.25 | <0.0002 | <0.0006 | 11.5 | <0.0001 | 0.142 | 2.7 |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | 0.002 | 16.7 | 0.1 | 0.0092 | 15.5 | 0.002 | 0.0003 | 0.017 | 0.0002 | <0.0006 | 4.67 | <0.0001 | 0.666 | 14.7 |
| W6 | 8/6/2009 | 0.002 | 16.7 | 0.0874 | 0.0088 | 15.8 | 0.001 | 0.0006 | 0.015 | 0.0003 | 0.0007 | 4.68 | <0.0001 | 0.566 | 15 |
| W6 | 8/18/2009 | | | | | | | | | | | | | | |
| W6 | 8/25/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | 0.002 | 15.4 | 0.28 | 0.016 | 19.4 | 0.002 | 0.0007 | <0.05 | 0.0006 | 0.0018 | 3.6 | <0.0001 | 0.842 | 22.4 |
| W6 | 10/25/2009 | <0.005 | 16.9 | 0.229 | 0.015 | 18.4 | 0.001 | <0.0002 | | 0.0006 | 0.0019 | 4.48 | <0.005 | 0.844 | 27 |
| W6 | 4/19/2010 | 0.002 | 14.7 | 0.119 | 0.0017 | 9.35 | 0.002 | 0.0006 | 0.08 | <0.0002 | <0.0006 | 6.58 | <0.0001 | 0.392 | 10.9 |
| W6 | 5/16/2010 | <0.005 | 8.41 | 0.027 | <0.001 | 4.4 | <0.001 | <0.0002 | 0.021 | <0.0005 | 0.0002 | 5.35 | <0.005 | 0.197 | <3 |
| W6 | 5/17/2010 | <0.005 | 4.84 | 0.05 | <0.001 | 2.96 | <0.001 | <0.0002 | 0.027 | <0.0005 | <0.0001 | 2.02 | <0.005 | 0.19 | <3 |
| W6 | 5/19/2010 | <0.005 | 8.01 | 0.026 | <0.001 | 5.29 | <0.003 | <0.0002 | 0.037 | <0.0005 | 0.0002 | 2.87 | <0.005 | 0.304 | 4 |
| W6 | 5/21/2010 | <0.01 | 6 | 0.092 | <0.001 | 4 | <0.001 | <0.0002 | | <0.0005 | <0.0008 | 2.38 | <0.005 | 0.279 | <60 |
| W6 | 5/23/2010 | <0.01 | 7 | 0.024 | <0.001 | 5 | <0.001 | <0.0002 | | <0.0005 | <0.0008 | 2.36 | <0.005 | 0.284 | <60 |
| W6 | 5/25/2010 | <0.01 | 10 | 0.03 | <0.001 | 8 | <0.003 | 0.0004 | | <0.0005 | <0.001 | 2.95 | <0.005 | 0.328 | <60 |
| W6 | 5/29/2010 | <0.01 | 4 | 0.039 | <0.001 | 2 | <0.001 | <0.0002 | | <0.0005 | <0.0008 | <2 | <0.005 | 0.225 | <60 |
| W6 | 6/2/2010 | <0.01 | 22 | 0.044 | 0.003 | 15 | <0.001 | <0.0002 | | <0.0005 | <0.0008 | 5.61 | <0.005 | 0.704 | <60 |
| W6 | 6/4/2010 | <0.01 | 7 | 0.008 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <0.0008 | 7.13 | <0.005 | 0.116 | <60 |
| W6 | 6/6/2010 | <0.01 | 8 | 0.012 | <0.001 | 4 | 0.001 | 0.0005 | | <0.0005 | <0.0008 | 6.82 | <0.005 | 0.121 | <60 |
| W6 | 6/14/2010 | <0.01 | 7 | 0.014 | <0.001 | 4 | 0.002 | 0.0002 | | <0.0005 | <0.0008 | 7.45 | <0.005 | 0.123 | <60 |
| W6 | 6/16/2010 | <0.01 | 7 | 0.013 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <0.0008 | 7.12 | <0.005 | 0.114 | <60 |
| W6 | 6/18/2010 | <0.01 | 7 | 0.01 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <0.0008 | 6.99 | <0.005 | 0.111 | <60 |
| W6 | 6/20/2010 | <0.01 | 7 | 0.009 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <0.0008 | 7.28 | <0.005 | 0.116 | <60 |
| W6 | 6/22/2010 | <0.01 | 7 | 0.011 | <0.001 | 4 | 0.002 | <0.0002 | | <0.0005 | <0.0008 | 8.49 | <0.005 | 0.119 | <60 |
| W6 | 6/24/2010 | <0.01 | 6 | 0.006 | <0.001 | 3 | <0.001 | 0.0003 | | <0.0005 | <0.0008 | 5.99 | <0.005 | 0.095 | <60 |
| W6 | 6/26/2010 | <0.01 | 7 | 0.009 | <0.001 | 4 | 0.001 | <0.0002 | | <0.0005 | <0.0008 | 6.95 | <0.005 | 0.114 | <60 |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | <0.01 | 6 | 0.023 | <0.001 | 4 | 0.002 | 0.0003 | | <0.0005 | <0.0008 | 9.39 | <0.005 | 0.117 | <60 |
| W6 | 7/5/2010 | <0.01 | 7 | 0.053 | <0.001 | 3 | 0.004 | 0.0006 | | <0.0005 | <0.0008 | 8.82 | <0.005 | 0.112 | <60 |
| W6 | 8/5/2010 | <0.01 | 8 | 0.023 | <0.001 | 4 | 0.002 | <0.0002 | | <0.0005 | <0.0008 | 7.78 | <0.005 | 0.121 | <60 |
| W6 | 9/9/2010 | <0.01 | 8 | 0.045 | <0.001 | 4 | 0.003 | 0.0004 | | <0.0005 | <0.0008 | 8.17 | <0.005 | 0.142 | <60 |
| W6 | 10/8/2010 | <0.005 | 8.87 | 0.043 | <0.001 | 4.58 | 0.002 | 0.0002 | | <0.0005 | <0.0001 | 6.6 | <0.005 | 0.141 | <3 |
| W6 | 8/19/2011 | <0.005 | 20.9 | 0.02 | 0.003 | 14.6 | 0.001 | <0.0002 | <0.01 | <0.0005 | 0.0004 | 4.9 | <0.005 | 0.614 | 18 |
| W6 | 7/17/2012 | 0.0136 | 14.6 | 0.771 | 0.0012 | 4.89 | 0.0348 | 0.00971 | 0.99 | 0.00072 | 0.00068 | 42.3 | <0.0050 | 0.23 | <3.0 |
| W6 | 7/30/2012 | 0.0088 | 12.1 | 0.513 | <0.0010 | 4.72 | 0.0236 | 0.00627 | 0.642 | 0.00051 | 0.00061 | 33.1 | <0.0050 | 0.202 | <3.0 |
| W6 | 8/9/2012 | 0.0061 | 10.7 | 0.376 | <0.0010 | 4.85 | 0.0126 | 0.00343 | 0.373 | <0.00050 | 0.00041 | 21.7 | <0.0050 | 0.174 | <3.0 |
| W6 | 8/25/2012 | <0.0050 | 11.7 | 0.619 | <0.0010 | 4.59 | 0.0192 | 0.00505 | 0.647 | <0.00050 | 0.00016 | 13.4 | <0.0050 | 0.227 | <3.0 |
| W6 | 9/13/2012 | <0.0050 | 6.92 | 0.0619 | <0.0010 | 4.05 | 0.005 | 0.00025 | 0.04 | <0.00050 | <0.00010 | 6.82 | <0.0050 | 0.12 | <3.0 |
| W6 | 10/13/2012 | <0.0050 | 9.61 | 0.0661 | <0.0010 | 5.31 | 0.0016 | 0.00023 | 0.048 | <0.00050 | 0.00014 | 8.91 | <0.0050 | 0.154 | 3.2 |
| W6 | 11/12/2012 | <0.0050 | 11.3 | 0.0021 | <0.0010 | 6.12 | 0.0013 | <0.00020 | 0.015 | <0.00050 | 0.00011 | 9.52 | <0.0050 | 0.185 | <3.0 |
| W6 | 5/14/2013 | <0.0050 | 2.5 | 0.0637 | <0.0010 | 1.07 | 0.0023 | 0.00024 | 0.086 | <0.00050 | <0.00010 | 3.97 | <0.0050 | 0.0391 | <3.0 |
| W6 | 6/22/2013 | <0.0050 | 9.52 | 0.161 | <0.0010 | 4.63 | 0.0102 | 0.00184 | 0.184 | <0.00050 | 0.00022 | 15.9 | <0.0050 | 0.15 | <3.0 |
| W6 | 7/12/2013 | <0.0050 | 6.98 | 0.0413 | <0.0010 | 4.18 | 0.0021 | 0.00021 | 0.032 | <0.00050 | 0.00012 | 7.44 | <0.0050 | 0.129 | <3.0 |
| W6 | 8/22/2013 | <0.0050 | 7.74 | 0.0358 | <0.0010 | 4.67 | 0.0013 | <0.00020 | 0.018 | <0.00050 | <0.00010 | 8 | <0.0050 | 0.134 | <3.0 |
| W6 | 9/6/2013 | <0.0050 | 8.38 | 0.0387 | <0.0010 | 4.75 | 0.0014 | <0.00020 | 0.016 | <0.00050 | 0.00013 | 8.12 | <0.0050 | 0.142 | <3.0 |
| W6 | 10/7/2013 | <0.0050 | 8 | 0.0965 | <0.0010 | 4.45 | 0.0039 | 0.00081 | 0.098 | <0.00050 | 0.00015 | 11.3 | <0.0050 | 0.136 | <3.0 |
| W6 | 11/16/2013 | <0.0050 | 9.65 | 0.0488 | <0.0010 | 5.26 | 0.0014 | <0.00020 | 0.022 | <0.00050 | <0.00010 | 8.78 | <0.0050 | 0.163 | <3.0 |
| W6 | 12/7/2013 | <0.0050 | 14.5 | 0.0036 | <0.0010 | 7.78 | 0.0013 | <0.00020 | 0.031 | <0.00050 | 0.00018 | 9.08 | <0.0050 | 0.225 | <3.0 |
| W7 | 5/27/2005 | <0.0050 | 6.82 | 0.0519 | 0.001 | 3.9 | 0.003 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W7 | 6/30/2005 | <0.0050 | 10.1 | 0.0514 | 0.00119 | 6.8 | 0.00141 | 0.000134 | <0.30 | <0.00010 | <0.0010 | 5.85 | <0.00010 | 0.279 | |
| W7 | 7/29/2005 | <0.0050 | 14.2 | 0.0468 | 0.00121 | 7.7 | 0.00174 | 0.000332 | <0.30 | <0.00010 | <0.0010 | 6.39 | <0.00010 | 0.287 | |
| W7 | 8/30/2005 | <0.0050 | 9.67 | 0.0368 | 0.0011 | 5.9 | 0.0016 | <0.00050 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W7 | 9/28/2005 | <0.0050 | 9.57 | 0.314 | <0.0010 | 4.9 | 0.0068 | 0.0011 | | <0.00050 | <0.0010 | | <0.00050 | | |
| W7 | 10/15/2005 | <0.0050 | 8.77 | 0.0473 | 0.000959 | 5.1 | 0.00176 | 0.000061 | <0.30 | <0.00010 | <0.0010 | 6.09 | <0.00010 | 0.24 | |
| W7 | 6/2/2006 | 0.0079 | 10.7 | 0.589 | 0.000988 | 4.5 | 0.0275 | 0.00547 | 0.77 | 0.00037 | <0.001 | 22.4 | 0.00036 | 0.204 | |
| W7 | 6/8/2006 | <0.005 | 7.12 | 0.0645 | 0.000843 | 4.4 | 0.00402 | 0.00045 | <0.3 | <0.0001 | <0.001 | 5.27 | <0.0001 | 0.174 | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Li (mg/L) | Total Mg (mg/L) | Total Mn (mg/L) | Total Mo (mg/L) | Total Na (mg/L) | Total Ni (mg/L) | Total Pb (mg/L) | Total P (mg/L) | Total Sb (mg/L) | Total Se (mg/L) | Total Si (mg/L) | Total Sn (mg/L) | Total Sr (mg/L) | Total S (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | 0.002 | 8.8 | 0.079 | 0.001 | 5.8 | 0.0052 | 0.0006 | | <0.0002 | 0.0002 | 7.24 | <0.001 | 0.276 | 3.2 |
| W7 | 6/23/2006 | 0.005 | 12.5 | 0.226 | 0.001 | 7 | 0.0117 | 0.002 | | <0.0002 | 0.0004 | 12.3 | <0.001 | 0.367 | 4.2 |
| W7 | 6/28/2006 | 0.002 | 9.3 | 0.086 | 0.001 | 6 | 0.0042 | 0.0007 | | <0.0002 | <0.0002 | 8.36 | <0.001 | 0.267 | 3.1 |
| W7 | 7/7/2006 | 0.001 | 10.1 | 0.035 | 0.001 | 7.4 | 0.0019 | <0.0001 | | <0.0002 | 0.0002 | 5.57 | <0.001 | 0.329 | 3.7 |
| W7 | 7/12/2006 | 0.001 | 9.5 | 0.035 | 0.001 | 6.5 | 0.0014 | <0.0001 | | <0.0002 | 0.0002 | 5.73 | <0.001 | 0.323 | 3.8 |
| W7 | 7/20/2006 | 0.001 | 11.2 | 0.042 | 0.001 | 6.4 | 0.0011 | <0.0001 | | <0.0002 | <0.0002 | 5.72 | <0.001 | 0.334 | 3.9 |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | 0.001 | 11.7 | 0.051 | 0.001 | 6.5 | 0.0009 | 0.0001 | | <0.0002 | <0.0002 | 6.21 | <0.001 | 0.362 | 4.1 |
| W7 | 8/2/2006 | 0.001 | 10.8 | 0.033 | 0.001 | 6.9 | 0.001 | <0.0001 | | <0.0002 | 0.0005 | 5.94 | <0.001 | 0.342 | 3.6 |
| W7 | 8/10/2006 | 0.001 | 11.3 | 0.04 | 0.001 | 7.2 | 0.0009 | <0.0001 | | <0.0002 | <0.0002 | 5.82 | <0.001 | 0.362 | 4 |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | <0.002 | 10 | 0.039 | <0.002 | 6.7 | 0.001 | <0.0002 | | <0.0004 | <0.0004 | 5.49 | <0.002 | 0.335 | 3.3 |
| W7 | 8/30/2006 | 0.001 | 10.3 | 0.035 | 0.001 | 6.7 | 0.0013 | <0.0001 | | <0.0002 | <0.0002 | 5.49 | <0.001 | 0.309 | 3.5 |
| W7 | 9/6/2006 | 0.001 | 10.3 | 0.035 | 0.001 | 6.8 | 0.0013 | 0.0002 | | <0.0002 | 0.0004 | 5.74 | <0.001 | 0.332 | 3.7 |
| W7 | 9/13/2006 | <0.001 | 11 | 0.033 | <0.001 | 7.1 | 0.0007 | <0.0001 | | <0.0002 | 0.0002 | 6.36 | <0.001 | 0.187 | 3.6 |
| W7 | 9/20/2006 | 0.001 | 11.7 | 0.042 | 0.001 | 6.6 | 0.0014 | 0.0001 | | <0.0002 | 0.0004 | 5.89 | <0.001 | 0.347 | 3.7 |
| W7 | 9/28/2006 | <0.002 | 11 | 0.037 | <0.002 | 6.9 | 0.002 | <0.0002 | | <0.0004 | 0.0004 | 5.35 | <0.002 | 0.328 | 3.6 |
| W7 | 10/4/2006 | <0.002 | 11 | 0.038 | <0.002 | 7 | 0.002 | <0.0002 | | <0.0004 | 0.0006 | 5.75 | <0.002 | 0.347 | 3.5 |
| W7 | 10/12/2006 | 0.001 | 11.8 | 0.063 | 0.001 | 6.6 | 0.0015 | 0.0002 | | <0.0002 | <0.0002 | 6.51 | <0.001 | 0.35 | 4 |
| W7 | 6/5/2007 | 0.002 | 10.2 | 0.126 | 0.001 | 5.8 | 0.0033 | 0.0006 | 0.14 | <0.0002 | <0.0002 | 7.47 | <0.001 | 0.275 | 3.4 |
| W7 | 6/5/2007 | <0.002 | 11 | 0.14 | <0.002 | 6.1 | 0.0039 | 0.0007 | 0.11 | <0.0004 | <0.0004 | 8.37 | <0.002 | 0.302 | 3.5 |
| W7 | 6/5/2007 | 0.002 | 10.6 | 0.135 | 0.001 | 6 | 0.0041 | 0.0007 | 0.14 | <0.0002 | <0.0002 | 8.3 | <0.001 | 0.276 | 3.5 |
| W7 | 6/20/2007 | 0.001 | 9.8 | 0.044 | 0.002 | 7.2 | 0.0016 | 0.0001 | <0.05 | <0.0002 | 0.0003 | 5.45 | <0.001 | 0.304 | 4.2 |
| W7 | 7/18/2007 | 0.001 | 11 | 0.03 | 0.001 | 7.7 | <0.0005 | 0.0004 | | <0.0002 | 0.0004 | 5.78 | <0.001 | 0.38 | 4 |
| W7 | 7/18/2007 | 0.001 | 11 | 0.035 | 0.001 | 7.6 | 0.0009 | 0.0001 | | <0.0002 | 0.0007 | 5.77 | <0.001 | 0.379 | 3.9 |
| W7 | 7/18/2007 | 0.001 | 11 | 0.026 | 0.001 | 7.6 | 0.0005 | <0.0001 | | <0.0002 | 0.0005 | 5.73 | <0.001 | 0.37 | 3.9 |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | 0.001 | 10.7 | 0.033 | 0.001 | 7.9 | 0.0014 | 0.0001 | <0.05 | <0.0002 | <0.0002 | 5.8 | <0.001 | 0.34 | 3.3 |
| W7 | 8/24/2007 | 0.001 | 10.8 | 0.03 | 0.001 | 7.6 | 0.0013 | <0.0001 | <0.05 | <0.0002 | <0.0002 | 5.92 | <0.001 | 0.34 | 3.3 |
| W7 | 8/24/2007 | 0.001 | 11.2 | 0.031 | 0.002 | 8 | 0.0014 | <0.0001 | <0.05 | <0.0002 | <0.0002 | 6.3 | <0.001 | 0.376 | 3.5 |
| W7 | 9/18/2007 | 0.002 | 9.5 | 0.034 | 0.001 | 7.3 | 0.0015 | 0.0002 | <0.05 | <0.0002 | <0.0002 | 6.34 | <0.001 | 0.309 | 2.8 |
| W7 | 10/30/2007 | 0.001 | 11.2 | 0.054 | 0.002 | 8.1 | 0.0008 | 0.0023 | | <0.0002 | 0.0007 | 5.94 | <0.001 | 0.395 | 4.6 |
| W7 | 10/30/2007 | 0.001 | 11 | 0.046 | 0.001 | 7.7 | 0.001 | 0.0005 | | <0.0002 | 0.0003 | 5.09 | <0.001 | 0.388 | 4.3 |
| W7 | 10/30/2007 | 0.001 | 11.3 | 0.047 | 0.001 | 7.6 | 0.0009 | 0.0003 | | <0.0002 | <0.0002 | 5.97 | <0.001 | 0.385 | 4.2 |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | 0.002 | 19 | 0.0257 | 0.00165 | 11.8 | <0.001 | <0.0001 | 0.02 | <0.0002 | <0.0006 | 3.8 | <0.004 | 0.487 | |
| W7 | 4/22/2008 | 0.002 | 20.6 | 0.0268 | 0.00185 | 12.4 | <0.001 | <0.0001 | 0.02 | <0.0002 | <0.0006 | 4.15 | <0.004 | 0.518 | |
| W7 | 4/22/2008 | 0.002 | 20.2 | 0.0268 | 0.00174 | 12 | 0.001 | <0.0001 | 0.02 | <0.0002 | <0.0006 | 4.03 | <0.004 | 0.514 | |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | 0.001 | 8.68 | 0.0693 | 0.00131 | 6.6 | 0.002 | 0.0002 | 0.05 | <0.0002 | <0.0006 | 2.66 | <0.0001 | 0.234 | |
| W7 | 6/3/2008 | 0.001 | 8.71 | 0.0616 | 0.00129 | 6.8 | 0.002 | 0.0001 | 0.05 | <0.0002 | <0.0006 | 2.68 | <0.0001 | 0.232 | |
| W7 | 6/3/2008 | 0.001 | 9.15 | 0.065 | 0.00129 | 7 | 0.002 | 0.0002 | 0.05 | <0.0002 | 0.0009 | 2.77 | <0.0001 | 0.24 | |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/17/2008 | <0.001 | 10.1 | 0.0833 | 0.00148 | 7.5 | 0.001 | 0.0001 | 0.06 | <0.0002 | 0.0008 | 4.43 | <0.0001 | 0.294 | |
| W7 | 8/6/2008 | 0.002 | 10.8 | 0.064 | 0.001 | 7 | 0.003 | 0.0003 | | <0.0002 | <0.0002 | 6.15 | <0.001 | 0.363 | 3.5 |
| W7 | 8/6/2008 | 0.002 | 10.8 | 0.059 | 0.001 | 7.4 | 0.0034 | 0.0003 | | <0.0002 | <0.0002 | 6.45 | <0.001 | 0.361 | 3.5 |
| W7 | 8/6/2008 | 0.002 | 11 | 0.071 | 0.001 | 7.4 | 0.0036 | 0.0004 | | <0.0002 | <0.0002 | 7.39 | <0.001 | 0.36 | 3.5 |
| W7 | 8/6/2008 | | | | | | | | | | | | | | |
| W7 | 9/18/2008 | <0.001 | 7.62 | 0.0347 | 0.00082 | 5.1 | 0.002 | 0.0003 | 0.04 | <0.0002 | 0.0008 | 7.09 | <0.0001 | 0.201 | |
| W7 | 10/28/2008 | <0.001 | 11.6 | 0.0347 | 0.00107 | 6.52 | 0.001 | 0.0001 | 0.016 | <0.0002 | <0.0006 | 7.13 | <0.0001 | 0.263 | |
| W7 | 10/28/2008 | <0.001 | 11.5 | 0.0396 | 0.00114 | 6.24 | 0.003 | 0.0026 | 0.031 | <0.0002 | <0.0006 | 7.08 | <0.0001 | 0.271 | |
| W7 | 10/28/2008 | <0.001 | 11.5 | 0.0337 | 0.00111 | 6.26 | 0.004 | <0.0001 | 0.013 | <0.0002 | <0.0006 | 7.04 | <0.0001 | 0.274 | |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 4/30/2009 | <0.001 | 1.97 | 0.0153 | 0.00016 | 1.29 | <0.001 | 0.0002 | 0.09 | <0.0002 | <0.0006 | 1.67 | <0.0001 | 0.036 | 0.5 |
| W7 | 6/8/2009 | 0.001 | 9.53 | 0.0449 | 0.00141 | 6.08 | 0.002 | 0.0003 | <0.05 | <0.0002 | <0.0006 | 5.67 | <0.0001 | 0.281 | 3.2 |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | 0.001 | 12.2 | 0.0278 | 0.0015 | 7.17 | 0.001 | 0.0004 | 0.011 | <0.0002 | <0.0006 | 5.7 | <0.0001 | 0.38 | 4.3 |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | 0.017 | | | | | | |
| W7 | 10/7/2009 | 0.001 | 11.9 | 0.0346 | 0.0013 | 7.38 | 0.002 | 0.0015 | <0.05 | <0.0002 | <0.0006 | 6.46 | <0.0001 | 0.312 | 4 |
| W7 | 10/25/2009 | <0.005 | 12.6 | 0.029 | 0.002 | 7.41 | 0.001 | <0.0002 | | <0.0005 | 0.0001 | 7.24 | <0.005 | 0.361 | <3 |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | <0.001 | 7.53 | 0.0207 | 0.0008 | 5.17 | 0.001 | 0.0001 | 0.1 | <0.0002 | <0.0006 | 4.44 | <0.0001 | 0.218 | 2.8 |
| W7 | 4/27/2010 | <0.005 | 2.83 | 0.007 | <0.001 | 1.89 | 0.001 | <0.0002 | | <0.0005 | <0.0001 | 3.14 | <0.005 | 0.073 | <3 |
| W7 | 4/29/2010 | <0.005 | 3.01 | 0.01 | <0.001 | 1.91 | 0.001 | <0.0002 | | <0.0005 | <0.0001 | 3.2 | <0.005 | 0.077 | <3 |
| W7 | 5/1/2010 | <0.005 | 3.62 | 0.03 | <0.001 | 2.25 | 0.002 | 0.0003 | 0.052 | <0.0005 | <0.0001 | 4.34 | <0.005 | 0.095 | <3 |
| W7 | 5/3/2010 | <0.005 | 3.78 | 0.033 | <0.001 | 2.55 | 0.002 | 0.0003 | | <0.0005 | <0.0001 | 4.17 | <0.005 | 0.108 | <3 |
| W7 | 5/5/2010 | <0.005 | 4.7 | 0.03 | <0.001 | 3.03 | 0.002 | 0.002 | 0.058 | <0.0005 | <0.0001 | 4.7 | <0.005 | 0.12 | <3 |
| W7 | 5/7/2010 | <0.005 | 4.7 | 0.039 | <0.001 | 3.01 | 0.003 | 0.0003 | 0.049 | <0.0005 | <0.0001 | 4.5 | <0.005 | 0.13 | <3 |
| W7 | 5/9/2010 | <0.005 | 6.2 | 0.016 | <0.001 | 3.97 | 0.002 | 0.0003 | 0.027 | <0.0005 | 0.0001 | 4.24 | <0.005 | 0.17 | <3 |
| W7 | 5/10/2010 | <0.005 | 7.83 | 0.018 | 0.001 | 5.1 | 0.002 | 0.0003 | 0.03 | <0.0005 | 0.0002 | 5.37 | <0.005 | 0.22 | <3 |
| W7 | 5/12/2010 | | | <.01 | | | | | | | | | | | |
| W7 | 5/12/2010 | <0.005 | 7.14 | 0.021 | 0.001 | 4.83 | 0.001 | 0.0002 | 0.022 | <0.0005 | 0.0001 | 5.23 | <0.005 | 0.206 | <3 |
| W7 | 5/14/2010 | <0.005 | 6.29 | 0.042 | <0.001 | 4.05 | 0.003 | 0.0002 | | <0.0005 | 0.0001 | 4.69 | <0.005 | 0.177 | <3 |
| W7 | 5/16/2010 | <0.005 | 6.52 | 0.037 | <0.001 | 4.02 | 0.001 | <0.0002 | 0.041 | <0.0005 | 0.0001 | 4.45 | <0.005 | 0.188 | <3 |
| W7 | 5/17/2010 | <0.005 | 6.47 | 0.045 | 0.001 | 3.92 | 0.001 | 0.0002 | 0.031 | <0.0005 | 0.0002 | 4.32 | <0.005 | 0.193 | <3 |
| W7 | 5/19/2010 | <0.005 | 9.58 | 0.019 | 0.001 | 6.7 | <0.003 | <0.0002 | 0.024 | <0.0005 | 0.0002 | 5.4 | <0.005 | 0.261 | <3 |
| W7 | 5/21/2010 | <0.01 | 8 | 0.035 | 0.001 | 5 | 0.002 | 0.0002 | | <0.0005 | <0.0008 | 5.41 | <0.005 | 0.246 | <60 |
| W7 | 5/23/2010 | <0.01 | 10 | 0.13 | 0.001 | 5 | 0.007 | 0.0013 | | <0.0005 | <0.0008 | 8.91 | <0.005 | 0.261 | <60 |
| W7 | 5/25/2010 | <0.01 | 13 | 0.158 | 0.002 | 8 | 0.008 | 0.0018 | | <0.0005 | <0.001 | 13.2 | <0.005 | 0.279 | <60 |
| W7 | 5/27/2010 | <0.01 | 17 | 0.391 | 0.002 | 8 | 0.03 | 0.0052 | | 0.0007 | <0.001 | 24.4 | <0.005 | 0.316 | <60 |
| W7 | 5/29/2010 | <0.01 | 13 | 0.248 | 0.002 | 6 | 0.013 | 0.0025 | | <0.0005 | <0.0008 | 12.9 | <0.005 | 0.314 | <60 |
| W7 | 5/31/2010 | <0.01 | 13 | 0.226 | 0.002 | 7 | 0.015 | 0.0028 | | <0.0005 | <0.0008 | 14.2 | <0.005 | 0.307 | <60 |
| W7 | 6/2/2010 | <0.01 | 13 | 0.148 | 0.002 | 8 | 0.009 | 0.0014 | | <0.0005 | <0.0008 | 10.2 | <0.005 | 0.337 | <60 |
| W7 | 6/4/2010 | <0.01 | 11 | 0.081 | 0.002 | 7 | 0.006 | 0.001 | | <0.0005 | <0.0008 | 8.48 | <0.005 | 0.311 | <60 |
| W7 | 6/6/2010 | <0.01 | 12 | 0.091 | 0.002 | 7 | 0.006 | 0.0012 | | <0.0005 | <0.0008 | 9.38 | <0.005 | 0.337 | <60 |
| W7 | 6/14/2010 | <0.01 | 12 | 0.073 | 0.002 | 7 | 0.004 | 0.0006 | | <0.0005 | <0.0008 | 7.65 | <0.005 | 0.356 | <60 |
| W7 | 6/16/2010 | <0.01 | 12 | 0.036 | 0.002 | 7 | 0.002 | <0.0002 | | <0.0005 | <0.0008 | 6.5 | <0.005 | 0.342 | <60 |
| W7 | 6/18/2010 | <0.01 | 11 | 0.042 | 0.002 | 7 | 0.002 | 0.0003 | | <0.0005 | <0.0008 | 6.69 | <0.005 | 0.323 | <60 |
| W7 | 6/20/2010 | <0.01 | 11 | 0.059 | 0.002 | 7 | 0.004 | 0.0007 | | <0.0005 | <0.0008 | 8.16 | <0.005 | 0.308 | <60 |
| W7 | 6/22/2010 | <0.01 | 11 | 0.26 | 0.001 | 6 | 0.016 | 0.0031 | | <0.0005 | <0.0008 | 18.4 | <0.005 | 0.298 | <60 |
| W7 | 6/24/2010 | <0.01 | 12 | 0.067 | 0.001 | 8 | 0.006 | 0.0006 | | <0.0005 | <0.0008 | 8.82 | <0.005 | 0.285 | <60 |
| W7 | 6/26/2010 | <0.01 | 10 | 0.032 | 0.001 | 6 | 0.002 | 0.0003 | | <0.0005 | <0.0008 | 6.6 | <0.005 | 0.277 | <60 |
| W7 | 6/28/2010 | <0.01 | 9 | 0.021 | 0.001 | 6 | 0.002 | 0.0003 | | <0.0005 | <0.0008 | 7.12 | <0.005 | 0.312 | <60 |
| W7 | 7/5/2010 | <0.01 | 9 | 0.078 | 0.001 | 6 | 0.005 | 0.0008 | | <0.0005 | <0.0008 | 9.55 | <0.005 | 0.263 | <60 |
| W7 | 8/5/2010 | <0.01 | 10 | 0.029 | 0.001 | 6 | 0.003 | <0.0002 | | <0.0005 | <0.0008 | 6.81 | <0.005 | 0.306 | <60 |
| W7 | 9/12/2010 | <0.01 | 9 | 0.052 | <0.001 | 5 | 0.002 | <0.0002 | | <0.0005 | <0.0008 | 7.25 | <0.005 | 0.253 | <60 |
| W7 | 9/12/2010 | <0.01 | 9 | 0.026 | <0.001 | 5 | 0.002 | <0.0002 | | <0.0005 | <0.0008 | 7.18 | <0.005 | 0.248 | <60 |
| W7 | 10/8/2010 | <0.005 | 11.1 | 0.036 | 0.001 | 6.52 | 0.002 | <0.0002 | | <0.0005 | <0.0001 | 7.13 | <0.005 | 0.316 | <3 |
| W7 | 4/27/2011 | <0.005 | 3.72 | 0.03 | <0.001 | 2.16 | <0.001 | <0.0002 | 0.067 | <0.0005 | <0.0001 | 2.96 | <0.005 | 0.089 | <3 |
| W7 | 5/2/2011 | <0.005 | 2.78 | 0.039 | <0.001 | 1.51 | 0.001 | <0.0002 | | <0.0005 | <0.0001 | 2.73 | <0.005 | 0.069 | <3 |
| W7 | 6/1/2011 | <0.005 | 8.93 | 0.035 | 0.001 | 5.45 | 0.002 | 0.0002 | 0.043 | <0.0005 | 0.0001 | 5.82 | <0.005 | 0.25 | <3 |
| W7 | 6/16/2011 | <0.005 | 10.2 | 0.097 | 0.001 | 5.94 | 0.008 | 0.0012 | 0.226 | <0.0005 | 0.0002 | 10.3 | <0.005 | 0.24 | <3 |
| W7 | 7/1/2011 | <0.005 | 7.82 | 0.162 | 0.001 | 5.16 | 0.012 | 0.0021 | 0.267 | <0.0005 | 0.0003 | 11.9 | <0.005 | 0.179 | <3 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Li (mg/L) | Total Mg (mg/L) | Total Mn (mg/L) | Total Mo (mg/L) | Total Na (mg/L) | Total Ni (mg/L) | Total Pb (mg/L) | Total P (mg/L) | Total Sb (mg/L) | Total Se (mg/L) | Total Si (mg/L) | Total Sn (mg/L) | Total Sr (mg/L) | Total S (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | 0.005 | 8.29 | 0.304 | <0.001 | 4.04 | 0.019 | 0.0035 | 0.412 | <0.0005 | 0.0003 | 22.3 | <0.005 | 0.161 | <3 |
| W7 | 8/16/2011 | <0.005 | 8.1 | 0.081 | <0.001 | 4.64 | 0.003 | 0.0004 | 0.058 | <0.0005 | 0.0001 | 7 | <0.005 | 0.209 | <3 |
| W7 | 8/19/2011 | <0.005 | 8.05 | 0.078 | <0.001 | 4.62 | 0.003 | 0.0002 | 0.043 | <0.0005 | 0.0001 | 7 | <0.005 | 0.201 | <3 |
| W7 | 9/12/2011 | <0.005 | 10.6 | 0.083 | 0.001 | 6.09 | 0.002 | <0.0002 | 0.033 | <0.0005 | 0.0002 | 7.49 | <0.005 | 0.247 | <3 |
| W7 | 10/6/2011 | <0.005 | 10.2 | 0.073 | 0.001 | 5.59 | 0.001 | <0.0002 | 0.023 | <0.0005 | 0.0001 | 6.27 | <0.005 | 0.264 | <3 |
| W7 | 11/22/2011 | <0.005 | 12.8 | 0.093 | 0.001 | 6.69 | 0.002 | 0.0008 | 0.077 | <0.0005 | 0.0002 | 7.33 | <0.005 | 0.358 | 6.5 |
| W7 | 1/24/2012 | <0.005 | 14.5 | 0.06 | 0.001 | 8.39 | <0.001 | <0.0002 | 0.014 | <0.0005 | 0.0003 | 6.36 | <0.005 | 0.449 | 5.9 |
| W7 | 2/25/2012 | <0.005 | 13.9 | 0.004 | 0.001 | 8.08 | <0.001 | <0.0002 | 0.012 | <0.0005 | 0.0003 | 6.3 | <0.005 | 0.468 | 6 |
| W7 | 3/5/2012 | <0.005 | 14.6 | 0.005 | 0.001 | 8.36 | <0.001 | <0.0002 | 0.016 | <0.0005 | 0.0004 | 6.35 | <0.005 | 0.485 | 5.6 |
| W7 | 4/24/2012 | <0.0050 | 3.17 | 0.0582 | <0.0010 | 1.84 | 0.0019 | 0.00029 | 0.048 | <0.00050 | <0.00010 | 4.08 | <0.0050 | 0.0798 | <3.0 |
| W7 | 5/6/2012 | <0.0050 | 4.06 | 0.0133 | <0.0010 | 2.47 | 0.0013 | <0.00020 | 0.031 | <0.00050 | 0.00014 | 3.65 | <0.0050 | 0.105 | <3.0 |
| W7 | 5/6/2012 | <0.0050 | 4.12 | 0.0145 | <0.0010 | 2.53 | 0.0014 | <0.00020 | 0.034 | <0.00050 | 0.00011 | 3.57 | <0.0050 | 0.103 | <3.0 |
| W7 | 6/19/2012 | <0.0050 | 9.46 | 0.199 | 0.0012 | 5.45 | 0.0107 | 0.00178 | 0.222 | <0.00050 | 0.0002 | 16.3 | <0.0050 | 0.236 | <3.0 |
| W7 | 7/17/2012 | <0.0050 | 11 | 0.0937 | 0.0015 | 6.4 | 0.0032 | 0.00026 | 0.074 | <0.00050 | 0.00019 | 8.31 | <0.0050 | 0.305 | <3.0 |
| W7 | 7/30/2012 | <0.0050 | 11.6 | 0.0683 | 0.0014 | 6.83 | 0.0025 | <0.00020 | 0.044 | <0.00050 | 0.00022 | 6.59 | <0.0050 | 0.318 | 3.3 |
| W7 | 8/8/2012 | <0.0050 | 12.7 | 0.0626 | 0.0014 | 7.25 | 0.0016 | <0.00020 | 0.036 | <0.00050 | 0.00028 | 7.38 | <0.0050 | 0.334 | <3.0 |
| W7 | 8/23/2012 | <0.0050 | 13 | 0.0627 | 0.0016 | 7.39 | 0.0016 | <0.00020 | 0.035 | <0.00050 | 0.00017 | 7.8 | <0.0050 | 0.374 | <3.0 |
| W7 | 9/13/2012 | <0.0050 | 10.5 | 0.126 | <0.0010 | 6 | 0.0022 | <0.00020 | 0.034 | <0.00050 | 0.00021 | 6.83 | <0.0050 | 0.269 | <3.0 |
| W7 | 10/16/2012 | <0.0050 | 13 | 0.101 | 0.0012 | 7.25 | 0.0023 | <0.00020 | 0.046 | <0.00050 | 0.0002 | 7.29 | <0.0050 | 0.327 | <3.0 |
| W7 | 11/2/2012 | <0.0050 | 14.4 | 0.103 | 0.0013 | 7.87 | 0.0014 | <0.00020 | 0.023 | <0.00050 | 0.00023 | 6.3 | <0.0050 | 0.411 | 5.1 |
| W7 | 12/29/2012 | <0.0050 | 19.9 | 0.0405 | 0.0012 | 11.7 | 0.0016 | <0.00020 | 0.022 | <0.00050 | 0.00032 | 7.67 | <0.0050 | 0.488 | 7.9 |
| W7 | 4/30/2013 | <0.0050 | 19 | 0.053 | 0.0013 | 10.1 | <0.0010 | <0.00020 | <0.01 | <0.00050 | 0.00042 | 7.29 | <0.0050 | 0.603 | 8.1 |
| W7 | 5/14/2013 | <0.0050 | 3 | 0.164 | <0.0010 | 1.5 | 0.0029 | 0.00046 | 0.116 | <0.00050 | 0.00011 | 4.78 | <0.0050 | 0.0703 | <3.0 |
| W7 | 6/19/2013 | <0.0050 | 9.98 | 0.0448 | 0.0013 | 6.12 | 0.0018 | <0.00020 | 0.036 | <0.00050 | 0.00018 | 6.43 | <0.0050 | 0.275 | <3.0 |
| W7 | 6/19/2013 | <0.0050 | 9.92 | 0.042 | 0.0014 | 6.28 | 0.0019 | <0.00020 | 0.028 | <0.00050 | 0.00012 | 6.47 | <0.0050 | 0.275 | <3.0 |
| W7 | 7/13/2013 | <0.0050 | 12.1 | 0.0336 | 0.0016 | 7.03 | 0.0017 | <0.00020 | 0.027 | <0.00050 | 0.0002 | 6.88 | <0.0050 | 0.341 | <3.0 |
| W7 | 8/21/2013 | <0.0050 | 13.3 | 0.0492 | 0.0016 | 7.75 | 0.0014 | <0.00020 | 0.028 | <0.00050 | 0.00014 | 6.97 | <0.0050 | 0.364 | <3.0 |
| W7 | 9/6/2013 | <0.0050 | 13.9 | 0.102 | 0.0013 | 8.11 | 0.0019 | <0.00020 | 0.044 | <0.00050 | 0.00017 | 7.96 | <0.0050 | 0.364 | <3.0 |
| W7 | 10/21/2013 | <0.0050 | 11.3 | 0.0934 | 0.0011 | 6.34 | 0.0016 | <0.00020 | 0.027 | <0.00050 | 0.00021 | 6.38 | <0.0050 | 0.303 | <3.0 |
| W7 | 11/16/2013 | <0.0050 | 15.6 | 0.0906 | 0.0017 | 8.83 | <0.0010 | <0.00020 | 0.026 | <0.00050 | 0.00017 | 6.95 | <0.0050 | 0.436 | <3.0 |
| W7 | 12/7/2013 | <0.0050 | 17.5 | 0.162 | 0.0013 | 10.1 | 0.001 | <0.00020 | 0.021 | <0.00050 | 0.00019 | 6.56 | <0.0050 | 0.476 | 5.8 |
| C4 | 5/6/2012 | 0.0188 | 14.4 | 0.936 | 0.0015 | 3.45 | 0.0498 | 0.0126 | 1.11 | 0.00084 | 0.00069 | 57.5 | <0.0050 | 0.168 | <3.0 |
| C4 | 8/1/2012 | <0.0050 | 11.5 | 0.868 | <0.0010 | 5.22 | 0.0139 | 0.00303 | 0.41 | <0.00050 | 0.00019 | 18.8 | <0.0050 | 0.237 | <3.0 |
| C4 | 8/8/2012 | 0.0057 | 12.3 | 1 | 0.001 | 5.55 | 0.0151 | 0.00371 | 0.478 | <0.00050 | 0.00021 | 18 | <0.0050 | 0.26 | <3.0 |
| C4 | 8/25/2012 | <0.0050 | 14.3 | 1.32 | <0.0010 | 5.64 | 0.0179 | 0.00439 | 0.657 | <0.00050 | 0.00016 | 13 | <0.0050 | 0.321 | <3.0 |
| C4 | 6/22/2013 | 0.0152 | 20.2 | 1.24 | 0.0023 | 7.08 | 0.0483 | 0.00977 | 1.28 | 0.00084 | 0.00059 | 40.7 | <0.0050 | 0.337 | 3.6 |
| C4 | 7/19/2013 | 0.0106 | 15.8 | 0.913 | 0.002 | 6.66 | 0.0314 | 0.00631 | 0.591 | 0.00064 | 0.00071 | 32 | <0.0050 | 0.323 | <3.0 |
| C4 | 8/22/2013 | 0.0094 | 17.3 | 1.25 | 0.0014 | 6.83 | 0.0352 | 0.00784 | 1.01 | 0.00058 | 0.00053 | 31 | <0.0050 | 0.346 | <3.0 |
| C4 | 9/6/2013 | <0.0050 | 14.2 | 0.732 | 0.0014 | 6.74 | 0.0124 | 0.00208 | 0.342 | <0.00050 | 0.00016 | 18.3 | <0.0050 | 0.276 | <3.0 |
| C4 | 10/18/2013 | <0.0050 | 11.8 | 0.427 | <0.0010 | 6.15 | 0.0031 | <0.00020 | 0.06 | <0.00050 | <0.00010 | 8.27 | <0.0050 | 0.237 | 4.6 |
| C4 | 10/18/2013 | <0.0050 | 11.3 | 0.425 | <0.0010 | 6.01 | 0.0029 | <0.00020 | 0.065 | <0.00050 | 0.00011 | 8.14 | <0.0050 | 0.236 | 3.6 |
| C4 | 11/17/2013 | <0.0050 | 21.5 | 3.19 | 0.0011 | 8.09 | 0.0077 | <0.00020 | 0.158 | <0.00050 | 0.00027 | 9.05 | <0.0050 | 0.409 | 8.2 |
| C10 | 5/12/2012 | 0.0292 | 21.1 | 2.09 | 0.0021 | 4.3 | 0.074 | 0.0214 | 2.08 | 0.00117 | 0.00116 | 66.7 | <0.0050 | 0.307 | <3.0 |
| C10 | 7/30/2012 | 0.015 | 16.2 | 0.947 | 0.0021 | 6.41 | 0.041 | 0.00995 | 0.967 | 0.00096 | 0.00073 | 42.7 | <0.0050 | 0.315 | <3.0 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | 0.0172 | 18.8 | 1.31 | 0.0017 | 6.4 | 0.0467 | 0.0125 | 1.15 | 0.00087 | 0.00057 | 44.2 | <0.0050 | 0.363 | <3.0 |
| C10 | 8/27/2012 | 0.0198 | 20.2 | 1.7 | 0.0023 | 6.34 | 0.0524 | 0.013 | 1.39 | 0.00115 | 0.00086 | 44 | <0.0050 | 0.404 | <3.0 |
| C10 | 6/22/2013 | <0.0050 | 9.68 | 0.0986 | 0.0012 | 6.32 | 0.0044 | 0.0006 | 0.083 | <0.00050 | 0.0001 | 8.47 | <0.0050 | 0.223 | <3.0 |
| C10 | 7/23/2013 | <0.0050 | 10.6 | 0.407 | 0.0012 | 6.52 | 0.0099 | 0.00212 | 0.239 | <0.00050 | 0.00024 | 15.9 | <0.0050 | 0.226 | <3.0 |
| C10 | 8/22/2013 | <0.0050 | 10.7 | 0.11 | <0.0010 | 6.49 | 0.0038 | 0.00044 | 0.073 | <0.00050 | 0.00013 | 8.98 | <0.0050 | 0.259 | <3.0 |
| C10 | 9/8/2013 | <0.0050 | 10.2 | 0.172 | 0.0014 | 6.24 | 0.0033 | 0.00025 | 0.063 | <0.00050 | 0.00017 | 7.06 | <0.0050 | 0.256 | <3.0 |
| C10 | 9/8/2013 | <0.0050 | 10.3 | 0.174 | <0.0010 | 6.4 | 0.0032 | 0.00025 | 0.067 | <0.00050 | 0.00014 | 7.27 | <0.0050 | 0.255 | <3.0 |
| C10 | 10/18/2013 | <0.0050 | 10.4 | 0.321 | <0.0010 | 6.3 | 0.0038 | 0.00054 | 0.105 | <0.00050 | 0.00015 | 8.99 | <0.0050 | 0.231 | <3.0 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Te (mg/L) | Total Th (mg/L) | Total Ti (mg/L) | Total Tl (mg/L) | Total U (mg/L) | Total V (mg/L) | Total W (mg/L) | Total Zn (mg/L) | Total Zr (mg/L) | Total N (mg/L) | Ammonia (mg/L) | Ammonium (mg/L) | Ammonium (mg/L) | NO2+NO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | | | 0.022 | <0.00020 | 0.0006 | <0.030 | | 0.0096 | | | 0.039 | | | |
| W1 | 6/30/2005 | | | <0.010 | <0.00010 | 0.00113 | <0.0010 | | <0.0010 | | | <0.020 | | | |
| W1 | 7/28/2005 | | | <0.010 | <0.00010 | 0.00122 | <0.0010 | | <0.0010 | | | <0.020 | | | |
| W1 | 8/29/2005 | | | <0.010 | <0.00020 | 0.00077 | <0.030 | | <0.0050 | | | 0.041 | | | |
| W1 | 9/28/2005 | | | <0.010 | <0.00020 | 0.00058 | <0.030 | | <0.0050 | | | 0.026 | | | |
| W1 | 10/15/2005 | | | <0.010 | <0.00010 | 0.000786 | 0.0013 | | 0.001 | | | 0.02 | | | |
| W2 | 5/27/2005 | | | 0.016 | <0.00020 | 0.00054 | <0.030 | | <0.0050 | | | 0.026 | | | |
| W2 | 5/27/2005 | | | 0.057 | | 0.00096 | | | 0.006 | | | <0.02 | | | |
| W2 | 6/30/2005 | | | <0.010 | <0.00010 | 0.00108 | <0.0010 | | <0.0010 | | | <0.020 | | | |
| W2 | 7/28/2005 | | | <0.010 | <0.00010 | 0.00136 | <0.0010 | | <0.0010 | | | <0.020 | | | |
| W2 | 8/30/2005 | | | <0.010 | <0.00020 | 0.00082 | <0.030 | | <0.0050 | | | 0.029 | | | |
| W2 | 9/28/2005 | | | <0.010 | <0.00020 | 0.00059 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W2 | 10/15/2005 | | | <0.010 | <0.00010 | 0.000756 | 0.001 | | 0.0011 | | | <0.020 | | | |
| W3 | 5/27/2005 | | | <0.010 | <0.00020 | 0.00035 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W3 | 6/30/2005 | | | <0.010 | <0.00010 | 0.0009 | <0.0010 | | <0.0020 | | | <0.020 | | | |
| W3 | 7/29/2005 | | | 0.045 | <0.00010 | 0.000778 | 0.0032 | | <0.0070 | | | <0.020 | | | |
| W3 | 8/29/2005 | | | <0.010 | <0.00020 | 0.00051 | <0.030 | | <0.0050 | | | 0.042 | | | |
| W3 | 9/28/2005 | | | <0.010 | <0.00020 | 0.00039 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W3 | 10/15/2005 | | | <0.010 | <0.00010 | 0.00044 | <0.0010 | | <0.0010 | | | 0.023 | | | |
| W8 | 5/27/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W8 | 6/30/2005 | | | <0.010 | <0.00010 | 0.000063 | <0.0010 | | <0.0020 | | | 0.041 | | | |
| W8 | 7/29/2005 | | | <0.010 | <0.00010 | 0.000083 | <0.0010 | | 0.0011 | | | <0.020 | | | |
| W8 | 8/30/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | 0.023 | | | |
| W8 | 9/28/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W8 | 10/15/2005 | | | <0.010 | <0.00010 | 0.0001 | <0.0010 | | 0.0011 | | | 0.026 | | | |
| W9 | 5/27/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W9 | 6/30/2005 | | | <0.010 | <0.00010 | 0.000027 | <0.0010 | | <0.0050 | | | 0.02 | | | |
| W9 | 7/29/2005 | | | <0.010 | <0.00010 | 0.000052 | <0.0010 | | <0.0040 | | | <0.020 | | | |
| W9 | 8/29/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | 0.026 | | | |
| W9 | 9/28/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W9 | 10/15/2005 | | | <0.010 | <0.00010 | 0.000025 | <0.0010 | | <0.0010 | | | <0.020 | | | |
| W10 | 5/27/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | 0.027 | | | |
| W10 | 5/27/2005 | | | <0.01 | <0.0002 | 0.00092 | <0.03 | | <0.005 | | | <0.02 | | | |
| W10 | 6/30/2005 | | | <0.010 | <0.00010 | 0.000034 | 0.0015 | | 0.0289 | | | 0.036 | | | |
| W10 | 7/29/2005 | | | 0.09 | <0.00010 | 0.000097 | 0.0067 | | 0.017 | | | <0.020 | | | |
| W10 | 8/29/2005 | | | 0.018 | <0.00020 | <0.00020 | <0.030 | | 0.0071 | | | 0.033 | | | |
| W10 | 9/28/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W10 | 10/15/2005 | | | <0.010 | <0.00010 | 0.000017 | <0.0010 | | 0.0014 | | | <0.020 | | | |
| W6 | 5/27/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W6 | 6/30/2005 | | | <0.010 | <0.00010 | 0.000151 | 0.0012 | | <0.0030 | | | <0.020 | | | |
| W6 | 7/29/2005 | | | 0.033 | <0.00010 | 0.00106 | 0.0027 | | <0.0060 | | | <0.020 | | | |
| W6 | 8/30/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W6 | 9/28/2005 | | | <0.010 | <0.00020 | <0.00020 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W6 | 10/15/2005 | | | <0.010 | <0.00010 | 0.000129 | <0.0010 | | <0.0010 | | | <0.020 | | | |
| W6 | 6/2/2006 | | | 0.077 | <0.0001 | 0.000215 | 0.0066 | | 0.0085 | | | 0.021 | | | |
| W6 | 8/25/2006 | | | <0.0010 | <0.0001 | <0.001 | 0.0008 | | 0.005 | <0.002 | | | | | |
| W6 | 9/6/2006 | | | 0.0014 | <0.00005 | <0.0005 | 0.0008 | | <0.001 | <0.001 | | | | | |
| W6 | 6/20/2007 | | | <0.0005 | <0.00005 | <0.0005 | 0.0011 | | 0.004 | <0.001 | | <0.05 | | | <0.1 |
| W6 | 9/18/2007 | | | 0.0015 | <0.00005 | <0.0005 | 0.0007 | | 0.008 | <0.001 | | <0.05 | | | <0.1 |
| W6 | 6/17/2008 | <0.0001 | <0.0001 | 0.0059 | <0.00001 | <0.0004 | 0.00094 | | 0.007 | 0.0004 | | <0.05 | | | 0.01 |
| W6 | 9/18/2008 | <0.0001 | <0.0001 | 0.0015 | <0.00001 | <0.0004 | 0.00065 | | 0.004 | 0.0003 | | <0.05 | | | <0.01 |
| W6 | 4/14/2009 | 0.0001 | 0.0001 | 0.064 | <0.00001 | 0.0041 | 0.00381 | | 0.276 | 0.0038 | | | 0.12 | 0.12 | 0.59 |
| W6 | 4/30/2009 | <0.0001 | <0.0001 | 0.222 | 0.00003 | 0.0004 | 0.0142 | | 0.023 | 0.0013 | | | <0.05 | <0.05 | 0.04 |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | <0.0001 | <0.0004 | 0.0024 | <0.00001 | 0.0015 | 0.0008 | | 0.003 | <0.0001 | | | | | |
| W6 | 8/6/2009 | <0.0001 | <0.0004 | 0.0019 | <0.00001 | 0.0015 | 0.0007 | | 0.006 | 0.0001 | | | 0.06 | 0.06 | 2.93 |
| W6 | 8/18/2009 | | | | | | | | | | | | | | |
| W6 | 8/25/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | <0.0001 | <0.0004 | 0.0022 | <0.00001 | 0.0005 | 0.0006 | | 0.005 | <0.0001 | | | 0.1 | 0.1 | 8.18 |
| W6 | 10/25/2009 | | | <0.005 | <0.00005 | 0.0009 | <0.005 | | <0.005 | <0.0005 | | 0.134 | | | 7.9 |
| W6 | 4/19/2010 | <0.0001 | <0.0004 | | <0.00001 | 0.0014 | 0.0043 | | 0.014 | 0.0003 | | | <0.05 | <0.05 | 0.54 |
| W6 | 5/16/2010 | | | <0.005 | <0.00005 | 0.0001 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.046 | | | <0.02 |
| W6 | 5/17/2010 | | | <0.005 | <0.00005 | 0.0004 | <0.005 | <0.001 | <0.005 | <0.0005 | | <0.005 | | | <0.02 |
| W6 | 5/19/2010 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.08 | | | <0.02 |
| W6 | 5/21/2010 | | | <0.01 | <0.00005 | 0.0006 | <0.005 | | <0.01 | <0.002 | | 0.006 | | | <0.02 |
| W6 | 5/23/2010 | | | <0.01 | <0.00005 | 0.0006 | <0.005 | | <0.01 | <0.002 | | 0.031 | | | <0.02 |
| W6 | 5/25/2010 | | | <0.01 | <0.00005 | 0.0006 | <0.005 | | <0.01 | <0.002 | | 0.17 | | | <0.02 |
| W6 | 5/29/2010 | | | <0.01 | <0.00005 | 0.0005 | <0.005 | | <0.01 | <0.002 | | 0.08 | | | <0.02 |
| W6 | 6/2/2010 | | | <0.01 | <0.00005 | 0.003 | <0.005 | | <0.01 | <0.002 | | 0.031 | | | 0.97 |
| W6 | 6/4/2010 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | 0.034 | | | <0.02 |
| W6 | 6/6/2010 | | | <0.01 | <0.00005 | 0.0004 | <0.005 | | <0.01 | <0.002 | | 0.06 | | | <0.02 |
| W6 | 6/14/2010 | | | 0.011 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | 0.016 | | | <0.02 |
| W6 | 6/16/2010 | | | 0.012 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | 0.013 | | | 0.03 |
| W6 | 6/18/2010 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | <0.5 | | | <0.02 |
| W6 | 6/20/2010 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | <0.5 | | | 0.02 |
| W6 | 6/22/2010 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | 0.01 | | | <0.02 |
| W6 | 6/24/2010 | | | <0.01 | <0.00005 | 0.0002 | <0.005 | | <0.01 | <0.002 | | 0.012 | | | <0.02 |
| W6 | 6/26/2010 | | | <0.01 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | 0.034 | | | <0.02 |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | | | 0.019 | <0.00005 | 0.0003 | <0.005 | | <0.01 | <0.002 | | 0.031 | | | <0.02 |
| W6 | 7/5/2010 | | | 0.051 | <0.00005 | 0.0004 | <0.005 | | <0.01 | <0.002 | | 0.15 | | | <0.02 |
| W6 | 8/5/2010 | | | <0.01 | <0.00005 | 0.0002 | <0.005 | | <0.01 | <0.002 | | 0.014 | | | <0.02 |
| W6 | 9/9/2010 | | | 0.018 | <0.00005 | 0.0003 | <0.005 | | 0.015 | <0.002 | | <0.005 | | | <0.02 |
| W6 | 10/8/2010 | | | 0.016 | <0.00005 | 0.0003 | <0.005 | | <0.005 | <0.0005 | | 0.053 | | | <0.02 |
| W6 | 8/19/2011 | | | <0.005 | <0.00005 | 0.0025 | <0.005 | | 0.008 | <0.0005 | | 0.006 | | | 1.05 |
| W6 | 7/17/2012 | | | 0.747 | 0.000147 | 0.0022 | 0.0672 | | 0.073 | 0.00302 | | 0.14 | | | 0.026 |
| W6 | 7/30/2012 | | | 0.529 | 0.000108 | 0.0017 | 0.0475 | | 0.0504 | 0.00202 | | 0.07 | | | 0.059 |
| W6 | 8/9/2012 | | | 0.299 | 0.000068 | 0.00102 | 0.0252 | | 0.027 | 0.00116 | | 0.025 | | | 0.029 |
| W6 | 8/25/2012 | | | 0.063 | <0.000050 | 0.00167 | 0.0348 | | 0.0392 | 0.00101 | | 0.023 | | | 0.045 |
| W6 | 9/13/2012 | | | 0.0071 | <0.000050 | 0.00018 | <0.0050 | | <0.0050 | <0.00050 | | 0.011 | | | 0.034 |
| W6 | 10/13/2012 | | | 0.0098 | <0.000050 | 0.00027 | <0.0050 | | <0.0050 | <0.00050 | | 0.016 | | | 0.042 |
| W6 | 11/12/2012 | | | <0.0050 | <0.000050 | 0.00034 | <0.0050 | | <0.0050 | <0.00050 | | 0.025 | | | <0.020 |
| W6 | 5/14/2013 | | | 0.024 | <0.000050 | <0.00010 | <0.0050 | | 0.0057 | <0.00050 | | 0.13 | | | <0.020 |
| W6 | 6/22/2013 | | | 0.2 | 0.000066 | 0.0005 | 0.014 | | 0.0169 | 0.0016 | | 0.024 | | | 0.042 |
| W6 | 7/12/2013 | | | 0.0218 | <0.000050 | 0.00022 | <0.0050 | | <0.0050 | <0.00050 | | 0.012 | | | <0.020 |
| W6 | 8/22/2013 | | | <0.0050 | <0.000050 | 0.00017 | <0.0050 | | <0.0050 | <0.00050 | | 0.014 | | | <0.020 |
| W6 | 9/6/2013 | | | 0.007 | <0.000050 | 0.0002 | <0.0050 | | <0.0050 | <0.00050 | | 0.0061 | | | 0.03 |
| W6 | 10/7/2013 | | | 0.0916 | <0.000050 | 0.0003 | 0.0074 | | 0.0079 | 0.0006 | | 0.044 | | | 0.042 |
| W6 | 11/16/2013 | | | 0.0133 | <0.000050 | 0.00022 | <0.0050 | | <0.0050 | <0.00050 | | 0.015 | | | <0.020 |
| W6 | 12/7/2013 | | | <0.0050 | <0.000050 | 0.00046 | <0.0050 | | <0.0050 | <0.00050 | | 0.0076 | | | <0.020 |
| W7 | 5/27/2005 | | | 0.022 | <0.00020 | 0.00047 | <0.030 | | <0.0050 | | | <0.020 | | | |
| W7 | 6/30/2005 | | | <0.010 | <0.00010 | 0.000769 | 0.0013 | | <0.0020 | | | <0.020 | | | |
| W7 | 7/29/2005 | | | 0.027 | <0.00010 | 0.0012 | 0.0024 | | <0.0050 | | | <0.020 | | | |
| W7 | 8/30/2005 | | | <0.010 | <0.00020 | 0.00058 | <0.030 | | <0.0050 | | | 0.02 | | | |
| W7 | 9/28/2005 | | | 0.06 | <0.00020 | 0.00079 | <0.030 | | 0.0101 | | | <0.020 | | | |
| W7 | 10/15/2005 | | | <0.010 | <0.00010 | 0.000547 | <0.0010 | | 0.0017 | | | 0.021 | | | |
| W7 | 6/2/2006 | | | 0.378 | <0.0001 | 0.00201 | 0.0379 | | 0.0484 | | | 0.062 | | | |
| W7 | 6/8/2006 | | | 0.015 | <0.0001 | 0.000529 | 0.0035 | | 0.0048 | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Te (mg/L) | Total Th (mg/L) | Total Ti (mg/L) | Total Tl (mg/L) | Total U (mg/L) | Total V (mg/L) | Total W (mg/L) | Total Zn (mg/L) | Total Zr (mg/L) | Total N (mg/L) | Ammonia (mg/L) | Ammonium (mg/L) | Ammonium (mg/L) | NO2+NO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | 0.027 | | | |
| W7 | 6/15/2006 | | | 0.0685 | <0.00005 | 0.0008 | 0.0062 | | 0.006 | 0.001 | | | | | |
| W7 | 6/23/2006 | | | 0.257 | <0.00005 | 0.0014 | 0.0173 | | 0.022 | 0.002 | | 0.028 | | | |
| W7 | 6/28/2006 | | | 0.0822 | <0.00005 | 0.0011 | 0.0064 | | 0.006 | 0.001 | | 0.01 | | | |
| W7 | 7/7/2006 | | | 0.0044 | <0.00005 | 0.0011 | 0.001 | | <0.001 | <0.001 | | | | | |
| W7 | 7/12/2006 | | | 0.0036 | <0.00005 | 0.001 | 0.0009 | | 0.015 | <0.001 | | 0.014 | | | |
| W7 | 7/20/2006 | | | 0.0026 | <0.00005 | 0.0012 | 0.0008 | | 0.002 | <0.001 | | 0.012 | | | |
| W7 | 7/26/2006 | | | | | | | | | | | 0.016 | | | |
| W7 | 7/26/2006 | | | 0.006 | <0.00005 | 0.0012 | 0.0011 | | 0.002 | <0.001 | | | | | |
| W7 | 8/2/2006 | | | 0.004 | <0.00005 | 0.001 | 0.001 | | 0.001 | <0.001 | | 0.015 | | | |
| W7 | 8/10/2006 | | | 0.0018 | <0.00005 | 0.0009 | 0.0009 | | 0.002 | <0.001 | | 0.014 | | | |
| W7 | 8/25/2006 | | | | | | | | | | | 0.027 | | | |
| W7 | 8/25/2006 | | | <0.0010 | <0.0001 | 0.001 | 0.0009 | | 0.004 | <0.002 | | | | | |
| W7 | 8/30/2006 | | | 0.003 | <0.00005 | 0.0011 | 0.0008 | | 0.003 | <0.001 | | 0.012 | | | |
| W7 | 9/6/2006 | | | 0.0026 | <0.00005 | 0.0011 | 0.0009 | | 0.001 | <0.001 | | 0.011 | 0.011 | 0.011 | |
| W7 | 9/13/2006 | | | 0.0014 | <0.00005 | 0.0006 | 0.0005 | | <0.001 | <0.001 | | 0.011 | | | |
| W7 | 9/20/2006 | | | 0.0037 | <0.00005 | 0.0011 | 0.0009 | | 0.005 | <0.001 | | 0.008 | | | |
| W7 | 9/28/2006 | | | 0.002 | <0.0001 | 0.001 | 0.0009 | | 0.008 | <0.002 | | 0.011 | | | |
| W7 | 10/4/2006 | | | 0.0042 | <0.0001 | 0.001 | 0.001 | | <0.002 | <0.002 | | 0.079 | | | |
| W7 | 10/12/2006 | | | 0.0124 | <0.00005 | 0.0011 | 0.0014 | | 0.006 | <0.001 | | 0.024 | | | |
| W7 | 6/5/2007 | | | 0.0776 | <0.00005 | 0.0014 | 0.0054 | | 0.009 | 0.001 | | <0.05 | | | <0.1 |
| W7 | 6/5/2007 | | | 0.0898 | <0.0001 | 0.001 | 0.0059 | | 0.01 | <0.002 | | <0.05 | | | 0.28 |
| W7 | 6/5/2007 | | | 0.0915 | <0.00005 | 0.0015 | 0.006 | | 0.012 | 0.001 | | <0.05 | | | <0.1 |
| W7 | 6/20/2007 | | | 0.0055 | <0.00005 | 0.0014 | 0.0016 | | 0.004 | <0.001 | | <0.05 | | | 0.18 |
| W7 | 7/18/2007 | | | 0.0096 | <0.00005 | 0.0012 | 0.0014 | | 0.005 | <0.001 | | <0.05 | | | 0.22 |
| W7 | 7/18/2007 | | | 0.0103 | <0.00005 | 0.0013 | 0.0014 | | 0.006 | <0.001 | | <0.05 | | | 0.2 |
| W7 | 7/18/2007 | | | 0.0096 | <0.00005 | 0.0012 | 0.0013 | | 0.003 | <0.001 | | <0.05 | | | 0.2 |
| W7 | 8/24/2007 | | | | | | | | | | | <0.05 | | | |
| W7 | 8/24/2007 | | | | | | | | | | | <0.05 | | | |
| W7 | 8/24/2007 | | | | | | | | | | | <0.05 | | | |
| W7 | 8/24/2007 | | | <0.0005 | <0.00005 | 0.0012 | 0.0013 | | 0.01 | <0.001 | | | | | 0.14 |
| W7 | 8/24/2007 | | | <0.0005 | <0.00005 | 0.0012 | 0.0011 | | 0.009 | <0.001 | | | | | 0.14 |
| W7 | 8/24/2007 | | | <0.0005 | <0.00005 | 0.0013 | 0.0012 | | 0.006 | <0.001 | | | | | 0.16 |
| W7 | 8/24/2007 | | | <0.0005 | <0.00005 | 0.0012 | 0.0011 | | 0.009 | <0.001 | | | | | 0.14 |
| W7 | 8/24/2007 | | | <0.0005 | <0.00005 | 0.0013 | 0.0012 | | 0.006 | <0.001 | | | | | 0.16 |
| W7 | 9/18/2007 | | | 0.016 | <0.00005 | 0.0008 | 0.002 | | 0.008 | <0.001 | | <0.05 | | | 0.06 |
| W7 | 10/30/2007 | | | 0.0066 | <0.00005 | 0.0009 | 0.0011 | | 0.013 | <0.001 | | <0.05 | | | 0.2 |
| W7 | 10/30/2007 | | | 0.0043 | <0.00005 | 0.0009 | 0.0008 | | 0.011 | <0.001 | | <0.05 | | | 0.24 |
| W7 | 10/30/2007 | | | 0.0041 | <0.00005 | 0.0009 | 0.0008 | | 0.01 | <0.001 | | <0.05 | | | 0.19 |
| W7 | 10/30/2007 | | | | | | | | | | | | | | |
| W7 | 4/22/2008 | <0.0001 | <0.0001 | 0.0004 | <0.00001 | 0.0021 | 0.00032 | | 0.004 | <0.0001 | | <0.05 | | | <0.01 |
| W7 | 4/22/2008 | 0.0001 | 0.0002 | 0.0017 | 0.00002 | 0.0021 | 0.0003 | | 0.005 | 0.0001 | | <0.05 | | | <0.01 |
| W7 | 4/22/2008 | <0.0001 | 0.0002 | 0.0003 | 0.00001 | 0.0023 | 0.0003 | | 0.007 | 0.0002 | | <0.05 | | | <0.01 |
| W7 | 4/22/2008 | | | | | | | | | | | | | | |
| W7 | 6/3/2008 | <0.0001 | <0.0001 | 0.0128 | <0.00001 | 0.0011 | 0.00207 | | 0.004 | 0.0004 | | <0.05 | | | 0.03 |
| W7 | 6/3/2008 | <0.0001 | <0.0001 | 0.0122 | <0.00001 | 0.0011 | 0.002 | | 0.005 | 0.0005 | | <0.05 | | | 0.04 |
| W7 | 6/3/2008 | <0.0001 | <0.0001 | 0.0134 | <0.00001 | 0.0011 | 0.00224 | | 0.007 | 0.0005 | | <0.05 | | | 0.04 |
| W7 | 6/3/2008 | | | | | | | | | | | | | | |
| W7 | 6/17/2008 | <0.0001 | <0.0001 | 0.0081 | <0.00001 | 0.0014 | 0.0014 | | 0.007 | 0.0004 | | <0.05 | | | 0.14 |
| W7 | 8/6/2008 | | | 0.0357 | <0.00005 | 0.0012 | 0.0031 | | 0.01 | <0.001 | | <0.05 | | | 0.16 |
| W7 | 8/6/2008 | | | 0.0618 | <0.00005 | 0.0011 | 0.004 | | 0.011 | <0.001 | | <0.05 | | | 0.16 |
| W7 | 8/6/2008 | | | 0.0628 | <0.00005 | 0.0012 | 0.0042 | | 0.01 | <0.001 | | | | | |
| W7 | 8/6/2008 | | | | | | | | | | | <0.05 | | | 0.14 |
| W7 | 9/18/2008 | <0.0001 | <0.0001 | 0.0194 | <0.00001 | 0.0004 | 0.00224 | | 0.009 | 0.0006 | | <0.05 | | | 0.04 |
| W7 | 10/28/2008 | <0.0001 | <0.0001 | 0.0045 | <0.00001 | 0.0007 | 0.00086 | | 0.008 | 0.0003 | | <0.05 | | | 0.13 |
| W7 | 10/28/2008 | <0.0001 | <0.0001 | 0.0026 | <0.00001 | 0.0007 | 0.00073 | | 0.121 | 0.0003 | | <0.05 | | | 0.12 |
| W7 | 10/28/2008 | <0.0001 | <0.0001 | 0.002 | <0.00001 | 0.0007 | 0.00072 | | 0.049 | 0.0003 | | <0.05 | | | 0.13 |
| W7 | 10/28/2008 | | | | | | | | | | | | | | |
| W7 | 4/30/2009 | <0.0001 | <0.0001 | 0.0046 | <0.00001 | <0.0004 | 0.00037 | | 0.008 | 0.0002 | | | <0.05 | <0.05 | <0.01 |
| W7 | 6/8/2009 | <0.0001 | <0.0001 | 0.0256 | <0.00001 | 0.001 | 0.00265 | | 0.002 | 0.0005 | | | <0.05 | <0.05 | 0.15 |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | <0.0001 | <0.0004 | 0.0034 | <0.00001 | 0.0014 | 0.0009 | | 0.003 | 0.0002 | | | <0.05 | <0.05 | 0.18 |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | <0.01 | <0.01 | |
| W7 | 10/7/2009 | <0.0001 | <0.0004 | 0.0068 | <0.00001 | 0.0009 | 0.001 | | 0.008 | 0.0002 | | | <0.05 | <0.05 | 0.12 |
| W7 | 10/25/2009 | | | <0.005 | <0.00005 | 0.0013 | <0.005 | | <0.005 | <0.0005 | | 0.01 | | | 0.15 |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | <0.0001 | <0.0004 | | <0.00001 | 0.0005 | 0.0005 | | 0.008 | 0.0002 | | | 0.16 | 0.16 | 0.01 |
| W7 | 4/27/2010 | | | <0.005 | <0.00005 | 0.0001 | <0.005 | | <0.005 | <0.0005 | | 0.015 | | | <0.02 |
| W7 | 4/29/2010 | | | <0.005 | <0.00005 | 0.0001 | <0.005 | | <0.005 | <0.0005 | | 0.016 | | | <0.04 |
| W7 | 5/1/2010 | | | 0.015 | <0.00005 | 0.0002 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.031 | | | 0.08 |
| W7 | 5/3/2010 | | | 0.014 | <0.00005 | 0.0002 | <0.005 | | <0.005 | <0.0005 | | 0.016 | | | <0.02 |
| W7 | 5/5/2010 | | | 0.016 | <0.00005 | 0.0002 | <0.005 | <0.001 | 0.007 | <0.0005 | | <0.01 | | | <0.02 |
| W7 | 5/7/2010 | | | 0.016 | <0.00005 | 0.0003 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.051 | | | 0.11 |
| W7 | 5/9/2010 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | <0.001 | <0.005 | <0.0005 | | <0.005 | | | 0.07 |
| W7 | 5/10/2010 | | | <0.005 | <0.00005 | 0.0007 | <0.005 | <0.001 | 0.005 | <0.0005 | | 0.015 | | | 0.14 |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | <0.001 | 0.007 | <0.0005 | | <0.05 | | | 0.03 |
| W7 | 5/14/2010 | | | 0.008 | <0.00005 | 0.0005 | <0.005 | | <0.005 | <0.0005 | | 0.034 | | | <0.02 |
| W7 | 5/16/2010 | | | 0.008 | <0.00005 | 0.0007 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.068 | | | 0.03 |
| W7 | 5/17/2010 | | | 0.01 | <0.00005 | 0.0007 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.037 | | | <0.02 |
| W7 | 5/19/2010 | | | 0.007 | <0.00005 | 0.0008 | <0.005 | <0.001 | <0.005 | <0.0005 | | 0.02 | | | 0.06 |
| W7 | 5/21/2010 | | | 0.016 | <0.00005 | 0.0009 | <0.005 | | <0.01 | <0.002 | | 0.017 | | | 0.05 |
| W7 | 5/23/2010 | | | 0.086 | <0.00005 | 0.0012 | 0.007 | | 0.012 | <0.002 | | 0.013 | | | 0.07 |
| W7 | 5/25/2010 | | | 0.143 | 0.00005 | 0.0011 | 0.01 | | 0.017 | <0.002 | | 0.07 | | | 0.1 |
| W7 | 5/27/2010 | | | 0.285 | 0.00017 | 0.0016 | 0.024 | | 0.049 | <0.002 | | 0.052 | | | 0.13 |
| W7 | 5/29/2010 | | | 0.117 | 0.00006 | 0.0017 | 0.012 | | 0.021 | <0.002 | | 0.1 | | | 0.23 |
| W7 | 5/31/2010 | | | 0.14 | 0.00007 | 0.002 | 0.013 | | 0.023 | <0.002 | | <0.05 | | | 0.14 |
| W7 | 6/2/2010 | | | 0.105 | <0.00005 | 0.0018 | 0.01 | | 0.011 | <0.002 | | <0.01 | | | 0.17 |
| W7 | 6/4/2010 | | | 0.057 | <0.00005 | 0.0015 | 0.005 | | <0.01 | <0.002 | | 0.34 | | | 0.18 |
| W7 | 6/6/2010 | | | 0.082 | <0.00005 | 0.0018 | 0.006 | | 0.011 | <0.002 | | 0.1 | | | 0.18 |
| W7 | 6/14/2010 | | | 0.051 | <0.00005 | 0.0018 | <0.005 | | <0.01 | <0.002 | | 0.016 | | | 0.16 |
| W7 | 6/16/2010 | | | 0.016 | <0.00005 | 0.0016 | <0.005 | | <0.01 | <0.002 | | 0.016 | | | 0.17 |
| W7 | 6/18/2010 | | | 0.02 | <0.00005 | 0.0015 | <0.005 | | <0.01 | <0.002 | | | 0.052 | | 0.15 |
| W7 | 6/20/2010 | | | 0.043 | <0.00005 | 0.0014 | <0.005 | | <0.01 | <0.002 | | | | | 0.13 |
| W7 | 6/22/2010 | | | 0.174 | 0.00007 | 0.0012 | 0.017 | | 0.027 | <0.002 | | 0.014 | | | 0.12 |
| W7 | 6/24/2010 | | | 0.049 | <0.00005 | 0.0009 | 0.005 | | <0.01 | <0.002 | | 0.012 | | | 0.08 |
| W7 | 6/26/2010 | | | 0.019 | <0.00005 | 0.0009 | <0.005 | | <0.01 | <0.002 | | 0.009 | | | 0.1 |
| W7 | 6/28/2010 | | | 0.01 | <0.00005 | 0.001 | <0.005 | | <0.01 | <0.002 | | 0.022 | | | 0.13 |
| W7 | 7/5/2010 | | | 0.061 | <0.00005 | 0.0007 | <0.005 | | <0.01 | <0.002 | | 0.027 | | | 0.07 |
| W7 | 8/5/2010 | | | <0.01 | <0.00005 | 0.0008 | <0.005 | | <0.01 | <0.002 | | | | | |
| W7 | 9/12/2010 | | | 0.014 | <0.00005 | 0.0005 | <0.005 | | <0.01 | <0.002 | | | | | |
| W7 | 9/12/2010 | | | 0.012 | <0.00005 | 0.0005 | <0.005 | | <0.01 | <0.002 | | 0.039 | | | 0.03 |
| W7 | 10/8/2010 | | | <0.005 | <0.00005 | 0.0008 | <0.005 | | <0.005 | <0.0005 | | 0.069 | | | 0.07 |
| W7 | 4/27/2011 | | | <0.005 | <0.00005 | 0.0002 | <0.005 | | <0.005 | <0.0005 | | 0.01 | | | <0.02 |
| W7 | 5/2/2011 | | | 0.009 | <0.00005 | 0.0001 | <0.005 | | 0.019 | <0.0005 | | | | | <0.02 |
| W7 | 6/1/2011 | | | 0.022 | <0.00005 | 0.0007 | <0.005 | | <0.005 | <0.0005 | | 0.012 | | | |
| W7 | 6/16/2011 | | | 0.114 | <0.00005 | 0.0007 | 0.008 | | 0.013 | 0.0007 | | 0.013 | | | 0.1 |
| W7 | 7/1/2011 | | | 0.126 | <0.00005 | 0.0009 | 0.015 | | 0.016 | 0.0012 | | 0.016 | | | 0.05 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Total Te (mg/L) | Total Th (mg/L) | Total Ti (mg/L) | Total Tl (mg/L) | Total U (mg/L) | Total V (mg/L) | Total W (mg/L) | Total Zn (mg/L) | Total Zr (mg/L) | Total N (mg/L) | Ammonia (mg/L) | Ammonium (mg/L) | Ammonium (mg/L) | NO2+NO3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | | | 0.354 | 0.00008 | 0.0009 | 0.031 | | 0.029 | 0.002 | | | | | 0.06 |
| W7 | 8/16/2011 | | | 0.016 | <0.00005 | 0.0005 | <0.005 | | 0.017 | 0.0005 | | 0.015 | | | 0.06 |
| W7 | 8/19/2011 | | | 0.02 | <0.00005 | 0.0004 | <0.005 | | <0.005 | <0.0005 | | 0.006 | | | 0.04 |
| W7 | 9/12/2011 | | | <0.005 | <0.00005 | 0.0005 | <0.005 | | <0.005 | <0.0005 | | 0.025 | | | 0.05 |
| W7 | 10/6/2011 | | | <0.005 | <0.00005 | 0.0006 | <0.005 | | <0.005 | <0.0005 | | 0.019 | | | 0.11 |
| W7 | 11/22/2011 | | | 0.02 | <0.00005 | 0.001 | <0.005 | | 0.009 | <0.0005 | | 0.0214 | | | 0.136 |
| W7 | 1/24/2012 | | | <0.005 | <0.00005 | 0.0019 | <0.005 | | <0.005 | <0.0005 | | 0.005 | | | 0.324 |
| W7 | 2/25/2012 | | | <0.005 | <0.00005 | 0.0015 | <0.005 | | <0.005 | <0.0005 | | 0.006 | | | 0.289 |
| W7 | 3/5/2012 | | | <0.005 | <0.00005 | 0.0015 | <0.005 | | <0.005 | <0.0005 | | 0.0067 | | | 0.195 |
| W7 | 4/24/2012 | | | 0.0264 | <0.000050 | 0.00018 | <0.0050 | | <0.0050 | <0.00050 | | <0.0050 | | | 0.02 |
| W7 | 5/6/2012 | | | 0.0055 | <0.000050 | <0.00010 | <0.0050 | | <0.0050 | <0.00050 | | 0.01 | | | <0.020 |
| W7 | 5/6/2012 | | | 0.0062 | <0.000050 | <0.00010 | <0.0050 | | <0.0050 | <0.00050 | | 0.011 | | | <0.020 |
| W7 | 6/19/2012 | | | 0.182 | 0.00005 | 0.00072 | 0.0164 | | 0.015 | 0.00125 | | 0.18 | | | 0.098 |
| W7 | 7/17/2012 | | | 0.0379 | <0.000050 | 0.00076 | <0.0050 | | <0.0050 | <0.00050 | | 0.065 | | | 0.089 |
| W7 | 7/30/2012 | | | 0.0092 | <0.000050 | 0.00088 | <0.0050 | | 0.0063 | <0.00050 | | 0.13 | | | 0.124 |
| W7 | 8/8/2012 | | | <0.0050 | <0.000050 | 0.00087 | <0.0050 | | <0.0050 | <0.00050 | | 0.014 | | | 0.13 |
| W7 | 8/23/2012 | | | <0.0050 | <0.000050 | 0.00097 | <0.0050 | | <0.0050 | <0.00050 | | 0.049 | | | 0.21 |
| W7 | 9/13/2012 | | | <0.0050 | <0.000050 | 0.00054 | <0.0050 | | 0.0055 | <0.00050 | | 0.0087 | | | 0.078 |
| W7 | 10/16/2012 | | | 0.0061 | <0.000050 | 0.00084 | <0.0050 | | <0.0050 | <0.00050 | | 0.028 | | | 0.125 |
| W7 | 11/2/2012 | | | <0.0050 | <0.000050 | 0.00137 | <0.0050 | | 0.0062 | <0.00050 | | 0.026 | | | 0.219 |
| W7 | 12/29/2012 | | | <0.0050 | <0.000050 | 0.00121 | <0.0050 | | <0.0050 | <0.00050 | | 0.025 | | | 0.063 |
| W7 | 4/30/2013 | | | <0.0050 | <0.000050 | 0.00209 | <0.0050 | | <0.0050 | <0.00050 | | 0.0082 | | | 0.132 |
| W7 | 5/14/2013 | | | 0.0551 | <0.000050 | 0.00016 | <0.0050 | | 0.0059 | <0.00050 | | 0.066 | | | <0.020 |
| W7 | 6/19/2013 | | | 0.0122 | <0.000050 | 0.001 | <0.0050 | | <0.0050 | <0.00050 | | 0.052 | | | 0.143 |
| W7 | 6/19/2013 | | | 0.0094 | <0.000050 | 0.00097 | <0.0050 | | <0.0050 | <0.00050 | | 0.04 | | | 0.141 |
| W7 | 7/13/2013 | | | 0.0073 | <0.000050 | 0.001 | <0.0050 | | <0.0050 | <0.00050 | | 0.023 | | | 0.17 |
| W7 | 8/21/2013 | | | 0.0086 | <0.000050 | 0.00114 | <0.0050 | | <0.0050 | <0.00050 | | 0.051 | | | 0.157 |
| W7 | 9/6/2013 | | | 0.0127 | <0.000050 | 0.00095 | <0.0050 | | <0.0050 | <0.00050 | | 0.017 | | | 0.128 |
| W7 | 10/21/2013 | | | <0.0050 | <0.000050 | 0.00083 | <0.0050 | | <0.0050 | <0.00050 | | 0.048 | | | 0.168 |
| W7 | 11/16/2013 | | | <0.0050 | <0.000050 | 0.00148 | <0.0050 | | <0.0050 | <0.00050 | | 0.027 | | | 0.257 |
| W7 | 12/7/2013 | | | <0.0050 | <0.000050 | 0.00139 | <0.0050 | | <0.0050 | <0.00050 | | 0.025 | | | 0.206 |
| C4 | 5/6/2012 | | | 1.21 | 0.000244 | 0.00209 | 0.0946 | | 0.0961 | 0.00346 | | 0.088 | | | 0.029 |
| C4 | 8/1/2012 | | | 0.248 | 0.000063 | 0.00116 | 0.0276 | | 0.0272 | 0.0016 | | 0.089 | | | 0.091 |
| C4 | 8/8/2012 | | | 0.254 | 0.000066 | 0.00144 | 0.0292 | | 0.0279 | 0.00138 | | 0.09 | | | 0.107 |
| C4 | 8/25/2012 | | | 0.08 | <0.000050 | 0.00159 | 0.0377 | | 0.0325 | 0.00202 | | 0.005 | | | <0.020 |
| C4 | 6/22/2013 | | | 0.8 | <0.000050 | 0.00305 | 0.0731 | | 0.0872 | 0.00409 | | 0.36 | | | 0.377 |
| C4 | 7/19/2013 | | | 0.466 | 0.000122 | 0.00277 | 0.0477 | | 0.0502 | 0.00309 | | 0.26 | | | 0.089 |
| C4 | 8/22/2013 | | | 0.497 | 0.000103 | 0.00228 | 0.055 | | 0.0597 | 0.003 | | 0.2 | | | 0.095 |
| C4 | 9/6/2013 | | | 0.237 | 0.000053 | 0.00119 | 0.0188 | | 0.0172 | 0.00149 | | 0.12 | | | 0.07 |
| C4 | 10/18/2013 | | | 0.0165 | <0.000050 | 0.00083 | <0.0050 | | <0.0050 | <0.00050 | | 0.091 | | | 0.069 |
| C4 | 10/18/2013 | | | 0.017 | <0.000050 | 0.00079 | <0.0050 | | <0.0050 | <0.00050 | | 0.08 | | | 0.065 |
| C4 | 11/17/2013 | | | 0.006 | <0.000050 | 0.00063 | <0.0050 | | <0.0050 | 0.001 | | 0.28 | | | <0.20 |
| C10 | 5/12/2012 | | | 1.17 | 0.000369 | 0.00532 | 0.142 | | 0.186 | 0.00514 | | 0.18 | | | 0.058 |
| C10 | 7/30/2012 | | | 0.571 | 0.000202 | 0.00449 | 0.0653 | | 0.0956 | 0.0033 | | 0.2 | | | 0.207 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | | | 0.554 | 0.000202 | 0.00407 | 0.0718 | | 0.105 | 0.00332 | | 0.12 | | | 0.196 |
| C10 | 8/27/2012 | | | 0.805 | 0.000241 | 0.00375 | 0.0836 | | 0.119 | 0.00453 | | <0.0050 | | | 0.103 |
| C10 | 6/22/2013 | | | 0.0562 | <0.000050 | 0.00114 | 0.0053 | | 0.0055 | 0.00094 | | 0.19 | | | 0.172 |
| C10 | 7/23/2013 | | | 0.179 | 0.000067 | 0.00113 | 0.0156 | | 0.0198 | 0.0017 | | 0.14 | | | <0.20 |
| C10 | 8/22/2013 | | | 0.0342 | <0.000050 | 0.00119 | <0.0050 | | <0.0050 | 0.00065 | | 0.056 | | | 0.143 |
| C10 | 9/8/2013 | | | 0.017 | <0.000050 | 0.00099 | <0.0050 | | <0.0050 | <0.00050 | | 0.046 | | | 0.183 |
| C10 | 9/8/2013 | | | 0.0166 | <0.000050 | 0.00099 | <0.0050 | | <0.0050 | <0.00050 | | 0.055 | | | 0.199 |
| C10 | 10/18/2013 | | | 0.0427 | <0.000050 | 0.00091 | <0.0050 | | 0.0054 | 0.00051 | | 0.1 | | | 0.167 |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | N-NO2 (mg/L) | N-NO3 (mg/L) | N-TKN (mg/L) | P-PO4-T (mg/L) | P-TDP (mg/L) | P-TRP (Ortho) (mg/L) | C-TIC (mg/L) | C-TOC (mg/L) | C-DOC (mg/L) | Cation Sum (meq/L) | Anion Sum (meq/L) | Hardness (CaCO3) (mg/L) | Acidity (pH 4.5) (mg/L) | Acidity pH 8.3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | 0.002 | 0.0539 | | | | | | | | | | | | |
| W1 | 6/30/2005 | <0.0010 | 0.0626 | | | | | | | | | | | | |
| W1 | 7/28/2005 | <0.0010 | 0.0584 | | | | | | | | | | | | |
| W1 | 8/29/2005 | <0.0010 | 0.0217 | | | | | | | | | | | | |
| W1 | 9/28/2005 | <0.0010 | 0.0482 | | | | | | | | | | | | |
| W1 | 10/15/2005 | <0.0010 | 0.132 | | | | | | | | | | | | |
| W2 | 5/27/2005 | 0.0015 | 0.0565 | | | | | | | | | | | | |
| W2 | 5/27/2005 | <0.001 | 0.0339 | | | | | | | | | | | | |
| W2 | 6/30/2005 | <0.0010 | 0.0621 | | | | | | | | | | | | |
| W2 | 7/28/2005 | <0.0010 | 0.0124 | | | | | | | | | | | | |
| W2 | 8/30/2005 | <0.0010 | 0.0141 | | | | | | | | | | | | |
| W2 | 9/28/2005 | 0.001 | 0.0458 | | | | | | | | | | | | |
| W2 | 10/15/2005 | <0.0010 | 0.133 | | | | | | | | | | | | |
| W3 | 5/27/2005 | <0.0010 | 0.0121 | | | | | | | | | | | | |
| W3 | 6/30/2005 | <0.0010 | 0.0519 | | | | | | | | | | | | |
| W3 | 7/29/2005 | <0.0010 | 0.0284 | | | | | | | | | | | | |
| W3 | 8/29/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W3 | 9/28/2005 | <0.0010 | 0.0132 | | | | | | | | | | | | |
| W3 | 10/15/2005 | <0.0010 | 0.0393 | | | | | | | | | | | | |
| W8 | 5/27/2005 | <0.0010 | 0.0225 | | | | | | | | | | | | |
| W8 | 6/30/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W8 | 7/29/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W8 | 8/30/2005 | 0.0011 | <0.0050 | | | | | | | | | | | | |
| W8 | 9/28/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W8 | 10/15/2005 | <0.0010 | 0.0374 | | | | | | | | | | | | |
| W9 | 5/27/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W9 | 6/30/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W9 | 7/29/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W9 | 8/29/2005 | 0.0016 | <0.0050 | | | | | | | | | | | | |
| W9 | 9/28/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W9 | 10/15/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W10 | 5/27/2005 | <0.0010 | 0.0094 | | | | | | | | | | | | |
| W10 | 5/27/2005 | <0.001 | | | | | | | | | | | | | |
| W10 | 6/30/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W10 | 7/29/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W10 | 8/29/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W10 | 9/28/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W10 | 10/15/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W6 | 5/27/2005 | 0.0016 | 0.0316 | | | | | | | | | | | | |
| W6 | 6/30/2005 | <0.0010 | 0.0086 | | | | | | | | | | | | |
| W6 | 7/29/2005 | <0.0010 | 0.0223 | | | | | | | | | | | | |
| W6 | 8/30/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W6 | 9/28/2005 | <0.0010 | <0.0050 | | | | | | | | | | | | |
| W6 | 10/15/2005 | <0.0010 | 0.0061 | | | | | | | | | | | | |
| W6 | 6/2/2006 | <0.001 | 0.0241 | | | | | | | | | | | | |
| W6 | 8/25/2006 | | <0.03 | | | | | | | | | | | | |
| W6 | 9/6/2006 | | <0.03 | | | | | | | | | | | | |
| W6 | 6/20/2007 | <0.05 | 0.1 | 0.6 | 0.14 | <0.02 | | | | | | | | | |
| W6 | 9/18/2007 | <0.02 | <0.02 | 0.3 | 0.04 | <0.02 | | | | | | | | | |
| W6 | 6/17/2008 | 0.07 | 0.01 | 0.44 | 0.07 | | | | | | | | | | |
| W6 | 9/18/2008 | <0.01 | <0.01 | 0.47 | <0.05 | | 0.1 | | 17.3 | 17.7 | | | | | |
| W6 | 4/14/2009 | | | 5.73 | 0.06 | | | | | | | | | | |
| W6 | 4/30/2009 | | | 1.22 | 0.05 | | | | | | | | | | |
| W6 | 7/28/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | | 2.92 | 0.5 | 0.02 | | <0.05 | | | | | | | | |
| W6 | 8/18/2009 | | | | | | | | | | | | | | |
| W6 | 8/25/2009 | | | | | | | | 9.2 | 7.9 | | | | | |
| W6 | 10/7/2009 | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | | 8.09 | 0.54 | 0.05 | | | | 6.4 | 6.3 | | | | | |
| W6 | 10/25/2009 | 0.061 | 7.8 | | | | <0.005 | | | | | | | | |
| W6 | 4/19/2010 | | | 0.53 | 0.05 | | | | | | | | | | |
| W6 | 5/16/2010 | <0.005 | <0.02 | | | | <0.005 | | | 5.3 | | | | | |
| W6 | 5/17/2010 | <0.005 | <0.02 | | | | <0.005 | | | 2.9 | | | | | |
| W6 | 5/19/2010 | <0.005 | <0.02 | | | | <0.005 | | | 3.4 | | | | | |
| W6 | 5/21/2010 | <0.005 | <0.02 | | | | <0.005 | | | 1.6 | | | | | |
| W6 | 5/23/2010 | <0.005 | <0.02 | | | | <0.005 | | | 5.2 | | | | | |
| W6 | 5/25/2010 | <0.005 | <0.02 | | | | <0.005 | | | 5.7 | | | | | |
| W6 | 5/29/2010 | <0.005 | <0.02 | | | | <0.005 | | | 1.4 | | | | | |
| W6 | 6/2/2010 | <0.005 | 0.97 | | | | <0.005 | | | 3.7 | | | | | |
| W6 | 6/4/2010 | <0.005 | <0.02 | | | | <0.005 | | | 6.7 | | | | | |
| W6 | 6/6/2010 | <0.005 | <0.02 | | | | <0.005 | | | | | | | | |
| W6 | 6/14/2010 | <0.005 | <0.02 | | | | <0.005 | | | 7.2 | | | | | |
| W6 | 6/16/2010 | <0.005 | 0.03 | | | | <0.005 | | | 7.9 | | | | | |
| W6 | 6/18/2010 | <0.005 | <0.02 | | | | <0.005 | | | 7.7 | | | | | |
| W6 | 6/20/2010 | <0.005 | 0.02 | | | | <0.005 | | | 7.8 | | | | | |
| W6 | 6/22/2010 | <0.005 | <0.02 | | | | <0.005 | | 8.6 | 7.8 | | | | | |
| W6 | 6/24/2010 | <0.005 | <0.02 | | | | <0.005 | | 8.2 | 7.9 | | | | | |
| W6 | 6/26/2010 | <0.005 | <0.02 | | | | <0.005 | | 7.8 | 7.7 | | | | | |
| W6 | 6/26/2010 | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | <0.005 | <0.02 | | | | <0.005 | | | 7.8 | | | | | |
| W6 | 7/5/2010 | <0.005 | <0.02 | | | | <0.005 | | | 15 | | | | | |
| W6 | 8/5/2010 | <0.005 | <0.02 | | | | <0.005 | | | 13 | | | | | |
| W6 | 9/9/2010 | <0.005 | <0.02 | | | | <0.005 | | | 12.9 | | | | | |
| W6 | 10/8/2010 | <0.005 | <0.02 | | | | <0.005 | | | 13.2 | | | | | |
| W6 | 8/19/2011 | <0.005 | 1.05 | | | | | | | 8.4 | | | | | |
| W6 | 7/17/2012 | <0.0050 | 0.026 | | 1.01 | | | | | 7.98 | | | | | |
| W6 | 7/30/2012 | 0.0072 | 0.052 | | 0.599 | | | | | 8.08 | | | | | |
| W6 | 8/9/2012 | 0.0066 | 0.022 | | | | | | | | | | | | |
| W6 | 8/25/2012 | <0.0050 | 0.045 | | | | | | | 7.68 | | | | | |
| W6 | 9/13/2012 | <0.0050 | 0.034 | | | | | | 13.1 | 14.4 | | | | | |
| W6 | 10/13/2012 | <0.0050 | 0.042 | | | | | | | 9.91 | | | | | |
| W6 | 11/12/2012 | <0.0050 | <0.020 | | | | | | | 8.74 | | | | | |
| W6 | 5/14/2013 | <0.0050 | <0.020 | | | | | | | 22.2 | | | | | |
| W6 | 6/22/2013 | 0.0132 | 0.028 | | | | | | | 7.79 | | | | | |
| W6 | 7/12/2013 | <0.0050 | <0.020 | | | | | | | 8.29 | | | | | |
| W6 | 8/22/2013 | <0.0050 | <0.020 | | | | | | | 7.4 | | | | | |
| W6 | 9/6/2013 | <0.0050 | 0.03 | | | | | | | 6.36 | | | | | |
| W6 | 10/7/2013 | <0.0050 | 0.042 | | | | | | | 8.17 | | | | | |
| W6 | 11/16/2013 | <0.0050 | <0.020 | | | | | | | 8.79 | | | | | |
| W6 | 12/7/2013 | <0.0050 | <0.020 | | | | | | | 8.77 | | | | | |
| W7 | 5/27/2005 | 0.0018 | 0.0824 | | | | | | | | | | | | |
| W7 | 6/30/2005 | 0.0017 | 0.172 | | | | | | | | | | | | |
| W7 | 7/29/2005 | <0.0010 | 0.169 | | | | | | | | | | | | |
| W7 | 8/30/2005 | <0.0010 | 0.0226 | | | | | | | | | | | | |
| W7 | 9/28/2005 | <0.0010 | 0.0586 | | | | | | | | | | | | |
| W7 | 10/15/2005 | <0.0010 | 0.102 | | | | | | | | | | | | |
| W7 | 6/2/2006 | 0.0015 | 0.0449 | | | | | | | | | | | | |
| W7 | 6/8/2006 | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | N-NO2 (mg/L) | N-NO3 (mg/L) | N-TKN (mg/L) | P-PO4-T (mg/L) | P-TDP (mg/L) | P-TRP (Ortho) (mg/L) | C-TIC (mg/L) | C-TOC (mg/L) | C-DOC (mg/L) | Cation Sum (meq/L) | Anion Sum (meq/L) | Hardness (CaCO3) (mg/L) | Acidity (pH 4.5) (mg/L) | Acidity pH 8.3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | | 0.18 | | | | | | | | | | | | |
| W7 | 6/23/2006 | | 0.23 | | | | | | | | | | | | |
| W7 | 6/28/2006 | | 0.112 | | | | | | | | | | | | |
| W7 | 7/7/2006 | | 0.205 | | | | | | | | | | | | |
| W7 | 7/12/2006 | | 0.18 | | | | | | | | | | | | |
| W7 | 7/20/2006 | | 0.19 | | | | | | | | | | | | |
| W7 | 7/26/2006 | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | | 0.18 | | | | | | | | | | | | |
| W7 | 8/2/2006 | | 0.15 | | | | | | | | | | | | |
| W7 | 8/10/2006 | | 0.16 | | | | | | | | | | | | |
| W7 | 8/25/2006 | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | | 0.12 | | | | | | | | | | | | |
| W7 | 8/30/2006 | | 0.11 | | | | | | | | | | | | |
| W7 | 9/6/2006 | | 0.08 | | | | | | | | | | | | |
| W7 | 9/13/2006 | | 0.094 | | | | | | | | | | | | |
| W7 | 9/20/2006 | | 0.11 | | | | | | | | | | | | |
| W7 | 9/28/2006 | | 0.08 | | | | | | | | | | | | |
| W7 | 10/4/2006 | | 0.1 | | | | | | | | | | | | |
| W7 | 10/12/2006 | | 0.12 | | | | | | | | | | | | |
| W7 | 6/5/2007 | <0.05 | <0.1 | 0.5 | 0.15 | <0.02 | | | | | | | | | |
| W7 | 6/5/2007 | 0.05 | <0.1 | 0.11 | 0.12 | <0.02 | | | | | | | | | |
| W7 | 6/5/2007 | <0.05 | <0.1 | 0.4 | 0.13 | <0.02 | | | | | | | | | |
| W7 | 6/20/2007 | <0.05 | 0.3 | 0.3 | 0.05 | <0.02 | | | | 8.2 | | | | | |
| W7 | 7/18/2007 | <0.05 | 0.3 | 0.31 | <0.05 | <0.02 | 0.05 | | | 14.3 | | | | | |
| W7 | 7/18/2007 | <0.05 | 0.3 | 0.36 | 0.05 | <0.02 | 0.05 | | | | | | | | |
| W7 | 7/18/2007 | <0.05 | 0.3 | 0.33 | 0.06 | <0.02 | 0.05 | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | <0.05 | 0.2 | 0.3 | 0.04 | <0.02 | | | | | | | | | |
| W7 | 8/24/2007 | <0.05 | 0.2 | 0.26 | 0.04 | <0.02 | | | | | | | | | |
| W7 | 8/24/2007 | <0.05 | 0.2 | 0.24 | 0.04 | <0.02 | | | | | | | | | |
| W7 | 8/24/2007 | <0.05 | 0.2 | 0.26 | 0.04 | <0.02 | | | | | | | | | |
| W7 | 8/24/2007 | <0.05 | 0.2 | 0.24 | 0.04 | <0.02 | | | | | | | | | |
| W7 | 9/18/2007 | <0.02 | 0.05 | 0.38 | 0.07 | <0.02 | | | | 11 | | | | | |
| W7 | 10/30/2007 | 0.14 | <0.02 | 0.51 | <0.02 | <0.02 | <0.01 | | | | | | | | |
| W7 | 10/30/2007 | 0.14 | <0.02 | 0.46 | 0.02 | <0.02 | <0.01 | | | | | | | | |
| W7 | 10/30/2007 | 0.13 | <0.02 | 0.54 | 0.02 | <0.02 | <0.01 | | | | | | | | |
| W7 | 10/30/2007 | 0.13 | <0.02 | | 0.02 | <0.02 | <0.01 | | | | | | | | |
| W7 | 4/22/2008 | 0.07 | <0.02 | 2.02 | <0.05 | | 0.09 | | | | | | | | |
| W7 | 4/22/2008 | 0.04 | <0.02 | 0.34 | <0.05 | | 0.09 | | | | | | | | |
| W7 | 4/22/2008 | 0.07 | <0.02 | 0.24 | <0.05 | | 0.09 | | | | | | | | |
| W7 | 4/22/2008 | 0.04 | <0.02 | | | | | | | | | | | | |
| W7 | 6/3/2008 | 0.04 | 0.03 | 0.38 | <0.05 | | 0.04 | | | | | | | | |
| W7 | 6/3/2008 | 0.04 | 0.04 | 0.45 | <0.05 | | 0.04 | | | | | | | | |
| W7 | 6/3/2008 | 0.04 | 0.04 | 0.4 | <0.05 | | 0.04 | | | | | | | | |
| W7 | 6/3/2008 | | | | | <0.01 | | | | | | | | | |
| W7 | 6/17/2008 | 0.05 | 0.14 | 0.34 | 0.06 | | | | 6.8 | | | | | | |
| W7 | 8/6/2008 | <0.01 | 0.14 | 0.38 | <0.05 | | 0.06 | | | | | | | | |
| W7 | 8/6/2008 | <0.01 | 0.14 | 0.32 | 0.08 | | 0.06 | | | | | | | | |
| W7 | 8/6/2008 | <0.01 | 0.15 | | <0.05 | | | | | | | | | | |
| W7 | 8/6/2008 | | | 0.32 | 0.05 | | 0.06 | | 9.3 | 9 | | | | | |
| W7 | 9/18/2008 | <0.01 | 0.03 | 0.51 | <0.05 | | 0.09 | | 17.6 | 17.4 | | | | | |
| W7 | 10/28/2008 | | | 0.33 | <0.05 | | 0.08 | | | | | | | | |
| W7 | 10/28/2008 | | | 0.37 | <0.05 | | 0.08 | | | | | | | | |
| W7 | 10/28/2008 | | | 0.32 | <0.05 | | 0.08 | | | | | | | | |
| W7 | 10/28/2008 | | | | | | | | 10.7 | 11 | | | | | |
| W7 | 4/30/2009 | | | 0.76 | 0.06 | | | | 17.6 | 17.6 | | | | | |
| W7 | 6/8/2009 | | | 0.49 | 0.03 | | | | 9.4 | 9.2 | | | | | |
| W7 | 7/28/2009 | | | | | | | | | | | | | | |
| W7 | 8/6/2009 | | 0.18 | 0.24 | 0.02 | | <0.05 | | | | | | | | |
| W7 | 8/24/2009 | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | 9.4 | 8.2 | | | | | |
| W7 | 8/31/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | | 0.12 | 0.35 | 0.07 | | | | 8.1 | 6.9 | | | | | |
| W7 | 10/25/2009 | <0.005 | 0.15 | | | | <0.005 | | 7.5 | 8.7 | | | | | |
| W7 | 10/25/2009 | | | | | | | | | | | | | | |
| W7 | 4/19/2010 | | | 0.82 | 0.06 | | | | | | | | | | |
| W7 | 4/27/2010 | <0.005 | <0.02 | | | | 0.008 | | | 22.7 | | | | | |
| W7 | 4/29/2010 | <0.01 | <0.04 | | | | <0.005 | | | 19.3 | | | | | |
| W7 | 5/1/2010 | 0.008 | 0.07 | | | | <0.005 | | | 19 | | | | | |
| W7 | 5/3/2010 | <0.005 | <0.02 | | | | <0.005 | | | 22.2 | | | | | |
| W7 | 5/5/2010 | <0.005 | <0.02 | | | | <0.005 | | | 14.5 | | | | | |
| W7 | 5/7/2010 | 0.007 | 0.1 | | | | <0.005 | | | 12.8 | | | | | |
| W7 | 5/9/2010 | <0.005 | 0.07 | | | | <0.005 | | | 13.2 | | | | | |
| W7 | 5/10/2010 | 0.006 | 0.13 | | | | <0.005 | | | 11.7 | | | | | |
| W7 | 5/12/2010 | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | <0.005 | 0.03 | | | | <0.005 | | | 10.4 | | | | | |
| W7 | 5/14/2010 | <0.005 | <0.02 | | | | <0.005 | | | 9.2 | | | | | |
| W7 | 5/16/2010 | <0.005 | 0.03 | | | | <0.005 | | | 8.8 | | | | | |
| W7 | 5/17/2010 | <0.005 | <0.02 | | | | <0.005 | | | 7.2 | | | | | |
| W7 | 5/19/2010 | <0.005 | 0.06 | | | | <0.005 | | | 7.5 | | | | | |
| W7 | 5/21/2010 | <0.005 | 0.05 | | | | <0.005 | | | 8.7 | | | | | |
| W7 | 5/23/2010 | 0.006 | 0.06 | | | | <0.005 | | | 8.2 | | | | | |
| W7 | 5/25/2010 | 0.025 | 0.08 | | | | <0.005 | | | 8.1 | | | | | |
| W7 | 5/27/2010 | <0.005 | 0.13 | | | | <0.005 | | | 8.1 | | | | | |
| W7 | 5/29/2010 | 0.011 | 0.22 | | | | <0.005 | | | 6.3 | | | | | |
| W7 | 5/31/2010 | 0.023 | 0.12 | | | | <0.005 | | | 7.2 | | | | | |
| W7 | 6/2/2010 | 0.023 | 0.14 | | | | <0.005 | | | 4.9 | | | | | |
| W7 | 6/4/2010 | 0.014 | 0.16 | | | | <0.005 | | | 6.4 | | | | | |
| W7 | 6/6/2010 | 0.013 | 0.16 | | | | <0.005 | | | | | | | | |
| W7 | 6/14/2010 | <0.005 | 0.16 | | | | <0.005 | | | 5.9 | | | | | |
| W7 | 6/16/2010 | <0.005 | 0.17 | | | | <0.005 | | | 6.1 | | | | | |
| W7 | 6/18/2010 | <0.005 | 0.15 | | | | <0.005 | | | 6.2 | | | | | |
| W7 | 6/20/2010 | 0.008 | 0.13 | | | | <0.005 | | | 7.6 | | | | | |
| W7 | 6/22/2010 | <0.005 | 0.12 | | | | <0.005 | | 10.5 | 10.4 | | | | | |
| W7 | 6/24/2010 | 0.007 | 0.07 | | | | <0.005 | | 10.5 | 10.2 | | | | | |
| W7 | 6/26/2010 | <0.005 | 0.1 | | | | <0.005 | | 9.2 | 9.3 | | | | | |
| W7 | 6/28/2010 | <0.005 | 0.13 | | | | <0.005 | | | 8.7 | | | | | |
| W7 | 7/5/2010 | <0.005 | 0.07 | | | | <0.005 | | | 16.1 | | | | | |
| W7 | 8/5/2010 | | | | | | | | | 13.2 | | | | | |
| W7 | 9/12/2010 | | | | | | | | | | | | | | |
| W7 | 9/12/2010 | <0.005 | 0.03 | | | | <0.005 | | 17.4 | 16.7 | | | | | |
| W7 | 10/8/2010 | <0.005 | 0.07 | | | | <0.005 | | | 12.7 | | | | | |
| W7 | 4/27/2011 | <0.005 | <0.02 | | | | | | 22 | 23 | | | | | |
| W7 | 5/2/2011 | <0.005 | <0.02 | | | | | | | 22 | | | | | |
| W7 | 6/1/2011 | | | | | | | | | 10.7 | | | | | |
| W7 | 6/16/2011 | <0.005 | 0.1 | | | | | | | 12.6 | | | | | |
| W7 | 7/1/2011 | 0.007 | 0.05 | | | | | | | 21.1 | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | N-NO2 (mg/L) | N-NO3 (mg/L) | N-TKN (mg/L) | P-PO4-T (mg/L) | P-TDP (mg/L) | P-TRP (Ortho) (mg/L) | C-TIC (mg/L) | C-TOC (mg/L) | C-DOC (mg/L) | Cation Sum (meq/L) | Anion Sum (meq/L) | Hardness (CaCO3) (mg/L) | Acidity (pH 4.5) (mg/L) | Acidity pH 8.3 (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | <0.005 | 0.06 | | | | | | | 24.2 | | | | | |
| W7 | 8/16/2011 | <0.005 | 0.06 | | | | | | | 18.3 | | | | | |
| W7 | 8/19/2011 | <0.005 | 0.04 | | | | | | | 18.8 | | | | | |
| W7 | 9/12/2011 | <0.005 | 0.05 | | | | | | 14 | 13.2 | | | | | |
| W7 | 10/6/2011 | <0.005 | 0.11 | | | | | | 11.5 | 11.7 | | | | | |
| W7 | 11/22/2011 | <0.005 | 0.136 | | | | | | 7.69 | 7.73 | | | | | |
| W7 | 1/24/2012 | <0.005 | 0.324 | | | | | | | 5.33 | | | | | |
| W7 | 2/25/2012 | <0.005 | 0.289 | | | | <0.0050 | | | 6.08 | | | | | |
| W7 | 3/5/2012 | <0.005 | 0.195 | | | | | | | 5.17 | | | | | |
| W7 | 4/24/2012 | 0.0101 | <0.020 | | 0.0566 | | | | 13.3 | 13.6 | | | | | |
| W7 | 5/6/2012 | <0.0050 | <0.020 | | 0.0297 | | | | | 17.4 | | | | | |
| W7 | 5/6/2012 | <0.0050 | <0.020 | | 0.0303 | | | | | 17 | | | | | |
| W7 | 6/19/2012 | 0.0148 | 0.083 | | 0.176 | | | | 19.2 | 16.2 | | | | | |
| W7 | 7/17/2012 | <0.0050 | 0.089 | | 0.078 | | | | | 13.3 | | | | | |
| W7 | 7/30/2012 | <0.0050 | 0.124 | | 0.0432 | | | | | 12.7 | | | | | |
| W7 | 8/8/2012 | <0.0050 | 0.13 | | | | | | | 12.6 | | | | | |
| W7 | 8/23/2012 | <0.050 | 0.21 | | 0.0322 | | | | 11.3 | 10.3 | | | | | |
| W7 | 9/13/2012 | <0.0050 | 0.078 | | | | | | 16.3 | 16.3 | | | | | |
| W7 | 10/16/2012 | <0.0050 | 0.125 | | | | | | 12.1 | 12.6 | | | | | |
| W7 | 11/2/2012 | <0.0050 | 0.219 | | 0.0227 | | | | | 8.19 | | | | | |
| W7 | 12/29/2012 | <0.0050 | 0.063 | | | | | | | 10.2 | | | | | |
| W7 | 4/30/2013 | <0.0050 | 0.132 | | | | | | 4.71 | 4.64 | | | | | |
| W7 | 5/14/2013 | <0.0050 | <0.020 | | | | | | | 15.3 | | | | | |
| W7 | 6/19/2013 | <0.0050 | 0.143 | | | | | | | 11.3 | | | | | |
| W7 | 6/19/2013 | <0.0050 | 0.141 | | | | | | | 10.5 | | | | | |
| W7 | 7/13/2013 | <0.0050 | 0.17 | | | | | | | 9.88 | | | | | |
| W7 | 8/21/2013 | <0.0050 | 0.157 | | | | | | | 9.84 | | | | | |
| W7 | 9/6/2013 | <0.0050 | 0.128 | | | | | | | 11 | | | | | |
| W7 | 10/21/2013 | <0.0050 | 0.168 | | | | | | | 11.9 | | | | | |
| W7 | 11/16/2013 | <0.0050 | 0.257 | | | | | | | 7.47 | | | | | |
| W7 | 12/7/2013 | <0.0050 | 0.206 | | | | | | | 7.3 | | | | | |
| C4 | 5/6/2012 | <0.0050 | 0.029 | | 1.21 | | | | | 10.5 | | | | | |
| C4 | 8/1/2012 | 0.0177 | 0.074 | | 0.386 | | | | | 16.2 | | | | | |
| C4 | 8/8/2012 | 0.012 | 0.095 | | | | | | | | | | | | |
| C4 | 8/25/2012 | <0.0050 | <0.020 | | | | | | | <0.50 | | | | | |
| C4 | 6/22/2013 | 0.0066 | 0.371 | | | | | | | 17.4 | | | | | |
| C4 | 7/19/2013 | 0.0069 | 0.082 | | | | | | | | | | | | |
| C4 | 8/22/2013 | 0.0084 | 0.086 | | | | | | | 18.9 | | | | | |
| C4 | 9/6/2013 | <0.0050 | 0.07 | | | | | | | 15.1 | | | | | |
| C4 | 10/18/2013 | <0.0050 | 0.069 | | | | | | | 12.7 | | | | | |
| C4 | 10/18/2013 | <0.0050 | 0.065 | | | | | | | 12.5 | | | | | |
| C4 | 11/17/2013 | <0.050 | <0.20 | | | | | | | 31.6 | | | | | |
| C10 | 5/12/2012 | 0.0114 | 0.047 | | 2.25 | | | | | 13.3 | | | | | |
| C10 | 7/30/2012 | 0.0229 | 0.184 | | 0.903 | | | | | 17.8 | | | | | |
| C10 | 7/30/2012 | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | 0.0111 | 0.184 | | | | | | | | | | | | |
| C10 | 8/27/2012 | 0.0086 | 0.095 | | | | | | | 17.8 | | | | | |
| C10 | 6/22/2013 | 0.0198 | 0.152 | | | | | | | 15.3 | | | | | |
| C10 | 7/23/2013 | <0.050 | <0.20 | | | | | | | | | | | | |
| C10 | 8/22/2013 | 0.0072 | 0.135 | | | | | | | 17.2 | | | | | |
| C10 | 9/8/2013 | 0.0076 | 0.175 | | | | | | | 16 | | | | | |
| C10 | 9/8/2013 | 0.007 | 0.192 | | | | | | | 16.2 | | | | | |
| C10 | 10/18/2013 | <0.0050 | 0.167 | | | | | | | 14.3 | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

| Station Name | Sample Date | Lab pH (pH units) | Lab Conductance (µS/cm) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | Hardness-E (mg/L) | Turbidity (NTU) | Temp-obs-pH (°C) | IB (%) | TDS (mg/L) | TSS (mg/L) | Total Alkalinity (mg/L) | Alkalinity-P (mg/L) | Alkalinity-OH (mg/L) | Alkalinity-Carb (mg/L) | Alkalinity-Bicrb (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | 8.05 | 195 | | 97.3 | | | | | 137 | 26.5 | 78.7 | | | 89.2 | |
| W1 | 6/30/2005 | 8.17 | 290 | | | | | | | 189 | <3.0 | 141 | | | 141 | |
| W1 | 7/28/2005 | 8.03 | 312 | | 157 | | | | | 189 | <3.0 | | | | 151 | |
| W1 | 8/29/2005 | 8.28 | 266 | | 138 | | | | | 186 | 4 | 138 | | | 138 | |
| W1 | 9/28/2005 | 7.59 | 244 | | 134 | | | | | 178 | 9.5 | 117 | | | 117 | |
| W1 | 10/15/2005 | 8.13 | 253 | | 140 | | | | | 181 | 14.5 | | | | 121 | |
| W2 | 5/27/2005 | 8.06 | 198 | | 99.8 | | | | | 138 | 20.5 | | | | 89.3 | |
| W2 | 5/27/2005 | 8.03 | 148 | | 72.2 | | | | | 80 | 79 | 67.1 | | | | |
| W2 | 6/30/2005 | 8.17 | 287 | | | | | | | 190 | <3.0 | 140 | | | 140 | |
| W2 | 7/28/2005 | 8.01 | 305 | | 153 | | | | | 194 | <3.0 | | | | 146 | |
| W2 | 8/30/2005 | 8.26 | 268 | | 138 | | | | | 193 | 3.5 | 143 | | | 143 | |
| W2 | 9/28/2005 | 7.9 | 243 | | 134 | | | | | 170 | 9 | 115 | | | 115 | |
| W2 | 10/15/2005 | 8.11 | 249 | | 137 | | | | | 179 | 5.5 | | | | 120 | |
| W3 | 5/27/2005 | 7.99 | 188 | | 93.9 | | | | | 141 | 8.5 | 61.2 | | | 78.7 | |
| W3 | 6/30/2005 | 8.22 | 341 | | | | | | | 224 | <3.0 | 153 | | | 153 | |
| W3 | 7/29/2005 | 8.06 | 322 | | 166 | | | | | 198 | 25.7 | | | | 143 | |
| W3 | 8/29/2005 | 8.24 | 267 | | 135 | | | | | 182 | 7.5 | 122 | | | 122 | |
| W3 | 9/28/2005 | 7.99 | 238 | | 129 | | | | | 174 | 8 | 101 | | | 101 | |
| W3 | 10/15/2005 | 8.08 | 245 | | 134 | | | | | 176 | <3.0 | | | | 106 | |
| W8 | 5/27/2005 | 7.78 | 113 | | 62.3 | | | | | 111 | <3.0 | 174 | | | 49.1 | |
| W8 | 6/30/2005 | 7.83 | 176 | | | | | | | 144 | <3.0 | 89 | | | 89 | |
| W8 | 7/29/2005 | 7.45 | 203 | | 116 | | | | | 141 | 24.7 | | | | 104 | |
| W8 | 8/30/2005 | 8.12 | 179 | | 99.8 | | | | | 147 | <3.0 | 99.2 | | | 99.2 | |
| W8 | 9/28/2005 | 7.96 | 165 | | 95 | | | | | 135 | <3.0 | 74.7 | | | 74.7 | |
| W8 | 10/15/2005 | 7.06 | 190 | | 99.4 | | | | | 140 | 5.5 | | | | 87.1 | |
| W9 | 5/27/2005 | 7.56 | 93.2 | | 49.4 | | | | | 104 | <3.0 | 142 | | | 32 | |
| W9 | 6/30/2005 | 7.63 | 145 | | | | | | | 126 | <3.0 | 56.1 | | | 56.1 | |
| W9 | 7/29/2005 | 7.51 | 176 | | 95.3 | | | | | 129 | 3.7 | | | | 74.2 | |
| W9 | 8/29/2005 | 7.84 | 146 | | 73.6 | | | | | 126 | <3.0 | 57.7 | | | 57.7 | |
| W9 | 9/28/2005 | 7.62 | 125 | | 67.8 | | | | | 118 | <3.0 | 44 | | | 44 | |
| W9 | 10/15/2005 | 7.19 | 121 | | 64.4 | | | | | 111 | <3.0 | | | | 51.8 | |
| W10 | 5/27/2005 | 7.47 | 75.4 | | 46.3 | | | | | 115 | <3.0 | | | | 36.7 | |
| W10 | 5/27/2005 | | | | | | | | | | | | | | | |
| W10 | 6/30/2005 | 7.31 | 84.2 | | | | | | | 116 | 6 | 41.5 | | | 41.5 | |
| W10 | 7/29/2005 | 7.34 | 111 | | 54.9 | | | | | 105 | 4.2 | | | | 58.2 | |
| W10 | 8/29/2005 | 7.74 | 145 | | 70 | | | | | 117 | 13 | 79.1 | | | 79.1 | |
| W10 | 9/28/2005 | 7.77 | 181 | | 101 | | | | | 141 | 14.5 | 92.3 | | | 92.3 | |
| W10 | 10/15/2005 | 7.3 | 175 | | 100 | | | | | 138 | 6.5 | | | | 96.4 | |
| W6 | 5/27/2005 | 7.91 | 127 | | 65.4 | | | | | 103 | 13.5 | 32 | | | 61.2 | |
| W6 | 6/30/2005 | 7.41 | 174 | | | | | | | 123 | 11.5 | 99.1 | | | 99.1 | |
| W6 | 7/29/2005 | 8.01 | 319 | | 171 | | | | | 198 | 22.2 | | | | 147 | |
| W6 | 8/30/2005 | 8.17 | 200 | | 106 | | | | | 147 | <3.0 | 109 | | | 109 | |
| W6 | 9/28/2005 | 7.95 | 192 | | 106 | | | | | 133 | 3.5 | 93 | | | 93 | |
| W6 | 10/15/2005 | 7.92 | 180 | | 98.3 | | | | | 128 | <3.0 | | | | 99.3 | |
| W6 | 6/2/2006 | 7.64 | 112 | | | | | | | 96 | 115 | 76.6 | | | | |
| W6 | 8/25/2006 | 8.01 | 223 | 120 | | | | | | 160 | | 120 | | <5 | <6 | 146 |
| W6 | 9/6/2006 | 7.86 | 212 | 110 | | | | | | | 4 | 112 | | <5 | <6 | 137 |
| W6 | 6/20/2007 | 7.77 | 151 | | 81 | | 0.6 | | | 130 | 16 | 83 | | <5 | <6 | 100 |
| W6 | 9/18/2007 | 7.95 | 194 | | 93 | | 0.2 | | | 172 | 8 | 112 | | <5 | <6 | 137 |
| W6 | 6/17/2008 | 7.82 | 175 | | 86 | | 0.9 | | | 120 | 17 | 93 | | <5 | <6 | 100 |
| W6 | 9/18/2008 | 7.8 | 174 | | | | <0.1 | | | 150 | 4 | 87 | | <5 | <6 | 100 |
| W6 | 4/14/2009 | 7.92 | 624 | 248 | | | 24 | | | 464 | 138 | 201 | | <5 | <6 | 240 |
| W6 | 4/30/2009 | 7.34 | 104 | 56 | | | 39 | | | 112 | 190 | 41 | | <5 | <6 | 50 |
| W6 | 7/28/2009 | 7.86 | 338 | 148 | | | 27 | | | 228 | 38 | 92 | | <5 | <6 | 100 |
| W6 | 8/6/2009 | | | | | | | | | | | | | | | |
| W6 | 8/6/2009 | 8.05 | 413 | 177 | | | 0.3 | | | 296 | <2 | 155 | | <5 | <6 | 190 |
| W6 | 8/18/2009 | | | 173 | | | | | | | | | | | | |
| W6 | 8/25/2009 | | | | | | | | | | | | | | | |
| W6 | 10/7/2009 | 7.86 | 478 | 195 | | | 0.5 | | | 314 | <2 | 95 | | <5 | <6 | 100 |
| W6 | 10/7/2009 | 7.83 | 475 | 195 | | | 0.6 | | | 352 | <3 | 96 | | <5 | <6 | 100 |
| W6 | 10/25/2009 | 8.1 | 501 | 207 | 219 | | 1.8 | | | 270 | <4 | 120 | <0.5 | <0.5 | <0.5 | 150 |
| W6 | 4/19/2010 | 7.93 | 292 | | 135 | | 38 | | | 196 | 29 | 117 | | <5 | <6 | 140 |
| W6 | 5/16/2010 | 8.1 | 200 | 98 | 97.2 | | 0.7 | | | 130 | <4 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 5/17/2010 | 7.8 | 152 | 73.7 | 68.8 | | 1.6 | | | 120 | <4 | 71 | <0.5 | <0.5 | <0.5 | 87 |
| W6 | 5/19/2010 | 8.1 | 192 | 95.5 | 101 | | 1.2 | | | 120 | 3 | 90 | <0.5 | <0.5 | <0.5 | 110 |
| W6 | 5/21/2010 | 8 | 160 | 82.6 | 88.1 | | 2.9 | | | 84 | 10 | 80 | <0.5 | <0.5 | <0.5 | 97 |
| W6 | 5/23/2010 | 8.1 | 219 | 102 | 96.4 | | 2 | | | 150 | 9 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 5/25/2010 | 7.9 | 221 | 108 | 120 | | 1.6 | | | 120 | 4 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 5/29/2010 | 8 | 141 | 69.2 | 70.1 | | 2.8 | | | 84 | 10 | 74 | <0.5 | <0.5 | <0.5 | 90 |
| W6 | 6/2/2010 | 8.4 | 466 | 221 | 243 | | 0.7 | | | 280 | 2 | 200 | 5.2 | <0.5 | 6.3 | 230 |
| W6 | 6/4/2010 | 8.1 | 189 | 81 | 92.6 | | 1.7 | | | 96 | 1 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 6/6/2010 | 8 | 187 | 98.3 | 98.8 | | 3.1 | | | 120 | 5 | 100 | <0.5 | <0.5 | <0.5 | 130 |
| W6 | 6/14/2010 | 8.2 | 184 | 92.4 | 94.5 | | 3.6 | | | 130 | 13 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 6/16/2010 | 8.2 | 188 | 92 | 90.8 | | 2.7 | | | 120 | 5 | 100 | <0.5 | <0.5 | <0.5 | 130 |
| W6 | 6/18/2010 | 8.2 | 191 | 93.9 | 89.2 | | 1.7 | | | 120 | 6 | 100 | <0.5 | <0.5 | <0.5 | 130 |
| W6 | 6/20/2010 | 8.2 | 182 | 88.8 | 92.7 | | 2.7 | | | 110 | 5 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 6/22/2010 | 8.17 | 190 | 92.6 | 94.3 | | 3.4 | | | 120 | 8 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 6/24/2010 | 8.11 | 189 | 92.6 | 74.4 | | 2.1 | | | 96 | 4 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 6/26/2010 | 8.11 | 189 | 90.3 | 90.7 | | 3 | | | 92 | 5 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 6/26/2010 | | | | | | | | | | | | | | | |
| W6 | 6/28/2010 | 7.87 | 189 | 89.5 | 91.4 | | 6.8 | | | 130 | 19 | 99 | <0.5 | <0.5 | <0.5 | 120 |
| W6 | 7/5/2010 | 7.95 | 170 | 79.5 | 86.9 | | 23 | | | 130 | 60 | 87 | <0.5 | <0.5 | <0.5 | 110 |
| W6 | 8/5/2010 | 8.06 | 207 | 108 | 101 | | 2.2 | | | 130 | 8 | 110 | <0.5 | <0.5 | <0.5 | 130 |
| W6 | 9/9/2010 | 8.07 | 210 | 108 | 107 | | 10.2 | | | 160 | 31 | 110 | <0.5 | <0.5 | <0.5 | 130 |
| W6 | 10/8/2010 | 8.07 | 209 | 103 | 100 | | 6.7 | | | 140 | 46 | 110 | <0.5 | <0.5 | <0.5 | 130 |
| W6 | 8/19/2011 | 8.3 | 485 | 225 | 214 | | | | | 280 | 2 | 190 | <0.5 | <0.5 | <0.5 | 240 |
| W6 | 7/17/2012 | 7.98 | 201 | 104 | 163 | | | | | 122 | 1130 | 103 | <0.50 | <0.50 | <0.50 | 126 |
| W6 | 7/30/2012 | 8.09 | 202 | 101 | 145 | | | | | 124 | 614 | 103 | <0.50 | <0.50 | <0.50 | 126 |
| W6 | 8/9/2012 | 8.17 | 220 | 112 | 136 | | | | | 144 | 566 | 116 | <0.50 | <0.50 | <0.50 | 141 |
| W6 | 8/25/2012 | 8 | 212 | 103 | 161 | | | | | 138 | 1160 | 109 | <0.50 | <0.50 | <0.50 | 133 |
| W6 | 9/13/2012 | 8.04 | 174 | 87.7 | 93.1 | | | | | 118 | 50.3 | 87.1 | <0.50 | <0.50 | <0.50 | 106 |
| W6 | 10/13/2012 | 7.92 | 193 | | 117 | | | | | 150 | 44.7 | 99.1 | <0.50 | <0.50 | <0.50 | 121 |
| W6 | 11/12/2012 | 7.93 | 275 | 153 | 155 | | | | | 162 | 2.2 | 138 | <0.50 | <0.50 | <0.50 | 168 |
| W6 | 5/14/2013 | 7.48 | 55.1 | 31.4 | 33.8 | | | | | 84 | 13.1 | 25.5 | <0.50 | <0.50 | <0.50 | 31.1 |
| W6 | 6/22/2013 | 8.07 | 195 | 94.9 | 115 | | | | | 118 | 172 | 97.8 | <0.50 | <0.50 | <0.50 | 119 |
| W6 | 7/12/2013 | 7.9 | 180 | 88.2 | 95.3 | | | | | 136 | 25.2 | 93.8 | <0.50 | <0.50 | <0.50 | 115 |
| W6 | 8/22/2013 | 8.04 | 205 | 102 | 106 | | | | | 144 | 19.7 | 107 | <0.50 | <0.50 | <0.50 | 130 |
| W6 | 9/6/2013 | 7.95 | 204 | 101 | 114 | | | | | 130 | 5.2 | 105 | <0.50 | <0.50 | <0.50 | 129 |
| W6 | 10/7/2013 | 8.08 | 191 | 107 | 106 | | | | | 176 | 74.4 | 98.1 | <0.50 | <0.50 | <0.50 | 120 |
| W6 | 11/16/2013 | 8.11 | 245 | 119 | 123 | | | | | 120 | 33.4 | 121 | <0.50 | <0.50 | <0.50 | 147 |
| W6 | 12/7/2013 | 8.21 | 326 | 159 | 182 | | | | | 194 | 3.6 | 164 | <0.50 | <0.50 | <0.50 | 200 |
| W7 | 5/27/2005 | 7.95 | 152 | | 76.6 | | | | | 116 | 30.5 | 36.7 | | | 68.4 | |
| W7 | 6/30/2005 | 7.87 | 233 | | | | | | | 153 | 14 | 117 | | | 117 | |
| W7 | 7/29/2005 | 7.18 | 323 | | 167 | | | | | 197 | 19.7 | | | | 146 | |
| W7 | 8/30/2005 | 8.19 | 211 | | 109 | | | | | 148 | 3 | 113 | | | 113 | |
| W7 | 9/28/2005 | 8.02 | 190 | | 107 | | | | | 142 | 361 | 95.9 | | | 95.9 | |
| W7 | 10/15/2005 | 6.75 | 194 | | 106 | | | | | 145 | 7.5 | | | | 107 | |
| W7 | 6/2/2006 | 7.61 | 98.8 | | | | | | | 104 | 705 | 49.4 | | | | |
| W7 | 6/8/2006 | | | | | | | | | | | | | | | |

**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

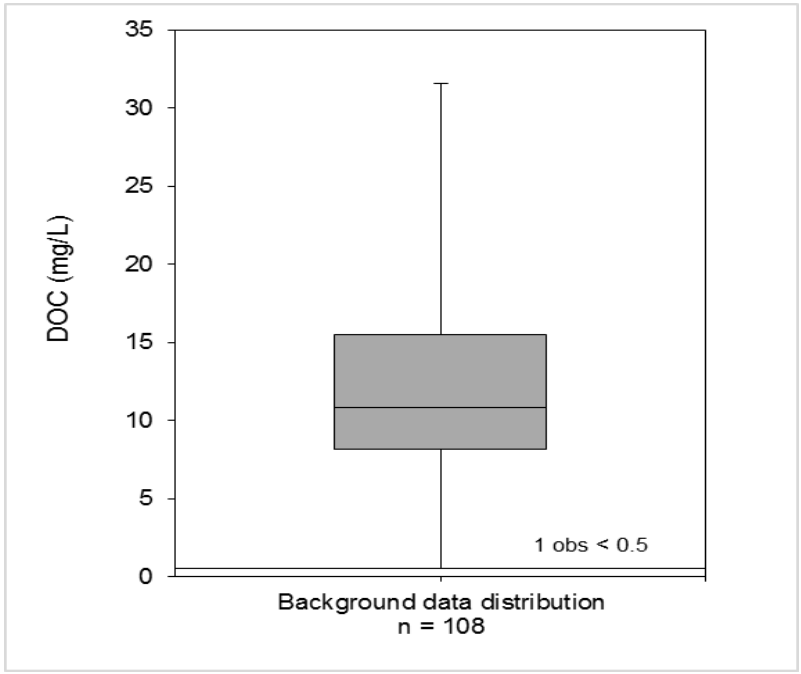
| Station Name | Sample Date | Lab pH (pH units) | Lab Conductance (µS/cm) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | Hardness-E (mg/L) | Turbidity (NTU) | Temp-obs-pH (°C) | IB (%) | TDS (mg/L) | TSS (mg/L) | Total Alkalinity (mg/L) | Alkalinity-P (mg/L) | Alkalinity-OH (mg/L) | Alkalinity-Carb (mg/L) | Alkalinity-Bicrb (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 6/15/2006 | | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | 7.86 | 193 | 100 | | | | | | 114 | 53 | 95 | | <5 | <6 | 116 |
| W7 | 6/23/2006 | 7.78 | 246 | 122 | | | | | | 176 | 328 | 130 | | <5 | <6 | 159 |
| W7 | 6/28/2006 | 7.9 | 213 | 107 | | | | | | 120 | 103 | 106 | | <5 | <6 | 129 |
| W7 | 7/7/2006 | 7.91 | 205 | 110 | | | | | | 184 | 3 | 120 | | <5 | <6 | 146 |
| W7 | 7/12/2006 | 7.77 | 238 | 110 | | | | | | | <2 | 120 | | <5 | <6 | 146 |
| W7 | 7/20/2006 | 7.88 | 233 | 130 | | | | | | | 2 | 122 | | <5 | <6 | 149 |
| W7 | 7/26/2006 | | | | | | | | | | | | | | | |
| W7 | 7/26/2006 | 7.87 | 259 | 128 | | | | | | | 9 | 121 | | <5 | <6 | 147 |
| W7 | 8/2/2006 | 7.79 | 256 | 128 | | | | | | | 4 | 125 | | <5 | <6 | 152 |
| W7 | 8/10/2006 | 7.8 | 259 | 126 | | | | | | | <2 | 125 | | <5 | <6 | 152 |
| W7 | 8/25/2006 | | | | | | | | | | | | | | | |
| W7 | 8/25/2006 | 7.92 | 261 | 129 | | | | | | 180 | | 131 | | <5 | <6 | 160 |
| W7 | 8/30/2006 | 7.79 | 258 | 132 | | | | | | 200 | <2 | 129 | | <5 | <6 | 157 |
| W7 | 9/6/2006 | 7.88 | 258 | 130 | | | | | | | 4 | 129 | | <5 | <6 | 157 |
| W7 | 9/13/2006 | 7.84 | 254 | 130 | | | | | | | 5 | 128 | | <5 | <6 | 157 |
| W7 | 9/20/2006 | 7.85 | 263 | 132 | | | | | | | 3 | 127 | | <5 | <6 | 154 |
| W7 | 9/28/2006 | 7.26 | 266 | 129 | | | | | | 182 | | 128 | | <5 | <6 | 156 |
| W7 | 10/4/2006 | 7.94 | 258 | 126 | | | | | | | 2 | 122 | | <5 | <6 | 149 |
| W7 | 10/12/2006 | 7.39 | 266 | 132 | | | | | | 164 | 4 | 130 | | <5 | <6 | 158 |
| W7 | 6/5/2007 | 7.98 | 208 | | 108 | | 2.4 | | | 162 | 76 | 118 | | <5 | <6 | 144 |
| W7 | 6/5/2007 | 7.97 | 207 | | 120 | | 3.1 | | | 158 | 76 | 121 | | <5 | <6 | 147 |
| W7 | 6/5/2007 | 7.97 | 207 | | 111 | | 2.2 | | | 166 | 73 | 105 | | <5 | <6 | 128 |
| W7 | 6/20/2007 | 7.84 | 230 | 110 | | | 0.5 | | | 164 | 6 | 116 | | <5 | <6 | 142 |
| W7 | 7/18/2007 | 7.72 | 250 | 128 | 126 | | 0.6 | | | 170 | 4 | 128 | | <5 | <6 | 156 |
| W7 | 7/18/2007 | 7.8 | 249 | | 125 | | 1 | | | 182 | 7 | 128 | | <5 | <6 | 156 |
| W7 | 7/18/2007 | 7.83 | 249 | | 125 | | 1.4 | | | 184 | 6 | 128 | | <5 | <6 | 157 |
| W7 | 8/24/2007 | | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | | | | | | | | | | | | | | | |
| W7 | 8/24/2007 | 8.04 | 246 | | 122 | | <0.1 | | | 198 | 4 | 139 | | <5 | <6 | 170 |
| W7 | 8/24/2007 | 8.05 | 245 | | 123 | | <0.1 | | | 192 | 4 | 136 | | <5 | <6 | 166 |
| W7 | 8/24/2007 | 8.04 | 244 | | 128 | | <0.1 | | | 186 | 6 | 136 | | <5 | <6 | 165 |
| W7 | 9/18/2007 | 8 | 224 | 110 | | | 0.2 | | | 182 | 20 | 124 | | <5 | <6 | 151 |
| W7 | 10/30/2007 | 7.74 | 268 | | 130 | | 0.9 | | | 176 | 3 | 128 | | <5 | <6 | 157 |
| W7 | 10/30/2007 | 7.74 | 274 | | 128 | | 1.9 | | | 182 | 10 | 131 | | <5 | <6 | 160 |
| W7 | 10/30/2007 | 7.74 | 269 | | 130 | | 1.9 | | | 166 | 7 | 128 | | <5 | <6 | 157 |
| W7 | 10/30/2007 | 7.68 | 272 | | | | 1.2 | | | 172 | 6 | 128 | | <5 | <6 | 157 |
| W7 | 4/22/2008 | 8.4 | 364 | 186 | | | 0.3 | | | 264 | <2 | 187 | | <5 | <6 | 218 |
| W7 | 4/22/2008 | 8.41 | 362 | 193 | | | 0.3 | | | 274 | <2 | 185 | | <5 | <6 | 215 |
| W7 | 4/22/2008 | 8.4 | 366 | 182 | | | 0.4 | | | 270 | <2 | 186 | | <5 | <6 | 216 |
| W7 | 4/22/2008 | 8.4 | 367 | | | | 0.5 | | | 262 | <2 | 188 | | <5 | <6 | 218 |
| W7 | 6/3/2008 | 8.01 | 201 | | 97 | | 1.3 | | | 134 | <2 | 94 | | <5 | <6 | 100 |
| W7 | 6/3/2008 | 8.01 | 203 | | 96 | | 1.3 | | | 132 | 19 | 95 | | <5 | <6 | 100 |
| W7 | 6/3/2008 | 8.03 | 205 | | 101 | | 1.1 | | | 146 | 26 | 95 | | <5 | <6 | 100 |
| W7 | 6/3/2008 | | | 92 | | | | | | | | | | | | |
| W7 | 6/17/2008 | 7.95 | 237 | | | | 1 | | | 156 | 10 | 115 | | <5 | <6 | 140 |
| W7 | 8/6/2008 | 7.9 | 234 | | 123 | | 1.4 | | | 162 | 92 | 128 | | <5 | <6 | 160 |
| W7 | 8/6/2008 | 7.91 | 235 | | 123 | | 1.4 | | | 168 | 139 | 127 | | <5 | <6 | 150 |
| W7 | 8/6/2008 | 7.96 | 233 | | 125 | | 1.2 | | | 170 | 85 | 127 | | <5 | <6 | 160 |
| W7 | 8/6/2008 | | | 123 | | | | | | | | | | | | |
| W7 | 9/18/2008 | 7.89 | 170 | | | | 1.8 | | | 170 | 28 | 82 | | <5 | <6 | 100 |
| W7 | 10/28/2008 | 7.84 | 217 | | | | 0.6 | | | 192 | 4 | 108 | | <5 | <6 | 130 |
| W7 | 10/28/2008 | 7.83 | 217 | | | | 0.7 | | | 188 | 6 | 108 | | <5 | <6 | 130 |
| W7 | 10/28/2008 | 7.85 | 218 | | | | 0.8 | | | 168 | 7 | 108 | | <5 | <6 | 130 |
| W7 | 10/28/2008 | | | 123 | | | | | | | | | | | | |
| W7 | 4/30/2009 | 6.84 | 36 | 20 | | | 1.6 | | | 52 | <2 | 12 | | <5 | <6 | 20 |
| W7 | 6/8/2009 | 7.9 | 208 | 93 | | | 1.4 | | | 156 | 32 | 95 | | <5 | <6 | 100 |
| W7 | 7/28/2009 | 8.07 | 270 | 137 | | | 0.2 | | | 184 | 4 | 128 | | <5 | <6 | 160 |
| W7 | 8/6/2009 | 8.35 | 260 | 121 | | | 0.2 | | | 202 | 2 | 159 | | <5 | <6 | 190 |
| W7 | 8/24/2009 | | | | | | | | | | | | | | | |
| W7 | 8/25/2009 | | | | | | | | | | | | | | | |
| W7 | 8/31/2009 | | | 110 | | | | | | | | | | | | |
| W7 | 10/7/2009 | | | | | | | | | | | | | | | |
| W7 | 10/7/2009 | 7.87 | 249 | 123 | | | 0.2 | | | 180 | 7 | 116 | | <5 | <6 | 140 |
| W7 | 10/25/2009 | 8.1 | 266 | 126 | 141 | | 0.7 | | | 130 | <4 | 130 | <0.5 | <0.5 | <0.5 | 160 |
| W7 | 10/25/2009 | 8 | 264 | | | | 0.3 | | | 110 | <4 | | | | | |
| W7 | 4/19/2010 | 7.81 | 167 | | 80 | | 1.2 | | | 142 | <7 | 82 | | <5 | <6 | 100 |
| W7 | 4/27/2010 | 7.6 | 64 | 36.3 | 35 | | 1.2 | | | 62 | <4 | 32 | <0.5 | <0.5 | <0.5 | 39 |
| W7 | 4/29/2010 | 7.5 | 66 | 36.2 | 36.2 | | 1.8 | | | 62 | <4 | 31 | <0.5 | <0.5 | <0.5 | 38 |
| W7 | 5/1/2010 | 7.7 | 78 | 40.8 | 43.6 | | 8.6 | | | 74 | 15 | 40 | <0.5 | <0.5 | <0.5 | 49 |
| W7 | 5/3/2010 | 7.7 | 85 | 44.9 | 46.2 | | 7.9 | | | 80 | 12 | 42 | <0.5 | <0.5 | <0.5 | 51 |
| W7 | 5/5/2010 | 7.8 | 102 | 49.1 | 55.1 | | 8.7 | | | 76 | 12 | 53 | <0.5 | <0.5 | <0.5 | 64 |
| W7 | 5/7/2010 | 7.8 | 113 | 56.9 | 56 | | 4.1 | | | 62 | 18 | 58 | <0.5 | <0.5 | <0.5 | 70 |
| W7 | 5/9/2010 | 8 | 180 | 79.9 | 71 | | 2.2 | | | 130 | <4 | 86 | <0.5 | <0.5 | <0.5 | 110 |
| W7 | 5/10/2010 | 8.1 | 163 | 80.9 | 90.3 | | 1 | | | 130 | <4 | 83 | <0.5 | <0.5 | <0.5 | 100 |
| W7 | 5/12/2010 | | | | | | | | | | | | | | | |
| W7 | 5/12/2010 | 8 | 166 | 81.6 | 84.6 | | 1.2 | | | 100 | <4 | 83 | <0.5 | <0.5 | <0.5 | 100 |
| W7 | 5/14/2010 | 8.1 | 149 | 72.6 | 71.4 | | 7.7 | | | 130 | 15 | 73 | <0.5 | <0.5 | <0.5 | 89 |
| W7 | 5/16/2010 | 8.3 | 590 | 85.6 | 76.3 | | 3.8 | | | 120 | 12 | 260 | <0.5 | <0.5 | <0.5 | 320 |
| W7 | 5/17/2010 | 8.2 | 160 | 80.4 | 75.6 | | 4 | | | 130 | 11 | 80 | <0.5 | <0.5 | <0.5 | 98 |
| W7 | 5/19/2010 | 8.2 | 195 | 98.6 | 103 | | 1.5 | | | 120 | 4 | 98 | <0.5 | <0.5 | <0.5 | 120 |
| W7 | 5/21/2010 | 8.1 | 191 | 91.5 | 95.6 | | 6.5 | | | 120 | 22 | 96 | <0.5 | <0.5 | <0.5 | 120 |
| W7 | 5/23/2010 | 8.1 | 204 | 98.1 | 103 | | 29.3 | | | 150 | 33 | 100 | <0.5 | <0.5 | <0.5 | 130 |
| W7 | 5/25/2010 | 7.9 | 211 | 125 | 124 | | 85.5 | | | 140 | 140 | 100 | <0.5 | <0.5 | <0.5 | 130 |
| W7 | 5/27/2010 | 8 | 231 | 113 | 148 | | 307 | | | 140 | 350 | 110 | <0.5 | <0.5 | <0.5 | 140 |
| W7 | 5/29/2010 | 8.2 | 232 | 111 | 129 | | 170 | | | 160 | 200 | 110 | <0.5 | <0.5 | <0.5 | 140 |
| W7 | 5/31/2010 | 8.2 | 236 | 109 | 130 | | 155 | | | 160 | 290 | 120 | <0.5 | <0.5 | <0.5 | 140 |
| W7 | 6/2/2010 | 8.2 | 243 | 113 | 135 | | 68.2 | | | 140 | 81 | 120 | <0.5 | <0.5 | <0.5 | 150 |
| W7 | 6/4/2010 | 8.2 | 240 | 111 | 125 | | 51.6 | | | 140 | 60 | 120 | <0.5 | <0.5 | <0.5 | 150 |
| W7 | 6/6/2010 | 8.2 | 250 | 128 | 133 | | 45.2 | | | 170 | 39 | 130 | <0.5 | <0.5 | <0.5 | 150 |
| W7 | 6/14/2010 | 8.29 | 250 | 122 | 128 | | 17 | | | 150 | 43 | 130 | <0.5 | <0.5 | <0.5 | 160 |
| W7 | 6/16/2010 | 8.3 | 259 | 120 | 128 | | 6.4 | | | 150 | 17 | 130 | <0.5 | <0.5 | <0.5 | 160 |
| W7 | 6/18/2010 | 8.17 | 256 | 122 | 123 | | 7.8 | | | 140 | 28 | 130 | <0.5 | <0.5 | <0.5 | 160 |
| W7 | 6/20/2010 | 8.2 | 240 | 112 | 118 | | 18.9 | | | 140 | 33 | 120 | <0.5 | <0.5 | <0.5 | 150 |
| W7 | 6/22/2010 | 8.03 | 208 | 97.6 | 115 | | 134 | | | 140 | 300 | 110 | <0.5 | <0.5 | <0.5 | 130 |
| W7 | 6/24/2010 | 8.03 | 214 | 99.7 | 116 | | 24.5 | | | 130 | 64 | 110 | <0.5 | <0.5 | <0.5 | 130 |
| W7 | 6/26/2010 | 8.26 | 230 | 106 | 106 | | 8.2 | | | 120 | 21 | 120 | <0.5 | <0.5 | <0.5 | 140 |
| W7 | 6/28/2010 | 8.03 | 248 | 114 | 107 | | 3 | | | 150 | 9 | 120 | <0.5 | <0.5 | <0.5 | 150 |
| W7 | 7/5/2010 | 8.06 | 202 | 92.5 | 106 | | 19 | | | 150 | 53 | 100 | <0.5 | <0.5 | <0.5 | 120 |
| W7 | 8/5/2010 | | | 118 | 116 | | | | | 170 | | | | | | |
| W7 | 9/12/2010 | | | | 105 | | | | | | | | | | | |
| W7 | 9/12/2010 | 7.98 | 212 | 107 | 102 | | 3.4 | | | 210 | 11 | 100 | <0.5 | <0.5 | <0.5 | 130 |
| W7 | 10/8/2010 | 8.1 | 233 | 111 | 126 | | 1.6 | | | 150 | 3 | 120 | <0.5 | <0.5 | <0.5 | 140 |
| W7 | 4/27/2011 | 7.41 | 79 | 42.6 | 42.6 | | | | | 72 | <1 | 34 | <0.5 | <0.5 | <0.5 | 41 |
| W7 | 5/2/2011 | 7.11 | 57 | 31.8 | 33.1 | | | | | 40 | 7 | 27 | <0.5 | <0.5 | <0.5 | 33 |
| W7 | 6/1/2011 | 8.09 | 196 | 92.3 | 94 | | | | | 120 | 23 | 96 | <0.5 | <0.5 | <0.5 | 120 |
| W7 | 6/16/2011 | 8 | 195 | 97.4 | 108 | | | | | 130 | 85 | 92 | <0.5 | <0.5 | <0.5 | 110 |
| W7 | 7/1/2011 | 7.76 | 146 | 77.1 | 87.5 | | | | | 120 | 150 | 73 | <0.5 | <0.5 | <0.5 | 89 |

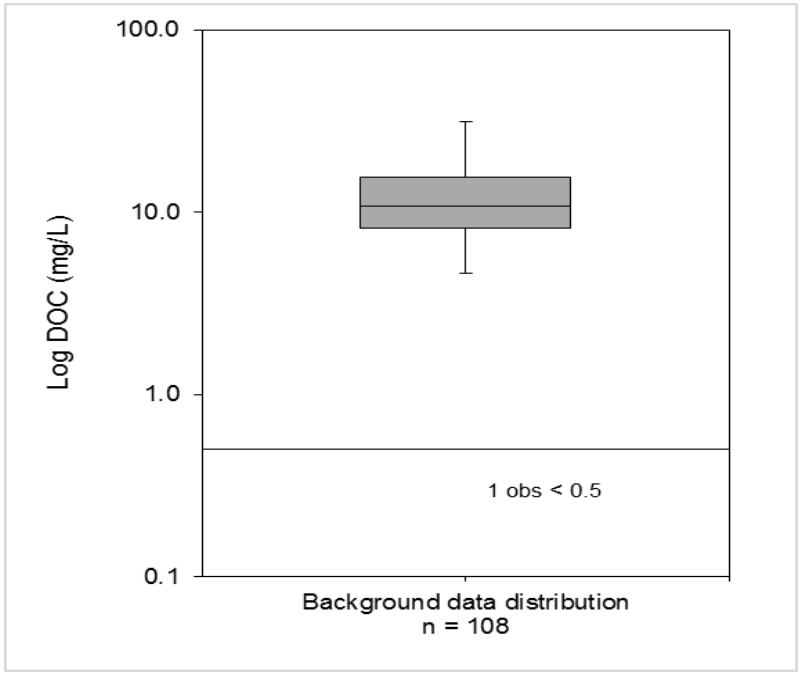
**Table B.1: Raw water quality data from Minto Mine, 2005 - 2013.**

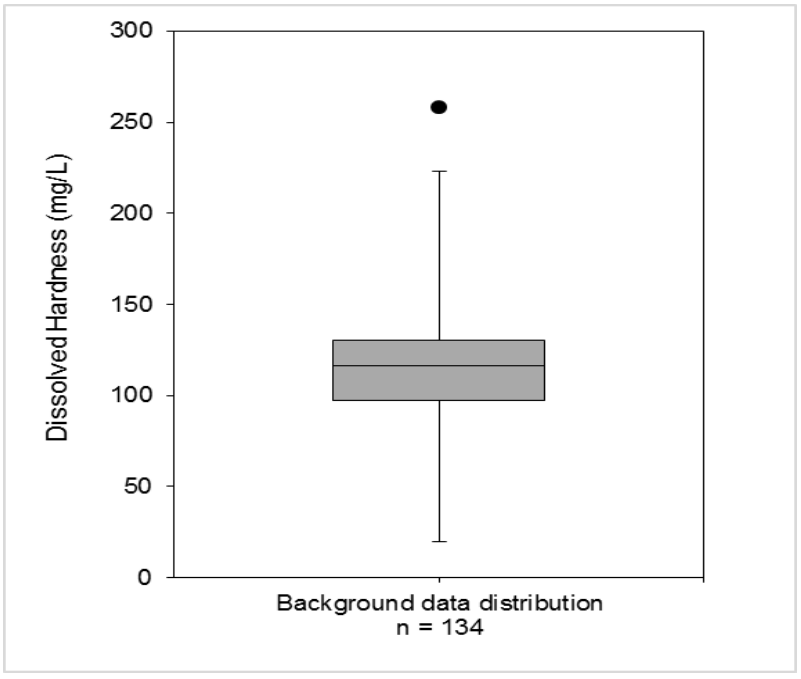
| Station Name | Sample Date | Lab pH (pH units) | Lab Conductance (µS/cm) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | Hardness-E (mg/L) | Turbidity (NTU) | Temp-obs-pH (°C) | IB (%) | TDS (mg/L) | TSS (mg/L) | Total Alkalinity (mg/L) | Alkalinity-P (mg/L) | Alkalinity-OH (mg/L) | Alkalinity-Carb (mg/L) | Alkalinity-Bicrb (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/2/2011 | 7.67 | 113 | 58.9 | 85.8 | | | | | 110 | 400 | 54 | <0.5 | <0.5 | <0.5 | 66 |
| W7 | 8/16/2011 | 7.9 | 191 | 97.6 | 96.8 | | | | | 150 | 22 | 94 | <0.5 | <0.5 | <0.5 | 110 |
| W7 | 8/19/2011 | 8.12 | 185 | 93 | 93.4 | | | | | 140 | 22 | 92 | <0.5 | <0.5 | <0.5 | 110 |
| W7 | 9/12/2011 | 8.03 | 217 | 118 | 119 | | | | | 170 | 1 | 110 | <0.5 | <0.5 | <0.5 | 130 |
| W7 | 10/6/2011 | 8.07 | 233 | 110 | 113 | | | | | 150 | <4 | 120 | <0.5 | <0.5 | <0.5 | 140 |
| W7 | 11/22/2011 | 7.96 | 280 | 148 | 144 | | | | | 156 | 26.7 | 134 | <0.50 | <0.50 | <0.50 | 163 |
| W7 | 1/24/2012 | 8.13 | 349 | 169 | 158 | | | | | 226 | <4.0 | 165 | <0.50 | <0.50 | <0.50 | 201 |
| W7 | 2/25/2012 | 7.99 | 339 | 165 | 160 | | | | | 216 | <4.0 | 155 | <0.50 | <0.50 | <0.50 | 189 |
| W7 | 3/5/2012 | 8.17 | 343 | 161 | 159 | | | | | 176 | 3.2 | 154 | <0.50 | <0.50 | <0.50 | 188 |
| W7 | 4/24/2012 | 7.63 | 75 | 38.7 | 37 | | | | | 100 | 11.2 | 36.2 | <0.50 | <0.50 | <0.50 | 44.1 |
| W7 | 5/6/2012 | 6.05 | 93.2 | 46.1 | 44.8 | | | | | 80 | 2.4 | 27.3 | <0.50 | <0.50 | <0.50 | 33.3 |
| W7 | 5/6/2012 | 5.74 | 92.3 | 46.4 | 44.7 | | | | | 88 | 4.2 | 8.45 | <0.50 | <0.50 | <0.50 | 10.3 |
| W7 | 6/19/2012 | 8.12 | 178 | 91.8 | 105 | | | | | 128 | 165 | 87.4 | <0.50 | <0.50 | <0.50 | 107 |
| W7 | 7/17/2012 | 8.15 | 254 | 128 | 124 | | | | | 164 | 34.1 | 128 | <0.50 | <0.50 | <0.50 | 156 |
| W7 | 7/30/2012 | 8.2 | 272 | 135 | 128 | | | | | 180 | 9.2 | 138 | <0.50 | <0.50 | <0.50 | 168 |
| W7 | 8/8/2012 | 8.26 | 278 | 141 | 141 | | | | | 192 | 3.3 | 143 | <0.50 | <0.50 | <0.50 | 175 |
| W7 | 8/23/2012 | 8.25 | 285 | 142 | 151 | | | | | 200 | 1.5 | 147 | <0.50 | <0.50 | <0.50 | 179 |
| W7 | 9/13/2012 | 8.13 | 230 | 116 | 121 | | | | | 154 | 15.3 | 115 | <0.50 | <0.50 | <0.50 | 140 |
| W7 | 10/16/2012 | 8.17 | 261 | 129 | 143 | | | | | 166 | 9.9 | 132 | <0.50 | <0.50 | <0.50 | 161 |
| W7 | 11/2/2012 | 7.93 | 319 | 158 | 153 | | | | | 214 | 2.2 | 150 | <0.50 | <0.50 | <0.50 | 183 |
| W7 | 12/29/2012 | 8.13 | 444 | 223 | 206 | | | | | 262 | <1.0 | 207 | <0.50 | <0.50 | <0.50 | 253 |
| W7 | 4/30/2013 | 8.27 | 387 | 192 | 198 | | | | | 246 | 5.8 | 187 | <0.50 | <0.50 | <0.50 | 228 |
| W7 | 5/14/2013 | 7.58 | 61.3 | 33.3 | 36.4 | | | | | 70 | 55.3 | 29.4 | <0.50 | <0.50 | <0.50 | 35.9 |
| W7 | 6/19/2013 | 8.08 | 238 | 113 | 114 | | | | | 152 | 11.2 | 113 | <0.50 | <0.50 | <0.50 | 138 |
| W7 | 6/19/2013 | 8.07 | 237 | 114 | 115 | | | | | 164 | 10.1 | 113 | <0.50 | <0.50 | <0.50 | 138 |
| W7 | 7/13/2013 | 8.1 | 263 | 132 | 137 | | | | | 156 | 5 | 127 | <0.50 | <0.50 | <0.50 | 155 |
| W7 | 8/21/2013 | 8.23 | 286 | 140 | 144 | | | | | 172 | 3.8 | 143 | <0.50 | <0.50 | <0.50 | 175 |
| W7 | 9/6/2013 | 8.02 | 280 | 138 | 154 | | | | | 280 | 11.8 | 140 | <0.50 | <0.50 | <0.50 | 170 |
| W7 | 10/21/2013 | 8.16 | 288 | 147 | 126 | | | | | 168 | 7.4 | 138 | <0.50 | <0.50 | <0.50 | 168 |
| W7 | 11/16/2013 | 8.24 | 324 | 153 | 164 | | | | | 164 | 1.5 | 153 | <0.50 | <0.50 | <0.50 | 187 |
| W7 | 12/7/2013 | 8.14 | 354 | 168 | 189 | | | | | 220 | <1.0 | 166 | <0.50 | <0.50 | <0.50 | 203 |
| C4 | 5/6/2012 | 7.59 | 88.8 | 43.9 | 119 | | | | | 84 | 1260 | 40.1 | <0.50 | <0.50 | <0.50 | 48.9 |
| C4 | 8/1/2012 | 8.04 | 228 | 117 | 133 | | | | | 166 | 246 | 115 | <0.50 | <0.50 | <0.50 | 140 |
| C4 | 8/8/2012 | 8.14 | 248 | 125 | 142 | | | | | 170 | 253 | 126 | <0.50 | <0.50 | <0.50 | 153 |
| C4 | 8/25/2012 | 7.94 | 254 | 130 | 173 | | | | | 192 | 855 | 128 | <0.50 | <0.50 | <0.50 | 156 |
| C4 | 6/22/2013 | 7.97 | 253 | 126 | 222 | | | | | 204 | 886 | 120 | <0.50 | <0.50 | <0.50 | 147 |
| C4 | 7/19/2013 | 8.12 | 253 | 128 | 200 | | | | | 184 | 487 | 125 | <0.50 | <0.50 | <0.50 | 152 |
| C4 | 8/22/2013 | 7.98 | 245 | 123 | 199 | | | | | 182 | 784 | 118 | <0.50 | <0.50 | <0.50 | 144 |
| C4 | 9/6/2013 | 7.93 | 248 | 125 | 166 | | | | | 176 | 172 | 120 | <0.50 | <0.50 | <0.50 | 146 |
| C4 | 10/18/2013 | 8.18 | 260 | 129 | 142 | | | | | 214 | 16.3 | 126 | <0.50 | <0.50 | <0.50 | 154 |
| C4 | 10/18/2013 | 8.24 | 260 | 129 | 139 | | | | | 220 | 16.3 | 126 | <0.50 | <0.50 | <0.50 | 154 |
| C4 | 11/17/2013 | 7.9 | 477 | 258 | 264 | | | | | 272 | 22.4 | 244 | <0.50 | <0.50 | <0.50 | 298 |
| C10 | 5/12/2012 | 7.73 | 136 | 67.2 | 215 | | | | | 132 | 2210 | 65.1 | <0.50 | <0.50 | <0.50 | 79.4 |
| C10 | 7/30/2012 | 8.23 | 254 | 130 | 207 | | | | | 180 | 995 | 132 | <0.50 | <0.50 | <0.50 | 161 |
| C10 | 7/30/2012 | | | | | | | | | | | | | | | |
| C10 | 8/10/2012 | 8.11 | 273 | 135 | 245 | | | | | 216 | 1320 | 146 | <0.50 | <0.50 | <0.50 | 178 |
| C10 | 8/27/2012 | 8.37 | 284 | 141 | 264 | | | | | 184 | 1650 | 154 | 2.03 | <0.50 | 2.44 | 183 |
| C10 | 6/22/2013 | 8.26 | 276 | 148 | 151 | | | | | 192 | 43.4 | 143 | <0.50 | <0.50 | <0.50 | 175 |
| C10 | 7/23/2013 | 8.19 | 251 | 125 | 156 | | | | | 174 | 199 | 133 | <0.50 | <0.50 | <0.50 | 162 |
| C10 | 8/22/2013 | 8.23 | 309 | 160 | 168 | | | | | 218 | 65.5 | 159 | <0.50 | <0.50 | <0.50 | 194 |
| C10 | 9/8/2013 | 7.94 | 287 | 150 | 163 | | | | | 186 | 25.4 | 147 | <0.50 | <0.50 | <0.50 | 180 |
| C10 | 9/8/2013 | 8.13 | 289 | 150 | 162 | | | | | 206 | 21.7 | 151 | <0.50 | <0.50 | <0.50 | 184 |
| C10 | 10/18/2013 | 8.25 | 263 | 136 | 160 | | | | | 212 | 61.2 | 136 | <0.50 | <0.50 | <0.50 | 166 |

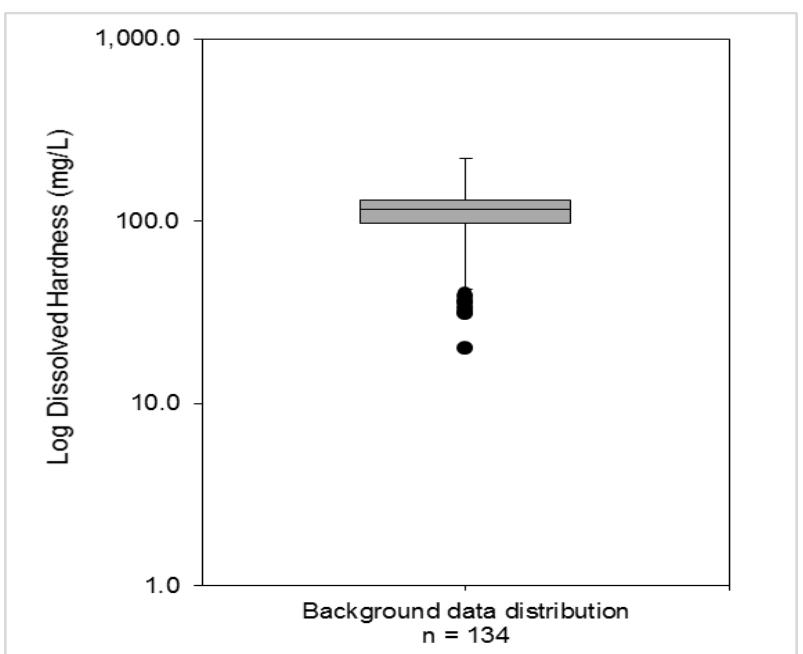
# APPENDIX C

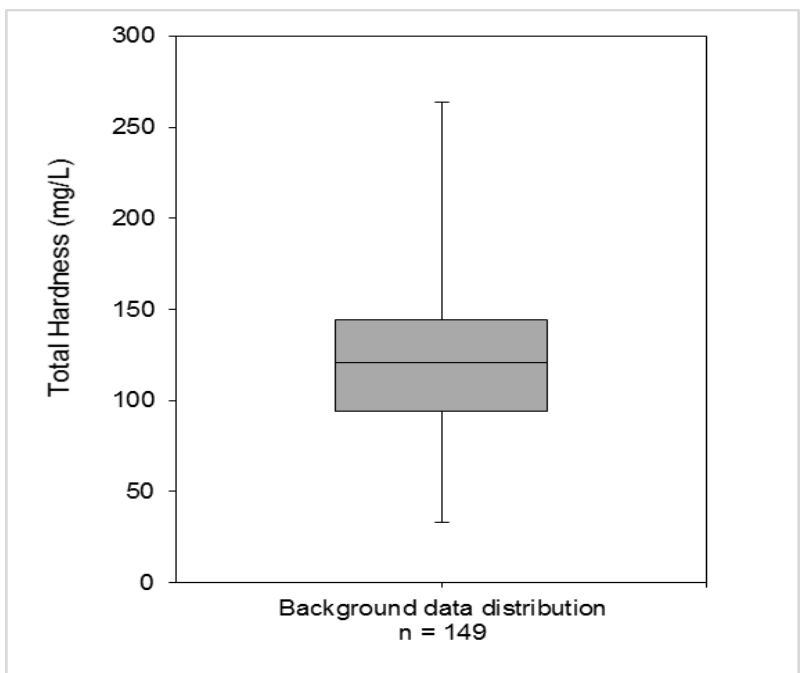
# BOXPLOT OUTLIER EXAMINATION

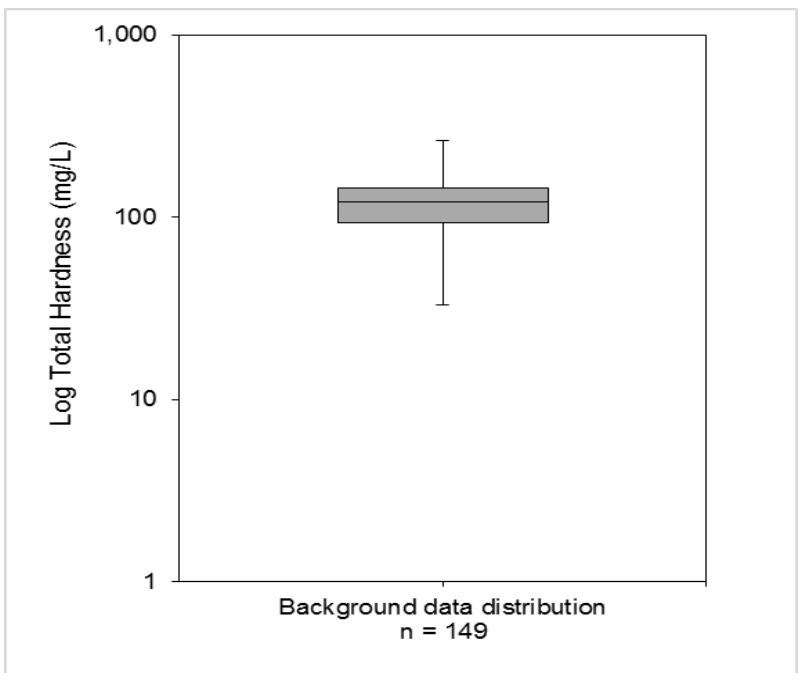


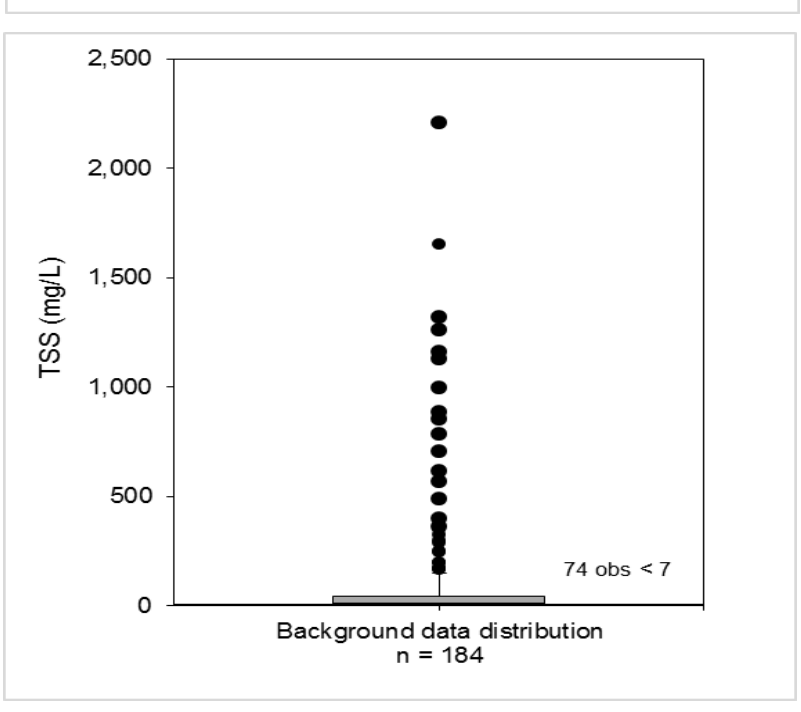



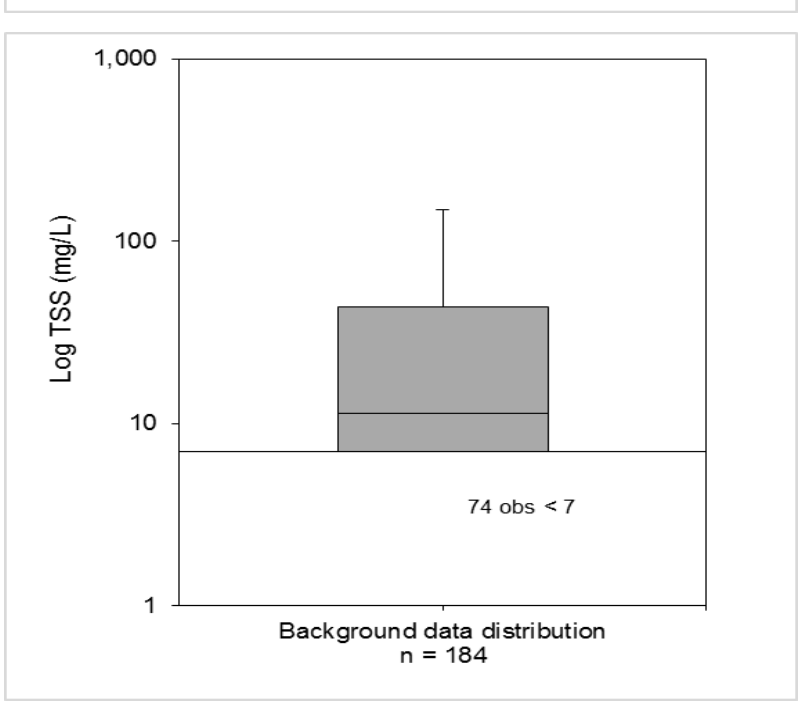




**Figure C.1: Boxplots of analytes on non-transformed and log transformed scales. Black dots represent possible outliers. Line represents highest < MDL and any < MDL below this are represented as number of observations below this line.**

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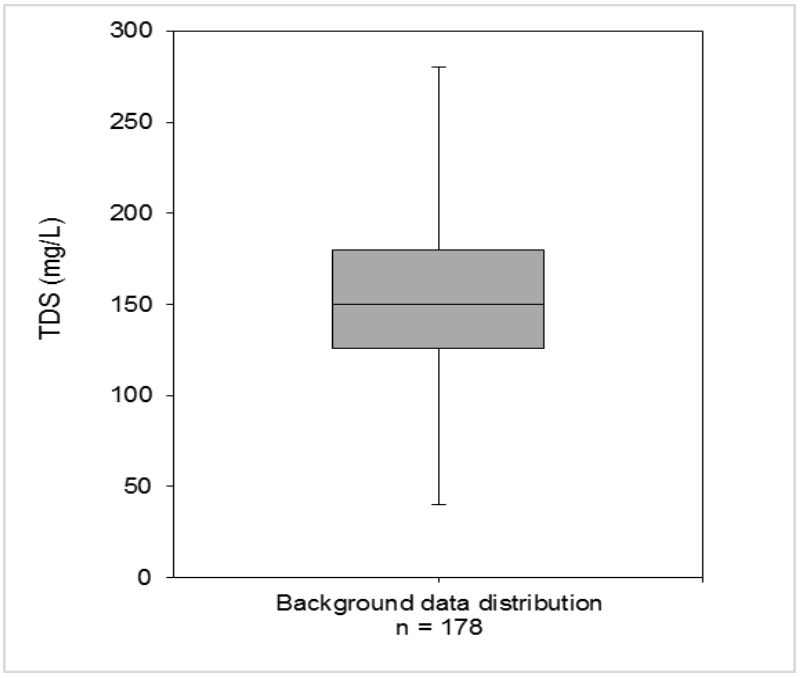


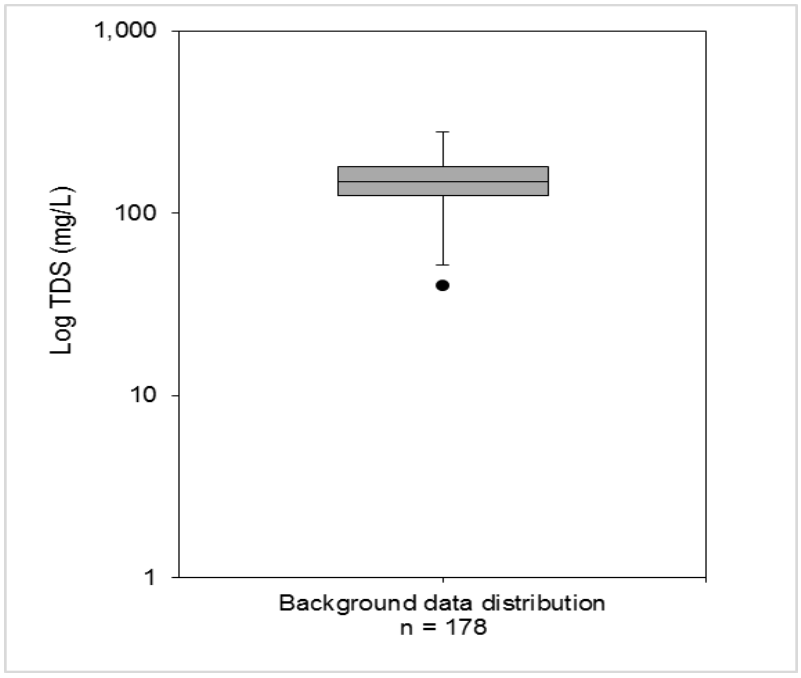


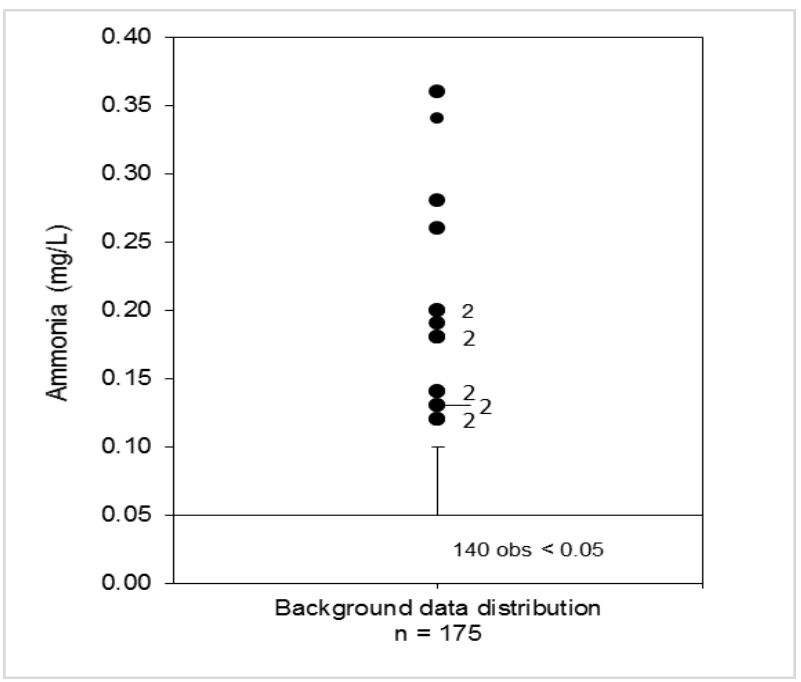


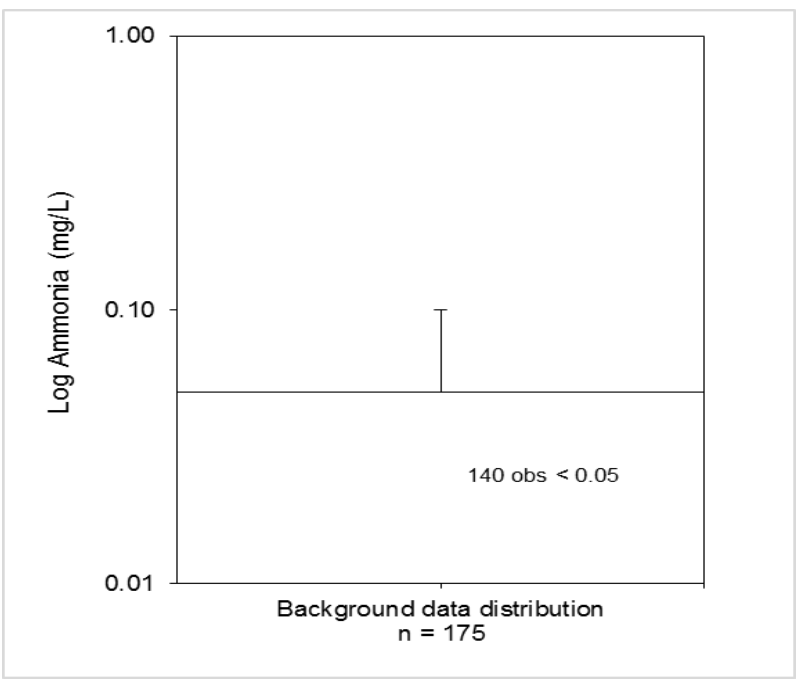


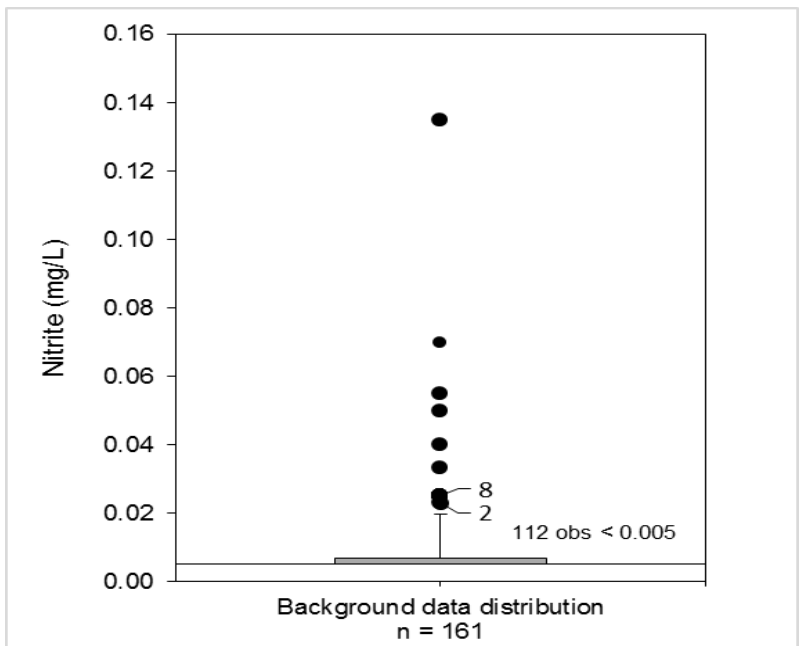


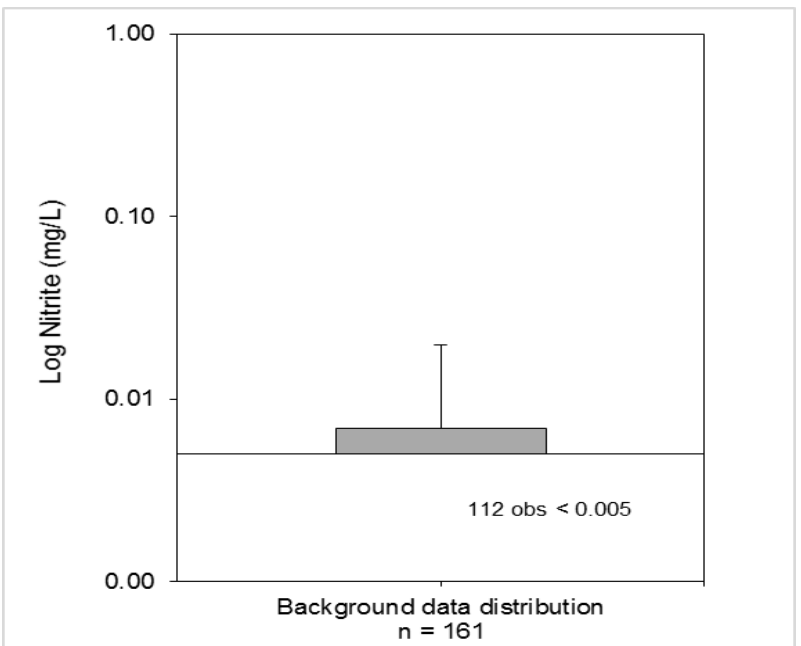


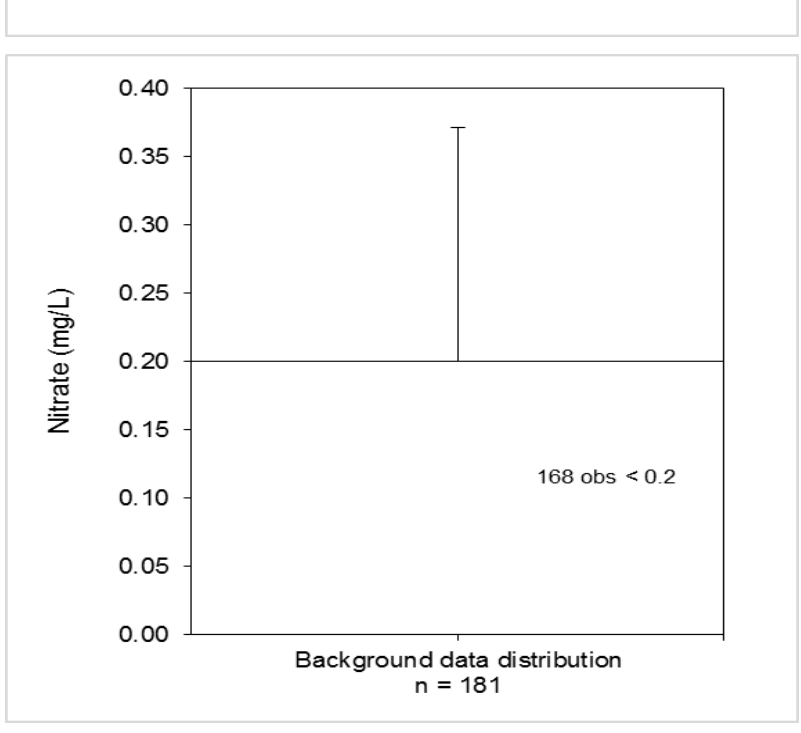


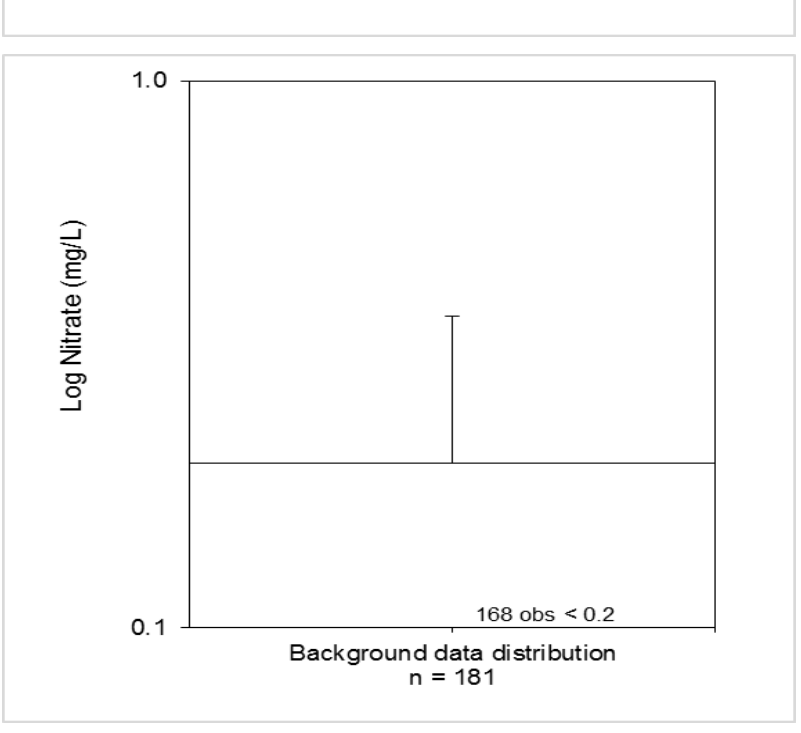


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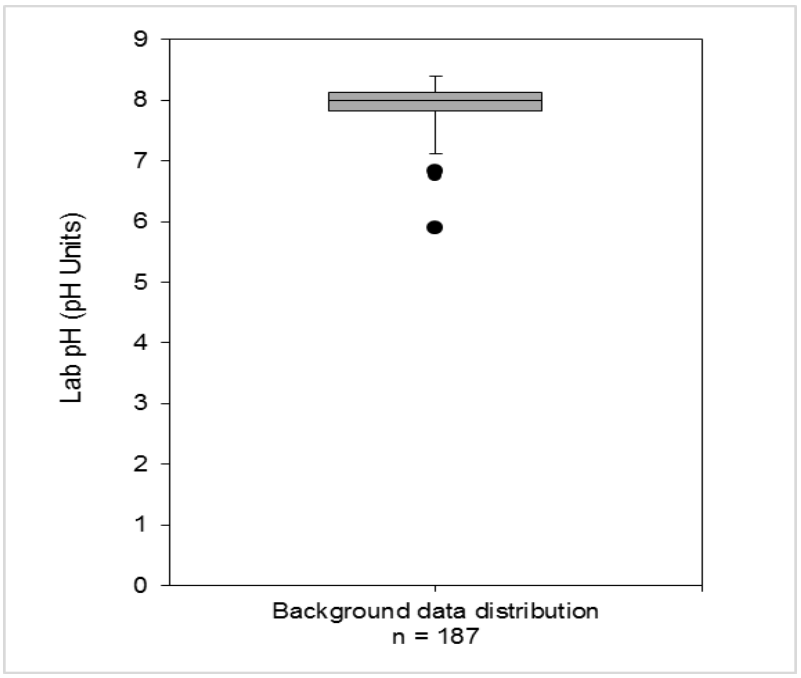


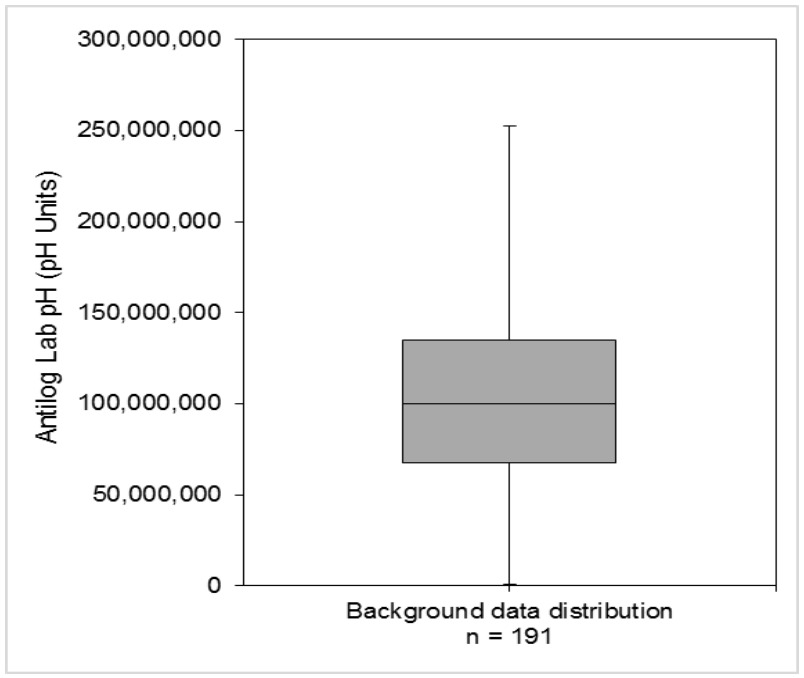


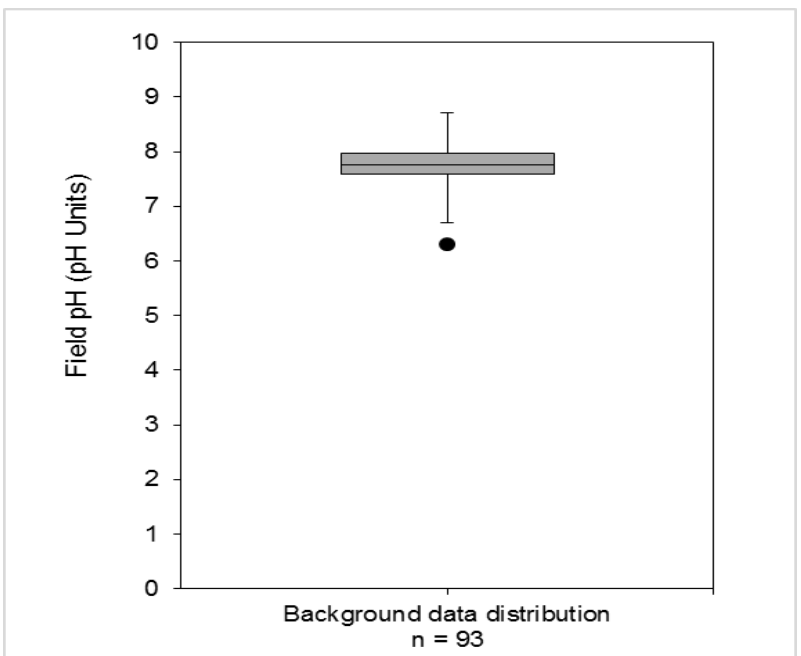


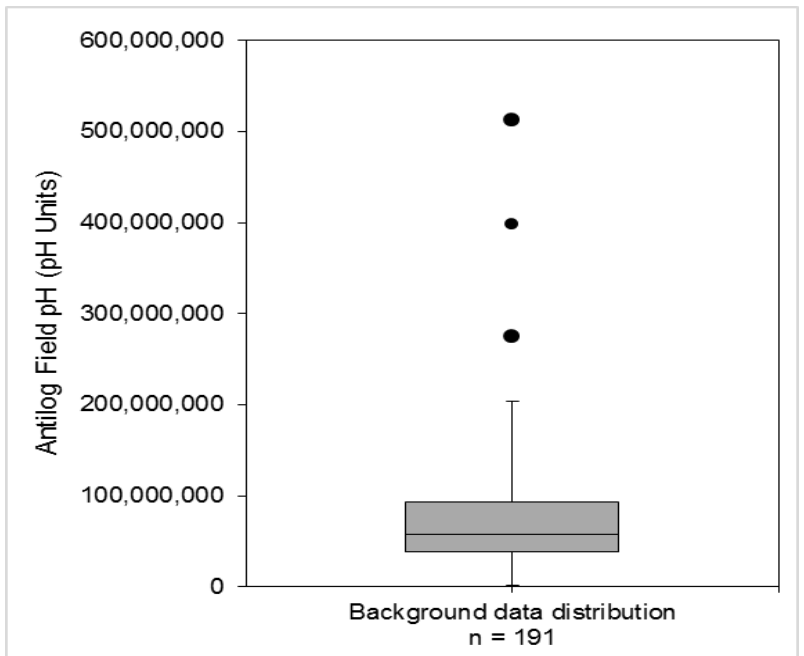


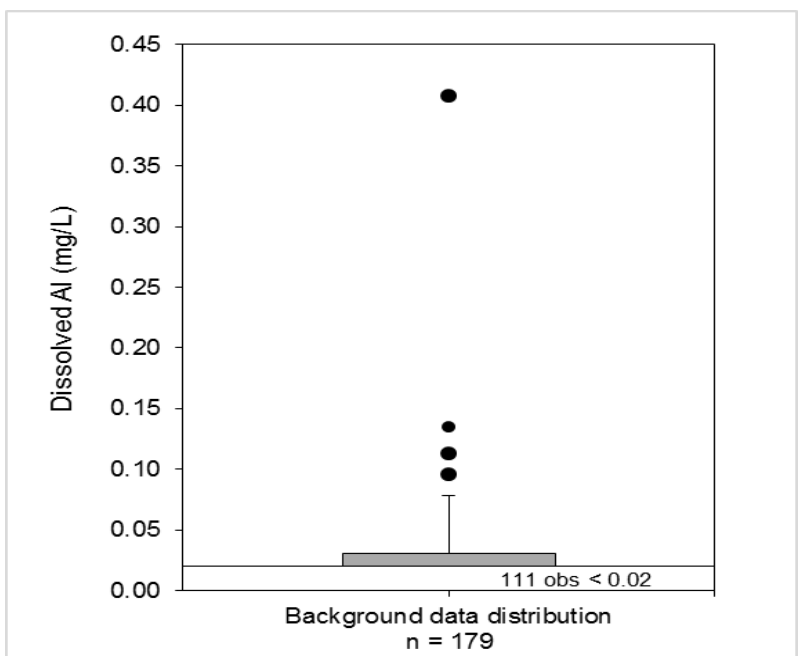


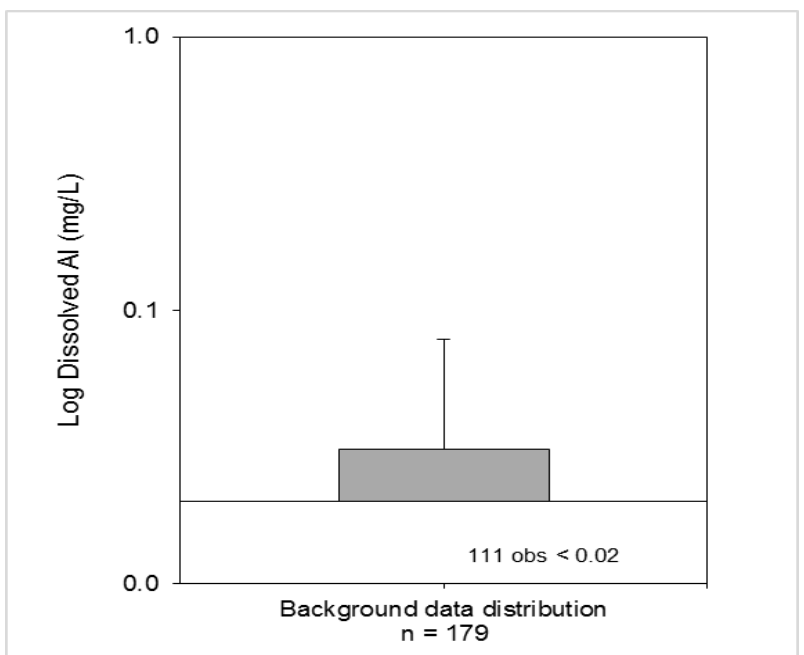


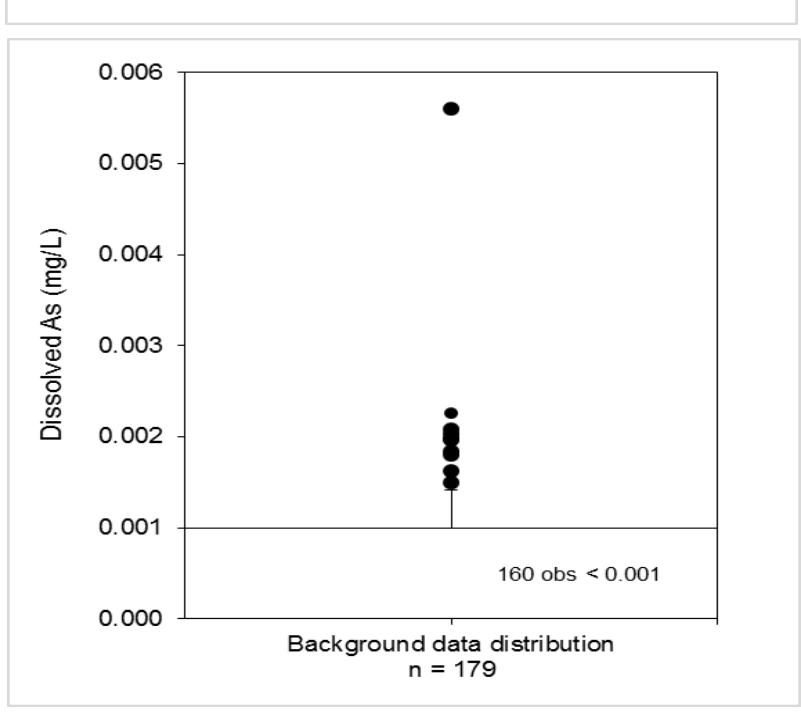


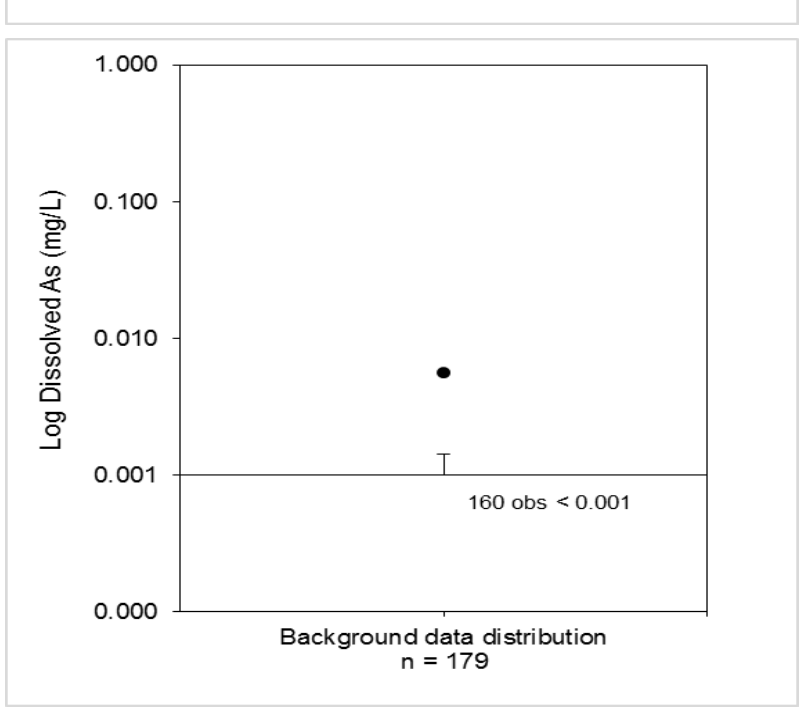


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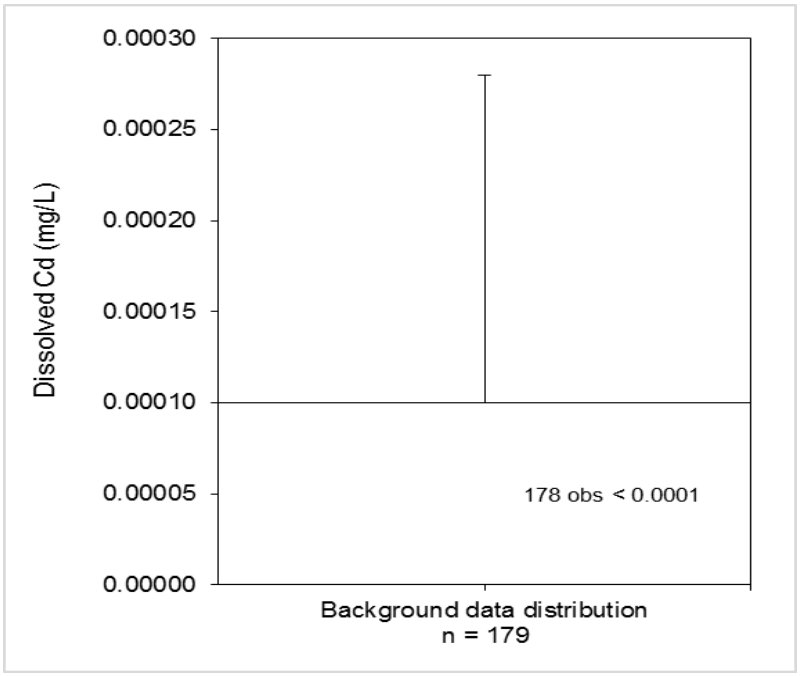


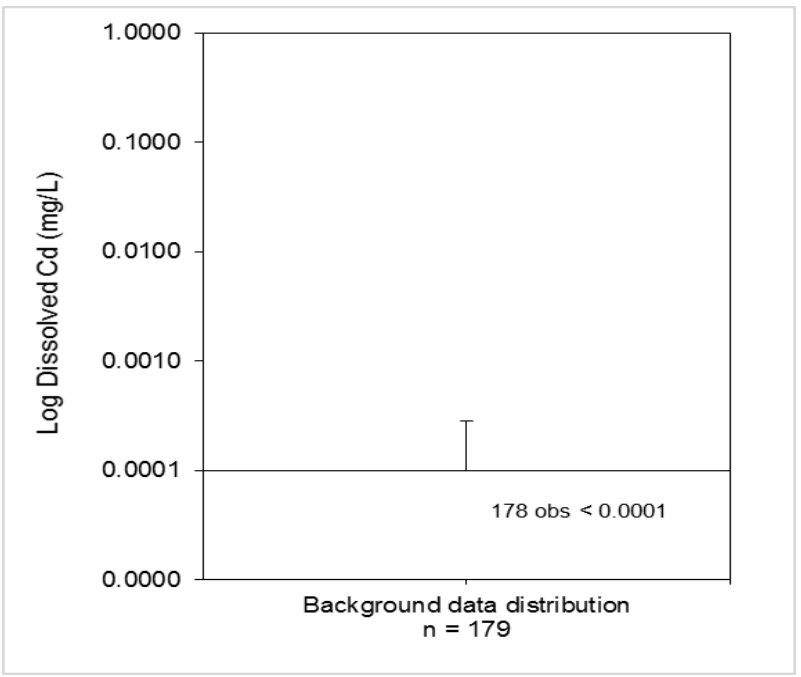


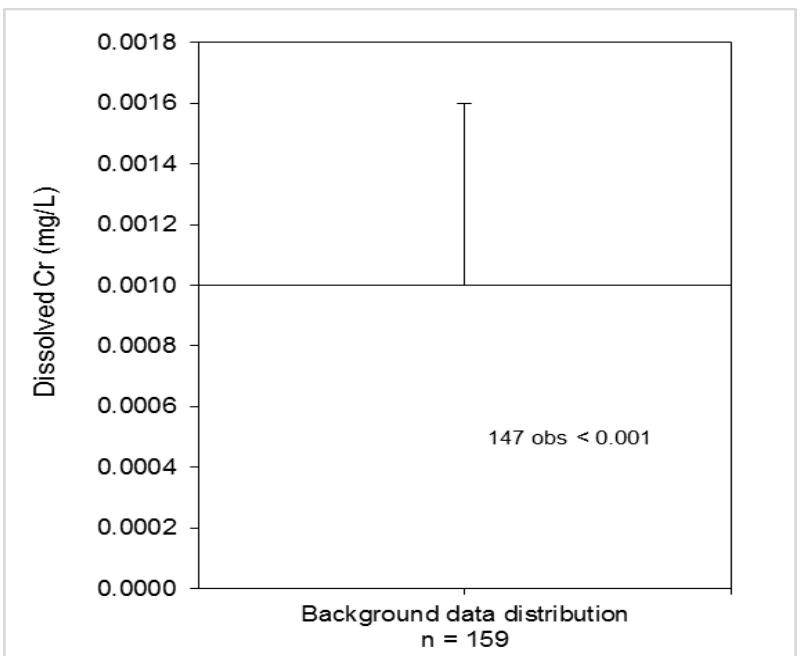


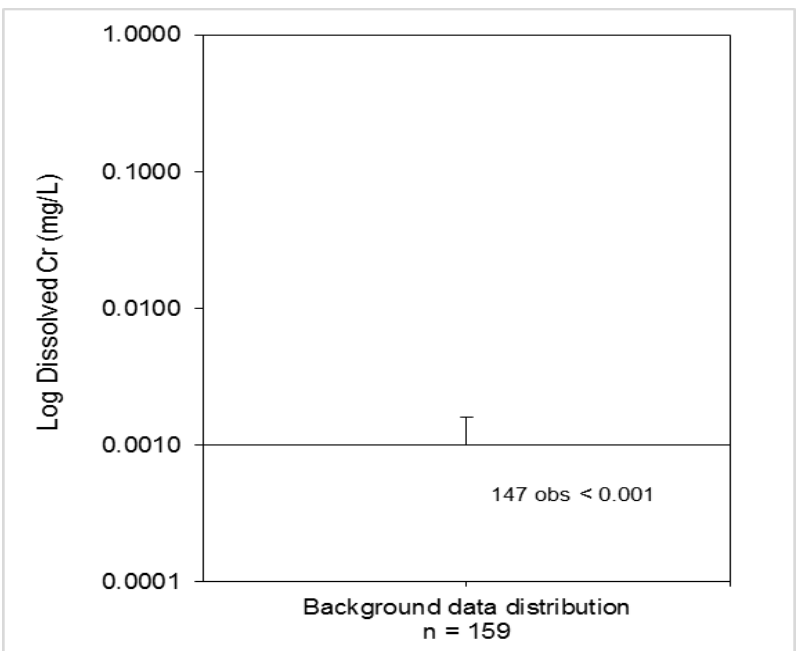


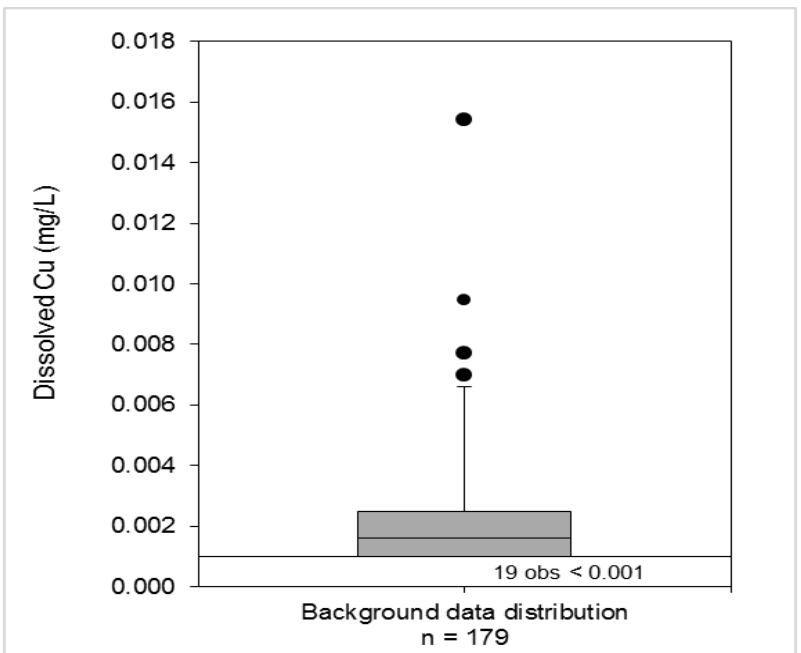


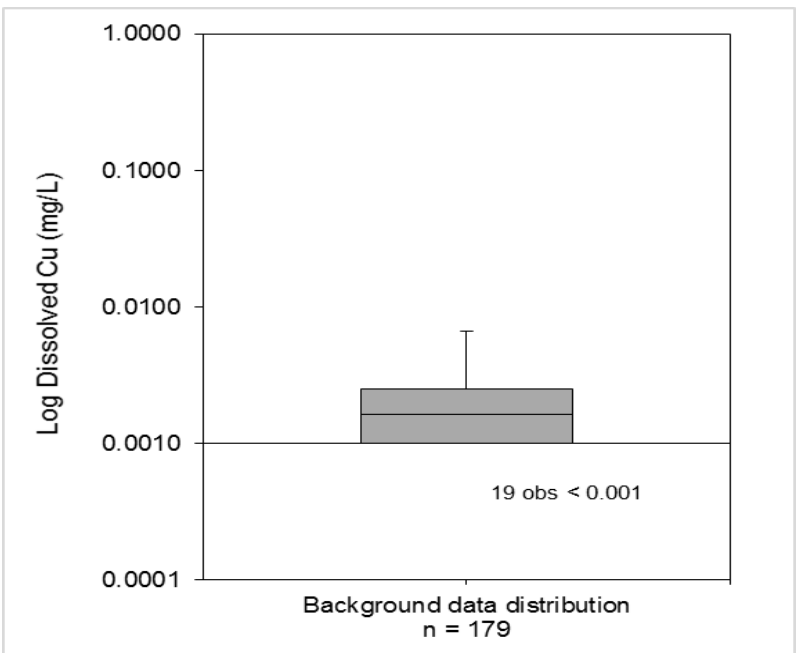


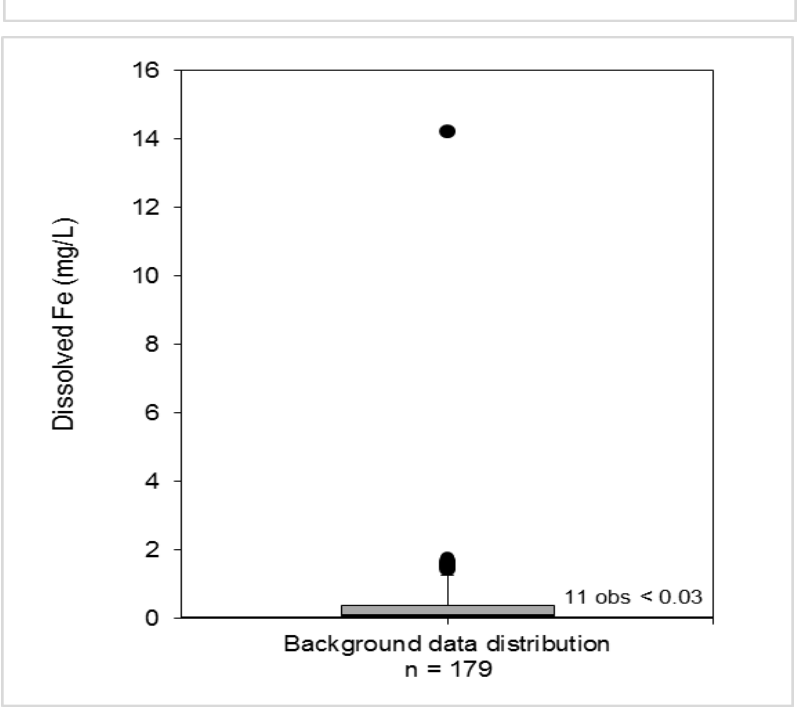


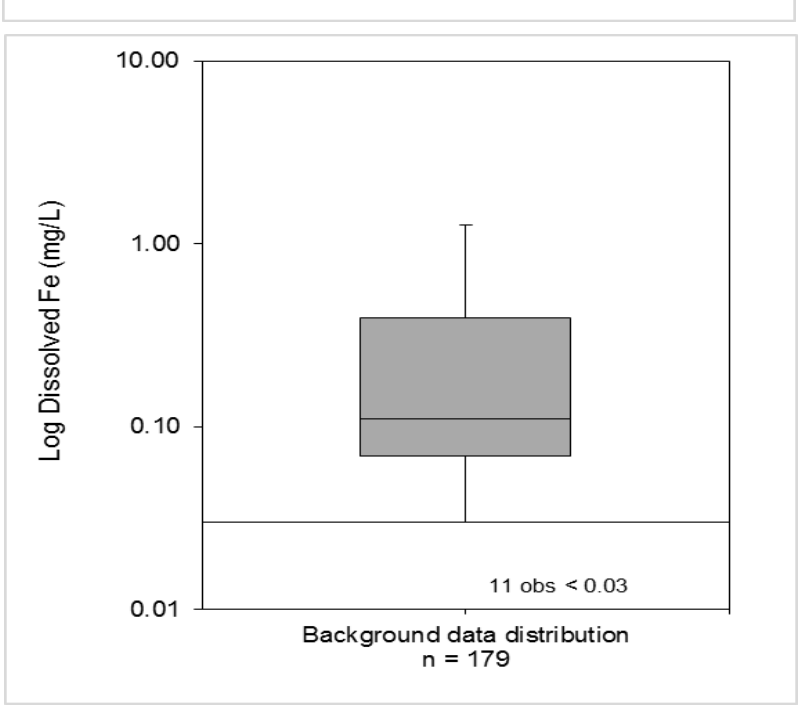


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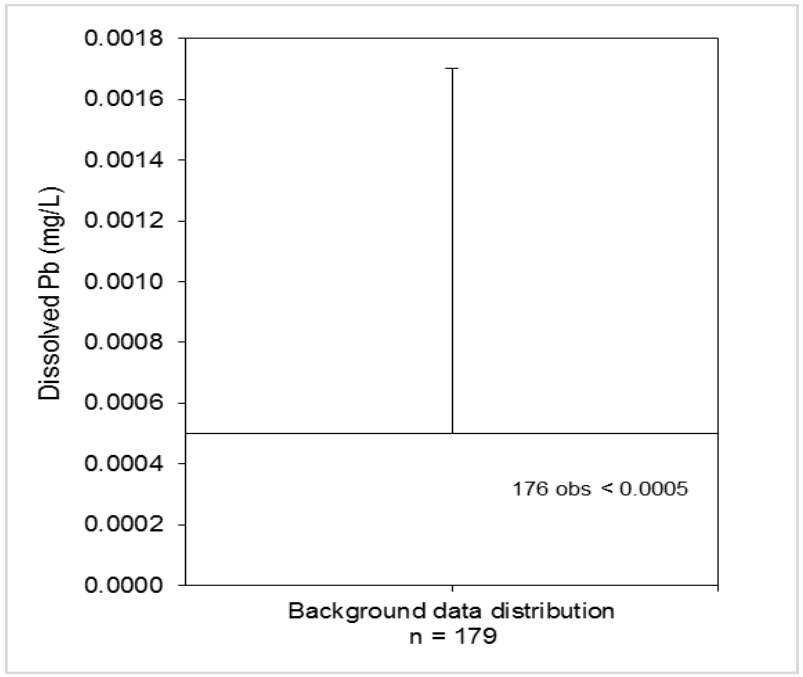


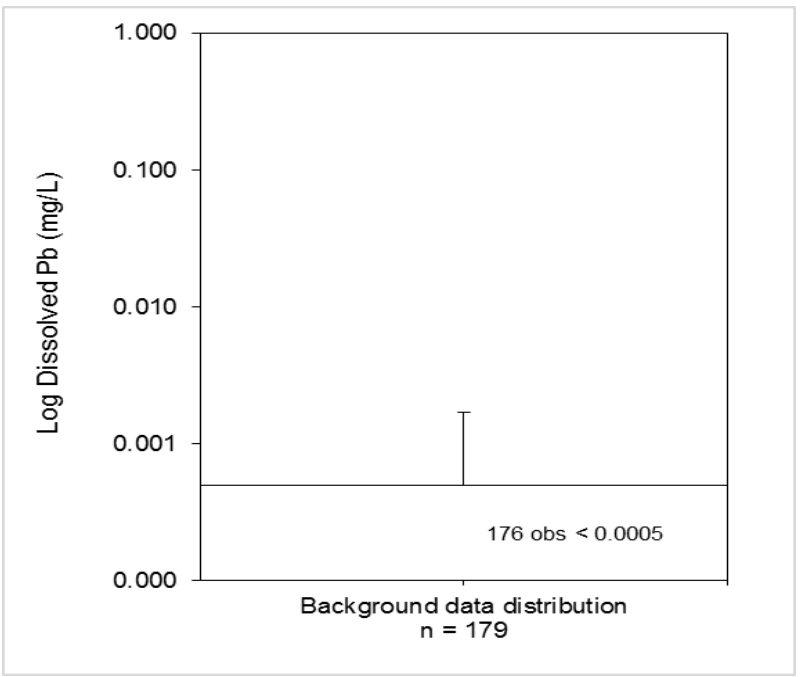


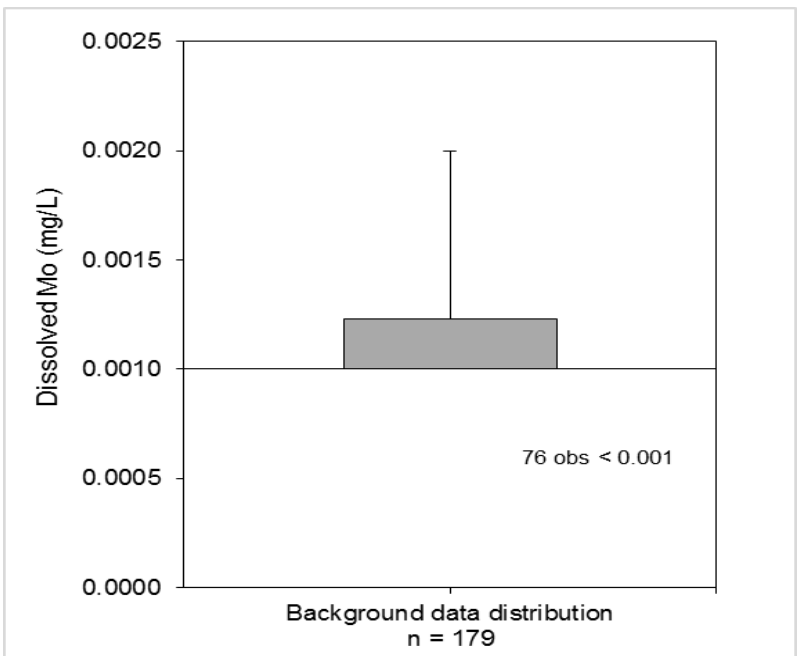


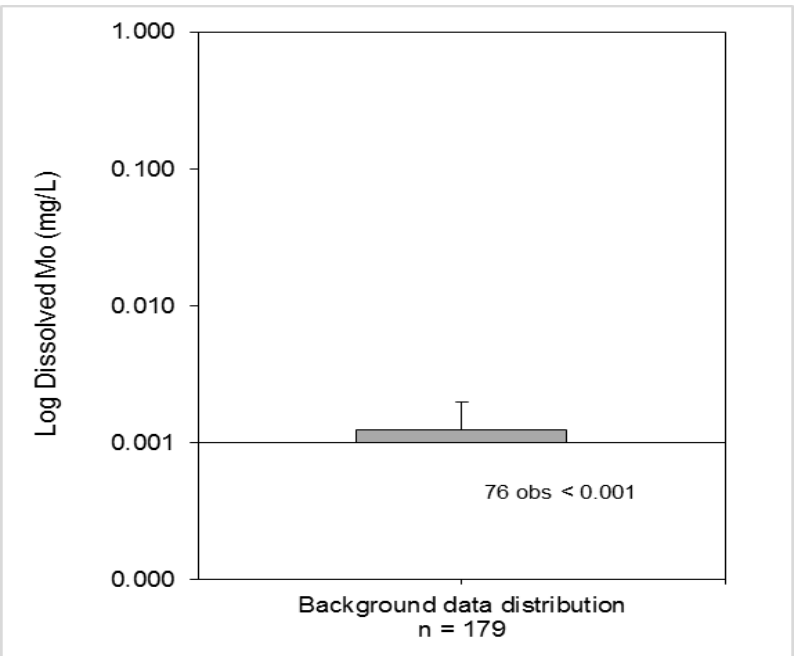


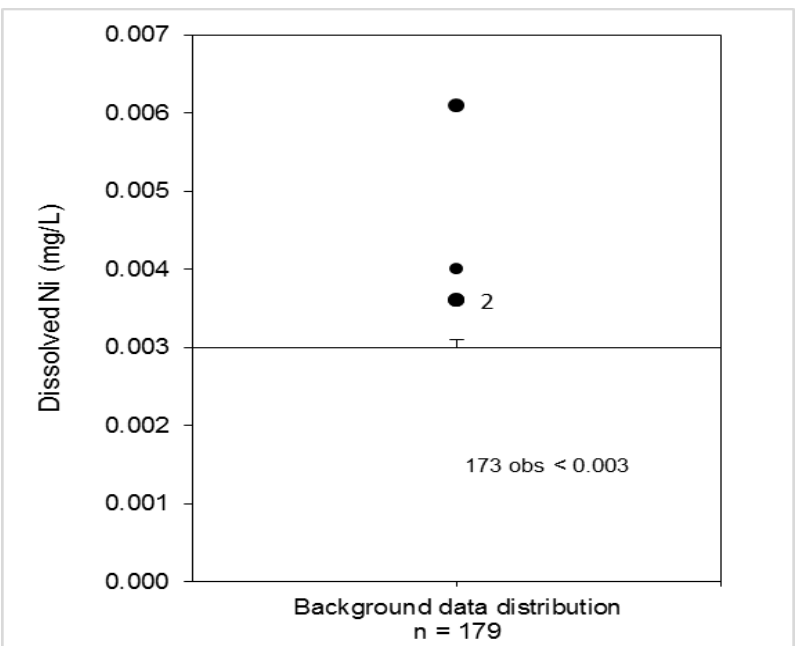


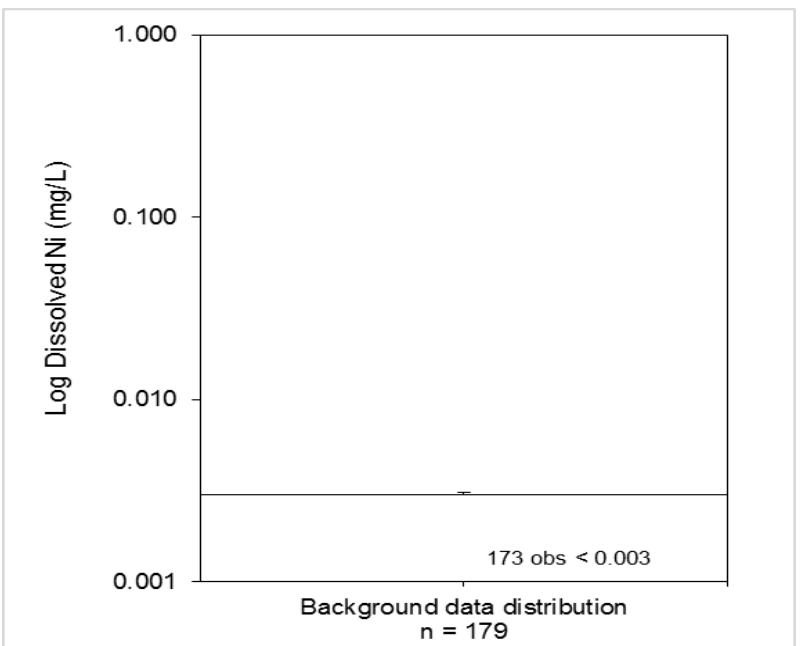


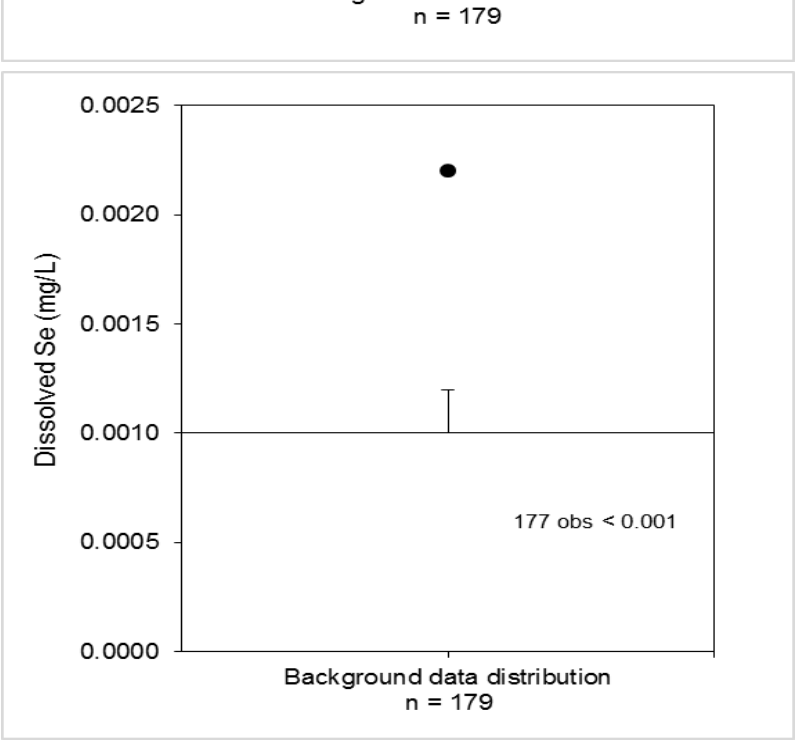


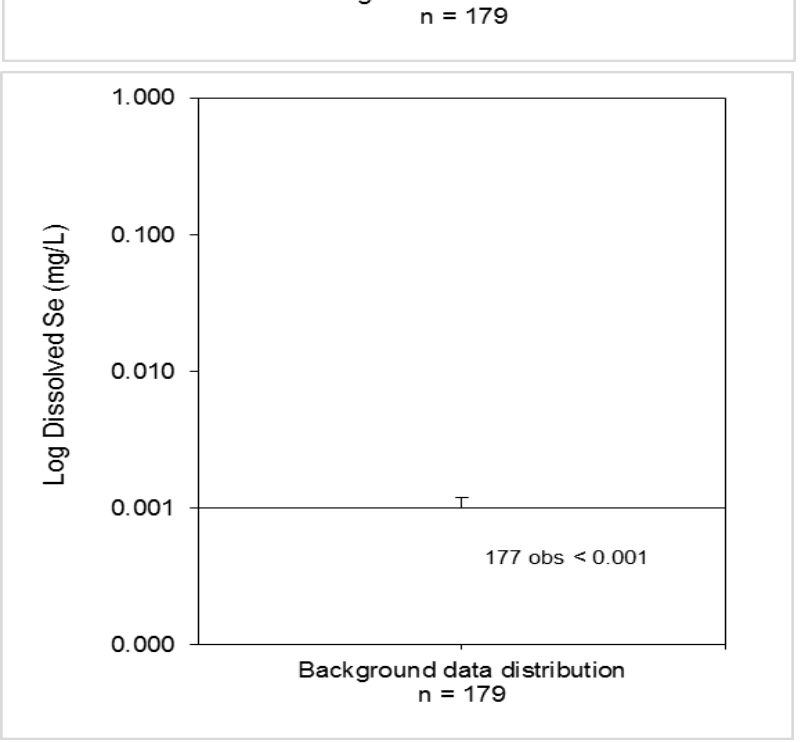


**Figure C.1: Boxplots of analytes on non-transformed and log transformed scales. Black dots represent possible outliers. Line represents highest < MDL and any < MDL below this are represented as number of observations below this line.**

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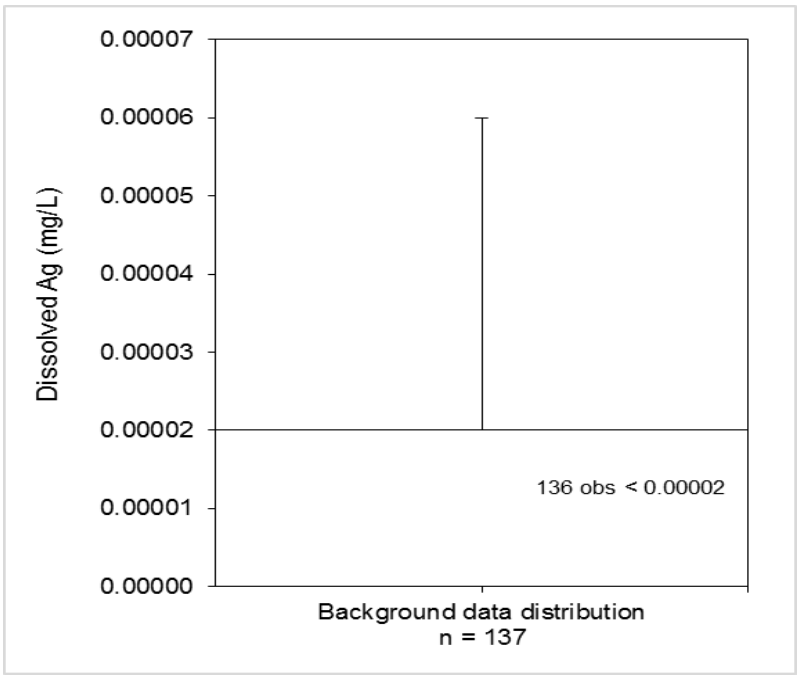


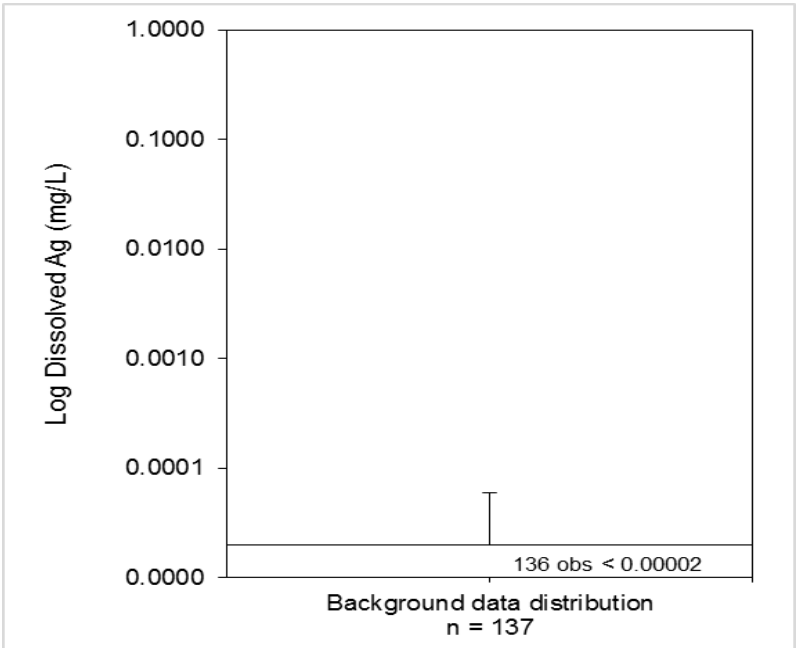


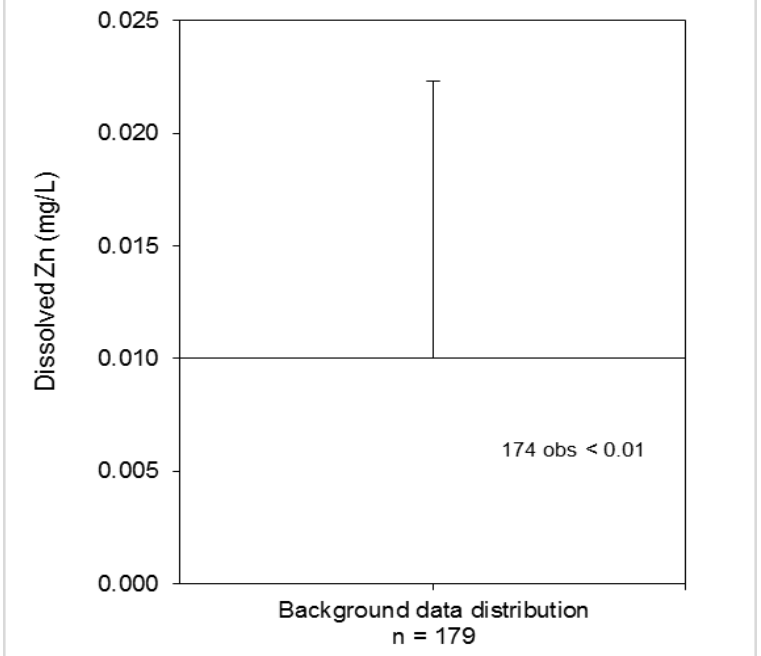


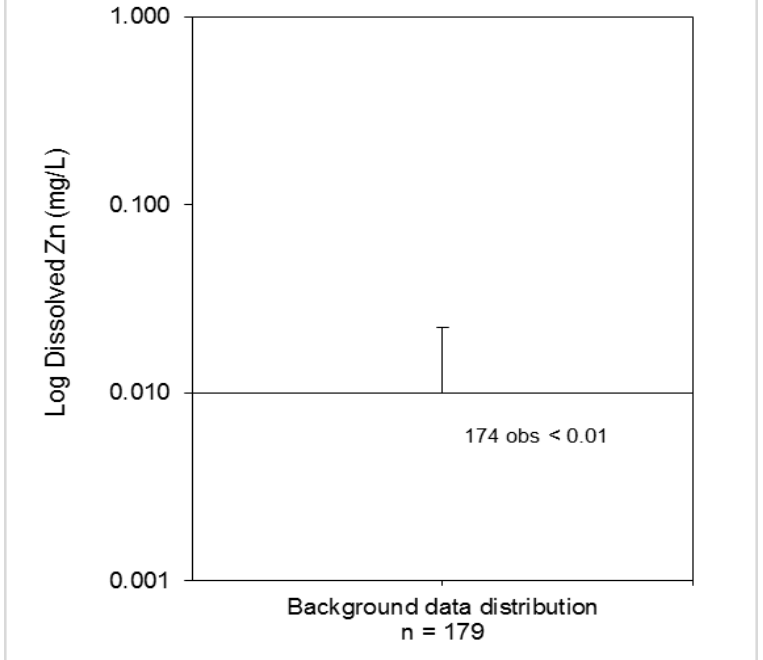


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NOTE: Possible outliers were only considered if they were detected on both non-transformed and log transformed scales

# APPENDIX D

# WATER QUALITY DATA SUMMARY CALCULATIONS

**Table D.1: Comparisons of dissolved arsenic ratios, relative to other analytes. Highlighted cells represent the sample with the potential arsenic concentration outlier**

| Station | Date | Arsenic Relative to: | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
| C4 | 11/17/2013 | 0.00018 | 0.000022 | 0.000021 | 0.00025 | 0.000021 | 0.020 | 0.22 | 0.056 | 0.00071 | 0.00078 | 0.17 | 254 | 4.3 | 5.9 | 0.00039 | 56 | 5.1 | 0.92 | 23 | 559 | 2.2 |
| Summary Statistics | Average | 0.00013 | 0.0000059 | 0.0000051 | 0.00010 | 0.0000038 | 0.034 | 0.32 | 0.026 | 0.000072 | 0.000093 | 0.038 | 76 | 1.2 | 0.40 | 0.0044 | 7.0 | 0.75 | 0.45 | 5.0 | 73 | 0.27 |
| | Minimum | 0.0000057 | 0.00000078 | 0.0000010 | 0.00000047 | 0.00000064 | 0.0012 | 0.0020 | 0.00067 | 0.000012 | 0.000013 | 0.0019 | 1.3 | 0.077 | 0.020 | 0.00039 | 0.18 | 0.067 | 0.10 | 0.045 | 6.7 | 0.011 |
| | Maximum | 0.0079 | 0.000024 | 0.000021 | 0.0011 | 0.000021 | 0.60 | 1.2 | 0.24 | 0.00071 | 0.00078 | 0.24 | 450 | 4.5 | 5.9 | 0.042 | 56 | 5.1 | 2.0 | 39 | 559 | 2.2 |
| | Median | 0.000047 | 0.0000046 | 0.0000044 | 0.000036 | 0.0000031 | 0.022 | 0.20 | 0.0083 | 0.000058 | 0.000064 | 0.033 | 60 | 1.0 | 0.25 | 0.0029 | 5.0 | 0.50 | 0.40 | 2.5 | 58 | 0.19 |
| | 95th Percentile | 0.00010 | 0.000016 | 0.000010 | 0.00037 | 0.000010 | 0.081 | 1.1 | 0.10 | 0.00018 | 0.00025 | 0.084 | 282 | 3.0 | 1.0 | 0.013 | 19 | 1.7 | 0.83 | 18 | 180 | 0.84 |
| | Standard Deviation | 0.00076 | 0.0000043 | 0.0000030 | 0.00016 | 0.0000026 | 0.058 | 0.32 | 0.044 | 0.000068 | 0.000096 | 0.032 | 89 | 0.87 | 0.51 | 0.0052 | 6.6 | 0.66 | 0.24 | 6.7 | 60 | 0.29 |

**Table D.2: Background data for Option 1 with median and 95th Percentile values.**

| Station | Date | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W1 | 5/27/2005 | | | 97 | 27 | 137 | 0.039 | 0.0020 | 0.054 | 8.05 | | 0.018 | 0.00051 | 0.000025 | 0.00050 | 0.0034 | 0.17 | 0.00025 | 0.00050 | 0.0015 | 0.00050 | 0.000010 | 0.0025 |
| W1 | 6/30/2005 | | | | 1.5 | 189 | 0.010 | 0.00050 | 0.063 | 8.17 | | 0.0065 | 0.00048 | 0.000025 | 0.00025 | 0.0020 | 0.046 | 0.000025 | 0.0011 | 0.00096 | 0.00050 | 0.0000050 | 0.0005 |
| W1 | 7/28/2005 | | | 157 | 1.5 | 189 | 0.010 | 0.00050 | 0.058 | 8.03 | | 0.0072 | 0.00048 | 0.000025 | 0.00025 | 0.0021 | 0.056 | 0.000073 | 0.0013 | 0.0011 | 0.00050 | 0.0000050 | 0.0025 |
| W1 | 8/29/2005 | | | 138 | 4.0 | 186 | 0.041 | 0.00050 | 0.022 | 8.28 | | 0.011 | 0.00060 | 0.0000085 | 0.00050 | 0.0024 | 0.25 | 0.00025 | 0.0010 | 0.0014 | 0.00050 | 0.000010 | 0.0025 |
| W1 | 9/28/2005 | | | 134 | 10 | 178 | 0.026 | 0.00050 | 0.048 | 7.59 | | 0.014 | 0.00058 | 0.0000085 | 0.00050 | 0.0026 | 0.33 | 0.00025 | 0.00050 | 0.0016 | 0.00050 | 0.000010 | 0.0025 |
| W1 | 10/15/2005 | | | 140 | 15 | 181 | 0.020 | 0.00050 | 0.13 | 8.13 | | 0.014 | 0.00054 | 0.000025 | 0.00025 | 0.0028 | 0.27 | 0.000025 | 0.00089 | 0.0014 | 0.00050 | 0.0000050 | 0.0014 |
| W2 | 5/27/2005 | | | 86 | 50 | 109 | 0.018 | 0.0010 | 0.045 | 8.05 | | 0.014 | 0.00025 | 0.000025 | 0.00050 | 0.0033 | 0.16 | 0.00025 | 0.00050 | 0.0015 | 0.00050 | 0.000010 | 0.0025 |
| W2 | 6/30/2005 | | | | 1.5 | 190 | 0.010 | 0.00050 | 0.062 | 8.17 | | 0.0073 | 0.00044 | 0.000025 | 0.00025 | 0.0021 | 0.039 | 0.000025 | 0.0011 | 0.0010 | 0.00050 | 0.0000050 | 0.0015 |
| W2 | 7/28/2005 | | | 153 | 1.5 | 194 | 0.010 | 0.00050 | 0.012 | 8.01 | | 0.0071 | 0.00044 | 0.000025 | 0.00025 | 0.0021 | 0.05 | 0.000025 | 0.0013 | 0.0011 | 0.00050 | 0.0000050 | 0.0011 |
| W2 | 8/30/2005 | | | 138 | 3.5 | 193 | 0.029 | 0.00050 | 0.014 | 8.26 | | 0.012 | 0.00058 | 0.0000085 | 0.00050 | 0.0024 | 0.23 | 0.00025 | 0.0010 | 0.0015 | 0.00050 | 0.000010 | 0.0025 |
| W2 | 9/28/2005 | | | 134 | 9.0 | 170 | 0.010 | 0.0010 | 0.046 | 7.90 | | 0.014 | 0.00059 | 0.0000085 | 0.00050 | 0.0025 | 0.34 | 0.00025 | 0.00050 | 0.0017 | 0.00050 | 0.000010 | 0.0025 |
| W2 | 10/15/2005 | | | 137 | 5.5 | 179 | 0.010 | 0.00050 | 0.13 | 8.11 | | 0.013 | 0.00053 | 0.000025 | 0.00025 | 0.0027 | 0.25 | 0.000025 | 0.00086 | 0.0014 | 0.00050 | 0.0000050 | 0.00050 |
| W3 | 5/27/2005 | | | 94 | 8.5 | 141 | 0.010 | 0.00050 | 0.012 | 7.99 | | 0.027 | 0.00025 | 0.000025 | 0.00050 | 0.0066 | 0.12 | 0.00025 | 0.00050 | 0.0014 | 0.00050 | 0.000010 | 0.0025 |
| W3 | 6/30/2005 | | | | 1.5 | 224 | 0.010 | 0.00050 | 0.052 | 8.22 | | 0.0080 | 0.00034 | 0.000025 | 0.00025 | 0.0034 | 0.042 | 0.00024 | 0.0016 | 0.00078 | 0.00050 | 0.0000050 | 0.012 |
| W3 | 7/29/2005 | | | 166 | 26 | 198 | 0.010 | 0.00050 | 0.028 | 8.06 | | 0.011 | 0.00041 | 0.000025 | 0.00025 | 0.0048 | 0.13 | 0.000025 | 0.0016 | 0.0012 | 0.00050 | 0.0000050 | 0.0015 |
| W3 | 8/29/2005 | | | 135 | 7.5 | 182 | 0.042 | 0.00050 | 0.0025 | 8.24 | | 0.018 | 0.00025 | 0.0000085 | 0.00050 | 0.0050 | 0.31 | 0.00025 | 0.0013 | 0.0014 | 0.00050 | 0.000010 | 0.0025 |
| W3 | 9/28/2005 | | | 129 | 8.0 | 174 | 0.010 | 0.00050 | 0.013 | 7.99 | | 0.026 | 0.00025 | 0.0000085 | 0.00050 | 0.0057 | 0.42 | 0.00025 | 0.0011 | 0.0014 | 0.00050 | 0.000010 | 0.0025 |
| W3 | 10/15/2005 | | | 134 | 1.5 | 176 | 0.023 | 0.00050 | 0.039 | 8.08 | | 0.022 | 0.00043 | 0.000025 | 0.00025 | 0.0061 | 0.39 | 0.000025 | 0.0012 | 0.0012 | 0.00050 | 0.0000050 | 0.0018 |
| W9 | 5/27/2005 | | | 49 | 1.5 | 104 | 0.010 | 0.00050 | 0.0025 | 7.56 | | 0.072 | 0.00025 | 0.000025 | 0.00050 | 0.0035 | 0.25 | 0.00025 | 0.00050 | 0.0013 | 0.00050 | 0.000010 | 0.0025 |
| W9 | 6/30/2005 | | | | 1.5 | 126 | 0.020 | 0.00050 | 0.0025 | 7.63 | | 0.035 | 0.00054 | 0.000025 | 0.00025 | 0.0018 | 0.53 | 0.000025 | 0.00037 | 0.0012 | 0.00050 | 0.0000050 | 0.00050 |
| W9 | 7/29/2005 | | | 95 | 3.7 | 129 | 0.010 | 0.00050 | 0.0025 | 7.51 | | 0.030 | 0.00057 | 0.000025 | 0.00025 | 0.0033 | 0.65 | 0.00019 | 0.0011 | 0.0013 | 0.00050 | 0.0000050 | 0.0040 |
| W9 | 8/29/2005 | | | 74 | 1.5 | 126 | 0.026 | 0.0016 | 0.0025 | 7.84 | | 0.045 | 0.00058 | 0.000022 | 0.00050 | 0.0017 | 0.67 | 0.00025 | 0.00050 | 0.0012 | 0.00050 | 0.000010 | 0.0025 |
| W9 | 9/28/2005 | | | 68 | 1.5 | 118 | 0.010 | 0.00050 | 0.0025 | 7.62 | | 0.058 | 0.00025 | 0.0000085 | 0.00050 | 0.0022 | 0.60 | 0.00025 | 0.00050 | 0.0011 | 0.00050 | 0.000010 | 0.0025 |
| W9 | 10/15/2005 | | | 64 | 1.5 | 111 | 0.010 | 0.00050 | 0.0025 | 7.19 | | 0.056 | 0.00039 | 0.000025 | 0.00025 | 0.0021 | 0.44 | 0.000025 | 0.00031 | 0.00096 | 0.00050 | 0.0000050 | 0.0017 |
| W10 | 5/27/2005 | | | 46 | 1.5 | 115 | 0.019 | 0.00050 | 0.0094 | 7.47 | | 0.14 | 0.00025 | 0.000025 | 0.00050 | 0.0095 | 0.061 | 0.00025 | 0.00050 | 0.0011 | 0.00050 | 0.000010 | 0.0055 |
| W10 | 6/30/2005 | | | | 6.0 | 116 | 0.036 | 0.00050 | 0.0025 | 7.31 | | 0.11 | 0.00059 | 0.000025 | 0.00062 | 0.0047 | 0.40 | 0.000082 | 0.00014 | 0.0018 | 0.00050 | 0.0000050 | 0.022 |
| W10 | 7/29/2005 | | | 55 | 4.2 | 105 | 0.010 | 0.00050 | 0.0025 | 7.34 | | 0.068 | 0.00037 | 0.000025 | 0.00025 | 0.0044 | 0.099 | 0.00011 | 0.00014 | 0.0012 | 0.00050 | 0.0000050 | 0.0074 |
| W10 | 8/29/2005 | | | 70 | 13 | 117 | 0.033 | 0.00050 | 0.0025 | 7.74 | | 0.043 | 0.00025 | 0.0000085 | 0.00050 | 0.0040 | 0.081 | 0.00025 | 0.00050 | 0.0016 | 0.00050 | 0.000010 | 0.0052 |
| W10 | 9/28/2005 | | | 101 | 15 | 141 | 0.010 | 0.00050 | 0.0025 | 7.77 | | 0.030 | 0.00025 | 0.0000085 | 0.00050 | 0.0033 | 0.048 | 0.00025 | 0.00050 | 0.00050 | 0.00050 | 0.000010 | 0.0025 |
| W10 | 10/15/2005 | | | 100 | 6.5 | 138 | 0.010 | 0.00050 | 0.0025 | 7.30 | | 0.036 | 0.00030 | 0.000025 | 0.00025 | 0.0041 | 0.055 | 0.00003 | 0.00024 | 0.00073 | 0.00050 | 0.0000050 | 0.0015 |
| W6 | 5/27/2005 | | | 65 | 14 | 103 | 0.010 | 0.0016 | 0.032 | 7.91 | | 0.014 | 0.00025 | 0.000025 | 0.00050 | 0.0016 | 0.072 | 0.00025 | 0.00050 | 0.0015 | 0.00050 | 0.000010 | 0.0025 |
| W6 | 6/30/2005 | | | | 12 | 123 | 0.010 | 0.00050 | 0.0086 | 7.41 | | 0.0056 | 0.00039 | 0.000025 | 0.00025 | 0.0010 | 0.015 | 0.000025 | 0.00045 | 0.00099 | 0.00050 | 0.0000050 | 0.021 |
| W6 | 7/29/2005 | | | 171 | 22 | 198 | 0.010 | 0.00050 | 0.022 | 8.01 | | 0.0070 | 0.00026 | 0.000025 | 0.00025 | 0.0025 | 0.062 | 0.000083 | 0.00082 | 0.00060 | 0.00050 | 0.0000050 | 0.0025 |
| W6 | 8/30/2005 | | | 106 | 1.5 | 147 | 0.010 | 0.00050 | 0.0025 | 8.17 | | 0.0067 | 0.00025 | 0.0000085 | 0.00050 | 0.0010 | 0.064 | 0.00025 | 0.00050 | 0.0011 | 0.00050 | 0.000010 | 0.0025 |
| W6 | 9/28/2005 | | | 106 | 3.5 | 133 | 0.010 | 0.00050 | 0.0025 | 7.95 | | 0.0067 | 0.00025 | 0.0000085 | 0.00050 | 0.0011 | 0.10 | 0.00025 | 0.00050 | 0.0012 | 0.00050 | 0.000010 | 0.0025 |
| W6 | 10/15/2005 | | | 98 | 1.5 | 128 | 0.010 | 0.00050 | 0.0061 | 7.92 | | 0.077 | 0.00042 | 0.000025 | 0.00025 | 0.0011 | 0.088 | 0.000025 | 0.00040 | 0.00118 | 0.00050 | 0.0000050 | 0.0015 |
| W6 | 6/2/2006 | | | | 115 | 96 | 0.021 | 0.00050 | 0.024 | 7.64 | | 0.025 | 0.00044 | 0.000025 | 0.00025 | 0.0018 | 0.096 | 0.000025 | 0.00031 | 0.00182 | 0.00050 | 0.0000050 | 0.0030 |
| W6 | 8/25/2006 | | 120 | | | 160 | | | 0.015 | 8.01 | | | | | | | | | | | | | |
| W6 | 9/6/2006 | | 110 | | 4.0 | | | | 0.015 | 7.86 | | 0.0080 | 0.00050 | 0.0000050 | 0.00060 | 0.0010 | 0.11 | 0.000050 | 0.00050 | 0.00060 | 0.00010 | | 0.0020 |
| W6 | 6/20/2007 | | | 81 | 16 | 130 | 0.025 | 0.025 | 0.10 | 7.77 | | | | | | | | | | | | | |
| W6 | 9/18/2007 | | | 93 | 8.0 | 172 | 0.025 | 0.010 | 0.010 | 7.95 | | | | | | | | | | | | | |
| W6 | 6/17/2008 | | | 86 | 17 | 120 | 0.025 | 0.070 | 0.010 | 7.82 | | | | | | | | | | | | | |
| W6 | 9/18/2008 | 18 | | | 4.0 | 150 | 0.025 | 0.0050 | 0.0050 | 7.80 | | 0.012 | 0.00040 | 0.0000050 | 0.0013 | 0.0020 | 0.090 | 0.000050 | 0.00027 | 0.0020 | 0.0012 | 0.0000050 | 0.0030 |
| W6 | 7/17/2012 | 8.0 | 104 | 163 | 1130 | 122 | 0.14 | 0.0025 | 0.026 | 7.98 | 7.92 | 0.016 | 0.00053 | 0.0000050 | 0.00050 | 0.0011 | 0.068 | 0.00010 | 0.00050 | 0.0010 | 0.00012 | 0.000010 | 0.0025 |
| W6 | 7/30/2012 | 8.1 | 101 | 145 | 614 | 124 | 0.070 | 0.0072 | 0.052 | 8.09 | 7.89 | 0.019 | 0.00059 | 0.0000050 | 0.00050 | 0.00089 | 0.081 | 0.00010 | 0.00050 | 0.00050 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 8/9/2012 | | 112 | 136 | 566 | 144 | 0.025 | 0.0066 | 0.022 | 8.17 | 8.09 | 0.017 | 0.00081 | 0.0000050 | 0.00050 | 0.00083 | 0.085 | 0.00010 | 0.00050 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W6 | 8/25/2012 | 7.7 | 103 | 161 | 1160 | 138 | 0.023 | 0.0025 | 0.045 | 8.00 | 7.76 | 0.014 | 0.00081 | 0.0000050 | 0.00050 | 0.0010 | 0.080 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 9/13/2012 | 14 | 88 | 93 | 50 | 118 | 0.011 | 0.0025 | 0.034 | 8.04 | 7.95 | 0.017 | 0.00047 | 0.0000050 | 0.00050 | 0.0015 | 0.11 | 0.00010 | 0.00050 | 0.0014 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 10/13/2012 | 10 | | 117 | 45 | 150 | 0.016 | 0.0025 | 0.042 | 7.92 | 8.30 | | | | | | | | | | | | |

**Table D.2: Background data for Option 1 with median and 95th Percentile values.**

| Station | Date | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W6 | 11/12/2012 | 8.7 | 153 | 155 | 2.2 | 162 | 0.025 | 0.0025 | 0.010 | 7.93 | 6.69 | 0.0062 | 0.00039 | 0.0000050 | 0.00050 | 0.0014 | 0.024 | 0.00010 | 0.00050 | 0.0014 | 0.00010 | 0.000010 | 0.0025 |
| W6 | 5/14/2013 | 22 | 31 | 34 | 13 | 84 | 0.13 | 0.0025 | 0.010 | 7.48 | 7.60 | 0.059 | 0.00037 | 0.000012 | 0.00050 | 0.0035 | 0.18 | 0.00010 | 0.00050 | 0.0013 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 6/22/2013 | 7.8 | 95 | 115 | 172 | 118 | 0.024 | 0.013 | 0.028 | 8.07 | 7.61 | 0.0095 | 0.00053 | 0.0000050 | 0.00050 | 0.00096 | 0.072 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 7/12/2013 | 8.3 | 88 | 95 | 25 | 136 | 0.012 | 0.0025 | 0.010 | 7.90 | 7.69 | 0.0066 | 0.00046 | 0.0000050 | 0.00050 | 0.00095 | 0.11 | 0.00010 | 0.00050 | 0.0011 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 8/22/2013 | 7.4 | 102 | 106 | 20 | 144 | 0.014 | 0.0025 | 0.010 | 8.04 | 7.81 | 0.0084 | 0.00052 | 0.0000050 | 0.00050 | 0.0012 | 0.10 | 0.00010 | 0.00050 | 0.0011 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 9/6/2013 | 6.4 | 101 | 114 | 5.2 | 130 | 0.0061 | 0.0025 | 0.030 | 7.95 | 7.60 | 0.0083 | 0.00056 | 0.0000050 | 0.00050 | 0.00089 | 0.11 | 0.00010 | 0.00050 | 0.0011 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 10/7/2013 | 8.2 | 107 | 106 | 74 | 176 | 0.044 | 0.0025 | 0.042 | 8.08 | 7.66 | 0.013 | 0.00051 | 0.0000050 | 0.00050 | 0.00097 | 0.15 | 0.00010 | 0.00050 | 0.0013 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 11/16/2013 | 8.8 | 119 | 123 | 33 | 120 | 0.015 | 0.0025 | 0.010 | 8.11 | 7.96 | 0.0057 | 0.00048 | 0.0000050 | 0.00050 | 0.00084 | 0.12 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W6 | 12/7/2013 | 8.8 | 159 | 182 | 3.6 | 194 | 0.0076 | 0.0025 | 0.010 | 8.21 | 7.50 | 0.0041 | 0.00061 | 0.000011 | 0.00050 | 0.0016 | 0.014 | 0.00010 | 0.00050 | 0.0011 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/27/2005 | | | 77 | 31 | 116 | 0.010 | 0.0018 | 0.082 | 7.95 | | 0.024 | 0.00025 | 0.000025 | 0.00050 | 0.0018 | 0.14 | 0.00025 | 0.00050 | 0.0016 | 0.00050 | 0.000010 | 0.0025 |
| W7 | 6/30/2005 | | | | 14 | 153 | 0.010 | 0.0017 | 0.17 | 7.87 | | 0.0086 | 0.00042 | 0.000025 | 0.00025 | 0.0012 | 0.070 | 0.000025 | 0.0012 | 0.00093 | 0.00050 | 0.0000050 | 0.0064 |
| W7 | 7/29/2005 | | | 167 | 20 | 197 | 0.010 | 0.00050 | 0.17 | 7.18 | | 0.0096 | 0.00035 | 0.000025 | 0.00025 | 0.0040 | 0.11 | 0.000025 | 0.0013 | 0.00095 | 0.00050 | 0.0000050 | 0.0020 |
| W7 | 8/30/2005 | | | 109 | 3.0 | 148 | 0.020 | 0.00050 | 0.023 | 8.19 | | 0.016 | 0.00051 | 0.0000085 | 0.00050 | 0.0014 | 0.29 | 0.00025 | 0.0010 | 0.0015 | 0.00050 | 0.000010 | 0.0025 |
| W7 | 9/28/2005 | | | 107 | 361 | 142 | 0.010 | 0.00050 | 0.059 | 8.02 | | 0.019 | 0.00054 | 0.0000085 | 0.00050 | 0.0016 | 0.32 | 0.00025 | 0.00050 | 0.0018 | 0.00050 | 0.000010 | 0.0025 |
| W7 | 10/15/2005 | | | 106 | 7.5 | 145 | 0.021 | 0.00050 | 0.10 | 6.75 | | 0.016 | 0.00048 | 0.000025 | 0.00025 | 0.0013 | 0.25 | 0.000025 | 0.00093 | 0.0015 | 0.00050 | 0.0000050 | 0.00050 |
| W7 | 6/2/2006 | | | | 705 | 104 | 0.062 | 0.0015 | 0.045 | 7.61 | | 0.071 | 0.00062 | 0.000025 | 0.00055 | 0.0021 | 0.55 | 0.000054 | 0.00070 | 0.0022 | 0.00050 | 0.0000050 | 0.00050 |
| W7 | 6/8/2006 | | | | | | | | | | | | | | | | | | | | | | |
| W7 | 6/15/2006 | | 100 | | 53 | 114 | 0.027 | | 0.18 | 7.86 | | 0.013 | 0.00040 | 0.0000050 | 0.00025 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.0010 | 0.00020 | | 0.00050 |
| W7 | 6/23/2006 | | 122 | | 328 | 176 | 0.028 | | 0.23 | 7.78 | | 0.011 | 0.00050 | 0.0000050 | 0.00070 | 0.00050 | 0.090 | 0.000050 | 0.0010 | 0.0013 | 0.00030 | | 0.0020 |
| W7 | 6/28/2006 | | 107 | | 103 | 120 | 0.010 | | 0.11 | 7.90 | | 0.41 | 0.00080 | 0.000030 | 0.0015 | 0.0030 | 0.060 | 0.00050 | 0.00050 | 0.0036 | 0.00010 | | 0.0050 |
| W7 | 7/7/2006 | | 110 | | 3.0 | 184 | | | 0.21 | 7.91 | | 0.0025 | 0.00060 | 0.0000050 | 0.0011 | 0.0010 | 0.060 | 0.000050 | 0.0020 | 0.0015 | 0.00010 | | 0.0010 |
| W7 | 7/12/2006 | | 110 | | 1.0 | | 0.014 | | 0.18 | 7.77 | | 0.0060 | 0.00050 | 0.0000050 | 0.0010 | 0.0010 | 0.060 | 0.000050 | 0.0010 | 0.00070 | 0.00020 | | 0.00050 |
| W7 | 7/20/2006 | | 130 | | 2.0 | | 0.012 | | 0.19 | 7.88 | | 0.0060 | 0.00040 | 0.0000050 | 0.00070 | 0.00050 | 0.11 | 0.00020 | 0.0010 | 0.00060 | 0.00010 | | 0.00050 |
| W7 | 7/26/2006 | | 128 | | 9.0 | | 0.016 | | 0.18 | 7.87 | | 0.0080 | 0.00040 | 0.0000050 | 0.00025 | 0.0020 | 0.10 | 0.000050 | 0.00050 | 0.0021 | 0.00010 | | 0.00050 |
| W7 | 8/2/2006 | | 128 | | 4.0 | | 0.015 | | 0.15 | 7.79 | | 0.0080 | 0.00010 | 0.0000050 | 0.00025 | 0.0010 | 0.070 | 0.000050 | 0.00050 | 0.00060 | 0.00010 | | 0.00050 |
| W7 | 8/10/2006 | | 126 | | 1.0 | | 0.014 | | 0.16 | 7.80 | | 0.0090 | 0.00050 | 0.0000050 | 0.00070 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00060 | 0.00010 | | 0.0010 |
| W7 | 8/25/2006 | | 129 | | | 180 | 0.027 | | 0.12 | 7.92 | | 0.012 | 0.00040 | 0.0000050 | 0.00060 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00090 | 0.00010 | | 0.0030 |
| W7 | 8/30/2006 | | 132 | | 1.0 | 200 | 0.012 | | 0.11 | 7.79 | | 0.013 | 0.00040 | 0.0000050 | 0.00080 | 0.0020 | 0.10 | 0.000050 | 0.0010 | 0.0012 | 0.00010 | | 0.0050 |
| W7 | 9/6/2006 | | 130 | | 4.0 | | 0.011 | | 0.080 | 7.88 | | 0.0050 | 0.00050 | 0.0000050 | 0.00080 | 0.0020 | 0.10 | 0.000050 | 0.0010 | 0.0010 | 0.00010 | | 0.0020 |
| W7 | 9/13/2006 | | 130 | | 5.0 | | 0.011 | | 0.094 | 7.84 | | 0.0080 | 0.00030 | 0.0000050 | 0.00090 | 0.0010 | 0.11 | 0.000050 | 0.0010 | 0.00090 | 0.00010 | | 0.0010 |
| W7 | 9/20/2006 | | 132 | | 3.0 | | 0.0080 | | 0.11 | 7.85 | | 0.0070 | 0.00050 | 0.00028 | 0.00070 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.00025 | 0.00020 | | 0.00050 |
| W7 | 9/28/2006 | | 129 | | | 182 | 0.011 | | 0.080 | 7.26 | | 0.011 | 0.00040 | 0.0000050 | 0.00080 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00080 | 0.00010 | | 0.0020 |
| W7 | 10/4/2006 | | 126 | | 2.0 | | 0.079 | | 0.10 | 7.94 | | 0.0025 | 0.00030 | 0.0000050 | 0.00025 | 0.00050 | 0.11 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0010 |
| W7 | 10/12/2006 | | 132 | | 4.0 | 164 | 0.024 | | 0.12 | 7.39 | | 0.0070 | 0.00040 | 0.0000050 | 0.00025 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.00060 | 0.00030 | | 0.0020 |
| W7 | 6/5/2007 | | | 113 | 75 | 162 | 0.025 | 0.033 | 0.050 | 7.97 | | | | | | | | | | | | | |
| W7 | 6/20/2007 | 8.2 | 110 | | 6.0 | 164 | 0.025 | 0.025 | 0.30 | 7.84 | | 0.014 | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00025 | 0.00010 | | 0.0040 |
| W7 | 7/18/2007 | 14 | 128 | 125 | 5.7 | 179 | 0.025 | 0.025 | 0.30 | 7.78 | | 0.011 | 0.00050 | 0.0000050 | 0.0010 | 0.0020 | 0.040 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0060 |
| W7 | 8/24/2007 | | | 124 | 4.7 | 192 | 0.025 | 0.025 | 0.20 | 8.04 | | | | | | | | | | | | | |
| W7 | 9/18/2007 | 11 | 110 | | 20 | 182 | 0.025 | 0.010 | 0.050 | 8.00 | | 0.0070 | 0.00040 | 0.0000050 | 0.0016 | 0.0010 | 0.080 | 0.000050 | 0.0020 | 0.00080 | 0.00010 | | 0.0020 |
| W7 | 10/30/2007 | | | 129 | 6.5 | 174 | 0.025 | 0.14 | 0.010 | 7.73 | | | | | | | | | | | | | |
| W7 | 4/22/2008 | | 187 | | 1.0 | 268 | 0.025 | 0.055 | 0.010 | 8.40 | | 0.010 | 0.00027 | 0.000040 | 0.00097 | 0.0012 | 0.030 | 0.000067 | 0.0017 | 0.0010 | 0.00030 | | 0.0017 |
| W7 | 6/3/2008 | | 92 | 98 | 15 | 137 | 0.025 | 0.040 | 0.037 | 8.02 | | 0.0050 | 0.00010 | 0.000040 | 0.0013 | 0.00050 | 0.050 | 0.000050 | 0.0012 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| W7 | 6/17/2008 | | | | 10 | 156 | 0.025 | 0.050 | 0.14 | 7.95 | | 0.020 | 0.00010 | 0.000040 | 0.0013 | 0.0010 | 0.070 | 0.000050 | 0.0015 | 0.0010 | 0.00220 | 0.0000050 | 0.0020 |
| W7 | 8/6/2008 | 9.0 | 123 | 124 | 105 | 167 | 0.025 | 0.0050 | 0.14 | 7.92 | | 0.014 | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.070 | 0.000050 | 0.0010 | 0.0010 | 0.00010 | 0.000060 | 0.0060 |
| W7 | 9/18/2008 | 17 | | | 28 | 170 | 0.025 | 0.0050 | 0.030 | 7.89 | | 0.070 | 0.00030 | 0.0000050 | 0.0016 | 0.0040 | 0.20 | 0.0017 | 0.00072 | 0.0010 | 0.00030 | 0.0000050 | 0.0030 |
| W7 | 10/28/2008 | 11 | 123 | | 5.7 | 183 | 0.025 | | | 7.84 | | 0.0090 | 0.00050 | 0.0000050 | 0.00050 | 0.0010 | 0.078 | 0.000050 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| W7 | 4/30/2009 | 18 | 20 | | 1.0 | 52 | | | | 6.84 | 7.60 | 0.053 | 0.00010 | 0.000080 | 0.00060 | 0.0050 | 0.070 | 0.00010 | 0.00013 | 0.00050 | 0.00030 | 0.0000050 | 0.0090 |
| W7 | 6/8/2009 | 9.2 | 93 | | 32 | 156 | | | | 7.90 | 7.74 | 0.013 | 0.00030 | 0.0000050 | 0.00020 | 0.0020 | 0.050 | 0.000050 | 0.0013 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| W7 | 7/28/2009 | | 137 | | 4.0 | 184 | | | | 8.07 | | | | | | | | | | | | | |

**Table D.2: Background data for Option 1 with median and 95th Percentile values.**

| Station | Date | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 8/6/2009 | | 121 | | 2.0 | 202 | | | 0.18 | 8.35 | 7.50 | | | | | | | | | | | | |
| W7 | 8/25/2009 | 8.2 | | | | | | | | | 8.04 | | | | | | | | | | | | |
| W7 | 8/31/2009 | | 110 | | | | | | | | | 0.010 | 0.00040 | 0.0000050 | 0.0012 | 0.0040 | 0.10 | 0.00040 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| W7 | 10/7/2009 | 7.8 | 125 | 141 | 3.7 | 140 | 0.010 | 0.0025 | 0.14 | 7.99 | 8.24 | 0.0070 | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |
| W7 | 10/25/2009 | 8.7 | 126 | 141 | 2.0 | 120 | 0.010 | 0.0025 | 0.15 | 8.05 | 8.23 | 0.0070 | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |
| W7 | 4/19/2010 | | | 80 | 3.5 | 142 | | | | 7.81 | 7.31 | 0.019 | 0.00030 | 0.000020 | 0.00040 | 0.0060 | 0.090 | 0.00030 | 0.00080 | 0.00050 | 0.00030 | 0.0000050 | 0.0050 |
| W7 | 4/27/2010 | 23 | 36 | 35 | 2.0 | 62 | 0.015 | 0.0025 | 0.010 | 7.60 | 7.65 | 0.075 | 0.00030 | 0.0000050 | 0.00050 | 0.0041 | 0.15 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 4/29/2010 | 19 | 36 | 36 | 2.0 | 62 | 0.016 | 0.0050 | 0.020 | 7.50 | 7.72 | 0.065 | 0.00030 | 0.0000050 | 0.00050 | 0.0034 | 0.18 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/1/2010 | 19 | 41 | 44 | 15 | 74 | 0.031 | 0.0080 | 0.070 | 7.70 | 7.15 | 0.053 | 0.00040 | 0.000020 | 0.00050 | 0.0032 | 0.26 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/3/2010 | 22 | 45 | 46 | 12 | 80 | 0.016 | 0.0025 | 0.010 | 7.70 | 7.74 | 0.047 | 0.00040 | 0.0000050 | 0.00050 | 0.0027 | 0.38 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/5/2010 | 15 | 49 | 55 | 12 | 76 | 0.0050 | 0.0025 | 0.010 | 7.80 | | 0.038 | 0.00050 | 0.0000050 | 0.00050 | 0.0025 | 0.57 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/7/2010 | 13 | 57 | 56 | 18 | 62 | 0.051 | 0.0070 | 0.10 | 7.80 | 7.95 | 0.028 | 0.00040 | 0.000010 | 0.00050 | 0.0026 | 0.36 | 0.00010 | 0.00050 | 0.0020 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/9/2010 | 13 | 80 | 71 | 2.0 | 130 | 0.0025 | 0.0025 | 0.070 | 8.00 | 8.03 | 0.023 | 0.00040 | 0.0000050 | 0.00050 | 0.0018 | 0.30 | 0.00010 | 0.00050 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 5/10/2010 | 12 | 81 | 90 | 2.0 | 130 | 0.015 | 0.0060 | 0.13 | 8.10 | 8.06 | 0.021 | 0.00040 | 0.000020 | 0.00050 | 0.0022 | 0.28 | 0.00010 | 0.00050 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 5/12/2010 | 10 | 82 | 85 | 2.0 | 100 | 0.025 | 0.0025 | 0.030 | 8.00 | | 0.017 | 0.00040 | 0.0000050 | 0.00050 | 0.0016 | 0.17 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 5/14/2010 | 9.2 | 73 | 71 | 15 | 130 | 0.034 | 0.0025 | 0.010 | 8.10 | 7.26 | 0.096 | 0.00040 | 0.000010 | 0.00050 | 0.0031 | 0.34 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 5/16/2010 | 8.8 | 86 | 76 | 12 | 120 | 0.068 | 0.0025 | 0.030 | 8.30 | 7.32 | 0.012 | 0.00030 | 0.0000050 | 0.00050 | 0.0013 | 0.080 | 0.00010 | 0.0010 | 0.00050 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 5/17/2010 | 7.2 | 80 | 76 | 11 | 130 | 0.037 | 0.0025 | 0.010 | 8.20 | 7.52 | 0.018 | 0.00040 | 0.0000050 | 0.00050 | 0.0012 | 0.068 | 0.00010 | 0.0010 | 0.00050 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 5/19/2010 | 7.5 | 99 | 103 | 4.0 | 120 | 0.020 | 0.0025 | 0.060 | 8.20 | 7.62 | 0.016 | 0.00030 | 0.0000050 | 0.00050 | 0.0017 | 0.069 | 0.00010 | 0.0010 | 0.00050 | 0.00030 | 0.000010 | 0.0025 |
| W7 | 5/21/2010 | 8.7 | 92 | 96 | 22 | 120 | 0.017 | 0.0025 | 0.050 | 8.10 | 8.02 | 0.013 | 0.00020 | 0.000050 | | 0.0010 | 0.057 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 5/23/2010 | 8.2 | 98 | 103 | 33 | 150 | 0.013 | 0.0060 | 0.060 | 8.10 | 7.61 | 0.017 | 0.00020 | 0.000050 | | 0.0010 | 0.069 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 5/25/2010 | 8.1 | 125 | 124 | 140 | 140 | 0.070 | 0.025 | 0.080 | 7.90 | 7.24 | 0.024 | 0.00050 | 0.000050 | | 0.0030 | 0.062 | 0.00010 | 0.0020 | 0.0015 | 0.00050 | | 0.0050 |
| W7 | 5/27/2010 | 8.1 | 113 | 148 | 350 | 140 | 0.052 | 0.0025 | 0.13 | 8.00 | 7.53 | 0.028 | 0.00050 | 0.000050 | | 0.0030 | 0.069 | 0.00010 | 0.0020 | 0.0015 | 0.00050 | | 0.0050 |
| W7 | 5/29/2010 | 6.3 | 111 | 129 | 200 | 160 | 0.10 | 0.011 | 0.22 | 8.20 | 7.73 | 0.017 | 0.00050 | 0.000050 | | 0.0020 | 0.051 | 0.00010 | 0.0020 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 5/31/2010 | 7.2 | 109 | 130 | 290 | 160 | 0.025 | 0.023 | 0.12 | 8.20 | 7.83 | 0.020 | 0.00020 | 0.000050 | | 0.0020 | 0.050 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/2/2010 | 4.9 | 113 | 135 | 81 | 140 | 0.0050 | 0.023 | 0.14 | 8.20 | 7.26 | 0.012 | 0.00040 | 0.000050 | | 0.0010 | 0.030 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/4/2010 | 6.4 | 111 | 125 | 60 | 140 | 0.34 | 0.014 | 0.16 | 8.20 | 7.48 | 0.013 | 0.00040 | 0.000050 | | 0.0010 | 0.030 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/6/2010 | | 128 | 133 | 39 | 170 | 0.10 | 0.013 | 0.16 | 8.20 | | 0.0050 | 0.00020 | 0.000050 | | 0.0010 | 0.024 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/14/2010 | 5.9 | 122 | 128 | 43 | 150 | 0.016 | 0.0025 | 0.16 | 8.29 | | 0.011 | 0.00020 | 0.000050 | | 0.00050 | 0.025 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/16/2010 | 6.1 | 120 | 128 | 17 | 150 | 0.016 | 0.0025 | 0.17 | 8.30 | 6.78 | 0.0050 | 0.00020 | 0.000050 | | 0.00050 | 0.026 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/18/2010 | 6.2 | 122 | 123 | 28 | 140 | | 0.0025 | 0.15 | 8.17 | 7.03 | 0.0050 | 0.00020 | 0.000050 | | 0.00050 | 0.023 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/20/2010 | 7.6 | 112 | 118 | 33 | 140 | | 0.0080 | 0.13 | 8.20 | 7.10 | 0.014 | 0.00020 | 0.000050 | | 0.0010 | 0.028 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 6/22/2010 | 10 | 98 | 115 | 300 | 140 | 0.014 | 0.0025 | 0.12 | 8.03 | 7.92 | 0.033 | 0.00050 | 0.000050 | | 0.0020 | 0.082 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 6/24/2010 | 10 | 100 | 116 | 64 | 130 | 0.012 | 0.0070 | 0.070 | 8.03 | 7.95 | 0.018 | 0.00020 | 0.000050 | | 0.0010 | 0.056 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 6/26/2010 | 9.3 | 106 | 106 | 21 | 120 | 0.0090 | 0.0025 | 0.10 | 8.26 | 8.03 | 0.012 | 0.00040 | 0.000050 | | 0.0010 | 0.038 | 0.00010 | 0.0010 | 0.0040 | 0.00040 | | 0.0050 |
| W7 | 6/28/2010 | 8.7 | 114 | 107 | 9.0 | 150 | 0.022 | 0.0025 | 0.13 | 8.03 | 7.89 | 0.0050 | 0.00020 | 0.000050 | | 0.0010 | 0.028 | 0.00010 | 0.0010 | 0.00050 | 0.00040 | | 0.0050 |
| W7 | 7/5/2010 | 16 | 93 | 106 | 53 | 150 | 0.027 | 0.0025 | 0.070 | 8.06 | 8.02 | 0.019 | 0.00020 | 0.000050 | | 0.0020 | 0.10 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 8/5/2010 | 13 | 118 | 116 | | 170 | | | | | 7.91 | 0.011 | 0.00040 | 0.000050 | | 0.0020 | 0.11 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| W7 | 9/12/2010 | 17 | 107 | 104 | 11 | 210 | 0.039 | 0.0025 | 0.030 | 7.98 | 8.02 | 0.016 | 0.00050 | 0.000050 | | 0.0010 | 0.23 | 0.00010 | 0.0010 | 0.0020 | 0.00040 | | 0.0050 |
| W7 | 10/8/2010 | 13 | 111 | 126 | 3.0 | 150 | 0.069 | 0.0025 | 0.070 | 8.10 | 7.85 | 0.011 | 0.00040 | 0.0000050 | 0.00050 | 0.0012 | 0.13 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 4/27/2011 | 23 | 43 | 43 | 0.5 | 72 | 0.010 | 0.0025 | 0.010 | 7.41 | | 0.057 | 0.00030 | 0.000030 | 0.00050 | 0.0077 | 0.15 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0050 |
| W7 | 5/2/2011 | 22 | 32 | 33 | 7.0 | 40 | | 0.0025 | 0.010 | 7.11 | | 0.076 | 0.00020 | 0.000040 | 0.00050 | 0.0070 | 0.17 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.010 |
| W7 | 6/1/2011 | 11 | 92 | 94 | 23 | 120 | 0.012 | | | 8.09 | | 0.013 | 0.00030 | 0.0000050 | 0.00050 | 0.0016 | 0.099 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 6/16/2011 | 13 | 97 | 108 | 85 | 130 | 0.013 | 0.0025 | 0.10 | 8.00 | | 0.022 | 0.00040 | 0.0000050 | 0.00050 | 0.0019 | 0.21 | 0.00010 | 0.0010 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 7/1/2011 | 21 | 77 | 88 | 150 | 120 | 0.016 | 0.0070 | 0.050 | 7.76 | | 0.034 | 0.00070 | 0.000010 | 0.00050 | 0.0031 | 0.44 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 8/2/2011 | 24 | 59 | 86 | 400 | 110 | | 0.0025 | 0.060 | 7.67 | | 0.051 | 0.00070 | 0.000020 | 0.00050 | 0.0041 | 0.61 | 0.00010 | 0.00050 | 0.0030 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 8/16/2011 | 18 | 98 | 97 | 22 | 150 | 0.015 | 0.0025 | 0.060 | 7.90 | | 0.036 | 0.00070 | 0.0000050 | 0.00050 | 0.0019 | 0.59 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 8/19/2011 | 19 | 93 | 93 | 22 | 140 | 0.0060 | 0.0025 | 0.040 | 8.12 | | 0.033 | 0.00080 | 0.000010 | 0.00050 | 0.0020 | 0.56 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 9/12/2011 | 13 | 118 | 119 | 1.0 | 170 | 0.025 | 0.0025 | 0.050 | 8.03 | 7.92 | 0.024 | 0.00070 | 0.000010 | 0.00050 | 0.0016 | 0.62 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |

**Table D.2: Background data for Option 1 with median and 95th Percentile values.**

| Station | Date | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W7 | 10/6/2011 | 12 | 110 | 113 | 2.0 | 150 | 0.019 | 0.0025 | 0.11 | 8.07 | 7.65 | 0.013 | 0.00060 | 0.000030 | 0.00050 | 0.0012 | 0.35 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| W7 | 11/22/2011 | 7.7 | 148 | 144 | 27 | 156 | 0.021 | 0.0025 | 0.14 | 7.96 | | 0.0076 | 0.00040 | 0.0000050 | 0.00050 | 0.0011 | 0.17 | 0.00010 | 0.0013 | 0.0012 | 0.00016 | 0.000010 | 0.0025 |
| W7 | 1/24/2012 | 5.3 | 169 | 158 | 2.0 | 226 | 0.0050 | 0.0025 | 0.32 | 8.13 | | 0.0053 | 0.00041 | 0.000035 | 0.00050 | 0.0011 | 0.094 | 0.00010 | 0.0015 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| W7 | 2/25/2012 | 6.1 | 165 | 160 | 2.0 | 216 | 0.0060 | 0.0025 | 0.29 | 7.99 | 7.16 | 0.021 | 0.00033 | 0.000064 | 0.00050 | 0.015 | 0.049 | 0.00024 | 0.0014 | 0.00050 | 0.00034 | 0.000010 | 0.0083 |
| W7 | 3/5/2012 | 5.2 | 161 | 159 | 3.2 | 176 | 0.0067 | 0.0025 | 0.20 | 8.17 | 6.72 | 0.0031 | 0.00039 | 0.0000050 | 0.00050 | 0.0012 | 0.012 | 0.00010 | 0.0011 | 0.00050 | 0.00031 | 0.000010 | 0.0025 |
| W7 | 4/24/2012 | 14 | 39 | 37 | 11 | 100 | 0.0025 | 0.010 | 0.010 | 7.63 | 7.43 | 0.050 | 0.00048 | 0.000023 | 0.00050 | 0.0052 | 0.48 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 5/6/2012 | 17 | 46 | 45 | 3.3 | 84 | 0.011 | 0.0025 | 0.010 | 5.90 | 7.10 | 0.037 | 0.00044 | 0.000015 | 0.00050 | 0.0029 | 0.44 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 6/19/2012 | 16 | 92 | 105 | 165 | 128 | 0.18 | 0.015 | 0.083 | 8.12 | 7.59 | 0.027 | 0.00070 | 0.0000050 | 0.00050 | 0.0016 | 0.56 | 0.00010 | 0.0013 | 0.0020 | 0.00015 | 0.000010 | 0.0025 |
| W7 | 7/17/2012 | 13 | 128 | 124 | 34 | 164 | 0.065 | 0.0025 | 0.089 | 8.15 | 7.76 | 0.020 | 0.00086 | 0.000012 | 0.00050 | 0.0013 | 0.97 | 0.00010 | 0.0015 | 0.0016 | 0.00013 | 0.000010 | 0.0025 |
| W7 | 7/30/2012 | 13 | 135 | 128 | 9.2 | 180 | 0.13 | 0.0025 | 0.12 | 8.20 | 7.86 | 0.017 | 0.00095 | 0.0000050 | 0.00050 | 0.0012 | 0.96 | 0.00010 | 0.0015 | 0.0015 | 0.00016 | 0.000010 | 0.0025 |
| W7 | 8/8/2012 | 13 | 141 | 141 | 3.3 | 192 | 0.014 | 0.0025 | 0.13 | 8.26 | 8.44 | 0.018 | 0.0010 | 0.0000050 | 0.00050 | 0.0011 | 1.1 | 0.00010 | 0.0016 | 0.0017 | 0.00014 | 0.000010 | 0.0025 |
| W7 | 8/23/2012 | 10 | 142 | 151 | 1.5 | 200 | 0.049 | 0.025 | 0.21 | 8.25 | 7.79 | 0.018 | 0.00088 | 0.0000050 | 0.00050 | 0.0017 | 0.98 | 0.00010 | 0.0016 | 0.0016 | 0.00015 | 0.000010 | 0.0025 |
| W7 | 9/13/2012 | 16 | 116 | 121 | 15 | 154 | 0.0087 | 0.0025 | 0.078 | 8.13 | 7.98 | 0.024 | 0.00074 | 0.0000050 | 0.00050 | 0.0024 | 0.73 | 0.00010 | 0.00050 | 0.0036 | 0.00014 | 0.000010 | 0.0025 |
| W7 | 10/16/2012 | 13 | 129 | 143 | 10 | 166 | 0.028 | 0.0025 | 0.13 | 8.17 | 7.89 | 0.011 | 0.00060 | 0.0000050 | 0.00050 | 0.00094 | 0.60 | 0.00010 | 0.0011 | 0.0015 | 0.00014 | 0.000010 | 0.0025 |
| W7 | 11/2/2012 | 8.2 | 158 | 153 | 2.2 | 214 | 0.026 | 0.0025 | 0.22 | 7.93 | | 0.0095 | 0.00053 | 0.000031 | 0.00050 | 0.0024 | 0.18 | 0.00021 | 0.0013 | 0.0012 | 0.00018 | 0.000010 | 0.0025 |
| W7 | 12/29/2012 | 10 | 223 | 206 | 0.50 | 262 | 0.025 | 0.0025 | 0.063 | 8.13 | 7.97 | 0.0061 | 0.00051 | 0.0000050 | 0.00050 | 0.0023 | 0.030 | 0.00010 | 0.0012 | 0.0011 | 0.00045 | 0.000010 | 0.0025 |
| W7 | 4/30/2013 | 4.6 | 192 | 198 | 5.8 | 246 | 0.0082 | 0.0025 | 0.13 | 8.27 | 8.18 | 0.0031 | 0.00025 | 0.0000050 | 0.00050 | 0.0011 | 0.014 | 0.00010 | 0.0013 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| W7 | 5/14/2013 | 15 | 33 | 36 | 55 | 70 | 0.066 | 0.0025 | 0.010 | 7.58 | 8.20 | 0.044 | 0.00029 | 0.000010 | 0.00050 | 0.0037 | 0.31 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| W7 | 6/19/2013 | 11 | 114 | 115 | 11 | 158 | 0.046 | 0.0025 | 0.14 | 8.08 | 8.60 | 0.013 | 0.00052 | 0.0000050 | 0.00050 | 0.0012 | 0.29 | 0.00010 | 0.0016 | 0.0013 | 0.00015 | 0.000010 | 0.0025 |
| W7 | 7/13/2013 | 10 | 132 | 137 | 5.0 | 156 | 0.023 | 0.0025 | 0.17 | 8.10 | 7.74 | 0.014 | 0.00053 | 0.0000050 | 0.00050 | 0.0012 | 0.42 | 0.00010 | 0.0015 | 0.0013 | 0.00015 | 0.000010 | 0.0025 |
| W7 | 8/21/2013 | 10 | 140 | 144 | 3.8 | 172 | 0.051 | 0.0025 | 0.16 | 8.23 | 7.81 | 0.012 | 0.00056 | 0.0000050 | 0.00050 | 0.0010 | 0.30 | 0.00010 | 0.0015 | 0.0012 | 0.00015 | 0.000010 | 0.0025 |
| W7 | 9/6/2013 | 11 | 138 | 154 | 12 | 280 | 0.017 | 0.0025 | 0.13 | 8.02 | 7.75 | 0.016 | 0.00081 | 0.0000050 | 0.00050 | 0.0011 | 0.66 | 0.00010 | 0.0013 | 0.0016 | 0.00017 | 0.000010 | 0.0025 |
| W7 | 10/21/2013 | 12 | 147 | 126 | 7.4 | 168 | 0.048 | 0.0025 | 0.17 | 8.16 | 7.58 | 0.0093 | 0.00067 | 0.0000050 | 0.00050 | 0.0011 | 0.55 | 0.00010 | 0.0012 | 0.0012 | 0.00017 | 0.000010 | 0.0025 |
| W7 | 11/16/2013 | 7.5 | 153 | 164 | 1.5 | 164 | 0.027 | 0.0025 | 0.26 | 8.24 | 7.69 | 0.0053 | 0.00048 | 0.0000050 | 0.00050 | 0.00080 | 0.17 | 0.00010 | 0.0016 | 0.00050 | 0.00024 | 0.000010 | 0.0025 |
| W7 | 12/7/2013 | 7.3 | 168 | 189 | 0.50 | 220 | 0.025 | 0.0025 | 0.21 | 8.14 | 6.30 | 0.0035 | 0.00053 | 0.0000050 | 0.00050 | 0.00078 | 0.11 | 0.00010 | 0.0011 | 0.00050 | 0.00024 | 0.000010 | 0.0025 |
| C4 | 5/6/2012 | 11 | 44 | 119 | 1,260 | 84 | 0.088 | 0.0025 | 0.029 | 7.59 | 7.51 | 0.062 | 0.00104 | 0.000029 | 0.00050 | 0.0031 | 1.1 | 0.00010 | 0.00050 | 0.0023 | 0.000050 | 0.000010 | 0.0025 |
| C4 | 8/1/2012 | 16 | 117 | 133 | 246 | 166 | 0.089 | 0.018 | 0.074 | 8.04 | 7.75 | 0.059 | 0.00184 | 0.0000050 | 0.00050 | 0.0018 | 1.5 | 0.00010 | 0.0011 | 0.0031 | 0.00011 | 0.000010 | 0.0025 |
| C4 | 8/8/2012 | | 125 | 142 | 253 | 170 | 0.090 | 0.012 | 0.095 | 8.14 | 7.81 | 0.043 | 0.00203 | 0.0000050 | 0.00050 | 0.0013 | 1.6 | 0.00010 | 0.0011 | 0.0027 | 0.00011 | 0.000010 | 0.0025 |
| C4 | 8/25/2012 | 0.25 | 130 | 173 | 855 | 192 | 0.0050 | 0.0025 | 0.010 | 7.94 | 7.81 | 0.040 | 0.0020 | 0.0000050 | 0.00050 | 0.0018 | 1.7 | 0.00010 | 0.0012 | 0.0029 | 0.000050 | 0.000010 | 0.0025 |
| C4 | 6/22/2013 | 17 | 126 | 222 | 886 | 204 | 0.36 | 0.0066 | 0.37 | 7.97 | 7.68 | 0.034 | 0.0023 | 0.0000050 | 0.00050 | 0.0017 | 1.2 | 0.00010 | 0.0018 | 0.0027 | 0.00013 | 0.000010 | 0.0025 |
| C4 | 7/19/2013 | | 128 | 200 | 487 | 184 | 0.26 | 0.0069 | 0.082 | 8.12 | 8.20 | 0.032 | 0.0021 | 0.0000050 | 0.00050 | 0.0014 | 1.6 | 0.00010 | 0.0017 | 0.0025 | 0.00012 | 0.000010 | 0.0025 |
| C4 | 8/22/2013 | 19 | 123 | 199 | 784 | 182 | 0.20 | 0.0084 | 0.086 | 7.98 | 7.88 | 0.046 | 0.0018 | 0.0000050 | 0.00050 | 0.0014 | 1.4 | 0.00010 | 0.0013 | 0.0027 | 0.00012 | 0.000010 | 0.0025 |
| C4 | 9/6/2013 | 15 | 125 | 166 | 172 | 176 | 0.12 | 0.0025 | 0.070 | 7.93 | 7.69 | 0.041 | 0.0020 | 0.0000050 | 0.00050 | 0.0016 | 1.8 | 0.00010 | 0.0010 | 0.0028 | 0.000050 | 0.000010 | 0.0025 |
| C4 | 10/18/2013 | 13 | 129 | 141 | 16 | 217 | 0.086 | 0.0025 | 0.067 | 8.21 | 7.16 | 0.024 | 0.0011 | 0.0000050 | 0.00050 | 0.0012 | 1.2 | 0.00010 | 0.00085 | 0.0024 | 0.000050 | 0.000010 | 0.0025 |
| C4 | 11/17/2013 | 32 | 258 | 264 | 22 | 272 | 0.28 | 0.025 | 0.10 | 7.90 | 7.17 | 0.033 | 0.0056 | 0.000022 | 0.0013 | 0.00095 | 14 | 0.00010 | 0.0011 | 0.0061 | 0.00024 | 0.000010 | 0.0025 |
| C10 | 5/12/2012 | 13 | 67 | 215 | 2,210 | 132 | 0.18 | 0.011 | 0.047 | 7.73 | 7.89 | 0.058 | 0.0012 | 0.000018 | 0.00050 | 0.0021 | 1.6 | 0.00025 | 0.00050 | 0.0019 | 0.00010 | 0.000010 | 0.0025 |
| C10 | 7/30/2012 | 18 | 130 | 207 | 995 | 180 | 0.20 | 0.023 | 0.18 | 8.23 | | 0.057 | 0.0014 | 0.0000050 | 0.00050 | 0.0020 | 1.2 | 0.00067 | 0.0014 | 0.0023 | 0.00014 | 0.000010 | 0.0025 |
| C10 | 8/10/2012 | | 135 | 245 | 1,320 | 216 | 0.12 | 0.011 | 0.18 | 8.11 | 8.71 | 0.051 | 0.0013 | 0.0000050 | 0.00050 | 0.0019 | 0.88 | 0.00010 | 0.0019 | 0.0022 | 0.00010 | 0.000010 | 0.0025 |
| C10 | 8/27/2012 | 18 | 141 | 264 | 1,650 | 184 | 0.0025 | 0.0086 | 0.095 | 8.37 | 8.30 | 0.026 | 0.0015 | 0.0000050 | 0.00050 | 0.0015 | 1.0 | 0.00010 | 0.0011 | 0.0023 | 0.00012 | 0.000010 | 0.0025 |
| C10 | 6/22/2013 | 15 | 148 | 151 | 43 | 192 | 0.19 | 0.020 | 0.15 | 8.26 | 8.29 | 0.079 | 0.0012 | 0.000019 | 0.00050 | 0.0031 | 0.80 | 0.00010 | 0.0012 | 0.0025 | 0.00011 | 0.000010 | 0.010 |
| C10 | 7/23/2013 | | 125 | 156 | 199 | 174 | 0.14 | 0.025 | 0.10 | 8.19 | 8.31 | 0.025 | 0.0012 | 0.0000050 | 0.00050 | 0.0014 | 0.54 | 0.00010 | 0.0010 | 0.0022 | 0.000050 | 0.000010 | 0.0025 |
| C10 | 8/22/2013 | 17 | 160 | 168 | 66 | 218 | 0.056 | 0.0072 | 0.14 | 8.23 | 8.18 | 0.020 | 0.0014 | 0.0000050 | 0.00050 | 0.0013 | 0.99 | 0.00010 | 0.0015 | 0.0023 | 0.000050 | 0.000010 | 0.0025 |
| C10 | 9/8/2013 | 16 | 150 | 163 | 24 | 196 | 0.051 | 0.0073 | 0.18 | 8.04 | 8.16 | 0.025 | 0.0016 | 0.0000075 | 0.0011 | 0.0013 | 1.3 | 0.00010 | 0.00050 | 0.0025 | 0.000050 | 0.000010 | 0.0025 |
| C10 | 10/18/2013 | 14 | 136 | 160 | 61 | 212 | 0.10 | 0.0025 | 0.17 | 8.25 | 7.78 | 0.011 | 0.00089 | 0.0000050 | 0.00050 | 0.00091 | 0.76 | 0.00010 | 0.00050 | 0.0019 | 0.000050 | 0.000010 | 0.0025 |
| **Median:** | | **11** | **117** | **121** | **11** | **150** | **0.021** | **0.0025** | **0.067** | **8.00** | **7.76** | **0.016** | **0.00044** | **0.0000085** | **0.00050** | **0.0016** | **0.11** | **0.00010** | **0.0010** | **0.0011** | **0.00020** | **0.000010** | **0.0025** |
| **95th Percentile:** | | **22** | **162** | **200** | **772** | **217** | **0.15** | **0.025** | **0.21** | **8.26** | **8.30** | **0.071** | **0.0015** | **0.000050** | **0.0011** | **0.0050** | **1.2** | **0.00025** | **0.0020** | **0.0027** | **0.00050** | **0.000010** | **0.0060** |

**Table D.3: Background data for Option 2 with median and 95th Percentile values.**

| Year | Month | Day | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | May | 27 | | | 78 | 22 | 118 | 0.016 | 0.0012 | 0.038 | 7.92 | | 0.028 | 0.00029 | 0.000025 | 0.00050 | 0.0034 | 0.15 | 0.00025 | 0.00050 | 0.0015 | 0.00050 | 0.000010 | 0.0025 |
| | June | 30 | | | | 5.4 | 160 | 0.015 | 0.00067 | 0.052 | 7.83 | | 0.026 | 0.00046 | 0.000025 | 0.00030 | 0.0023 | 0.16 | 0.000064 | 0.00085 | 0.0011 | 0.00050 | 0.0000050 | 0.0091 |
| | July | 28/29 | | | 138 | 11 | 173 | 0.010 | 0.00050 | 0.042 | 7.73 | | 0.020 | 0.00041 | 0.000025 | 0.00025 | 0.0033 | 0.16 | 0.000075 | 0.0011 | 0.0011 | 0.00050 | 0.0000050 | 0.0030 |
| | August | 29/30 | | | 110 | 4.9 | 157 | 0.029 | 0.00066 | 0.010 | 8.10 | | 0.022 | 0.00043 | 0.000010 | 0.00050 | 0.0026 | 0.27 | 0.00025 | 0.00083 | 0.0014 | 0.00050 | 0.000010 | 0.0029 |
| | September | 28 | | | 111 | 58 | 151 | 0.012 | 0.00057 | 0.025 | 7.83 | | 0.024 | 0.00039 | 0.0000085 | 0.00050 | 0.0027 | 0.31 | 0.00025 | 0.00059 | 0.0013 | 0.00050 | 0.000010 | 0.0025 |
| | October | 15 | | | 111 | 5.5 | 151 | 0.015 | 0.00050 | 0.060 | 7.64 | | 0.033 | 0.00044 | 0.000025 | 0.00025 | 0.0029 | 0.25 | 0.000025 | 0.00069 | 0.0012 | 0.00050 | 0.0000050 | 0.0013 |
| 2006 | | 2 | | | | 410 | 100 | 0.042 | 0.0010 | 0.035 | 7.63 | | 0.048 | 0.00053 | 0.000025 | 0.00040 | 0.0019 | 0.32 | 0.000040 | 0.00050 | 0.0020 | 0.00050 | 0.0000050 | 0.0018 |
| | | 8 | | | | | | | | | | | | | | | | | | | | | | |
| | June | 15 | | 100 | | 53 | 114 | 0.027 | | 0.18 | 7.86 | | 0.013 | 0.00040 | 0.0000050 | 0.00025 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.0010 | 0.00020 | | 0.00050 |
| | | 23 | | 122 | | 328 | 176 | 0.028 | | 0.23 | 7.78 | | 0.011 | 0.00050 | 0.0000050 | 0.00070 | 0.00050 | 0.090 | 0.000050 | 0.0010 | 0.0013 | 0.00030 | | 0.0020 |
| | | 28 | | 107 | | 103 | 120 | 0.010 | | 0.11 | 7.90 | | 0.41 | 0.00080 | 0.000030 | 0.0015 | 0.0030 | 0.060 | 0.00050 | 0.00050 | 0.0036 | 0.00010 | | 0.0050 |
| | July | 7 | | 110 | | 3.0 | 184 | | | 0.21 | 7.91 | | 0.0025 | 0.00060 | 0.0000050 | 0.0011 | 0.0010 | 0.060 | 0.000050 | 0.0020 | 0.0015 | 0.00010 | | 0.0010 |
| | | 12 | | 110 | | 1.0 | | 0.014 | | 0.18 | 7.77 | | 0.0060 | 0.00050 | 0.0000050 | 0.0010 | 0.0010 | 0.060 | 0.000050 | 0.0010 | 0.00070 | 0.00020 | | 0.00050 |
| | | 20 | | 130 | | 2.0 | | 0.012 | | 0.19 | 7.88 | | 0.0060 | 0.00040 | 0.0000050 | 0.00070 | 0.00050 | 0.11 | 0.00020 | 0.0010 | 0.00060 | 0.00010 | | 0.00050 |
| | | 26 | | 128 | | 9.0 | | 0.016 | | 0.18 | 7.87 | | 0.0080 | 0.00040 | 0.0000050 | 0.00025 | 0.0020 | 0.10 | 0.000050 | 0.00050 | 0.0021 | 0.00010 | | 0.00050 |
| | August | 2 | | 128 | | 4.0 | | 0.015 | | 0.15 | 7.79 | | 0.0080 | 0.00010 | 0.0000050 | 0.00025 | 0.0010 | 0.070 | 0.000050 | 0.00050 | 0.00060 | 0.00010 | | 0.00050 |
| | | 10 | | 126 | | 1.0 | | 0.014 | | 0.16 | 7.80 | | 0.0090 | 0.00050 | 0.0000050 | 0.00070 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00060 | 0.00010 | | 0.0010 |
| | | 25 | | 125 | | | 170 | 0.027 | | 0.068 | 7.97 | | 0.012 | 0.00040 | 0.0000050 | 0.00060 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00090 | 0.00010 | | 0.0030 |
| | | 30 | | 132 | | 1.0 | 200 | 0.012 | | 0.11 | 7.79 | | 0.013 | 0.00040 | 0.0000050 | 0.00080 | 0.0020 | 0.10 | 0.000050 | 0.0010 | 0.0012 | 0.00010 | | 0.0050 |
| | September | 6 | | 120 | | 4.0 | | 0.011 | | 0.048 | 7.87 | | 0.0065 | 0.00050 | 0.0000050 | 0.00070 | 0.0015 | 0.11 | 0.000050 | 0.00075 | 0.00080 | 0.00010 | | 0.0020 |
| | | 13 | | 130 | | 5.0 | | 0.011 | | 0.094 | 7.84 | | 0.0080 | 0.00030 | 0.0000050 | 0.00090 | 0.0010 | 0.11 | 0.000050 | 0.0010 | 0.00090 | 0.00010 | | 0.0010 |
| | | 20 | | 132 | | 3.0 | | 0.008 | | 0.11 | 7.85 | | 0.0070 | 0.00050 | 0.00028 | 0.00070 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.00025 | 0.00020 | | 0.00050 |
| | | 28 | | 129 | | | 182 | 0.011 | | 0.080 | 7.26 | | 0.011 | 0.00040 | 0.0000050 | 0.00080 | 0.0010 | 0.080 | 0.000050 | 0.0010 | 0.00080 | 0.00010 | | 0.0020 |
| | October | 4 | | 126 | | 2.0 | | 0.079 | | 0.10 | 7.94 | | 0.0025 | 0.00030 | 0.0000050 | 0.00025 | 0.00050 | 0.11 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0010 |
| | | 12 | | 132 | | 4.0 | 164 | 0.024 | | 0.12 | 7.39 | | 0.0070 | 0.00040 | 0.0000050 | 0.00025 | 0.0010 | 0.090 | 0.000050 | 0.0010 | 0.00060 | 0.00030 | | 0.0020 |
| 2007 | June | 5 | | | 113 | 75 | 162 | 0.025 | 0.033 | 0.050 | 7.97 | | | | | | | | | | | | | |
| | | 20 | 8.2 | 110 | 81 | 11 | 147 | 0.025 | 0.025 | 0.20 | 7.81 | | 0.014 | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00025 | 0.00010 | | 0.0040 |
| | July | 18 | 14 | 128 | 125 | 5.7 | 179 | 0.025 | 0.025 | 0.30 | 7.78 | | 0.011 | 0.00050 | 0.0000050 | 0.0010 | 0.0020 | 0.040 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0060 |
| | August | 24 | | | 124 | 4.7 | 192 | 0.025 | 0.025 | 0.20 | 8.04 | | | | | | | | | | | | | |
| | September | 18 | 11 | 110 | 93 | 14 | 177 | 0.025 | 0.010 | 0.030 | 7.98 | | 0.0070 | 0.00040 | 0.0000050 | 0.0016 | 0.0010 | 0.080 | 0.000050 | 0.0020 | 0.00080 | 0.00010 | | 0.0020 |
| | October | 30 | | | 129 | 6.5 | 174 | 0.025 | 0.14 | 0.010 | 7.73 | | | | | | | | | | | | | |
| 2008 | April | 22 | | 187 | | 1.0 | 268 | 0.025 | 0.055 | 0.010 | 8.40 | | 0.010 | 0.00027 | 0.000040 | 0.00097 | 0.0012 | 0.030 | 0.000067 | 0.0017 | 0.0010 | 0.00030 | | 0.0017 |
| | June | 3 | | 92 | 98 | 15 | 137 | 0.025 | 0.040 | 0.037 | 8.02 | | 0.0050 | 0.00010 | 0.000040 | 0.0013 | 0.00050 | 0.050 | 0.000050 | 0.0012 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | | 17 | | | 86 | 14 | 138 | 0.025 | 0.060 | 0.075 | 7.89 | | 0.020 | 0.00010 | 0.000040 | 0.0013 | 0.0010 | 0.070 | 0.000050 | 0.0015 | 0.0010 | 0.0022 | 0.0000050 | 0.0020 |
| | August | 6 | 9.0 | 123 | 124 | 105 | 167 | 0.025 | 0.0050 | 0.14 | 7.92 | | 0.014 | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.070 | 0.000050 | 0.0010 | 0.0010 | 0.00010 | 0.000060 | 0.0060 |
| | September | 18 | 18 | | | 16 | 160 | 0.025 | 0.0050 | 0.018 | 7.85 | | 0.041 | 0.00035 | 0.0000050 | 0.0015 | 0.0030 | 0.15 | 0.00088 | 0.00050 | 0.0015 | 0.00075 | 0.0000050 | 0.0030 |
| | October | 28 | 11 | 123 | | 5.7 | 183 | 0.025 | | | 7.84 | | 0.0090 | 0.00050 | 0.0000050 | 0.00050 | 0.0010 | 0.078 | 0.000050 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| 2009 | April | 30 | 18 | 20 | | 1.0 | 52 | | | | 6.84 | 7.60 | 0.053 | 0.00010 | 0.000080 | 0.00060 | 0.0050 | 0.070 | 0.00010 | 0.00013 | 0.00050 | 0.00030 | 0.0000050 | 0.0090 |
| | June | 8 | 9.2 | 93 | | 32 | 156 | | | | 7.90 | 7.74 | 0.013 | 0.00030 | 0.0000050 | 0.00020 | 0.0020 | 0.050 | 0.000050 | 0.0013 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | July | 27 | | 137 | | 4.0 | 184 | | | | 8.07 | | | | | | | | | | | | | |
| | August | 6 | | 121 | | 2.0 | 202 | | | 0.18 | 8.35 | 7.50 | | | | | | | | | | | | |
| | | 25 | 8.2 | | | | | | | | | 8.04 | | | | | | | | | | | | |
| | | 31 | | 110 | | | | | | | | | 0.010 | 0.00040 | 0.0000050 | 0.0012 | 0.0040 | 0.10 | 0.00040 | 0.0011 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| | October | 7 | 7.8 | 125 | 141 | 3.7 | 140 | 0.010 | 0.0025 | 0.14 | 7.99 | 8.24 | 0.0070 | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |
| | | 25 | 8.7 | 126 | 141 | 2.0 | 120 | 0.010 | 0.0025 | 0.15 | 8.05 | 8.23 | 0.0070 | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |

**Table D.3: Background data for Option 2 with median and 95th Percentile values.**

| Year | Month | Day | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | April | 19 | | | 80 | 3.5 | 142 | | | | 7.81 | 7.31 | 0.019 | 0.00030 | 0.000020 | 0.00040 | 0.0060 | 0.090 | 0.00030 | 0.00080 | 0.00050 | 0.00030 | 0.0000050 | 0.0050 |
| | | 27/29 | 21 | 36 | 36 | 2.0 | 62 | 0.016 | 0.0038 | 0.015 | 7.55 | 7.69 | 0.070 | 0.00030 | 0.0000050 | 0.00050 | 0.0038 | 0.17 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0025 |
| | May | 1-7 | 17 | 48 | 50 | 14 | 73 | 0.026 | 0.0050 | 0.048 | 7.75 | 7.61 | 0.042 | 0.00043 | 0.000010 | 0.00050 | 0.0028 | 0.39 | 0.00010 | 0.00050 | 0.0013 | 0.000050 | 0.000010 | 0.0025 |
| | | 9-14 | 11 | 79 | 79 | 5.3 | 123 | 0.019 | 0.0034 | 0.060 | 8.05 | 7.78 | 0.039 | 0.00040 | 0.000010 | 0.00050 | 0.0022 | 0.27 | 0.00010 | 0.00063 | 0.0013 | 0.00010 | 0.000010 | 0.0025 |
| | | 16-21 | 8.1 | 89 | 88 | 12 | 123 | 0.036 | 0.0025 | 0.038 | 8.20 | 7.62 | 0.015 | 0.00030 | 0.000016 | 0.00050 | 0.0013 | 0.069 | 0.00010 | 0.0010 | 0.00063 | 0.00023 | 0.000010 | 0.0031 |
| | | 23-29 | 7.7 | 112 | 126 | 181 | 148 | 0.059 | 0.011 | 0.12 | 8.05 | 7.53 | 0.022 | 0.00043 | 0.000050 | | 0.0023 | 0.063 | 0.00010 | 0.0018 | 0.0013 | 0.00045 | | 0.0050 |
| | May/June | 31-6 | 6.2 | 115 | 131 | 118 | 153 | 0.12 | 0.018 | 0.15 | 8.20 | 7.52 | 0.013 | 0.00030 | 0.000050 | | 0.0013 | 0.034 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| | June | 14-20 | 6.5 | 119 | 124 | 30 | 145 | 0.016 | 0.0039 | 0.15 | 8.24 | 6.97 | 0.0088 | 0.00020 | 0.000050 | | 0.00063 | 0.026 | 0.00010 | 0.0020 | 0.00050 | 0.00040 | | 0.0050 |
| | | 22-28 | 10 | 104 | 111 | 99 | 135 | 0.014 | 0.0036 | 0.11 | 8.09 | 7.95 | 0.017 | 0.00033 | 0.000050 | | 0.0013 | 0.051 | 0.00010 | 0.0010 | 0.0016 | 0.00040 | | 0.0050 |
| | July | 5 | 16 | 93 | 106 | 53 | 150 | 0.027 | 0.0025 | 0.070 | 8.06 | 8.02 | 0.019 | 0.00020 | 0.000050 | | 0.0020 | 0.10 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| | August | 5 | 13 | 118 | 116 | | 170 | | | | | 7.91 | 0.011 | 0.00040 | 0.000050 | | 0.0020 | 0.11 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| | September | 12 | 17 | 107 | 104 | 11 | 210 | 0.039 | 0.0025 | 0.030 | 7.98 | 8.02 | 0.016 | 0.00050 | 0.000050 | | 0.0010 | 0.23 | 0.00010 | 0.0010 | 0.0020 | 0.00040 | | 0.0050 |
| | October | 8 | 13 | 111 | 126 | 3.0 | 150 | 0.069 | 0.0025 | 0.070 | 8.10 | 7.85 | 0.011 | 0.00040 | 0.0000050 | 0.00050 | 0.0012 | 0.13 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| 2011 | April | 27 | 23 | 43 | 43 | 0.50 | 72 | 0.010 | 0.0025 | 0.010 | 7.41 | | 0.057 | 0.00030 | 0.000030 | 0.00050 | 0.0077 | 0.15 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.0050 |
| | May | 2 | 22 | 32 | 33 | 7.0 | 40 | | 0.0025 | 0.010 | 7.11 | | 0.076 | 0.00020 | 0.000040 | 0.00050 | 0.0070 | 0.17 | 0.00010 | 0.00050 | 0.0010 | 0.000050 | 0.000010 | 0.010 |
| | June | 1 | 11 | 92 | 94 | 23 | 120 | 0.012 | | | 8.09 | | 0.013 | 0.00030 | 0.0000050 | 0.00050 | 0.0016 | 0.10 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| | | 16 | 13 | 97 | 108 | 85 | 130 | 0.013 | 0.0025 | 0.10 | 8.00 | | 0.022 | 0.00040 | 0.0000050 | 0.00050 | 0.0019 | 0.21 | 0.00010 | 0.0010 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | July | 1 | 21 | 77 | 88 | 150 | 120 | 0.016 | 0.0070 | 0.050 | 7.76 | | 0.034 | 0.00070 | 0.000010 | 0.00050 | 0.0031 | 0.44 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | August | 2 | 24 | 59 | 86 | 400 | 110 | | 0.0025 | 0.060 | 7.67 | | 0.051 | 0.00070 | 0.000020 | 0.00050 | 0.0041 | 0.61 | 0.00010 | 0.00050 | 0.0030 | 0.00010 | 0.000010 | 0.0025 |
| | | 16/19 | 19 | 95 | 95 | 22 | 145 | 0.011 | 0.0025 | 0.050 | 8.01 | | 0.035 | 0.00075 | 0.0000075 | 0.00050 | 0.0020 | 0.57 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | September | 12 | 13 | 118 | 119 | 1.0 | 170 | 0.025 | 0.0025 | 0.050 | 8.03 | 7.92 | 0.024 | 0.00070 | 0.000010 | 0.00050 | 0.0016 | 0.62 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | October | 6 | 12 | 110 | 113 | 2.0 | 150 | 0.019 | 0.0025 | 0.11 | 8.07 | 7.65 | 0.013 | 0.00060 | 0.000030 | 0.00050 | 0.0012 | 0.35 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| | November | 22 | 7.7 | 148 | 144 | 27 | 156 | 0.021 | 0.0025 | 0.14 | 7.96 | | 0.0076 | 0.00040 | 0.0000050 | 0.00050 | 0.0011 | 0.17 | 0.00010 | 0.0013 | 0.0012 | 0.00016 | 0.000010 | 0.0025 |
| 2012 | January | 24 | 5.3 | 169 | 158 | 2.0 | 226 | 0.0050 | 0.0025 | 0.32 | 8.13 | | 0.0053 | 0.00041 | 0.000035 | 0.00050 | 0.0011 | 0.094 | 0.00010 | 0.0015 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| | February | 25 | 6.1 | 165 | 160 | 2.0 | 216 | 0.0060 | 0.0025 | 0.29 | 7.99 | 7.16 | 0.021 | 0.00033 | 0.000064 | 0.00050 | 0.015 | 0.049 | 0.00024 | 0.0014 | 0.00050 | 0.00034 | 0.000010 | 0.0083 |
| | March | 5 | 5.2 | 161 | 159 | 3.2 | 176 | 0.0067 | 0.0025 | 0.20 | 8.17 | 6.72 | 0.0031 | 0.00039 | 0.0000050 | 0.00050 | 0.0012 | 0.012 | 0.00010 | 0.0011 | 0.00050 | 0.00031 | 0.000010 | 0.0025 |
| | April | 24 | 14 | 39 | 37 | 11 | 100 | 0.0025 | 0.010 | 0.010 | 7.63 | 7.43 | 0.050 | 0.00048 | 0.000023 | 0.00050 | 0.0052 | 0.48 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| | May | 6/12 | 14 | 52 | 126 | 1158 | 100 | 0.093 | 0.0055 | 0.029 | 7.07 | 7.50 | 0.053 | 0.00089 | 0.000021 | 0.00050 | 0.0027 | 1.0 | 0.00015 | 0.00050 | 0.0018 | 0.000067 | 0.000010 | 0.0025 |
| | June | 19 | 16 | 92 | 105 | 165 | 128 | 0.18 | 0.015 | 0.083 | 8.12 | 7.59 | 0.027 | 0.00070 | 0.0000050 | 0.00050 | 0.0016 | 0.56 | 0.00010 | 0.0013 | 0.00200 | 0.00015 | 0.000010 | 0.0025 |
| | July | 17 | 11 | 116 | 144 | 582 | 143 | 0.10 | 0.0025 | 0.058 | 8.07 | 7.84 | 0.018 | 0.00070 | 0.0000085 | 0.00050 | 0.0012 | 0.52 | 0.00010 | 0.0010 | 0.0013 | 0.00013 | 0.000010 | 0.0025 |
| | | 30 | 13 | 122 | 160 | 539 | 161 | 0.13 | 0.011 | 0.12 | 8.17 | 7.88 | 0.031 | 0.00099 | 0.0000050 | 0.00050 | 0.0014 | 0.73 | 0.00029 | 0.0011 | 0.0014 | 0.00012 | 0.000010 | 0.0025 |
| | August | 1 | 16 | 117 | 133 | 246 | 166 | 0.089 | 0.018 | 0.074 | 8.04 | 7.75 | 0.059 | 0.0018 | 0.0000050 | 0.00050 | 0.0018 | 1.5 | 0.00010 | 0.0011 | 0.0031 | 0.00011 | 0.000010 | 0.0025 |
| | | 8-10 | 13 | 128 | 166 | 536 | 181 | 0.062 | 0.0081 | 0.11 | 8.17 | 8.26 | 0.032 | 0.0013 | 0.0000050 | 0.00050 | 0.0013 | 0.91 | 0.00010 | 0.0013 | 0.0019 | 0.00011 | 0.000010 | 0.0025 |
| | | 23-27 | 9.0 | 129 | 187 | 917 | 179 | 0.020 | 0.010 | 0.090 | 8.14 | 7.92 | 0.024 | 0.0013 | 0.0000050 | 0.00050 | 0.0015 | 0.93 | 0.00010 | 0.0011 | 0.0020 | 0.000093 | 0.000010 | 0.0025 |
| | September | 13 | 15 | 102 | 107 | 33 | 136 | 0.010 | 0.0025 | 0.056 | 8.09 | 7.97 | 0.020 | 0.00061 | 0.0000050 | 0.00050 | 0.0019 | 0.42 | 0.00010 | 0.00050 | 0.0025 | 0.000095 | 0.000010 | 0.0025 |
| | October | 13/16 | 11 | 129 | 130 | 27 | 158 | 0.022 | 0.0025 | 0.084 | 8.05 | 8.10 | 0.011 | 0.00060 | 0.0000050 | 0.00050 | 0.00094 | 0.60 | 0.00010 | 0.0011 | 0.0015 | 0.00014 | 0.000010 | 0.0025 |
| | November | 2 | 8.2 | 158 | 153 | 2.2 | 214 | 0.026 | 0.0025 | 0.22 | 7.93 | | 0.0095 | 0.00053 | 0.000031 | 0.00050 | 0.0024 | 0.18 | 0.00021 | 0.0013 | 0.0012 | 0.00018 | 0.000010 | 0.0025 |
| | | 12 | 8.7 | 153 | 155 | 2.2 | 162 | 0.025 | 0.0025 | 0.010 | 7.93 | 6.69 | 0.0062 | 0.00039 | 0.0000050 | 0.00050 | 0.0014 | 0.024 | 0.00010 | 0.00050 | 0.0014 | 0.00010 | 0.000010 | 0.0025 |
| | December | 29 | 10 | 223 | 206 | 0.50 | 262 | 0.025 | 0.0025 | 0.063 | 8.13 | 7.97 | 0.0061 | 0.00051 | 0.0000050 | 0.00050 | 0.0023 | 0.030 | 0.00010 | 0.0012 | 0.0011 | 0.00045 | 0.000010 | 0.0025 |
| 2013 | April | 30 | 4.6 | 192 | 198 | 5.8 | 246 | 0.0082 | 0.0025 | 0.13 | 8.27 | 8.18 | 0.0031 | 0.00025 | 0.0000050 | 0.00050 | 0.0011 | 0.014 | 0.00010 | 0.0013 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| | May | 14 | 19 | 32 | 35 | 34 | 77 | 0.10 | 0.0025 | 0.010 | 7.53 | 7.90 | 0.051 | 0.00033 | 0.000011 | 0.00050 | 0.0036 | 0.245 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| | June | 19/22 | 13 | 121 | 151 | 278 | 168 | 0.16 | 0.011 | 0.17 | 8.09 | 8.05 | 0.034 | 0.0011 | 0.0000085 | 0.00050 | 0.0017 | 0.590 | 0.00010 | 0.0013 | 0.0019 | 0.00011 | 0.000010 | 0.0045 |
| | July | 12/13 | 9.1 | 110 | 116 | 15 | 146 | 0.018 | 0.0025 | 0.090 | 8.00 | 7.72 | 0.010 | 0.00050 | 0.0000050 | 0.00050 | 0.0011 | 0.26 | 0.00010 | 0.0010 | 0.0012 | 0.00010 | 0.000010 | 0.0025 |
| | | 19/23 | | 127 | 178 | 343 | 179 | 0.20 | 0.016 | 0.091 | 8.16 | 8.26 | 0.028 | 0.0016 | 0.0000050 | 0.00050 | 0.0014 | 1.1 | 0.00010 | 0.0014 | 0.0024 | 0.000085 | 0.000010 | 0.0025 |
| | August | 21/22 | 13 | 131 | 154 | 218 | 179 | 0.080 | 0.0052 | 0.10 | 8.12 | 7.92 | 0.021 | 0.0011 | 0.0000050 | 0.00050 | 0.0012 | 0.71 | 0.00010 | 0.0012 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | September | 6/8 | 12 | 129 | 149 | 53 | 196 | 0.048 | 0.0037 | 0.10 | 7.98 | 7.80 | 0.022 | 0.0012 | 0.0000056 | 0.00065 | 0.0012 | 0.96 | 0.00010 | 0.00083 | 0.0020 | 0.000080 | 0.000010 | 0.0025 |
| | October | 7 | 8.2 | 107 | 106 | 74 | 176 | 0.044 | 0.0025 | 0.042 | 8.08 | 7.66 | 0.013 | 0.00051 | 0.0000050 | 0.00050 | 0.00097 | 0.15 | 0.00010 | 0.00050 | 0.0013 | 0.000050 | 0.000010 | 0.0025 |
| | | 18/21 | 13 | 137 | 142 | 28 | 199 | 0.078 | 0.0025 | 0.13 | 8.21 | 7.51 | 0.015 | 0.00088 | 0.0000050 | 0.00050 | 0.0011 | 0.82 | 0.00010 | 0.00085 | 0.0018 | 0.000090 | 0.000010 | 0.0025 |
| | November | 16/17 | 16 | 177 | 184 | 19 | 185 | 0.11 | 0.010 | 0.12 | 8.08 | 7.61 | 0.015 | 0.0022 | 0.000011 | 0.00077 | 0.00086 | 4.8 | 0.00010 | 0.0011 | 0.0025 | 0.00018 | 0.000010 | 0.0025 |
| | December | 7 | 8.0 | 164 | 186 | 2.1 | 207 | 0.016 | 0.0025 | 0.11 | 8.18 | 6.90 | 0.0038 | 0.00057 | 0.0000080 | 0.00050 | 0.0012 | 0.06 | 0.00010 | 0.00080 | 0.00080 | 0.00015 | 0.000010 | 0.0025 |
| **Median:** | | | **12** | **120** | **121** | **11** | **158** | **0.025** | **0.0025** | **0.090** | **7.97** | **7.77** | **0.014** | **0.00041** | **0.0000053** | **0.00050** | **0.0015** | **0.11** | **0.00010** | **0.0010** | **0.0011** | **0.00011** | **0.000010** | **0.0025** |
| **95th Percentile:** | | | **21** | **169** | **185** | **485** | **216** | **0.12** | **0.038** | **0.22** | **8.20** | **8.24** | **0.056** | **0.0013** | **0.000050** | **0.0013** | **0.0051** | **0.95** | **0.00028** | **0.0017** | **0.0024** | **0.00050** | **0.000010** | **0.0060** |

**Table D.4: Background data for Option 3 with median and 95th Percentile values.**

| Year | Month | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | May | | | 74 | 19 | 118 | 0.017 | 0.0011 | 0.034 | 7.85 | | 0.043 |
| | June | | | | 5.4 | 160 | 0.015 | 0.00067 | 0.052 | 7.83 | | 0.026 |
| | July | | | 138 | 11 | 173 | 0.010 | 0.00050 | 0.042 | 7.73 | | 0.020 |
| | August | | | 110 | 4.9 | 157 | 0.029 | 0.00066 | 0.010 | 8.10 | | 0.022 |
| | September | | | 111 | 58 | 151 | 0.012 | 0.00057 | 0.025 | 7.83 | | 0.024 |
| | October | | | 111 | 5.5 | 151 | 0.015 | 0.00050 | 0.060 | 7.64 | | 0.033 |
| 2006 | June | | 110 | | 206 | 112 | 0.026 | 0.0010 | 0.083 | 7.71 | | 0.075 |
| | July | | 120 | | 3.8 | 184 | 0.014 | | 0.19 | 7.86 | | 0.0056 |
| | August | | 124 | | 2.0 | 175 | 0.017 | | 0.075 | 7.92 | | 0.011 |
| | September | | 120 | | 4.0 | 182 | 0.010 | | 0.053 | 7.78 | | 0.0079 |
| | October | | 129 | | 3.0 | 164 | 0.052 | | 0.11 | 7.67 | | 0.0048 |
| 2007 | June | 8.2 | 110 | 97 | 28 | 147 | 0.025 | 0.027 | 0.14 | 7.84 | | 0.014 |
| | July | 14 | 128 | 125 | 5.7 | 179 | 0.025 | 0.025 | 0.30 | 7.78 | | 0.011 |
| | August | | | 124 | 4.7 | 192 | 0.025 | 0.025 | 0.20 | 8.04 | | |
| | September | 11 | 110 | 93 | 14 | 177 | 0.025 | 0.010 | 0.030 | 7.98 | | 0.0070 |
| | October | | | 129 | 6.5 | 174 | 0.025 | 0.14 | 0.010 | 7.73 | | |
| 2008 | April | | 187 | | 1.0 | 268 | 0.025 | 0.055 | 0.010 | 8.40 | | 0.010 |
| | June | | 92 | 92 | 15 | 133 | 0.025 | 0.058 | 0.049 | 7.90 | | 0.013 |
| | August | 9.0 | 123 | 124 | 105 | 167 | 0.025 | 0.005 | 0.143 | 7.92 | | 0.014 |
| | September | 18 | | | 16 | 160 | 0.025 | 0.005 | 0.018 | 7.85 | | 0.041 |
| | October | 11 | 123 | | 5.7 | 183 | 0.025 | | | 7.84 | | 0.0090 |
| 2009 | April | 18 | 20 | | 1.0 | 52 | | | | 6.84 | 7.60 | 0.053 |
| | June | 9.2 | 93 | | 32 | 156 | | | | 7.90 | 7.74 | 0.013 |
| | July | | 137 | | 4.0 | 184 | | | | 8.07 | | |
| | August | 12 | 96 | | 9.8 | 149 | | | 0.18 | 7.79 | 7.72 | 0.025 |
| | October | 8.3 | 125 | 141 | 2.8 | 130 | 0.010 | 0.0025 | 0.14 | 8.02 | 8.24 | 0.007 |
| 2010 | April | 21 | 36 | 50 | 2.5 | 89 | 0.016 | 0.0038 | 0.015 | 7.64 | 7.56 | 0.053 |
| | May | 11 | 83 | 88 | 67 | 119 | 0.034 | 0.0065 | 0.070 | 8.02 | 7.64 | 0.029 |
| | June | 7.6 | 113 | 121 | 63 | 143 | 0.059 | 0.0073 | 0.14 | 8.17 | 7.49 | 0.012 |
| | July | 16 | 93 | 106 | 53 | 150 | 0.027 | 0.0025 | 0.070 | 8.06 | 8.02 | 0.019 |
| | August | 13 | 118 | 116 | | 170 | | | | | 7.91 | 0.011 |
| | September | 17 | 107 | 104 | 11 | 210 | 0.039 | 0.0025 | 0.030 | 7.98 | 8.02 | 0.016 |
| | October | 13 | 111 | 126 | 3.0 | 150 | 0.069 | 0.0025 | 0.070 | 8.10 | 7.85 | 0.011 |
| 2011 | April | 23 | 43 | 43 | 0.50 | 72 | 0.010 | 0.0025 | 0.010 | 7.41 | | 0.057 |
| | May | 22 | 32 | 33 | 7.0 | 40 | | 0.0025 | 0.010 | 7.11 | | 0.076 |
| | June | 17 | 66 | 69 | 29 | 91 | 0.012 | 0.0025 | 0.040 | 7.65 | | 0.042 |
| | July | 21 | 77 | 88 | 150 | 120 | 0.016 | 0.0070 | 0.050 | 7.76 | | 0.034 |
| | August | 21 | 82 | 91 | 149 | 130 | 0.012 | 0.0036 | 0.053 | 7.86 | | 0.039 |
| | September | 13 | 118 | 119 | 1.0 | 170 | 0.025 | 0.0025 | 0.050 | 8.03 | 7.92 | 0.024 |
| | October | 12 | 110 | 113 | 2.0 | 150 | 0.019 | 0.0025 | 0.11 | 8.07 | 7.65 | 0.013 |
| | November | 7.7 | 148 | 144 | 27 | 156 | 0.021 | 0.0025 | 0.14 | 7.96 | | 0.0076 |
| 2012 | January | 5.3 | 169 | 158 | 2.0 | 226 | 0.0050 | 0.0025 | 0.32 | 8.13 | | 0.0053 |
| | February | 6.1 | 165 | 160 | 2.0 | 216 | 0.0060 | 0.0025 | 0.29 | 7.99 | 7.16 | 0.021 |
| | March | 5.2 | 161 | 159 | 3.2 | 176 | 0.0067 | 0.0025 | 0.20 | 8.17 | 6.72 | 0.0031 |
| | April | 14 | 39 | 37 | 11.2 | 100 | 0.0025 | 0.010 | 0.010 | 7.63 | 7.43 | 0.050 |
| | May | 14 | 52 | 126 | 1158 | 100 | 0.093 | 0.0055 | 0.029 | 7.07 | 7.50 | 0.053 |
| | June | 16 | 92 | 105 | 165 | 128 | 0.18 | 0.015 | 0.083 | 8.12 | 7.59 | 0.027 |
| | July | 13 | 121 | 162 | 630 | 158 | 0.134 | 0.010 | 0.11 | 8.15 | 7.86 | 0.031 |
| | August | 11 | 128 | 175 | 700 | 178 | 0.045 | 0.0097 | 0.10 | 8.16 | 8.08 | 0.030 |
| | September | 15 | 102 | 107 | 33 | 136 | 0.0099 | 0.0025 | 0.056 | 8.09 | 7.97 | 0.020 |
| | October | 11 | 129 | 130 | 27 | 158 | 0.022 | 0.0025 | 0.084 | 8.05 | 8.10 | 0.011 |
| | November | 8.5 | 156 | 154 | 2.2 | 188 | 0.026 | 0.0025 | 0.11 | 7.93 | 6.69 | 0.0079 |
| | December | 10 | 223 | 206 | 0.50 | 262 | 0.025 | 0.0025 | 0.063 | 8.13 | 7.97 | 0.0061 |
| 2013 | April | 4.6 | 192 | 198 | 5.8 | 246 | 0.0082 | 0.0025 | 0.13 | 8.27 | 8.18 | 0.0031 |
| | May | 19 | 32 | 35 | 34 | 77 | 0.098 | 0.0025 | 0.010 | 7.53 | 7.90 | 0.051 |
| | June | 13 | 121 | 151 | 278 | 168 | 0.16 | 0.011 | 0.17 | 8.09 | 8.05 | 0.034 |
| | July | 9.1 | 118 | 147 | 179 | 163 | 0.11 | 0.0092 | 0.091 | 8.08 | 7.99 | 0.019 |
| | August | 13 | 131 | 154 | 218 | 179 | 0.080 | 0.0052 | 0.097 | 8.12 | 7.92 | 0.021 |
| | September | 12 | 129 | 149 | 53 | 196 | 0.048 | 0.0037 | 0.10 | 7.98 | 7.80 | 0.022 |
| | October | 12 | 130 | 133 | 40 | 193 | 0.069 | 0.0025 | 0.11 | 8.18 | 7.55 | 0.014 |
| | November | 16 | 177 | 184 | 19 | 185 | 0.11 | 0.010 | 0.12 | 8.08 | 7.61 | 0.015 |
| | December | 8.0 | 164 | 186 | 2.1 | 207 | 0.016 | 0.0025 | 0.11 | 8.18 | 6.90 | 0.0038 |
| **Median:** | | **12** | **118** | **124** | **11** | **160** | **0.025** | **0.0025** | **0.075** | **7.96** | **7.80** | **0.019** |
| **95th Percentile:** | | **21** | **181** | **185** | **278** | **226** | **0.12** | **0.040** | **0.22** | **8.18** | **8.13** | **0.053** |

**Table D.4: Background data for Option 3 with median and 95th Percentile values.**

| Year | Month | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | May | 0.00029 | 0.000025 | 0.00050 | 0.0042 | 0.14 | 0.00025 | 0.00050 | 0.0014 | 0.00050 | 0.000010 | 0.0029 |
| | June | 0.00046 | 0.000025 | 0.00030 | 0.0023 | 0.16 | 0.000064 | 0.00085 | 0.0011 | 0.00050 | 0.0000050 | 0.0091 |
| | July | 0.00041 | 0.000025 | 0.00025 | 0.0033 | 0.16 | 0.000075 | 0.0011 | 0.0011 | 0.00050 | 0.0000050 | 0.0030 |
| | August | 0.00043 | 0.000010 | 0.00050 | 0.0026 | 0.27 | 0.00025 | 0.00083 | 0.0014 | 0.00050 | 0.000010 | 0.0029 |
| | September | 0.00039 | 0.0000085 | 0.00050 | 0.0027 | 0.31 | 0.00025 | 0.00059 | 0.0013 | 0.00050 | 0.000010 | 0.0025 |
| | October | 0.00044 | 0.000025 | 0.00025 | 0.0029 | 0.25 | 0.000025 | 0.00069 | 0.0012 | 0.00050 | 0.0000050 | 0.0013 |
| 2006 | June | 0.00051 | 0.000021 | 0.00050 | 0.0017 | 0.15 | 0.000094 | 0.00055 | 0.0019 | 0.00039 | 0.0000050 | 0.0025 |
| | July | 0.00048 | 0.0000050 | 0.00076 | 0.0011 | 0.083 | 0.000088 | 0.0011 | 0.0012 | 0.00013 | | 0.00063 |
| | August | 0.00035 | 0.0000050 | 0.00059 | 0.0013 | 0.083 | 0.000050 | 0.00088 | 0.00083 | 0.00010 | | 0.0024 |
| | September | 0.00046 | 0.000039 | 0.00070 | 0.0011 | 0.10 | 0.000050 | 0.00075 | 0.00067 | 0.00011 | | 0.0017 |
| | October | 0.00035 | 0.0000050 | 0.00025 | 0.00075 | 0.10 | 0.000050 | 0.0010 | 0.00065 | 0.00020 | | 0.0015 |
| 2007 | June | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00025 | 0.00010 | | 0.0040 |
| | July | 0.00050 | 0.0000050 | 0.0010 | 0.0020 | 0.040 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0060 |
| | August | | | | | | | | | | | |
| | September | 0.00040 | 0.0000050 | 0.0016 | 0.0010 | 0.080 | 0.000050 | 0.0020 | 0.00080 | 0.00010 | | 0.0020 |
| | October | | | | | | | | | | | |
| 2008 | April | 0.00027 | 0.000040 | 0.00097 | 0.0012 | 0.030 | 0.000067 | 0.0017 | 0.0010 | 0.00030 | | 0.0017 |
| | June | 0.00010 | 0.000040 | 0.0013 | 0.00075 | 0.060 | 0.000050 | 0.0014 | 0.0010 | 0.0013 | 0.0000050 | 0.0020 |
| | August | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.070 | 0.000050 | 0.0010 | 0.0010 | 0.00010 | 0.000060 | 0.0060 |
| | September | 0.00035 | 0.0000050 | 0.0015 | 0.0030 | 0.15 | 0.00088 | 0.00050 | 0.0015 | 0.00075 | 0.0000050 | 0.0030 |
| | October | 0.00050 | 0.0000050 | 0.00050 | 0.0010 | 0.078 | 0.000050 | 0.00108 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| 2009 | April | 0.00010 | 0.000080 | 0.00060 | 0.0050 | 0.070 | 0.00010 | 0.00013 | 0.00050 | 0.00030 | 0.0000050 | 0.0090 |
| | June | 0.00030 | 0.000005 | 0.00020 | 0.0020 | 0.050 | 0.000050 | 0.00127 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | July | | | | | | | | | | | |
| | August | 0.00027 | 0.000030 | 0.00067 | 0.0037 | 0.073 | 0.00018 | 0.00083 | 0.00083 | 0.00030 | 0.0000050 | 0.0040 |
| | October | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |
| 2010 | April | 0.00030 | 0.000010 | 0.00047 | 0.0045 | 0.14 | 0.00017 | 0.00060 | 0.00083 | 0.00013 | 0.0000083 | 0.0033 |
| | May | 0.00038 | 0.000023 | 0.00050 | 0.0021 | 0.19 | 0.00010 | 0.0010 | 0.0011 | 0.00022 | 0.000010 | 0.0034 |
| | June | 0.00028 | 0.000050 | | 0.00095 | 0.035 | 0.00010 | 0.0016 | 0.00091 | 0.00040 | | 0.0050 |
| | July | 0.00020 | 0.000050 | | 0.0020 | 0.10 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| | August | 0.00040 | 0.000050 | | 0.0020 | 0.11 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| | September | 0.00050 | 0.000050 | | 0.0010 | 0.23 | 0.00010 | 0.0010 | 0.0020 | 0.00040 | | 0.0050 |
| | October | 0.00040 | 0.0000050 | 0.00050 | 0.0012 | 0.13 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| 2011 | April | 0.00030 | 0.000030 | 0.00050 | 0.0077 | 0.15 | 0.00010 | 0.00050 | 0.0010 | 0.00005 | 0.000010 | 0.0050 |
| | May | 0.00020 | 0.000040 | 0.00050 | 0.0070 | 0.17 | 0.00010 | 0.00050 | 0.0010 | 0.00005 | 0.000010 | 0.010 |
| | June | 0.00030 | 0.000020 | 0.00050 | 0.0046 | 0.16 | 0.00010 | 0.00075 | 0.0013 | 0.000075 | 0.000010 | 0.005 |
| | July | 0.00070 | 0.000010 | 0.00050 | 0.0031 | 0.44 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | August | 0.00073 | 0.000011 | 0.00050 | 0.0028 | 0.55 | 0.00010 | 0.00050 | 0.0023 | 0.00010 | 0.000010 | 0.0025 |
| | September | 0.00070 | 0.000010 | 0.00050 | 0.0016 | 0.62 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | October | 0.00060 | 0.000030 | 0.00050 | 0.0012 | 0.35 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| | November | 0.00040 | 0.0000050 | 0.00050 | 0.0011 | 0.17 | 0.00010 | 0.0013 | 0.0012 | 0.00016 | 0.000010 | 0.0025 |
| 2012 | January | 0.00041 | 0.000035 | 0.00050 | 0.0011 | 0.094 | 0.00010 | 0.0015 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| | February | 0.00033 | 0.000064 | 0.00050 | 0.0154 | 0.049 | 0.00024 | 0.0014 | 0.00050 | 0.00034 | 0.000010 | 0.0083 |
| | March | 0.00039 | 0.0000050 | 0.00050 | 0.0012 | 0.012 | 0.00010 | 0.0011 | 0.00050 | 0.00031 | 0.000010 | 0.0025 |
| | April | 0.00048 | 0.000023 | 0.00050 | 0.0052 | 0.48 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| | May | 0.00089 | 0.000021 | 0.00050 | 0.0027 | 1.0 | 0.00015 | 0.00050 | 0.0018 | 0.000067 | 0.000010 | 0.0025 |
| | June | 0.00070 | 0.0000050 | 0.00050 | 0.0016 | 0.56 | 0.00010 | 0.0013 | 0.002 | 0.00015 | 0.000010 | 0.0025 |
| | July | 0.00096 | 0.0000062 | 0.00050 | 0.0014 | 0.73 | 0.00029 | 0.0011 | 0.0015 | 0.00012 | 0.000010 | 0.0025 |
| | August | 0.00128 | 0.0000050 | 0.00050 | 0.0014 | 0.91 | 0.00010 | 0.0012 | 0.0020 | 0.00011 | 0.000010 | 0.0025 |
| | September | 0.00061 | 0.0000050 | 0.00050 | 0.0019 | 0.42 | 0.00010 | 0.00050 | 0.0025 | 0.000095 | 0.000010 | 0.0025 |
| | October | 0.00060 | 0.0000050 | 0.00050 | 0.00094 | 0.60 | 0.00010 | 0.0011 | 0.0015 | 0.00014 | 0.000010 | 0.0025 |
| | November | 0.00046 | 0.000018 | 0.00050 | 0.0019 | 0.10 | 0.00016 | 0.00090 | 0.0013 | 0.00014 | 0.000010 | 0.0025 |
| | December | 0.00051 | 0.0000050 | 0.00050 | 0.0023 | 0.030 | 0.00010 | 0.0012 | 0.0011 | 0.00045 | 0.000010 | 0.0025 |
| 2013 | April | 0.00025 | 0.0000050 | 0.00050 | 0.0011 | 0.014 | 0.00010 | 0.0013 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| | May | 0.00033 | 0.000011 | 0.00050 | 0.0036 | 0.24 | 0.00010 | 0.00050 | 0.0012 | 0.00005 | 0.000010 | 0.0025 |
| | June | 0.0011 | 0.0000085 | 0.00050 | 0.0017 | 0.59 | 0.00010 | 0.0013 | 0.0019 | 0.00011 | 0.000010 | 0.0045 |
| | July | 0.0011 | 0.0000050 | 0.00050 | 0.0012 | 0.66 | 0.00010 | 0.0012 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | August | 0.0011 | 0.0000050 | 0.00050 | 0.0012 | 0.71 | 0.00010 | 0.0012 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | September | 0.0012 | 0.0000056 | 0.00065 | 0.0012 | 0.96 | 0.00010 | 0.00083 | 0.0020 | 0.000080 | 0.000010 | 0.0025 |
| | October | 0.00078 | 0.0000050 | 0.00050 | 0.0010 | 0.65 | 0.00010 | 0.00076 | 0.0017 | 0.000080 | 0.000010 | 0.0025 |
| | November | 0.0022 | 0.000011 | 0.00077 | 0.00086 | 4.8 | 0.00010 | 0.0011 | 0.0025 | 0.00018 | 0.000010 | 0.0025 |
| | December | 0.00057 | 0.0000080 | 0.00050 | 0.0012 | 0.062 | 0.00010 | 0.00080 | 0.00080 | 0.00015 | 0.000010 | 0.0025 |
| **Median:** | | **0.00041** | **0.000010** | **0.00050** | **0.0017** | **0.15** | **0.00010** | **0.0010** | **0.0011** | **0.00015** | **0.000010** | **0.0025** |
| **95th Percentile:** | | **0.0011** | **0.000050** | **0.0011** | **0.0054** | **0.91** | **0.00025** | **0.0015** | **0.0020** | **0.00050** | **0.000010** | **0.0084** |

**Table D.5: Annual Medians for Option 3.**

| Year | Month | DOC (mg/L) | Dissolved Hardness (mg/L) | Total Hardness (mg/L) | TSS (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrite (mg/L) | Nitrate (mg/L) | Lab pH (pH Units) | Field pH (pH Units) | Dissolved Aluminum (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | May | | | 74 | 19 | 118 | 0.017 | 0.0011 | 0.034 | 7.85 | | 0.043 |
| | June | | | | 5.4 | 160 | 0.015 | 0.00067 | 0.052 | 7.83 | | 0.026 |
| | July | | | 138 | 11 | 173 | 0.010 | 0.00050 | 0.042 | 7.73 | | 0.020 |
| | August | | | 110 | 4.9 | 157 | 0.029 | 0.00066 | 0.010 | 8.10 | | 0.022 |
| | September | | | 111 | 58 | 151 | 0.012 | 0.00057 | 0.025 | 7.83 | | 0.024 |
| | October | | | 111 | 5.5 | 151 | 0.015 | 0.00050 | 0.060 | 7.64 | | 0.033 |
| | **Annual Median** | | | **111** | **8.4** | **154** | **0.015** | **0.00061** | **0.038** | **7.83** | | **0.025** |
| 2006 | June | | 110 | | 206 | 112 | 0.026 | 0.0010 | 0.083 | 7.71 | | 0.075 |
| | July | | 120 | | 3.8 | 184 | 0.014 | | 0.19 | 7.86 | | 0.0056 |
| | August | | 124 | | 2.0 | 175 | 0.017 | | 0.075 | 7.92 | | 0.011 |
| | September | | 120 | | 4.0 | 182 | 0.010 | | 0.053 | 7.78 | | 0.0079 |
| | October | | 129 | | 3.0 | 164 | 0.052 | | 0.11 | 7.67 | | 0.0048 |
| | **Annual Median** | | **120** | | **3.8** | **175** | **0.017** | **0.0010** | **0.083** | **7.78** | | **0.0079** |
| 2007 | June | 8.2 | 110 | 97 | 28 | 147 | 0.025 | 0.027 | 0.14 | 7.84 | | 0.014 |
| | July | 14 | 128 | 125 | 5.7 | 179 | 0.025 | 0.025 | 0.30 | 7.78 | | 0.011 |
| | August | | | 124 | 4.7 | 192 | 0.025 | 0.025 | 0.20 | 8.04 | | |
| | September | 11 | 110 | 93 | 14 | 177 | 0.025 | 0.010 | 0.030 | 7.98 | | 0.0070 |
| | October | | | 129 | 6.5 | 174 | 0.025 | 0.14 | 0.010 | 7.73 | | |
| | **Annual Median** | **11** | **110** | **124** | **6.5** | **177** | **0.025** | **0.025** | **0.14** | **7.84** | | **0.011** |
| 2008 | April | | 187 | | 1.0 | 268 | 0.025 | 0.055 | 0.010 | 8.40 | | 0.010 |
| | June | | 92 | 92 | 15 | 133 | 0.025 | 0.058 | 0.049 | 7.90 | | 0.013 |
| | August | 9.0 | 123 | 124 | 105 | 167 | 0.025 | 0.005 | 0.143 | 7.92 | | 0.014 |
| | September | 18 | | | 16 | 160 | 0.025 | 0.005 | 0.018 | 7.85 | | 0.041 |
| | October | 11 | 123 | | 5.7 | 183 | 0.025 | | | 7.84 | | 0.0090 |
| | **Annual Median** | **11** | **123** | **108** | **15** | **167** | **0.025** | **0.030** | **0.033** | **7.90** | | **0.013** |
| 2009 | April | 18 | 20 | | 1.0 | 52 | | | | 6.84 | 7.60 | 0.053 |
| | June | 9.2 | 93 | | 32 | 156 | | | | 7.90 | 7.74 | 0.013 |
| | July | | 137 | | 4.0 | 184 | | | | 8.07 | | |
| | August | 12 | 96 | | 9.8 | 149 | | | 0.18 | 7.79 | 7.72 | 0.025 |
| | October | 8.3 | 125 | 141 | 2.8 | 130 | 0.010 | 0.0025 | 0.14 | 8.02 | 8.24 | 0.007 |
| | **Annual Median** | **10** | **96** | **141** | **4.0** | **149** | **0.010** | **0.0025** | **0.16** | **7.90** | **7.73** | **0.019** |
| 2010 | April | 21 | 36 | 50 | 2.5 | 89 | 0.016 | 0.0038 | 0.015 | 7.64 | 7.56 | 0.053 |
| | May | 11 | 83 | 88 | 67 | 119 | 0.034 | 0.0065 | 0.070 | 8.02 | 7.64 | 0.029 |
| | June | 7.6 | 113 | 121 | 63 | 143 | 0.059 | 0.0073 | 0.14 | 8.17 | 7.49 | 0.012 |
| | July | 16 | 93 | 106 | 53 | 150 | 0.027 | 0.0025 | 0.070 | 8.06 | 8.02 | 0.019 |
| | August | 13 | 118 | 116 | | 170 | | | | | 7.91 | 0.011 |
| | September | 17 | 107 | 104 | 11 | 210 | 0.039 | 0.0025 | 0.030 | 7.98 | 8.02 | 0.016 |
| | October | 13 | 111 | 126 | 3.0 | 150 | 0.069 | 0.0025 | 0.070 | 8.10 | 7.85 | 0.011 |
| | **Annual Median** | **13** | **107** | **106** | **32** | **150** | **0.037** | **0.0031** | **0.070** | **8.04** | **7.85** | **0.016** |
| 2011 | April | 23 | 43 | 43 | 0.50 | 72 | 0.010 | 0.0025 | 0.010 | 7.41 | | 0.057 |
| | May | 22 | 32 | 33 | 7.0 | 40 | | 0.0025 | 0.010 | 7.11 | | 0.076 |
| | June | 17 | 66 | 69 | 29 | 91 | 0.012 | 0.0025 | 0.040 | 7.65 | | 0.042 |
| | July | 21 | 77 | 88 | 150 | 120 | 0.016 | 0.0070 | 0.050 | 7.76 | | 0.034 |
| | August | 21 | 82 | 91 | 149 | 130 | 0.012 | 0.0036 | 0.053 | 7.86 | | 0.039 |
| | September | 13 | 118 | 119 | 1.0 | 170 | 0.025 | 0.0025 | 0.050 | 8.03 | 7.92 | 0.024 |
| | October | 12 | 110 | 113 | 2.0 | 150 | 0.019 | 0.0025 | 0.11 | 8.07 | 7.65 | 0.013 |
| | November | 7.7 | 148 | 144 | 27 | 156 | 0.021 | 0.0025 | 0.14 | 7.96 | | 0.0076 |
| | **Annual Median** | **19** | **79** | **89** | **17** | **125** | **0.016** | **0.0025** | **0.050** | **7.81** | **7.79** | **0.036** |
| 2012 | January | 5.3 | 169 | 158 | 2.0 | 226 | 0.0050 | 0.0025 | 0.32 | 8.13 | | 0.0053 |
| | February | 6.1 | 165 | 160 | 2.0 | 216 | 0.0060 | 0.0025 | 0.29 | 7.99 | 7.16 | 0.021 |
| | March | 5.2 | 161 | 159 | 3.2 | 176 | 0.0067 | 0.0025 | 0.20 | 8.17 | 6.72 | 0.0031 |
| | April | 14 | 39 | 37 | 11.2 | 100 | 0.0025 | 0.010 | 0.010 | 7.63 | 7.43 | 0.050 |
| | May | 14 | 52 | 126 | 1158 | 100 | 0.093 | 0.0055 | 0.029 | 7.07 | 7.50 | 0.053 |
| | June | 16 | 92 | 105 | 165 | 128 | 0.18 | 0.015 | 0.083 | 8.12 | 7.59 | 0.027 |
| | July | 13 | 121 | 162 | 630 | 158 | 0.134 | 0.010 | 0.11 | 8.15 | 7.86 | 0.031 |
| | August | 11 | 128 | 175 | 700 | 178 | 0.045 | 0.0097 | 0.10 | 8.16 | 8.08 | 0.030 |
| | September | 15 | 102 | 107 | 33 | 136 | 0.0099 | 0.0025 | 0.056 | 8.09 | 7.97 | 0.020 |
| | October | 11 | 129 | 130 | 27 | 158 | 0.022 | 0.0025 | 0.084 | 8.05 | 8.10 | 0.011 |
| | November | 8.5 | 156 | 154 | 2.2 | 188 | 0.026 | 0.0025 | 0.11 | 7.93 | 6.69 | 0.0079 |
| | December | 10 | 223 | 206 | 0.50 | 262 | 0.025 | 0.0025 | 0.063 | 8.13 | 7.97 | 0.0061 |
| | **Annual Median** | **11** | **128** | **156** | **19** | **167** | **0.024** | **0.0025** | **0.092** | **8.10** | **7.59** | **0.021** |
| 2013 | April | 4.6 | 192 | 198 | 5.8 | 246 | 0.0082 | 0.0025 | 0.13 | 8.27 | 8.18 | 0.0031 |
| | May | 19 | 32 | 35 | 34 | 77 | 0.098 | 0.0025 | 0.010 | 7.53 | 7.90 | 0.051 |
| | June | 13 | 121 | 151 | 278 | 168 | 0.16 | 0.011 | 0.17 | 8.09 | 8.05 | 0.034 |
| | July | 9.1 | 118 | 147 | 179 | 163 | 0.11 | 0.0092 | 0.091 | 8.08 | 7.99 | 0.019 |
| | August | 13 | 131 | 154 | 218 | 179 | 0.080 | 0.0052 | 0.097 | 8.12 | 7.92 | 0.021 |
| | September | 12 | 129 | 149 | 53 | 196 | 0.048 | 0.0037 | 0.10 | 7.98 | 7.80 | 0.022 |
| | October | 12 | 130 | 133 | 40 | 193 | 0.069 | 0.0025 | 0.11 | 8.18 | 7.55 | 0.014 |
| | November | 16 | 177 | 184 | 19 | 185 | 0.11 | 0.010 | 0.12 | 8.08 | 7.61 | 0.015 |
| | December | 8.0 | 164 | 186 | 2.1 | 207 | 0.016 | 0.0025 | 0.11 | 8.18 | 6.90 | 0.0038 |
| | **Annual Median** | **12** | **130** | **151** | **40** | **185** | **0.080** | **0.0037** | **0.11** | **8.09** | **7.90** | **0.019** |

**Table D.5: Annual Medians for Option 3.**

| Year | Month | Dissolved Arsenic (mg/L) | Dissolved Cadmium (mg/L) | Dissolved Chromium (mg/L) | Dissolved Copper (mg/L) | Dissolved Iron (mg/L) | Dissolved Lead (mg/L) | Dissolved Molybdenum (mg/L) | Dissolved Nickel (mg/L) | Dissolved Selenium (mg/L) | Dissolved Silver (mg/L) | Dissolved Zinc (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | May | 0.00029 | 0.000025 | 0.00050 | 0.0042 | 0.14 | 0.00025 | 0.00050 | 0.0014 | 0.00050 | 0.000010 | 0.0029 |
| | June | 0.00046 | 0.000025 | 0.00030 | 0.0023 | 0.16 | 0.000064 | 0.00085 | 0.0011 | 0.00050 | 0.0000050 | 0.0091 |
| | July | 0.00041 | 0.000025 | 0.00025 | 0.0033 | 0.16 | 0.000075 | 0.0011 | 0.0011 | 0.00050 | 0.0000050 | 0.0030 |
| | August | 0.00043 | 0.000010 | 0.00050 | 0.0026 | 0.27 | 0.00025 | 0.00083 | 0.0014 | 0.00050 | 0.000010 | 0.0029 |
| | September | 0.00039 | 0.0000085 | 0.00050 | 0.0027 | 0.31 | 0.00025 | 0.00059 | 0.0013 | 0.00050 | 0.000010 | 0.0025 |
| | October | 0.00044 | 0.000025 | 0.00025 | 0.0029 | 0.25 | 0.000025 | 0.00069 | 0.0012 | 0.00050 | 0.0000050 | 0.0013 |
| | **Annual Median** | **0.00042** | **0.000025** | **0.00040** | **0.0028** | **0.21** | **0.00016** | **0.00076** | **0.0013** | **0.00050** | **0.0000075** | **0.0029** |
| 2006 | June | 0.00051 | 0.000021 | 0.00050 | 0.0017 | 0.15 | 0.000094 | 0.00055 | 0.0019 | 0.00039 | 0.0000050 | 0.0025 |
| | July | 0.00048 | 0.0000050 | 0.00076 | 0.0011 | 0.083 | 0.000088 | 0.0011 | 0.0012 | 0.00013 | | 0.00063 |
| | August | 0.00035 | 0.0000050 | 0.00059 | 0.0013 | 0.083 | 0.000050 | 0.00088 | 0.00083 | 0.00010 | | 0.0024 |
| | September | 0.00046 | 0.000039 | 0.00070 | 0.0011 | 0.10 | 0.000050 | 0.00075 | 0.00067 | 0.00011 | | 0.0017 |
| | October | 0.00035 | 0.0000050 | 0.00025 | 0.00075 | 0.10 | 0.000050 | 0.0010 | 0.00065 | 0.00020 | | 0.0015 |
| | **Annual Median** | **0.00046** | **0.0000050** | **0.00059** | **0.0011** | **0.10** | **0.000050** | **0.00088** | **0.00083** | **0.00013** | **0.0000050** | **0.0017** |
| 2007 | June | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.050 | 0.000050 | 0.0010 | 0.00025 | 0.00010 | | 0.0040 |
| | July | 0.00050 | 0.0000050 | 0.0010 | 0.0020 | 0.040 | 0.000050 | 0.0010 | 0.00070 | 0.00010 | | 0.0060 |
| | August | | | | | | | | | | | |
| | September | 0.00040 | 0.0000050 | 0.0016 | 0.0010 | 0.080 | 0.000050 | 0.0020 | 0.00080 | 0.00010 | | 0.0020 |
| | October | | | | | | | | | | | |
| | **Annual Median** | **0.00040** | **0.0000050** | **0.0010** | **0.0020** | **0.050** | **0.000050** | **0.0010** | **0.00070** | **0.00010** | | **0.0040** |
| 2008 | April | 0.00027 | 0.000040 | 0.00097 | 0.0012 | 0.030 | 0.000067 | 0.0017 | 0.0010 | 0.00030 | | 0.0017 |
| | June | 0.00010 | 0.000040 | 0.0013 | 0.00075 | 0.060 | 0.000050 | 0.0014 | 0.0010 | 0.0013 | 0.0000050 | 0.0020 |
| | August | 0.00040 | 0.0000050 | 0.00060 | 0.0020 | 0.070 | 0.000050 | 0.0010 | 0.0010 | 0.00010 | 0.000060 | 0.0060 |
| | September | 0.00035 | 0.0000050 | 0.0015 | 0.0030 | 0.15 | 0.00088 | 0.00050 | 0.0015 | 0.00075 | 0.0000050 | 0.0030 |
| | October | 0.00050 | 0.0000050 | 0.00050 | 0.0010 | 0.078 | 0.000050 | 0.00108 | 0.0010 | 0.00030 | 0.0000050 | 0.0010 |
| | **Annual Median** | **0.00035** | **0.0000050** | **0.0010** | **0.0012** | **0.070** | **0.000050** | **0.0011** | **0.0010** | **0.00030** | **0.0000050** | **0.0020** |
| 2009 | April | 0.00010 | 0.000080 | 0.00060 | 0.0050 | 0.070 | 0.00010 | 0.00013 | 0.00050 | 0.00030 | 0.0000050 | 0.0090 |
| | June | 0.00030 | 0.000005 | 0.00020 | 0.0020 | 0.050 | 0.000050 | 0.00127 | 0.0010 | 0.00030 | 0.0000050 | 0.0020 |
| | July | | | | | | | | | | | |
| | August | 0.00027 | 0.000030 | 0.00067 | 0.0037 | 0.073 | 0.00018 | 0.00083 | 0.00083 | 0.00030 | 0.0000050 | 0.0040 |
| | October | 0.00030 | 0.000040 | 0.00050 | 0.0012 | 0.046 | 0.00010 | 0.0010 | 0.00050 | 0.00020 | 0.000010 | 0.0025 |
| | **Annual Median** | **0.00028** | **0.000035** | **0.00055** | **0.0028** | **0.060** | **0.00010** | **0.00092** | **0.00067** | **0.00030** | **0.0000050** | **0.0033** |
| 2010 | April | 0.00030 | 0.000010 | 0.00047 | 0.0045 | 0.14 | 0.00017 | 0.00060 | 0.00083 | 0.00013 | 0.0000083 | 0.0033 |
| | May | 0.00038 | 0.000023 | 0.00050 | 0.0021 | 0.19 | 0.00010 | 0.0010 | 0.0011 | 0.00022 | 0.000010 | 0.0034 |
| | June | 0.00028 | 0.000050 | | 0.00095 | 0.035 | 0.00010 | 0.0016 | 0.00091 | 0.00040 | | 0.0050 |
| | July | 0.00020 | 0.000050 | | 0.0020 | 0.10 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| | August | 0.00040 | 0.000050 | | 0.0020 | 0.11 | 0.00010 | 0.0010 | 0.0010 | 0.00040 | | 0.0050 |
| | September | 0.00050 | 0.000050 | | 0.0010 | 0.23 | 0.00010 | 0.0010 | 0.0020 | 0.00040 | | 0.0050 |
| | October | 0.00040 | 0.0000050 | 0.00050 | 0.0012 | 0.13 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| | **Annual Median** | **0.00038** | **0.000050** | **0.00050** | **0.0020** | **0.13** | **0.00010** | **0.0010** | **0.0010** | **0.00040** | **0.000010** | **0.0050** |
| 2011 | April | 0.00030 | 0.000030 | 0.00050 | 0.0077 | 0.15 | 0.00010 | 0.00050 | 0.0010 | 0.00005 | 0.000010 | 0.0050 |
| | May | 0.00020 | 0.000040 | 0.00050 | 0.0070 | 0.17 | 0.00010 | 0.00050 | 0.0010 | 0.00005 | 0.000010 | 0.010 |
| | June | 0.00030 | 0.000020 | 0.00050 | 0.0046 | 0.16 | 0.00010 | 0.00075 | 0.0013 | 0.000075 | 0.000010 | 0.005 |
| | July | 0.00070 | 0.000010 | 0.00050 | 0.0031 | 0.44 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | August | 0.00073 | 0.000011 | 0.00050 | 0.0028 | 0.55 | 0.00010 | 0.00050 | 0.0023 | 0.00010 | 0.000010 | 0.0025 |
| | September | 0.00070 | 0.000010 | 0.00050 | 0.0016 | 0.62 | 0.00010 | 0.00050 | 0.0020 | 0.00010 | 0.000010 | 0.0025 |
| | October | 0.00060 | 0.000030 | 0.00050 | 0.0012 | 0.35 | 0.00010 | 0.0010 | 0.0010 | 0.00010 | 0.000010 | 0.0025 |
| | November | 0.00040 | 0.0000050 | 0.00050 | 0.0011 | 0.17 | 0.00010 | 0.0013 | 0.0012 | 0.00016 | 0.000010 | 0.0025 |
| | **Annual Median** | **0.00050** | **0.000016** | **0.00050** | **0.0029** | **0.26** | **0.00010** | **0.00050** | **0.0012** | **0.00010** | **0.000010** | **0.000010** |
| 2012 | January | 0.00041 | 0.000035 | 0.00050 | 0.0011 | 0.094 | 0.00010 | 0.0015 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| | February | 0.00033 | 0.000064 | 0.00050 | 0.0154 | 0.049 | 0.00024 | 0.0014 | 0.00050 | 0.00034 | 0.000010 | 0.0083 |
| | March | 0.00039 | 0.0000050 | 0.00050 | 0.0012 | 0.012 | 0.00010 | 0.0011 | 0.00050 | 0.00031 | 0.000010 | 0.0025 |
| | April | 0.00048 | 0.000023 | 0.00050 | 0.0052 | 0.48 | 0.00010 | 0.00050 | 0.0012 | 0.000050 | 0.000010 | 0.0025 |
| | May | 0.00089 | 0.000021 | 0.00050 | 0.0027 | 1.0 | 0.00015 | 0.00050 | 0.0018 | 0.000067 | 0.000010 | 0.0025 |
| | June | 0.00070 | 0.0000050 | 0.00050 | 0.0016 | 0.56 | 0.00010 | 0.0013 | 0.002 | 0.00015 | 0.000010 | 0.0025 |
| | July | 0.00096 | 0.0000062 | 0.00050 | 0.0014 | 0.73 | 0.00029 | 0.0011 | 0.0015 | 0.00012 | 0.000010 | 0.0025 |
| | August | 0.00128 | 0.0000050 | 0.00050 | 0.0014 | 0.91 | 0.00010 | 0.0012 | 0.0020 | 0.00011 | 0.000010 | 0.0025 |
| | September | 0.00061 | 0.0000050 | 0.00050 | 0.0019 | 0.42 | 0.00010 | 0.00050 | 0.0025 | 0.000095 | 0.000010 | 0.0025 |
| | October | 0.00060 | 0.0000050 | 0.00050 | 0.00094 | 0.60 | 0.00010 | 0.0011 | 0.0015 | 0.00014 | 0.000010 | 0.0025 |
| | November | 0.00046 | 0.000018 | 0.00050 | 0.0019 | 0.10 | 0.00016 | 0.00090 | 0.0013 | 0.00014 | 0.000010 | 0.0025 |
| | December | 0.00051 | 0.0000050 | 0.00050 | 0.0023 | 0.030 | 0.00010 | 0.0012 | 0.0011 | 0.00045 | 0.000010 | 0.0025 |
| | **Annual Median** | **0.00056** | **0.0000056** | **0.00050** | **0.0018** | **0.45** | **0.00010** | **0.0011** | **0.0014** | **0.00014** | **0.000010** | **0.0025** |
| 2013 | April | 0.00025 | 0.0000050 | 0.00050 | 0.0011 | 0.014 | 0.00010 | 0.0013 | 0.00050 | 0.00043 | 0.000010 | 0.0025 |
| | May | 0.00033 | 0.000011 | 0.00050 | 0.0036 | 0.24 | 0.00010 | 0.00050 | 0.0012 | 0.00005 | 0.000010 | 0.0025 |
| | June | 0.0011 | 0.0000085 | 0.00050 | 0.0017 | 0.59 | 0.00010 | 0.0013 | 0.0019 | 0.00011 | 0.000010 | 0.0045 |
| | July | 0.0011 | 0.0000050 | 0.00050 | 0.0012 | 0.66 | 0.00010 | 0.0012 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | August | 0.0011 | 0.0000050 | 0.00050 | 0.0012 | 0.71 | 0.00010 | 0.0012 | 0.0018 | 0.000093 | 0.000010 | 0.0025 |
| | September | 0.0012 | 0.0000056 | 0.00065 | 0.0012 | 0.96 | 0.00010 | 0.00083 | 0.0020 | 0.000080 | 0.000010 | 0.0025 |
| | October | 0.00078 | 0.0000050 | 0.00050 | 0.0010 | 0.65 | 0.00010 | 0.00076 | 0.0017 | 0.000080 | 0.000010 | 0.0025 |
| | November | 0.0022 | 0.000011 | 0.00077 | 0.00086 | 4.8 | 0.00010 | 0.0011 | 0.0025 | 0.00018 | 0.000010 | 0.0025 |
| | December | 0.00057 | 0.0000080 | 0.00050 | 0.0012 | 0.062 | 0.00010 | 0.00080 | 0.00080 | 0.00015 | 0.000010 | 0.0025 |
| | **Annual Median** | **0.0011** | **0.0000056** | **0.00050** | **0.0012** | **0.65** | **0.00010** | **0.0011** | **0.0018** | **0.000093** | **0.000010** | **0.0025** |

**Table D.6: Background water quality summary statistics for Option 2 (Grouped by Week) representing lower Minto Creek (Minnow 2016) [1]**

| Analytes | Background Concentrations | |
|---|---|---|
| | Individual Data Point Evaluator (95th percentile) | Central Tendency Evaluator (95th percentile of annual medians) |
| Ammonia (mg/L) | 0.12 | 0.058 |
| Nitrite (mg/L) | 0.038 | 0.034 |
| Nitrate (mg/L) | 0.22 | 0.14 |
| Dissolved Aluminum (mg/L) | 0.056 | 0.027 |
| Dissolved Arsenic (mg/L) | 0.0013 | 0.00077 |
| Dissolved Cadmium (mg/L) | 0.000050 | 0.000046 |
| Dissolved Chromium (mg/L) | 0.00130 | 0.00108 |
| Dissolved Copper (mg/L) | 0.0051 | 0.0025 |
| Dissolved Iron (mg/L) | 0.95 | 0.55 |
| Dissolved Lead (mg/L) | 0.000276 | 0.000138 |
| Dissolved Molybdenum (mg/L) | 0.00172 | 0.00114 |
| Dissolved Nickel (mg/L) | 0.0024 | 0.0017 |
| Dissolved Selenium (mg/L) | 0.00050 | 0.00046 |
| Dissolved Silver (mg/L) | 0.000010 | 0.000010 |
| Dissolved Zinc (mg/L) | 0.0060 | 0.0046 |

[1] For contaminants of potential concern (COPCs)

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# Minto Mine Reclamation and Closure Plan – Preliminary Design Report for Treatment Wetland

Document – 011_0716_04C

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**Executive Summary**

Passive water treatment is desired in closure at the Minto Mine, with a focus on the constituents of cadmium (Cd), copper (Cu), and selenium (Se). To address this goal, a constructed wetland treatment system (CWTS) is being designed in a site-specific manner, through a phased approach.

This document outlines foundational scientific information used to select the passive water treatment technology and develop conceptual designs for the Minto Mine. This document then proceeds through to the preliminary CWTS design which is based on findings from phases that included: information gathering, site assessment, off-site pilot-scale testing, and preliminary on-site demonstration-scale confirmation and optimization.

This report specifically considers water treatment by a CWTS within the footprint of the water storage pond at the Minto Mine. The preliminary CWTS design described herein is a surface flow wetland, designed to create and maintain anaerobic conditions in the sediment to sequester cadmium and copper in sulphide mineral form, and selenium in a low bioavailable elemental form. The phased plan for site-specific design and optimization has demonstrated that these elements can be successfully and sustainably treated at the Minto Mine through passive treatment such as a CWTS. A CWTS of this type can be brought online effectively by having more rigorous monitoring and adjustments during an initial commissioning period, followed by progressive decreases in monitoring and maintenance requirements through early- and long-term operation. Conceptual monitoring and maintenance schedules are also described herein.

## 1. Introduction

The Minto Mine, operated by Capstone Mining Corp., is located 240 km northwest of Whitehorse on the west side of the Yukon River. The Minto property lies within the eastern part of the Dawson Range, with elevations from 700 to 1,000 m; the landscape has rounded mountains intersected by broad valleys and drainages that are part of the Yukon River watershed.

The Minto Mine has been in commercial operation since October 2007 and the deposits being mined are copper sulphide mineralized zones. Surface and groundwater water quality is a key consideration in the evaluation of potential effects of mining and mineral development projects and changes to water quality parameters have the potential to affect aquatic and human use of water resources. A Reclamation and Closure Plan (RCP) is required under both the Water Licence and the Quartz Mining Licence. The RCP is intended to address the long-term physical and chemical stability of the site and closure of the proposed features and disturbances associated with the mine. As a part of the RCP, a Constructed Wetland Treatment System (CWTS) is being designed, evaluated, and optimized for water treatment at closure through a phased program (Minto Phase V/VI Expansion Project, YOR Project Number 2013-0100).

The purpose of this report is to describe the design considerations and conceptual monitoring and maintenance associated with a CWTS in the Water Storage Pond (WSP) area of the Minto Mine (Minto) in closure. The scope of this report resides with maintaining performance and treatment capacity, while engineering aspects to maintain hydrology (which in turn, is necessary for treatment) are addressed in Appendix A (SRK, 2016b).

# 2. Design

## 2.1. Treatment Technologies

Passive treatment systems are proposed as key mitigation measures for the achievement of acceptable water quality from the Minto site in the closure condition (Access, June 2013).

Passive treatment as a remediation method for mine-impacted water can be a sustainable method used during post-closure of a mine, as they generally involve significantly less direct capital costs, as well as lower operations and maintenance costs, when compared to traditional active treatment options (Kilbourn Inc., 1999).

A detailed review of the site-wide water balance confirmed that a significant portion of the mining impacted seepage, surface flow and contaminant load could be passively intercepted at a few specific areas which have sufficient space and topography for the incorporation of a wide variety of passive treatment systems (PTS) such as constructed wetland treatment systems (CWTS).

The various potential passive treatment technologies were evaluated and ranked in order to determine which passive treatment technologies held the greatest promise for incorporation in Minto water management and closure planning. A guidance document to help short list and then select an appropriate method for managing mine waste sites was created by The Interstate Technology and Regulatory Council (ITRC), a body of socio- economic and environmental regulators, industry, federal government, and stakeholders that work towards innovative environmental decision making (ITRC, 2010).

ITRC's "Mining Waste Treatment Technology Selection" guidance document (and associated literature reviews) is an interactive and iterative web-based decision tree which provides a systematic framework that can be used to identify a short list of appropriate technologies (ITRC, 2010). The ITRC decision tree framework was used for identifying the range of potential passive treatment technologies which may be applicable at the Minto Mine because it provides a straightforward and transparent method for selecting treatment technologies. It also provides legitimacy in the selection process by using an internationally recognized method that was created specifically for mining waste sites.

Following the identification of potential passive treatment technologies, a screening level evaluation and ranking of the potential passive treatment technologies was conducted. Some of the key considerations evaluating the various treatment technologies included:

- Work acceptably in cold weather;
- Sustainable in the long-term;
- Minimal/low intensity active maintenance scenario;
- Suitable for addressing Minto's specific constituents of potential concern (i.e., Cu, Cd, Se);
- Robust technology with adequate precedent of successful application;

- Amenable to collaboration with SFN and consistent with their aspirations for long-term employment and future land use;
- Cost effective; and
- Amenable to incorporation in an Adaptive Management Plan and modifying/expanding if initial design underperforms.

Based on key site-specific considerations, CWTS were deemed promising and were selected for further investigation at Minto. This report specifically considers water treatment by a CWTS within the footprint of the water storage pond.

## 2.2. Design Basis

PTS such as CWTS rely on transfers (e.g., sorption, filtration) and transformations (e.g., geochemical and biogeochemical reactions) to remove constituents from water (Haakensen et al., 2015; Rodgers and Castle, 2008). These processes require no or infrequent (periodic) electricity, amendment addition, substrate replacement, or flow management. Moreover, these processes can be targeted through specific design aspects, therefore identifying the desired processes and mechanisms to promote their activity and enhance their robustness promotion forms the foundation of the design basis of a CWTS.

Once CWTS have undergone commissioning, they can be relatively self-sustaining, operationally passive (or remotely operated), with minimal periodic maintenance or management required (e.g., addition of sources of carbon), and therefore can provide effective low-cost water treatment in remote environments. This, coupled with the ability to work in the absence of power or the need for active management, suggests that PTS are suitable as a component of a long-term solution to post-closure management of mine-influenced water quality.

The following sections discuss treatment mechanisms for constituents of concern at the Minto Mine.

### *2.2.1. Transfers*

Some of the simplest treatment mechanisms within a CWTS are transfers. These include sorption and filtration, which are not greatly affected by the temperature of the water. While facilitating treatment in colder temperatures, the transfer sites need to be renewed as they are only present in a finite abundance. Transfer sites are renewed by the vegetation, which aids filtration (by submerged vegetation and aquatic roots), and provides sorption sites (on live and decomposing vegetation). Transfer sites are particularly abundant in aquatic mosses. Aquatic plants were selected for the Minto CWTS based on being obligate wetland plants, with a high generation of organic matter, and ideally being peat forming. Such plants were identified at the Minto site during the 2013 CWTS site assessment, with *Carex aquatilis* (known as Aquatic Sedge or Water Sedge) and aquatic bryophytes (aquatic mosses, capable of growing fully submerged in water) being selected as the most promising candidates, (Contango, March 2014) and confirmed through off-site pilot-scale testing (Contango, November 2014).

However, once the constituents have been transferred from one location (water) to another (soils, vegetation) within the wetland, they still need to be transformed to a more stable and less bioavailable form, otherwise known as a coupled biogeochemical reaction. As the CWTS design aspects associated with transfers are fairly generic, the remainder of the design basis was formed around the biogeochemical transformations needed for long-term treatment and sequestration of constituents.

### *2.2.2. Transformations*

Transformations in a CWTS are largely governed by biogeochemical reactions are catalyzed by microbes. Specific microbes (and therefore biogeochemical pathways) can be encouraged through the environmental conditions created by the design of a CWTS. For example, metals can be removed from water by forming insoluble compounds with sulphides. These sulphides are generated by bacteria (sulphide-producing bacteria) that use organic carbon sources (e.g., wood chips, plant matter, methanol) to reduce sulphate in the water under specific oxidation-reduction conditions (Figure 1 and Table 1). This mechanism can be used to treat multiple metals, however, some metals and metalloids will be more readily removed than others as a sulphide mineral, while others can be directly treated through oxidation or reductive processes (Table 1). Therefore, the constituents targeted for treatment at the Minto mine (cadmium, copper, and selenium) are individually addressed in the sections below.

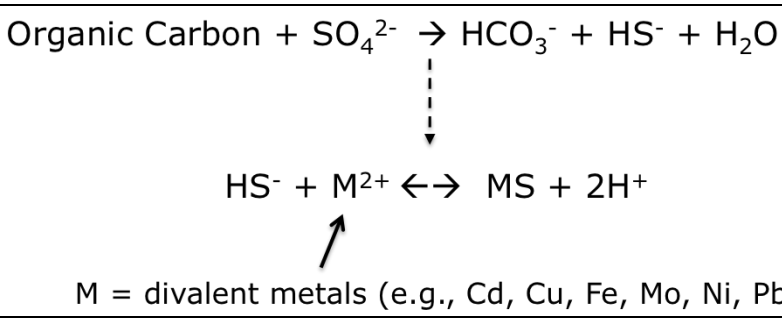



Figure 1 – Example equation of sulphate reduction and metals treatment.
The equation is not balanced and varies based on carbon source and pH. The equation shows the creation of alkalinity ($HCO_3^-$) and sulphides ($HS^-$), the latter which can then form insoluble metal sulphide complexes.

Table 1 – ORP values for various biochemical reactions.

| Biochemical Reaction | ORP (mV) |
|---|---|
| Nitrification | +100 to +350 |
| cBOD degradation with free molecular oxygen | +50 to +250 |
| Biological phosphorus removal | +25 to +250 |
| Denitrification | +50 to -50 |
| Selenium reduction | -50 to -200 |
| Sulphide formation | -50 to -250 |
| Biological phosphorus release | -100 to -250 |
| Acid formation (fermentation) | -100 to -225 |
| Methane production | -175 to -400 |
| Adapted from Gerardi, 2010. | |

### *2.2.3. Copper treatment mechanisms*

Copper treatment can be achieved in several ways, through oxidizing or reducing geochemical and biogeochemical reactions. When treated from water under appropriately designed reducing conditions, copper will form insoluble copper sulphides (Figure 1, Figure 2 and Figure 3). In contrast, in oxidizing conditions, copper can be removed from water as insoluble hydroxides, carbonates, or iron and manganese oxides (Figure 2).

Several copper treatment mechanisms can occur abiotically (i.e., geochemical reaction) given the right conditions and constituents in water (e.g., oxidizing and co-precipitation with iron). In contrast, formation of copper sulphides is generally biologically driven. It requires the production of sulphides by microbes under anaerobic (i.e., depleted dissolved oxygen) and reducing conditions (-50 to -250 mV; Table 1), with a carbon source to sustain the reaction. Although literature provides a range of -50 to -250mV for sulphate reduction, pilot-scale testing for the Minto CWTS, indicated the site-specific targeted soil redox is between -100 and -250 mV.

Within a CWTS, copper can be removed by both oxidizing and reducing conditions, oxidizing associated with actively growing aquatic mosses, and reduction associated with sediments and decaying mosses. These processes are often coupled, such that the long-term sequestration of the copper in the CWTS is as a copper sulphide. Some forms of mineralized copper are more stable and resistant to resolubilization, and the stability of these minerals is reflected by a $K_{sp}$ value (Table 2 and Table 3). Generally, the minerals that have been catalyzed by microbiological activity cannot spontaneously resolubilize under conditions periodically encountered in CWTS. Additionally, the CWTS forms other minerals, such as amorphous FeS which serves as a buffer to re-oxidation of minerals such as copper sulphides (Table 2). For these reasons, reductive mineralization of copper sulphides was chosen as the preferred treatment pathway for copper in this CWTS.

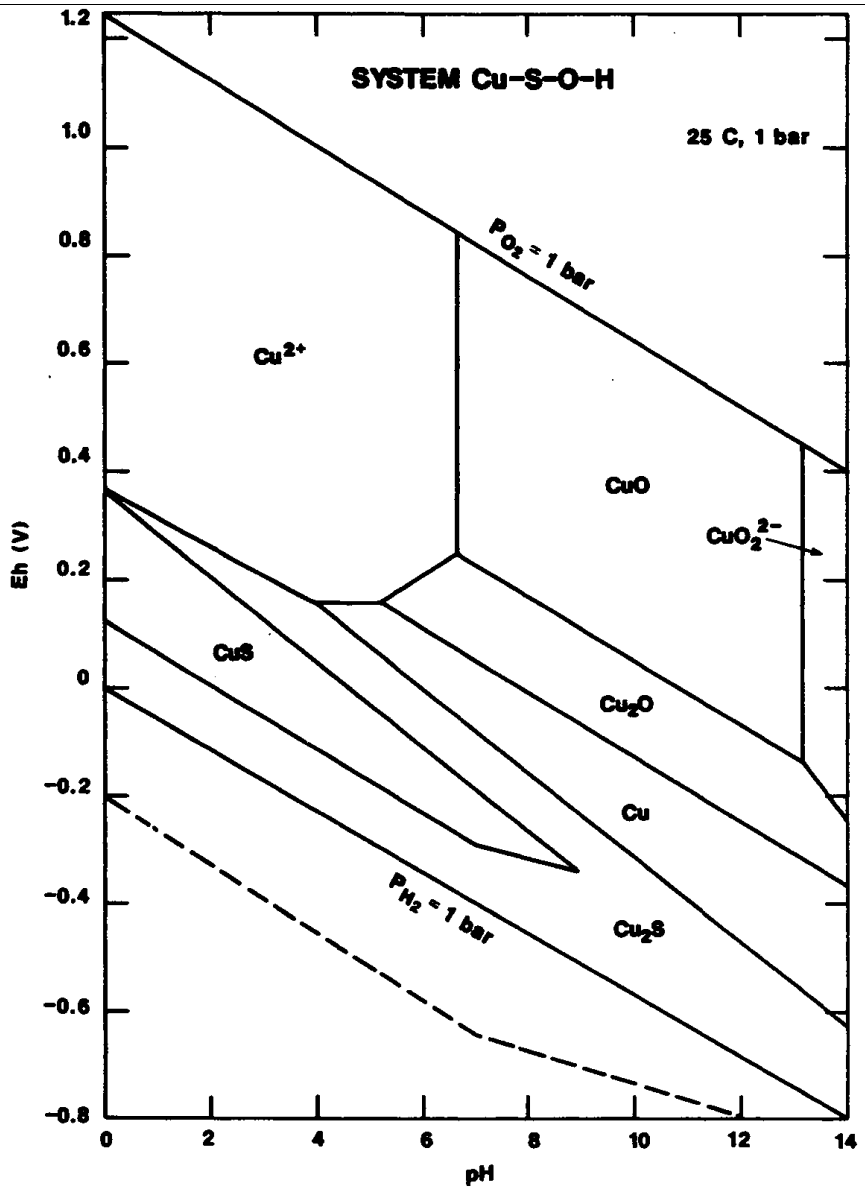



Figure 2 – Eh-pH diagram for part of the system Cu-S-O-H.
See Table 3 for thermodynamic data (Brookins 1988).

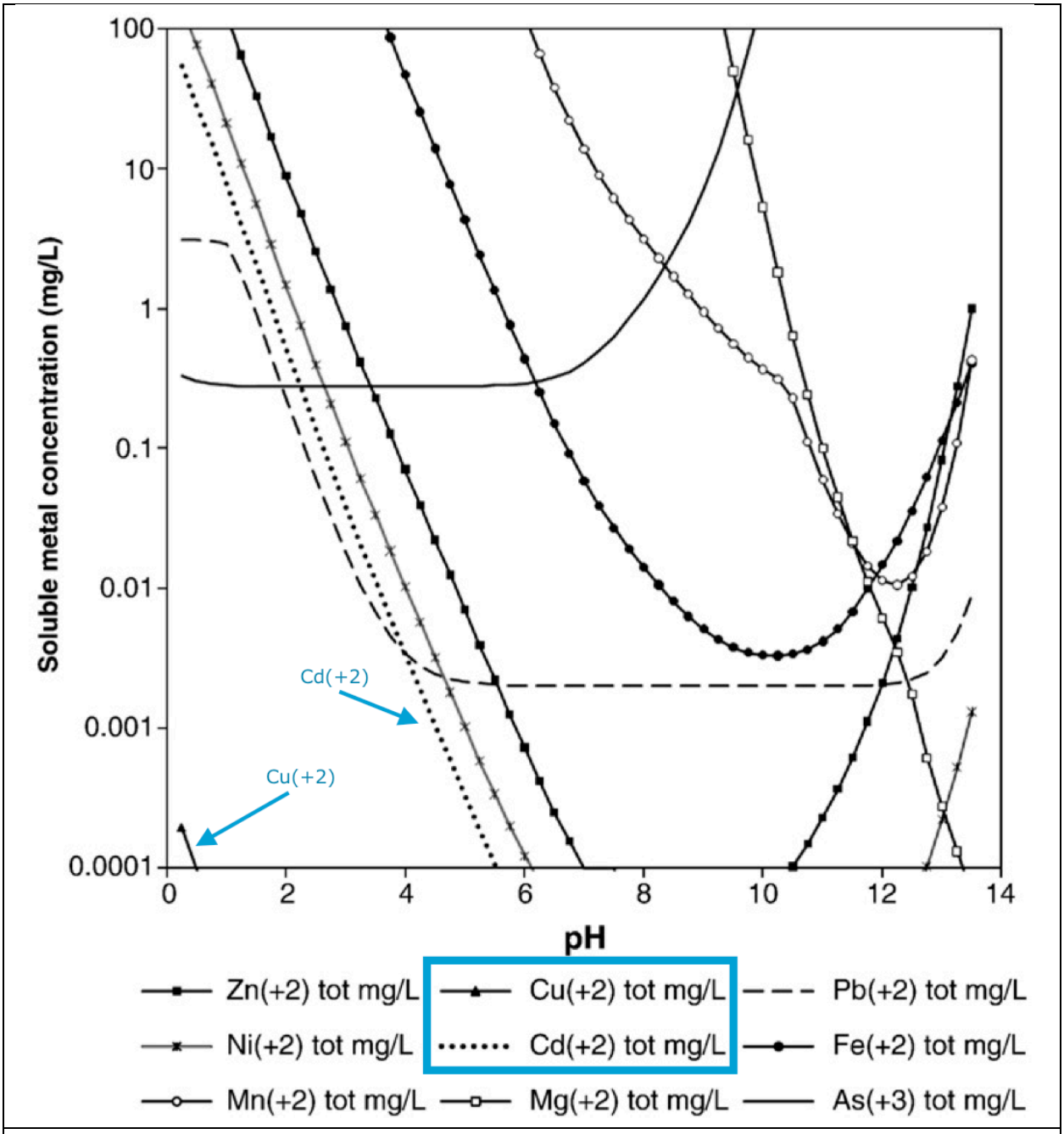



Figure 3 – pH dependence of metal sulphide solubility.
Copper- and cadmium-sulphide solubility indicated with blue arrows and box. Adapted from Lewis (2010).

Table 2 – Solubility of sulphide minerals.

| Metal Sulphide | Log $K_{sp}$ [1] |
|---|---|
| CdS | -25.8 |
| CuS | -36.1 |
| $Cu_2S$ | -47.7 |
| FeS | -18.1 |

[1] Solubility product ($K_{sp}$). Table adapted from Jackson (1986).

Table 3 – Thermodynamic data for copper.

| Species State | $\Delta G^0_f$(kcal/gfw) |
|---|---|
| $Cu_{(c)}$ | 0.00 |
| $Cu^+_{(aq)}$ | +11.94 |
| $Cu^{2+}_{(aq)}$ | +15.65 |
| $Cu_2S_{(c)}$ | -20.60 |
| $CuS_{(c)}$ | -12.81 |
| $Cu_2O_{(c)}$ | -34.98 |
| $CuO_{(c)}$ | -31.00 |
| $CuO_{2\,(aq)}^{2-}$ | -43.88 |
| $Cu_2(CO_3)(OH)_{2\ (c)}$ | -213.58 |
| $Cu_3(CO_3)_2(OH)_{2\ (c)}$ | -314.29 |

Adapted from Brookins, 1988; aq – aqueous (dissolved/soluble), c – crystalline (solid).

### *2.2.4. Cadmium treatment mechanisms*

Passive treatment mechanisms for cadmium are the same as copper, with precipitation as sulphides, hydroxides, carbonates, and iron and manganese oxides as means for removal depending on water chemistry and conditions (Figure 1, Figure 3, Figure 4, and Table 4). Both sulphides and iron and manganese oxides will achieve the ultralow concentrations desired for the Minto CWTS. Based on site-specific considerations and water chemistry at the Minto Mine, cadmium treatment is targeted to be removed in the most stable and low-bioavailable form, and therefore will be removed by the same mechanism as copper, by precipitation as a metal sulphide (cadmium sulphide, CdS; Table 2).

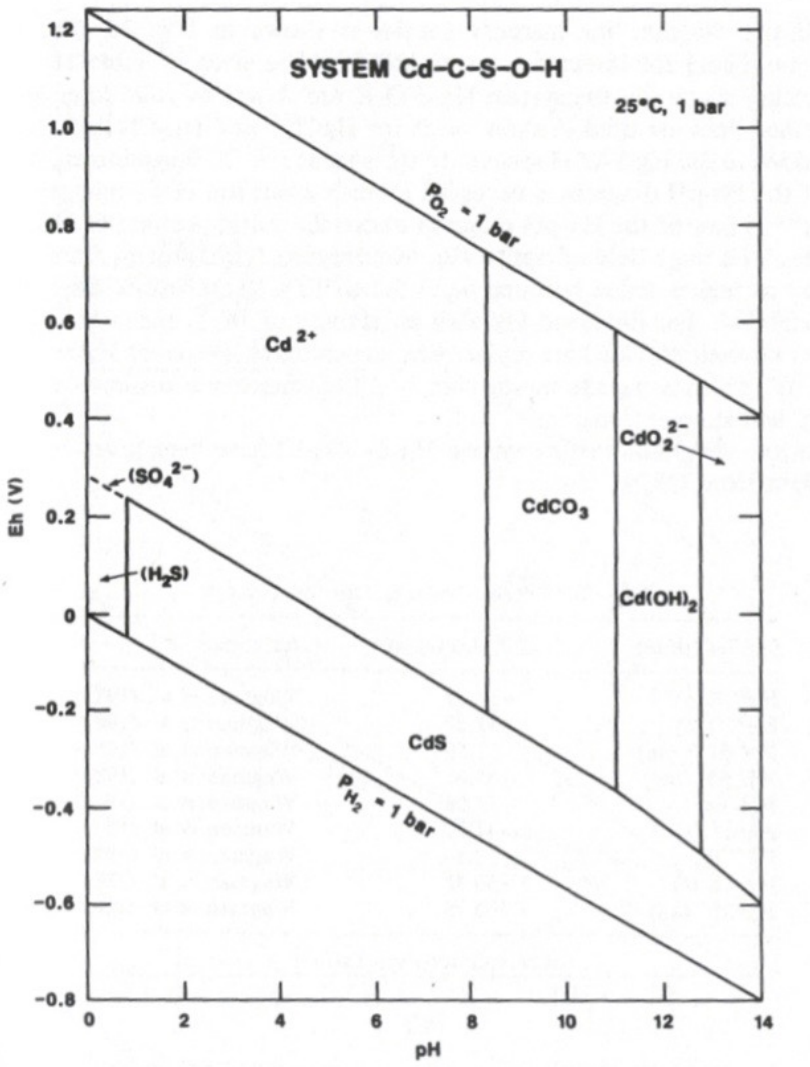



Figure 4 – Eh-pH diagram for cadmium.

Table 4 – Thermodynamic data for cadmium.

| Species State | $\Delta G^0_f$(kcal/gfw) |
|---|---|
| $Cd^{2+}{}_{(aq)}$ | -18.55 |
| $Cd(OH)_{2\ (c)}$ | -113.19 |
| $CdS_{\ (c)}$ | -37.40 |
| $CdO_2^{2-}{}_{(aq)}$ | -67.97 |
| $CdCO_{3\ \ (c)}$ | -160.00 |
| $CdSO_{4\ \ (c)}$ | -196.33 |
| $CdO_{\ (c)}$ | -54.59 |

Adapted from Brookins (1988); aq – aqueous (dissolved/soluble), c – crystalline (solid).

### *2.2.5. Selenium treatment mechanisms*

The mechanism for selenium treatment is more direct, through microbially catalyzed dissimilatory selenium reduction. This is performed directly by bacteria acting on the selenium. The most common forms of aqueous Se are selenite and selenate, with valence states of Se(IV) and Se(VI), respectively. When these are reduced in a wetland to an insoluble state, Se precipitates as elemental Se(0) (Figure 5), which is the lowest bioavailability (Chapman et al., 2010).

While selenium can be directly treated through microbial reduction in a CWTS, there are constituents that can interfere with this process. Most notably, nitrate has a high affinity for available electrons and is preferentially reduced before other compounds including selenium and sulphate. Nitrate especially interferes with selenium reduction, as it may be performed by the same metabolic pathways in the same bacteria (Oremland et al., 1989 and Oremland et al., 1990). While it is known that over time through closure nitrate concentrations will decrease as the source (blasting residue) has ceased, during early closure nitrate may affect the CWTS treatment capacity for selenium. As such, the pilot-scale CWTSs were subjected to a 6-week trial of synthetic water that mimicked an early closure scenario, with nitrate concentrations based on predicted maximum worst-case ammonia and nitrate concentrations. This was followed by a second phase of testing with depleted nitrate concentrations to simulate the chemistry expected in long-term closure (Contango, November 2014).

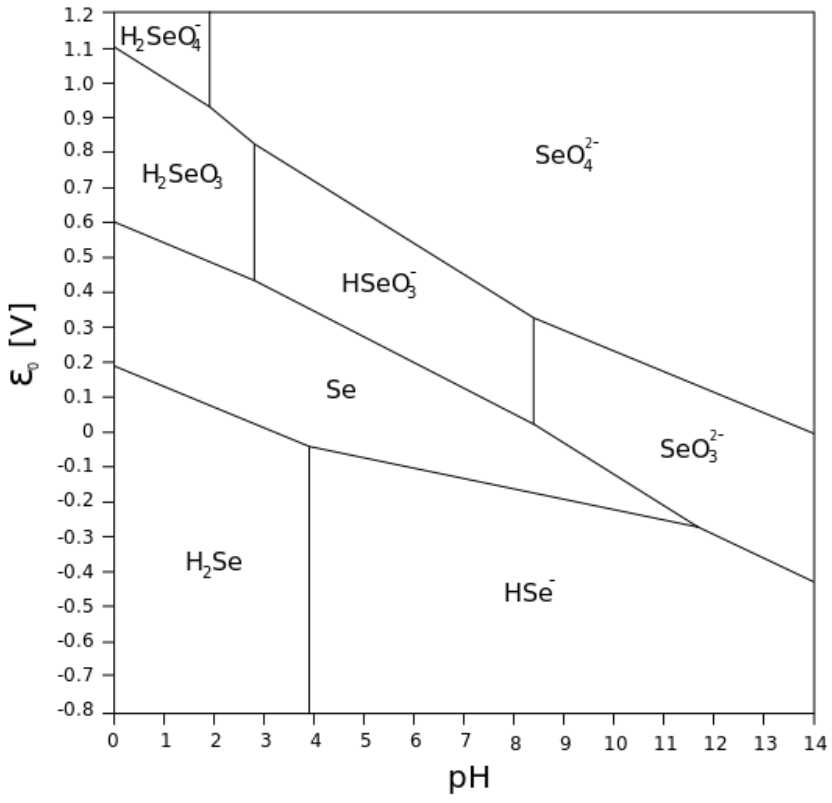



Figure 5 – Eh-pH diagram for selenium.

## 2.3. Design selection

There are numerous layouts and configurations that can be implemented for treatment wetlands, with varied hydrology, performance parameters, and operation and maintenance requirements. The most passive design was chosen as the goal of final mine site closure is to ensure long-term physical and geochemical stability and to minimize reliance on long-term active treatment. To meet the requirements for water treatment with minimal intervention, the selected passive treatment wetland design is one where there is no operational management necessary, and only minimal periodic maintenance is required, which could be performed by manpower (i.e., without machinery). Based on these guiding objectives, the selected configuration at the Minto Mine is a horizontal surface flow treatment wetland (Figure 6).

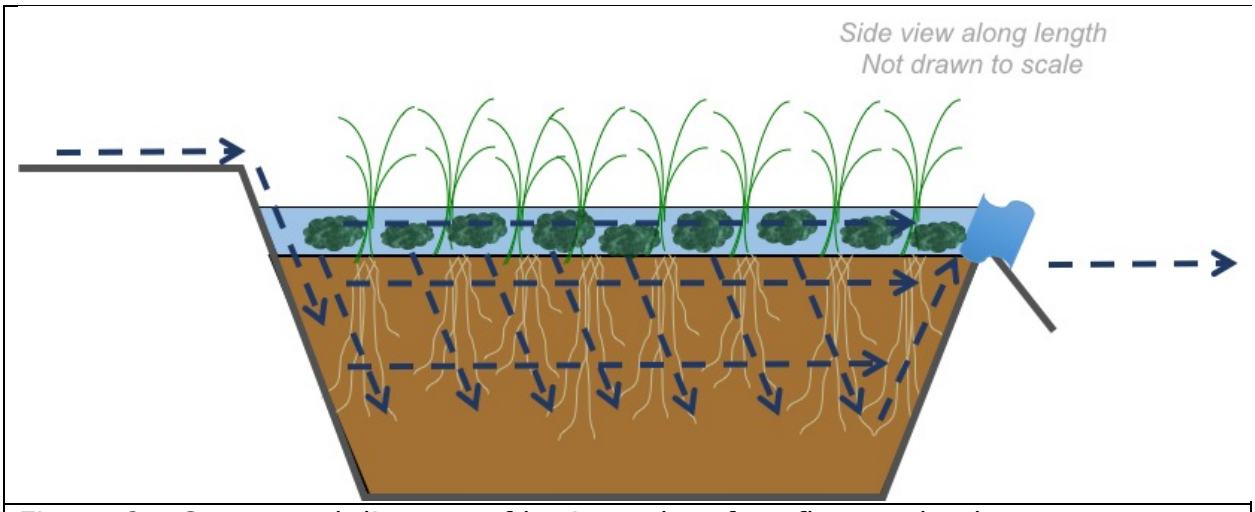



Figure 6 – Conceptual diagram of horizontal surface flow wetland.
Dotted arrows show flow path through wetland and into substrate and root zone. Vegetation in this example includes both emergent macrophytes (e.g., *Carex aquatilis* known as aquatic sedge), and bryophytes (aquatic mosses).

### *2.3.1. Plants*

For the CWTS, *Carex aquatilis* (aquatic sedge) was chosen, as it is readily available at the Minto site and was one of the first plants to colonize cleared areas, indicating that it may be a good candidate for quickly establishing the CWTS (Contango, March 2014). Moss was also used in pilot-scale CWTS designs, as locations at Minto with shallower water had *Carex* and Moss coexisting. The demonstration-scale CWTS was planted with *C. aquatilis* and mosses, as was determined by pilot-scale testing as being the best design for this site and application (Contango, November 2014).

### *2.3.2. Substrate*

The recommended soil for the CWTS is sand, with approximately 2-7% by volume as organic material (e.g., woodchips, straw). In the pilot-scale systems (Contango, November 2014), this resulted in a total organic carbon (TOC) content of 0.2-0.6% (the sand itself was at 0.1% TOC prior to adding amendment), and it was found that a higher concentration would likely decrease the duration of the commissioning

period. In this composition, the sand allows for circulation of water through the root zone of the plants, while the organic matter initiates reductive microbial processes that in future years will be sustained by decaying plant matter. Additionally, sandy soil will support weight while wet for planting the CWTS.

### *2.3.3. Water Depth*

The recommended water depth for the CWTS is based on plant selection. Once plants are well established and showing signs of colonizing through the wetland, the water depth may be increased to approximately 25-40 cm and the flow rate may also be increased.

A uniform water depth is necessary to prevent future issues such as channeling of water, open water spots due to plants being unable to grow because of excessive water depth, or conversely, drying out. The vegetation selected for the CWTS (*C. aquatilis* and aquatic mosses) are known to form peat, which will accrete in a generally uniform manner through the CWTS as long as it is initially planted uniformly and bare spots are addressed through commissioning.

### *2.3.4. Flow Field*

A uniform flow field is necessary in the CWTS to avoid channeling, as the plants will avoid higher flows and preferentially establish in low flow areas. As such, to ensure a uniform flow field, a distribution mechanism at the inflow and outflow areas of the CWTS is needed and will be addressed in the final wetland engineering design.

### *2.3.5. Water Velocity*

Linear flow velocity for the CWTS was selected to be no greater than 35 cm/s according to the Hjulstrom Curve (Figure 7) based on the selected substrate of coarse sand (grain diameter = 1mm). This maximum linear flow velocity is considered to be highly conservative, as it is based on resuspension of substrate to avoid scouring, and does not account for plant roots retaining the sediments in high flows. However, references specific for maximum flow velocity in CWTS recommend the ideal flow velocity for treatment should be less than 15 cm/s for effective treatment capacity (ITRC, 2003). Therefore, the flow through the CWTS should ideally be less than 15 cm/s under normal conditions, and not exceed 35 cm/s under high flow events. These flow rates should be tested in a site-specific manner through the reclamation research program, as actual tolerances will vary depending on plant species, substrates used, and targeted treatment processes.

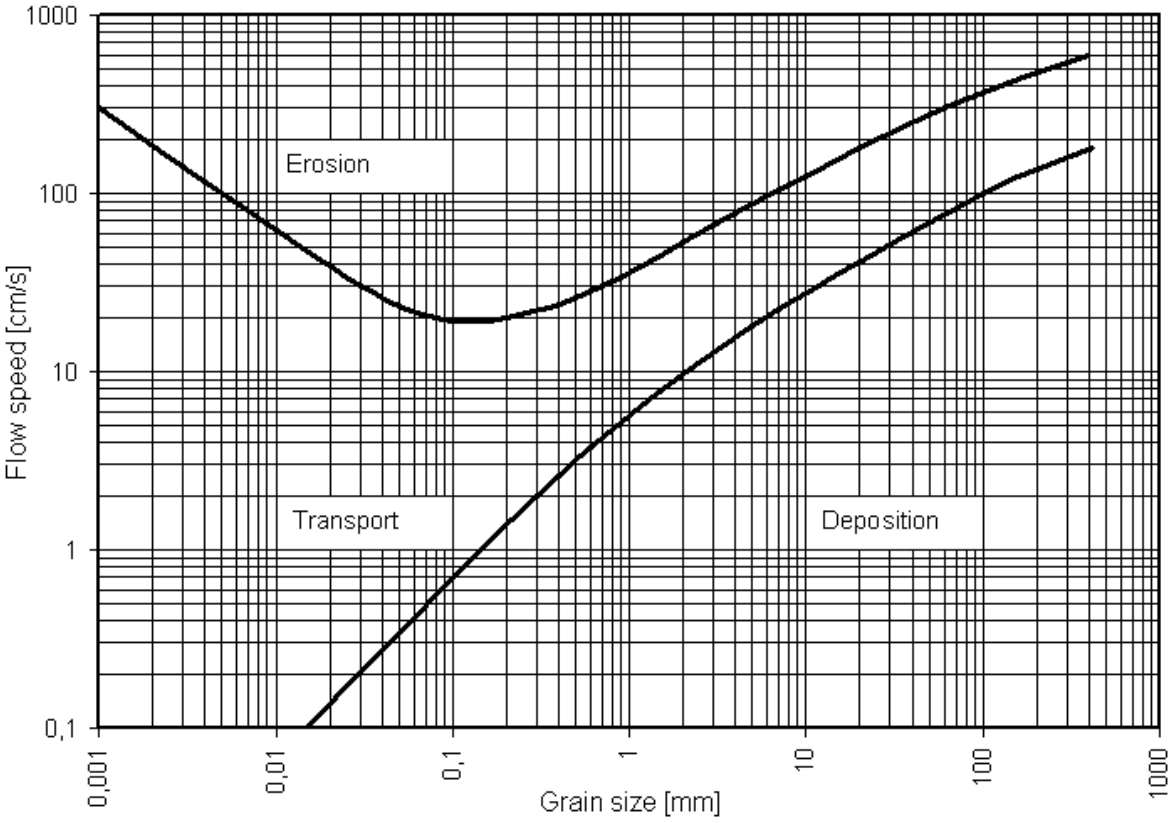



Figure 7 – Hjulstrom curve, demonstrating flow speed associated with resuspension of soils.

### 2.4. Removal Rate Coefficients and Calculations

An important factor for wetland design is the rate of treatment, also known as the treatment rate coefficient (*k*). The treatment rate coefficient is based on the treatability of a specific compound and the hydraulic retention time of the system, both of which are site-specific based on water chemistry, wetland designs, and characteristics of the system. The treatment rate coefficients in Table 5 are based on pilot-scale testing (Contango, November 2014) and are currently being refined with demonstration-scale (on site) testing (Contango March 2015, and Contango March 2016).

Based on pilot-scale testing for the Minto CWTS (Contango, November 2014), the treatment rate coefficient (k) applied for Se follows a zero-order reaction kinetic, while the rate coefficients for Cu and Cd follows first-order kinetics. In Equations 1-4, *Cf* is final concentration, *Ci* is initial concentration, V is volume of water in the system, and Q is flow rate. Using the removal rate coefficients (*k*) in Table 5 and Equations 1-4, parameters can be rearranged to solve for those of interest, such as the outflow concentration, given the available footprint in the WSP area.

Table 5 – Element treatment rate coefficient (*k*) values based on pilot-scale testing.

| Element | *k* [1] |
|---|---|
| Cd | 0.065 |
| Cu | 0.05 |
| Se | 0.0001 |

[1] All treatment rate coefficients are for first-order reaction kinetics except for selenium which is a zero-order reaction rate kinetic.

$$k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{V} \, x \, Q$$

Equation 1. Equation for calculation of first-order removal rate coefficient.

$$Cf = Ci \times e^{-k \, x \, \frac{V}{Q}}$$

Equation 2. Equation for calculation of first-order removal rate coefficient, rearranged to solve for outflow concentration.

$$k = \frac{(Ci - Cf)}{V} \, x \, Q$$

Equation 3. Equation for calculation of zero-order removal rate coefficient.

$$Cf = Ci - k \, x \, \frac{V}{Q}$$

Equation 4. Equation for calculation of zero-order removal rate coefficient, rearranged to solve for outflow concentration.

### 2.5. Thermodynamic minimum concentrations

Through all periods of pilot-scale testing, the outflow concentration of copper for any given system did not vary significantly, indicating that the thermodynamic minimum for copper removal has likely been approached within the system, with an average outflow concentration of 18 ± 5 µg/L. That is to say, making the wetland bigger using any of the tested designs would not result in a further significant decrease in outflow copper concentration, but rather, design alterations would need to be made in order to attempt to achieve lower outflow concentrations. It remains to be experimentally determined through the on-site demonstration-scale testing whether it is possible to achieve lower outflow concentrations of selenium and copper with this wetland design. Thermodynamic minimums developed through the site-specific testing for the Minto CWTS, have been applied to the conceptual performance modelling of a full-

scale CWTS (SRK, 2016a), these are: cadmium, 0.000009 mg/L; copper, 0.015 mg/L; and selenium, 0.004 mg/L. This is not to say that lower concentrations may not periodically occur through the CWTS treatment, however these are values that should be consistently attainable if sufficient retention time is provided, and lower concentrations and not expected to be consistently achieved.

## 2.6. Evapotranspiration

Evapotranspiration is another plant-mediated CWTS characteristic that must be considered (Beebe et al., 2014; Haakensen et al., 2015). Evapotranspiration can be defined as the total sum of water removed from a CWTS by evaporation from surface water of the system and transpiration from plant leaves. The degree of evapotranspiration is dependent primarily on the plant species/ecotype and controlled by meteorological conditions such as air temperature, relative humidity, and wind. Evapotranspiration drives an important aspect of the hydrology of a CWTS by enhancing the effective treatment area of surface flow wetlands.

Evapotranspiration can also affect the perceived treatment in a CWTS because removing water from the system concentrates the constituents, but also results in an increase of the hydraulic retention time (Beebe et al., 2014). That is to say, when evaporation and transpiration levels are high, an increased CWTS footprint may actually result in a higher outflow concentration of elements than is seen partway through the system, even though the total load of an element is lower at the outflow based on treatment.

Trials are being undertaken through the reclamation research program with the demonstration-scale CWTS to determine and model the effects of evapotranspiration on load removal, and current estimates are that approximately 1cm of water will be lost per day (equal to ~10 L per square meter of CWTS).

# 3. CWTS Implementation Overview

## 3.1. Timeline overview

The conceptual schedule for implementation of the CWTS is currently being refined through the reclamation research plan as part of the RCP. Through the reclamation research plan the monitoring and maintenance requirements for closure will be refined (research is currently planned through 2018 with the on-site demonstration-scale CWTS). Table 6 therefore provides the best estimate of site-specific maintenance and monitoring requirements for the CWTS based on information at this time.

Table 6 – Conceptual timeline.

| Closure | | CWTS Year | Period | Comments |
|---|---|---|---|---|
| Period | Year | | | |
| Interim and Active Closure | 5 | 0 | Construction | Construction and planting of system. |
| Post Closure I | 6-7 | 1-2 | Commissioning | Water from outflow can be recycled through CWTS or be sent to active water treatment if additional treatment is necessary. |
| | 8-10 | 3-5 | Early operation | System meeting performance targets, with frequent monitoring ongoing to refine site-specific long-term monitoring and maintenance requirements of CWTS. Minor adjustments may still be needed. |
| Post Closure II | 11-20 | 6+ | Long-term operation | Performance monitoring at reduced frequency, for confirmatory purposes. Maintenance as needed. |

## 3.2. Construction

Physical construction of the CWTS is described in Appendix A (SRK, 2016b), and therefore only vegetation is covered here. Either before or after planting, a bed of straw and/or wood chips, approximately 5-10 cm deep, should be laid on top of the substrate to serve as an initial source of carbon for the beneficial microbes and to initiate reductive processes and contribute to accretion in early years while there is less plant matter being produced. If planted at the same density (5 plants per square meter) as the demonstration-scale CWTS (on site), *Carex aquatilis* would take approximately 2 years to fill in the CWTS, and based on results from the demonstration-scale CWTS, it is expected that a range of 3 – 5 *C. aquatilis* plants per square meter would be sufficient to fill the CWTS within 2 years. It is recommended

that the aquatic mosses be added much more densely than originally distributed in the demonstration-scale CWTS, in order to avoid needing to add additional moss through the year. Approximately 3,000 $cm^3$ of moss (moist but compressed) is recommended per $m^2$ of area within the CWTS. It is expected that a team of 4 people can plant a hectare of wetland per day. It is expected that a sufficient quantity of plants for the full-scale wetland can be sourced from the demonstration-scale CWTS, and the W10 area (the original source of plants for the demonstration-scale CWTS), if required additional borrow sources will be utilized.

### 3.3. Commissioning

The time period between construction of the CWTS and achieving expected treatment performance is referred to as the commissioning period. This period is needed for operational adjustments (e.g., raising water depth, modifying outflow patterns), and for plant and microbial populations to establish and mature. Based on pilot-scale testing (Contango, November 2014), and preliminary results from on-site demonstration-scale operations (Contango, March 2016), the estimated commissioning period for the full-scale system is 4 – 8 months (of active growing season, or 1 – 2 calendar years). Progress through the commissioning period is assessed through a monitoring program, such as the conceptual schedule inTable 7.

The commissioning period involves guiding the CWTS from construction through to early operation. Commissioning activities can be divided into the categories of: flow management, vegetation establishment, and establishment of conditions for treatment. Flow management includes ensuring the flow field is as uniform as reasonably possible, with wide inflow and outflow berms. Flow management is addressed in Appendix A (SRK, 2016b). Establishment of vegetation will also aid in flow management, and based on observations from the on-site demonstration-scale CWTS (Contango, March 2016), is expected to take a period of approximately 2 years depending on seasonal variations and planting densities. During this time, it may be necessary to supplement vegetation in some areas of the CWTS depending upon transplantation success. The on-site demonstration-scale CWTS had >95% survival of planted vegetation, and a similar rate would be expected at full scale. Variable water depths can sometimes aid in vegetation establishment, and slow (or stagnant) water flows can aid in development of microbial populations. Therefore, during the first months of commissioning, water may be intermittently pumped to the CWTS and allowed to evaporate (but not allowed to dry out), rather than a constant flow. With an estimation of ~1 cm evapotranspiration per day (with *C. aquatilis* vegetation), water could be flowed through the CWTS for 1 week of every month, with the remaining time non-flowing.

# 4. Monitoring

Monitoring and maintenance schedules contained herein are conceptual, and are being refined with the guidance of the reclamation research plan. The monitoring parameters and schedules are selected to inform potential maintenance needs, and in turn, possible maintenance activities are designed to address performance considerations. The conceptual schedules outlined here are conservative, but not prescriptive. Monitoring includes testing for performance (i.e., decrease of cadmium, copper, and selenium concentrations), and during earlier periods (commissioning, early operations Table 1, Table 2). Explanatory parameters are quantifiable aspects of a CWTS environment that can explain the performance of a CWTS. The end goal of explanatory parameters is to develop a decision management tree to guide maintenance activities associated with treatment performance of the CWTS. This allows for prediction of potential performance issues so they can be addressed before they occur, or the ability to detect and appropriately respond to upsets. There are many parameters that can be included as explanatory parameters, and it is important to identify those which are informative to the constituents being treated, and the site-specific context. For the Minto Mine CWTS, the explanatory parameters are being developed through a phased reclamation research plan, and pilot-scale testing has thus far identified pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), conductivity, temperature, total organic carbon (TOC), nitrate, and soil redox potential as useful to understanding the performance of the CWTS. The explanatory parameters are continuing to be refined through the on-site demonstration-scale operation. Actual parameters and frequency of testing should be guided by the scientific analysis of the results from the previous operational period, therefore, the commissioning will be guided by the on-site demonstration, the early operations by the commissioning, and so forth. Maintenance of the system should be performed as necessary, and based on the results of monitoring activities.

## 4.1. Monitoring during commissioning (Years 1 – 2)

The commissioning period involves the most rigorous monitoring, to ensure the system is brought online effectively. Because biological systems are dynamic and could take several paths to maturation, rigorous monitoring during the commissioning phase is important to track progress and make corrections as necessary, allowing for the system to be guided through the desired maturation path. During the commissioning period, both performance and explanatory parameters are monitored in order to assess both the effectiveness and mechanisms of function of the CWTS. Some of these parameters would conceptually require weekly monitoring (e.g., visual inspections, water quality testing for total and dissolved metals, nitrate, pH, dissolved oxygen, oxidation reduction potential, and monitoring of plant health and establishment), while others would be tested less frequently. For example, water may be tested monthly for dissolved organic carbon and substrates for redox potential, while parameters such as substrate microbiology, nutrient and organic carbon content may be tested seasonally, and soils metals assays may occur on an annual basis. Parameter lists and testing schedules are being refined through the on-site demonstration-scale CWTS as part of the reclamation research plan.

Table 7 – Conceptual monitoring schedule.

| Closure Period | | Year 1 - 5 (Interim and Active Closure) | Year 6 - 10 (Post Closure I) | | | | | | | | Year 11 -20 (Post Closure II) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CWTS Stage | | Construction | Commissioning (Year 6-7) | | | | Early Operation (Year 8-10) | | | | Long-term Operation (Year 11-20) | | | |
| Site | Description | No Monitoring Required | Water | Substrate | Flow | Plants | Water | Substrate | Flow | Plants | Water | Substrate | Flow | Plants |
| CWTS IN | CWTS Inflow | NA | W,M | NA | W,M | NA | M | NA | M | NA | SSF | NA | SSF | NA |
| CWTS MID | Within CWTS | NA | W,M | M,SSF,A | W,M | W,M,A | M | M,A | NA | SSF,A | A | A | A | A |
| CWTS OUT | CWTS Outflow | NA | W,M | NA | W,M | NA | M | NA | M | NA | SSF | NA | SSF | NA |

W – weekly; M – monthly; SSF – spring, summer, fall; A – annually; NA – not applicable.
Where two frequencies are separated by a comma, multiple parameters are being tested, and on different schedules.

### 4.2. Monitoring during early operation (Years 3 – 5)

The CWTS will be transitioned from the commissioning monitoring schedule and considered to be operating in "Early Operations" once the explanatory parameter of targeted soil redox and outflow performance objectives for copper and cadmium are met. At this period targeted performance for selenium may or may not be met, depending on the depletion rate of residual nitrate concentrations. During Early Operations period, the CWTS is expected to be consistently meeting performance targets; however, frequent monitoring is continued to refine site-specific long-term monitoring and maintenance requirements of this system (Table 3). During early operations, the CWTS should be meeting performance targets, but with monitoring of performance and explanatory parameters ongoing to refine site-specific long-term monitoring and maintenance requirements of CWTS. Minor operational adjustments may still be needed during this period. Parameters that would conceptually continue on a monthly monitoring schedule include visual inspections, water quality testing for total and dissolved metals, nitrate, pH, dissolved oxygen, oxidation reduction potential, substrate redox potential, and general plant health. Parameters such as substrate microbiology, nutrient and organic carbon content, and metals assays may occur on an annual basis. Parameter lists and testing schedules are being refined through the on-site demonstration-scale CWTS as part of the reclamation research plan.

### 4.3. Monitoring during long-term operation (Years 6 – 10)

During long-term operation of the CWTS, monitoring is conducted mostly for performance, with a reduced frequency of monitoring for explanatory parameters (as defined from commissioning and early operations periods). The decision tree that was developed during demonstration-scale operation (and refined in full-scale commissioning and early operations) is applied to guide maintenance activities. During long-term operations, the CWTS should be meeting performance targets, with monitoring of performance and only those key explanatory parameters defined as leading indicators of performance (through the reclamation research plan and early operations of the full-scale CWTS). Conceptually, seasonal testing will be performed for performance (dissolved metals), and soil redox. Parameter lists and testing schedules are being refined through the on-site demonstration-scale CWTS as part of the reclamation research plan, and will be further refined through testing in commissioning and early operations of the full-scale CWTS.

## 5. Maintenance and operational adjustments

Maintenance of engineering and flow-management structures associated with the CWTS are covered in Appendix A (SRK, 2016b), and only performance related aspects are addressed here. Activities commonly associated with maintaining the performance of a CWTS are detailed in Table 8. The frequency of these activities should be guided by the monitoring activities, and is being refined through the on-site demonstration-scale CWTS as part of the reclamation research plan. A decision matrix based on the explanatory parameters is being developed through the reclamation research plan, and will be used to guide the operation of the full-scale CWTS. Additionally, periods of more intensive monitoring during commissioning and early operations will further guide the appropriate frequency of site-specific maintenance and refine the decision matrix. During early operations, minor adjustments may still be needed to the system, such as addition of solid phase organic materials (e.g., straw or wood chips), and corrections to non-uniform flows (e.g., adding sand bags at inflow and outflow of cells).

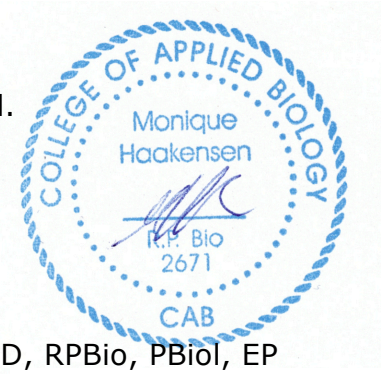
**Table 8 – Conceptual maintenance actions.**

| Observation | Monitoring | Item Addressed | Action | Follow up |
|---|---|---|---|---|
| **Soil redox drifting upwards** | Nutrients, TOC, microbiology | Decrease of treatment effectiveness due to low microbial activity or lack of food for microbes. | Add nutrients (fertilizer), and/or organic carbon. | Soil redox testing weekly until within stable range. Microbiology, TOC and/or nutrients testing bi-weekly until within desired range. |
| | Flow rates | Water volume to carbon ratio is too high. | Check inflow mechanism. | If ongoing issue (and not addressed by adding organic carbon), adjust inflow mechanism. |
| **Water depth decreasing** | Flow rates, accretion | System is designed to accrete (increase mass of soil), which causes soils to build within CWTS. Expected rate of 0.5-2mm/year (Robinson and Moore, 1999). | Increase height of outflow (and inflow) berms. | Record accretion rate to schedule for next depth increase event. |
| **Undesirable plants** | Vegetation monitoring | Channeling or decreased treatment effectiveness due to competing microbial habitats. | Remove undesirable plants. | Monitor to ensure undesirable plants have successfully been removed. |
| **Wildlife interferences** | Visual monitoring | Non-uniform flow field due to wildlife interferences (e.g., beaver dam) and decreased treatment performance. | Remove wildlife interferences. | Monitor to ensure interference is not re-established. |
| **Channeling** | Flow rates | Channeling can be due to undesirable plants, non-uniform flow fields, or flow rates beyond CWTS design. | Check inflow mechanism. | If ongoing issue, adjust inflow mechanism. |
| **Flow blockages** | Flow rates, visual monitoring | Blockages can be due to debris (fallen branches) and wildlife activity (beavers). | Remove blockages. | Adjust monitoring frequency accordingly. |
| **Poor plant health** | Nutrients | Decreased treatment effectiveness due to less active treatment zone if plants not actively transpiring and moving water through root zone. | Add nutrients (fertilizer). | Nutrients testing bi-weekly until within desired range. |

## 6. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Regards,
Contango Strategies Ltd.

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# Minto Creek Constructed Wetland: Physical Infrastructure Preliminary Design

**Prepared for**

Minto Explorations Ltd.



**Prepared by**

SRK Consulting (Canada) Inc.
1CM002.044
August 2016

# Minto Creek Constructed Wetland: Physical Infrastructure Preliminary Design

August 2016


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# 1 Introduction

Minto Explorations Ltd. (Minto) asked SRK develop designs for the necessary physical infrastructure to support a Constructed Wetland Treatment System (CWTS) proposed to be constructed within the footprint currently occupied by the Water Storage Pond (WSP) as part of mine closure works at Minto Mine, central Yukon Territory. This report describes the design basis and the accompanying drawings provide the preliminary design details.

This physical infrastructure preliminary design report was developed to support Contango Strategies' design of the treatment wetland (Minto Mine Reclamation and Closure Plan – Preliminary Design Report for Treatment Wetland (Contango 2016)). Details related to wetland establishment, monitoring, and maintenance are provided in Contango's design report, along with a thorough discussion of treatment mechanisms, on-site wetland trials (completed, in-progress, and planned), and performance expectations.

# 2 Background

Water Licence QZ14-031 was issued to Minto in 2015. The licence included a condition requiring Minto to submit a revised reclamation and closure plan (RCP), and the submission date for the revised RCP was extended to August 5, 2016 via a December 2015 amendment to QZ14-031. Minto's 2016 Reclamation and Closure Plan will be the sixth major revision of the site closure plan, and will be referred to as 'RCP 2016-01' in this document.

The CWTS preliminary infrastructure design is one component of RCP 2016-01.

## 2.1 Current Layout of Site

The Water Storage Dam was constructed during initial mine construction in 2006. It was constructed across the Minto Creek valley at a narrow point near the eastern limit of Minto's quartz claims and represents the eastern-most major infrastructure facility at Minto Mine. The dam construction formed the WSP reservoir, which was initially used for mill water supply and later as a clean water reservoir for storing water prior to discharge to Minto Creek. The outline of the WSP and the Water Storage Dam are shown in Drawing WC-01.

## 2.2 Closure Phases

For the closure and post closure periods, planning and management of site activities are guided by the Minto RCP. This includes the identification of distinct closure phases with defined activities and performance expectations:

1. Active Closure;
2. Post Closure I (transition to passive treatment); and
3. Post Closure II (passive treatment only).

# 3 Design

## 3.1 Overview

During Active Closure, the Water Storage Dam will be decommissioned and the footprint of the WSP will receive fill and be graded to allow the subsequent construction of a Constructed Wetland Treatment System (CWTS), which is also referred to as the Minto Creek Constructed Wetland. The CWTS will receive water from E3 Conveyance Channel in the closure conveyance system, which receives surface water from nearly all of the disturbed areas of the mine site that lie within the Minto Creek catchment. Flows up to 3000 $m^3$/day[1] will route through the CWTS, with inflows controlled by inlet control structures. To protect the CWTS from high flows, the inlet control structures are designed to convey higher flows through a spillway system to discharge into a high flow bypass channel. Details are presented in Drawings CW-03 in Appendix A.

During Post-Closure 1, commissioning of the CWTS will take place and CWTS effluent will be managed by a combination of reservoir and pumping-and-piping system, with water that meets discharge standards discharged off site and water that does not meet discharge standards pumped to one of the open pits for storage. As discussed in the Section 7.7.1 of the RCP the water treatment plant used during operations will remain in operational until WUL criteria can be achieved consistently without its utilization. Transition from Post-closure 1 to Post-closure 2 will occur when the CWTS effluent adequately meets performance objectives, at which time the effluent reservoir will be connected to the high flow bypass channel and the system will transition to being passively managed

Drawings WC-01 through WC-04 provide the preliminary designs for the physical infrastructure of the CWTS and bring in relevant conveyance design details from other components of the Minto Mine RCP for reference, including details from Appendix G2, *Closure Water Conveyance System Design Update Report, Minto Mine, Yukon* (SRK 2016a).

The following sections generally are organized sequentially by order in which the various components will be constructed.

## 3.2 Design Objectives, Considerations and Criteria

Summarized in this section are the objectives, considerations, and criteria for the preliminary CWTS design. Physical design elements are illustrated in the appended preliminary drawing package. Design criteria that are critical to the biological efficiency of the wetland system to sequester soluble metals were developed by Contango. These design elements are included in the physical wetland design and the water conveyance dynamics.

### 3.2.1 Head Pond and Wetland Intake Structure:

- Design flow rate for the passive treatment wetland system is based on a typical average monthly summer flow experienced in June, July and August. The maximum targeted flow rate

[1] Range of flows received by CWTS is expected to range from zero (during summer dry periods) to a maximum of 3000 $m^3$/day (under extreme high runoff conditions).

to be diverted into the wetland system is 3000 $m^3$/day or approximately 0.035 $m^3$/s. 3000 $m^3$/day is the upper limit of the flow rate that the CWTS is intended to handle.

### 3.2.2 Wetland Cell and Conveyance Channel Geometry:

- A 3:1 aspect ratio (Length to Width) is used to site the location of the passive treatment wetland cells. The cells are typically 15 m wide and 45 m long. Due to the limited width of the valley, space was limited in some areas- the cells were designed as typical 15 m wide and in some cases it was necessary to shorten the length of the cells to fit the site configuration.
- Substrate depth within the cells is designed to be a minimum of 0.5 m, substrate depths are illustrated in the design drawings to be 1 m thick and submerged by 0.3 m for a total of 1.3 m of initial design height above liner to the water surface in each cell. The substrate material will consist of sand with 2 to 7% by volume as organic matter (e.g. wood chips, straw).

### 3.2.3 Seepage Management:

- Seepage losses from the wetland cells and groundwater ingress into the cells is managed by inclusion of a low hydraulic conductivity geomembrane liner. The liner will prevent both groundwater from entering and seepage from leaving the CWTS and will avoid the performance uncertainty that would accompany unquantified inputs and losses of both flow and geochemical load.

### 3.2.4 Erosion Management:

- Internal erosion protection of the wetland pond system is limited to rip-rap channel protection because the CWTS inlet control structure is to be designed to limit inflows to a maximum flow rate of 3000 $m^3$/day.
- Distinct from limits on daily volumes, considerations around wetland plant establishment and propagation patterns require limits on water velocity as follows: maximum velocity 0.35 m/s, and typical velocities of <0.15m/s (Contango 2016).

### 3.2.5 Restrict Dam Classification for Designed Infrastructure:

- Design intentions have been focused on precluding the classification of any design infrastructure as a dam as defined by the Canadian Dam Safety Guidelines (CDA 2007) and dam classification guidelines in the Yukon Territory. CDA defines a dam as a constructed barrier that is at least 2.5 m tall and retains at least 30,000 $m^3$ of water. The Yukon Territory's definition of a constructed dam without a licence for a Schedule 7 Quartz Mining Undertaking as having a height greater than 3 m and less than 10,000 $m^3$ of water storage (Yukon Government 2012).

### 3.2.6 Exclusions

The following elements are outside of the limits of the preliminary physical infrastructure design:

- Establishment and success of wetland vegetation in the CWTS,
- Treatment performance of the CWTS,

- Revegetation of disturbed surfaces associated with the construction of the CWTS, and
- Construction compaction specifications of fill materials are not specified for this preliminary level of design. An assessment of available material properties is required at future stages of design to determine compaction requirements.

## 3.3 Constructability and Sequencing

The overall wetland layout and the configuration of the cells and intake structures have considered a long-term closure of the Minto site and the future needs of this site beyond the Post Closure 1 timeline. Intake and conveyance structure designs to the wetland ponds have been considered for their ability to be adaptive (i.e. allowance for the modification of conveyance elevations and flow rates to allow vegetation to establish).

In future stages of closure design it is recommended that a staged construction and decommissioning plan be developed to optimize water management resource needs and material handling. Additionally, a phased commissioning plan for a constructed closure conveyance system and wetlands must be developed.

Decommissioning of the Water Storage Pond Dam is required to construct the wetland and diversion channels. Initial decommissioning efforts require that the reservoir be drawn down and incoming flows routed around the construction area to allow for the partial excavation of the dam. Flow routing is expected to include excavating a water retention sump and back pumping water to the Main Pit to manage sedimentation and through pumping water from the Main Pit to Minto Creek. Retention sump locations details are provided in Drawing CW-02 in Appendix A.

Final decommissioning of the WSP dam will include the construction of the High Flow Bypass Channel that will convey flow around the wetlands. Additionally, it will require the removal of the sump and pumping diversion systems to allow flows to enter the wetland pond system. The infrastructure design, alignments, and specifications are located in the drawings in Appendix A.

Access for post-closure monitoring and maintenance at the CWTS is to be maintained after construction. The pond system is designed with a wide berm access of 4 m around the perimeters of each wetland cell to accommodate a vehicle or small excavator.

## 3.4 Foundation Preparation and Base Construction

To construct the passive treatment wetlands and provide a graded profile to the wetland area the existing WSP Dam will be decommissioned. Decommissioning of the WSP dam is illustrated in Drawing CW-02 located in Appendix A. The Dam is constructed of coarse waste rock and fine grained materials as segregated zones. During the decommissioning of the dam the segregated materials are repurposed in the construction of the wetland system. Coarse rock will be used to build up the basal area of the pond system, fine grained materials are to be used as separation layering between geomembranes and coarse materials.

During the decommissioning of the WSP Dam an existing access road will potentially require upgrades for haul truck access within the former ponded area. Material stockpiles, load and haul routes within the wetland area should be constructed as dam decommissioning advances.

## 3.5 Wetland Intake Flow Control Structure

A Primary Head Pond is designed to buffer turbulent flows exiting the E3 conveyance channel stilling basin. The pond elevation (715 masl) will be controlled by two hydraulic control structures: High Flow Discharge Channel and the Wetland Intake Structure. The Secondary Head Pond Intake Structure will convey 1% of the total flow entering the Primary Head Pond into the Secondary Head Pond the remainder of flows enter the High Flow Bypass Channel. Water entering the Secondary Head Pond will then be moderated where the design flow for the wetland system is conveyed in the wetland intake structure and the remainder of flow is conveyed through a spillway into the High Flow Bypass Channel.

The Secondary Head Pond and Wetland Intake structure are designed to reduce the intake flows and convey the expected design flows from the Primary Head Pond to the wetland cells. Flows exceeding this rate will be diverted to the High Flow Bypass Channel. Discharge flow from the wetland system is discharged to the High Flow Bypass Channel down gradient of the wetland system. Surface water quality monitoring station W50 is located approximately 50 m downstream of the confluence of these two flows.

At this stage of design the wetland intake structure has not been designed in detail. Conceptually, hydraulic principles that govern open channel flow have been considered to confirm that the system of ponds, inlet structures, and high flow spillways can reduce peak flows adequately to limit CWTS inflows to the design peak flow rate. The wetland infrastructure design is capable of separating a maximum of 3000 $m^3$/day from the mine closure conveyance system and conveying the flow through the wetland cells. It should be noted that this design peak flow rate is based on treatment performance limitations, and not on limitations of the hydraulic system to pass substantially greater flow volumes.

Future stages of design should consider an options analysis for common hydraulic structures such as weirs, flumes, and orifice flow control structures. Options to consider include orienting the inlet structure to be south facing to maximize early spring thaw, and applying a coating to the inlet structure to maximize solar heat absorption to melt and shed ice buildup.

## 3.6 Passive Treatment Wetland Cells and Conveyance Channels

Water depth within the wetland cells is designed to a targeted 0.15-0.4 m depth. After vegetation planting and during the initial growing seasons the water level in the cells will be controlled to be 0.2 m. Once the vegetation is rooted and acclimatized the wetland cells, water depth will be increased to 0.3-0.4 m. Section and plan details illustrating the CWTS designs are provided in Drawing CW-02 and CW-04 in Appendix A.

Internal cell-to-cell conveyance channels are designed as an excavated 4 m wide swale with 2:1 side slopes and a 1% slope. The mild channel slope is designed to have a 350 mm layer of rock

rip-rap with an average diameter of 200 mm. Flow velocities through the cell spillway sections are measured as 0.3 m/s and a water depth of 30 mm.

Underlying the passive treatment wetland cells and the cell-to-cell conveyance channels is a geomembrane to manage seepage loss and ingress. It is recommended that all exposed geomembranes be covered with a minimum of 0.3 m of fine grained material to reduce its exposure to radiation from the sun.

# 4 Physical Monitoring and Maintenance

The construction, commissioning, and operation of the passive treatment wetland is expected to have a variable management requirements for the physical monitoring and maintenance. This section discusses what physical attention is needed for the wetland infrastructure. Effective implementation of the *Closure Adaptive Management Plan* (SRK 2016b) will mitigate conditions beyond those expected during closure and post closure care and maintenance programs.

During construction and dam decommissioning water within the footprint of the CWTS construction will require ongoing and active monitoring and maintenance. The commissioning phase will require a site presence to monitor flow rates at the wetland intake structure to confirm that the wetland system is receiving the design flow rates. During this phase it may be required to make alterations to the flow regulating structure. After the commissioning phase it is expected that the frequency of inspection and maintenance decrease over time. However, long-term physical monitoring and maintenance will be required for this wetland system.

Monitoring frequency and maintenance requirements should be re-assessed and adapted based on the judgement of a qualified person as the site transitions through Active Closure, Post-Closure I and Post-Closure II periods. The proposed schedule for the monitoring programs is provided in Section 7.12 of the RCP. The following subsections suggest some of basic monitoring and maintenance needs for the structure of the wetland system.

## 4.1 Active Closure

Physical monitoring and maintenance requirements during the construction period include:

- Routine water quality sampling for sediment and metal composition at the intake and discharge of the pond system.
- Assessing the grading of the channels between ponds to assess the flow paths. Flow through the channels should be unobstructed and non-eroding.
- During initial rooting stages of pond vegetation commissioning the water depth in the ponds are expected to be lower than the final operational elevation. Once advised that the rooting is sufficient the elevation in the ponds can be increased to the final elevation.
- Routine removal of vegetation and debris that may block channels.

- Assessment of initial signs of settlement and erosion of surfaces adjacent to the wetland system. If settlement within the conveyance network is observed then remedial construction activities should be initiated as described in the closure adaptive management plan.
- Ground water seepage assessments of the surrounding area to determine if there will be exposed seeps in the former WSP area that may affect the pond system. If seepage volumes are considerable and are leading to erosion of soils then remedial construction activities should be initiated as described in the closure adaptive management plan.

## 4.2 Post-Closure I

The closure monitoring and maintenance requirements will be developed at the end of the active construction phase as the site transitions to passive treatment. Typically the monitoring will assess the following geotechnical and hydraulic conditions:

- Measure the flow rates into the wetland system and determine if the flow rates are appropriate and if there are meeting objectives. Field samples should be collected to determine the water quality at the intake and discharge of the pond system.
- Assess the flow profile through and in between each wetland cell to document the development or extent of erosion or blockages.
- The intake flow structures should be assessed for operation and integrity.
- Surface erosion and settlement deformations.

## 4.3 Post-Closure II

An assessment of the existing state of the wetland system is required to identify the needs of monitoring and maintenance as the site transitions to the Post Closure II phase.

# 5 Recommendations

This section summarizes design requirement to advance the design of the wetland system from preliminary to a feasibility level.

- Limnology study of sediments in WSP to quantify chemistry and thickness to determine if additional design and management allowance is needed for the wetland pond system.
- Geotechnical investigation of the wetland foundation area and the High Flow Bypass Channel for the existence of permafrost and other geotechnical considerations which may have a potential for thaw consolidation and settlement.
- Site wide definition of material sources including defining dam materials and potential opportunity to use local soils and local quarries near the existing WSP Dam. The site-wide materials assessment should define the volumes and material types that are needed for the wetland construction.

- Evaluation of merit of routing the High Flow Bypass Channel through a purpose built rock quarry located in south abutment of dam.
- Assessment of the suitability of rip-rap in the current WSP dam spillway for use as riprap in the long term. Evaluation of the existing spillway rip-rap covering is needed to determine if the condition of the armouring is suitable for reuse for closure activities as foundation fill material for the wetland area.
- Excavation optimization for the materials removed from the WSP Dam which can be reused as foundation fill material for the wetland area.
- Hydrologic assessment of the transition of the High Flow Bypass Channel from the former WSP Dam area downstream to the Minto Creek basin.
- Evaluation and design of the hydraulic intake structure that moderated flow from the head ponds into the wetland system at the specified rate of 3000 $m^3$/day or the rate required during the final engineering and design stages.
- Reassessment of the need for a geomembrane to line the ponds and conveyance channels between ponds.
- Future assessment to the efficiency of the wetland pond dynamics may redefine the cell geometry needs and peak flow rate requirements defined by Contango.
- Head Pond: design requires further optimization such that the final design (excessive storage water volume or height of impounded water) does not become defined as a dam.
- Tailings Diversion Ditch: energy dissipation area requires additional design consideration to transition flow exiting the Tailings Diversion Ditch into the High Flow Bypass Channel. Additional design should focus on managing flow hydraulics and erosion.

This report, Preliminary Design: Physical Infrastructure for the Water Storage Pond Constructed Wetland Treatment SystemPreliminary Design: Physical Infrastructure for the Water Storage Pond Constructed Wetland Treatment System, was prepared by

*Original Signed By*

Stuart McPhee, EIT

and reviewed by

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Victor Muñoz S., MEng, PEng.

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Dylan MacGregor, MASc, PGeo

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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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

# 6 References

CDA 2007. Canadian Dam Association Dam Safety Guidelines 2007 (2013 Edition). Prepared by the Canadian Dam Association.

Yukon Government 2012. Dam Guide: Design Expectations and Required Information. Prepared by the Yukon Government and Yukon Environmental and Socio-economic Assessment Branch. February 2012.

Contango Strategies Ltd. 2016. Minto Mine Reclamation and Closure Plan – Preliminary Design Report for Treatment Wetland. Prepared for Minto Explorations Ltd. July 2016.

SRK Consulting (Canada) Inc. 2016a. Closure Water Conveyance System Design Update Report, Minto Mine, Yukon. August 2016.SRK Consulting (Canada) Inc. 2016a. Closure Adaptive Management Plan. August 2016.

# Appendix A: Drawings

# Engineering Drawings for the Minto Creek Constructed Wetlands Minto Mine, Yukon, Canada

## ACTIVE DRAWING STATUS

| DWG NUMBER | DRAWING TITLE | REVISION | DATE | STATUS |
|---|---|---|---|---|
| CW-00 | Engineering Drawings for the WSP Constructed Wetlands, Minto Mine, Yukon, Canada | A | July 29, 2016 | Issued For Review |
| CW-01 | General Arrangement | A | July 29, 2016 | Issued For Review |
| CW-02 | Wetland Cell Configuration | A | July 29, 2016 | Issued For Review |
| CW-03 | Primary Head Pond Area Layout | A | July 29, 2016 | Issued For Review |
| CW-04 | Typical Cell and Cell Spillway Layout | A | July 29, 2016 | Issued For Review |

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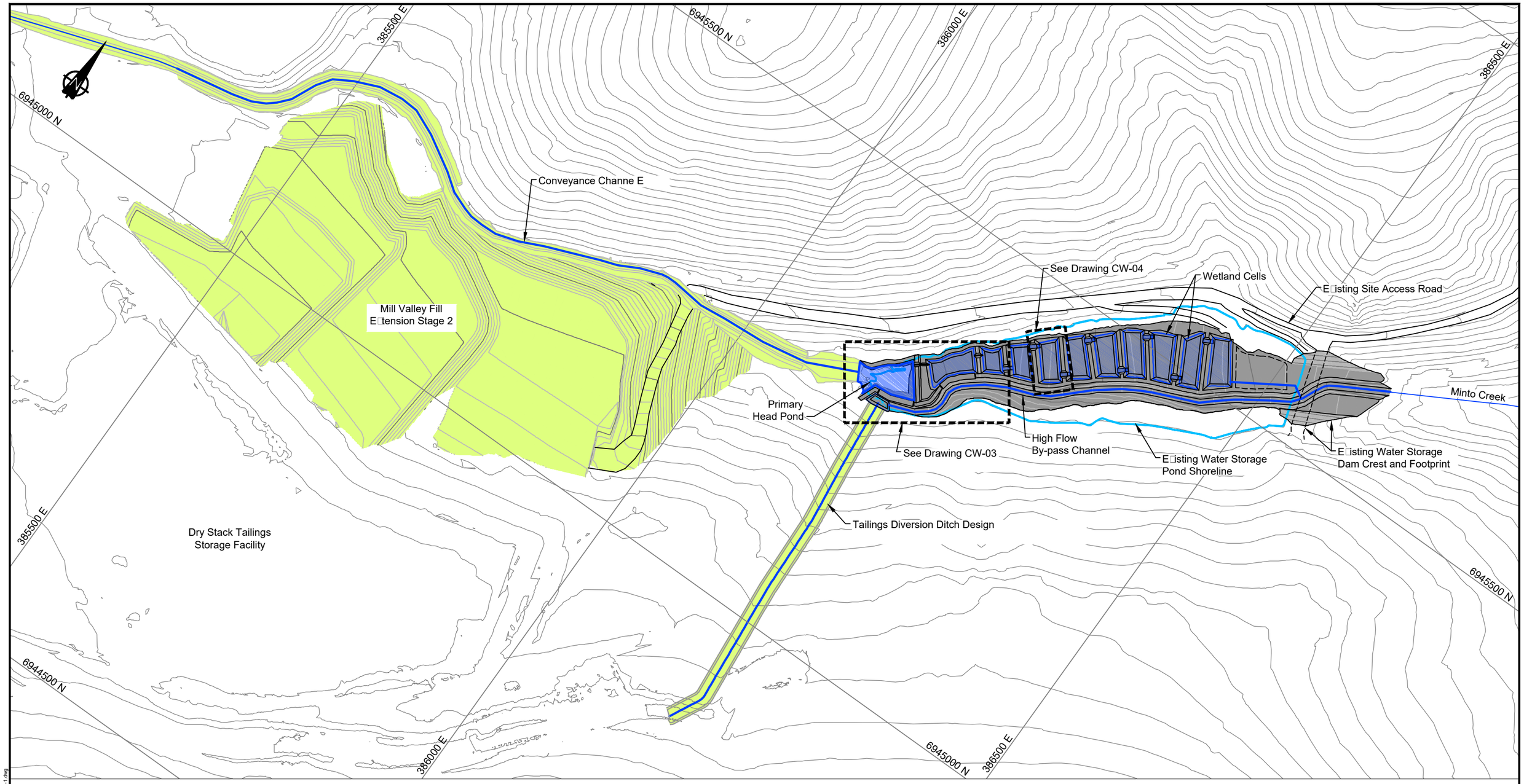
PROJECT NO: 1CM002.044
Revision A - Issued for Review
July 29, 2016
Drawing CC-00




## NOTES

1. Contour Interval 1m typical though drawing package.
2. Coordinate system is in NAD83 UTM □one 8
3. Digital topographic surface has been provided by Minto E□ploration ltd.
4. Notes on this drawing apply to all other drawings within this drawing package unless otherwise advised.

## LEGEND

- Constructed Wetlands Design
- Designed Infrastructure □Not Constructed□
- Design Toes □ Crests
- Flow Direction

**NOT FOR CONSTRUCTION**

0 40 80 120 160 200

Scale in Metres

| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE |
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REFERENCE DRAWINGS

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| SM | DM | July 2016 |

FILE NAME: 1CM002_044–Wetland–1.dwg

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SRK JOB NO.: 1CM002.042

Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: General Arrangement

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CW-01 | 2 OF 5 | A |

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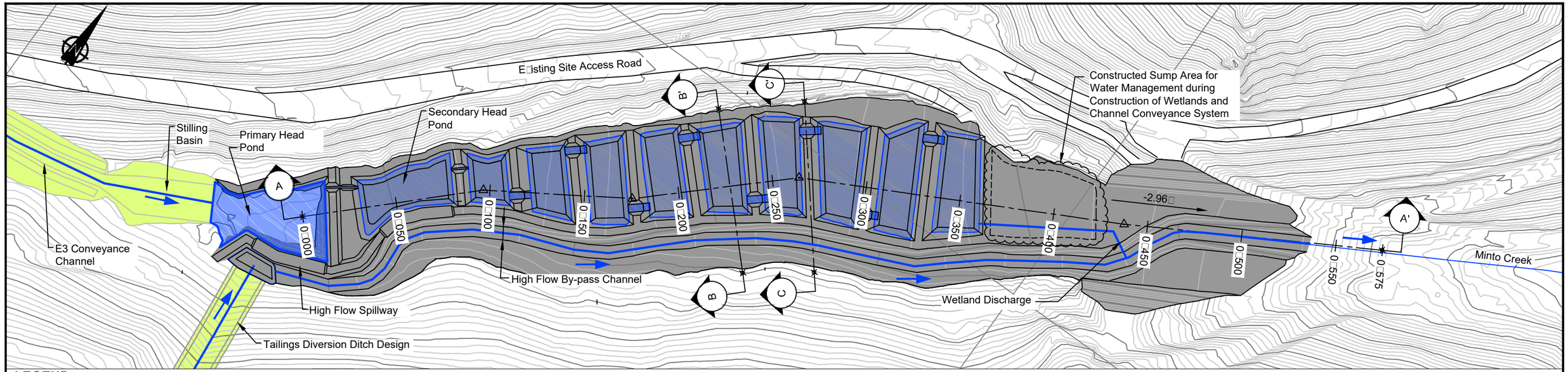


## LEGEND

- Wetland Foundation Fill Material
- Rip Rap
- Constructed Wetlands Design
- Designed Infrastructure (Not Constructed)
- Geomembrane
- Flow Direction

## NOTES

1. During the decommissioning of the dam the segregated materials are repurposed in the construction of the wetland system
2. Road access within WSP footprint will be required for construction.
3. Material stockpiles, load and haul routes within the wetland area should be constructed as dam decommissioning advances.
4. Decommissioning of the WSP dam will include the construction of the High Flow By-pass Channel that will convey flow around the wetlands as per SRK Closure Conveyance Channel Design 2016.
5. Supporting features: E3 Stilling Basin, Energy dissipation pond, and the High Flow By-pass Channel are designed by SRK in the Closure Conveyance Design Report 2016.
6. Notes on this drawing apply to all other drawings within this drawing package unless otherwise advised.

## CONSTRUCTED WETLANDS PLAN VIEW

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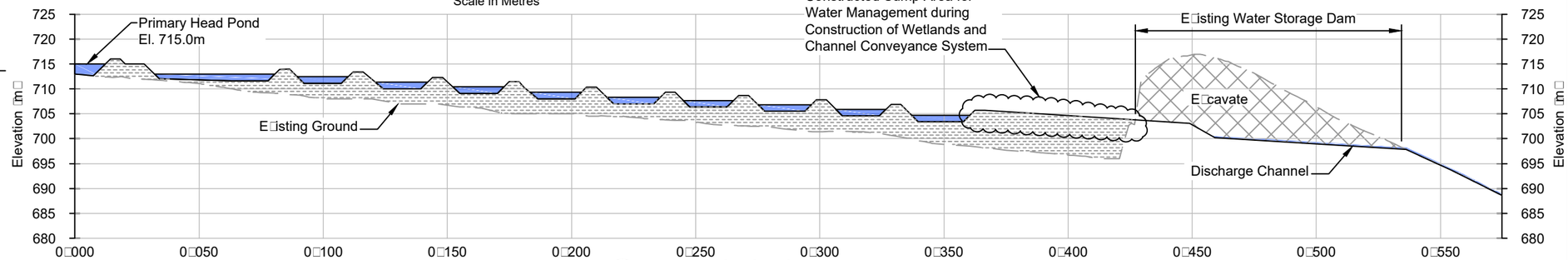
Scale in Metres

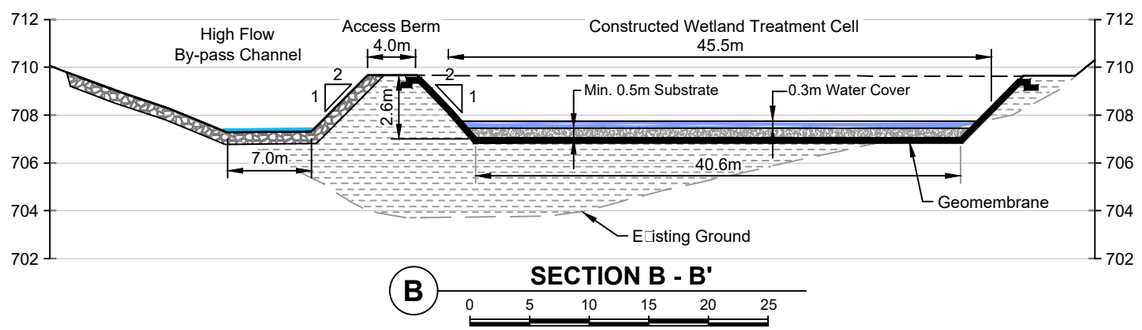



## SECTION A - A'

A

0 20 40 60 80 100

Horizontal Scale in Metres
Vertical Exaggeration 2x

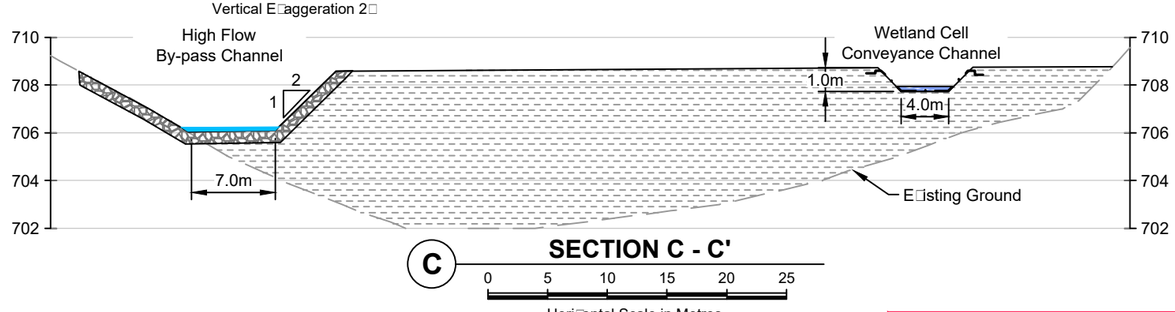



## SECTION B - B'

B

0 5 10 15 20 25

Horizontal Scale in Metres
Vertical Exaggeration 2x




## SECTION C - C'

C

0 5 10 15 20 25

Horizontal Scale in Metres
Vertical Exaggeration 2x

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REFERENCE DRAWINGS

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Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: Wetland Cell Configuration

| DRAWING NO. | SHEET | REVISION NO. |
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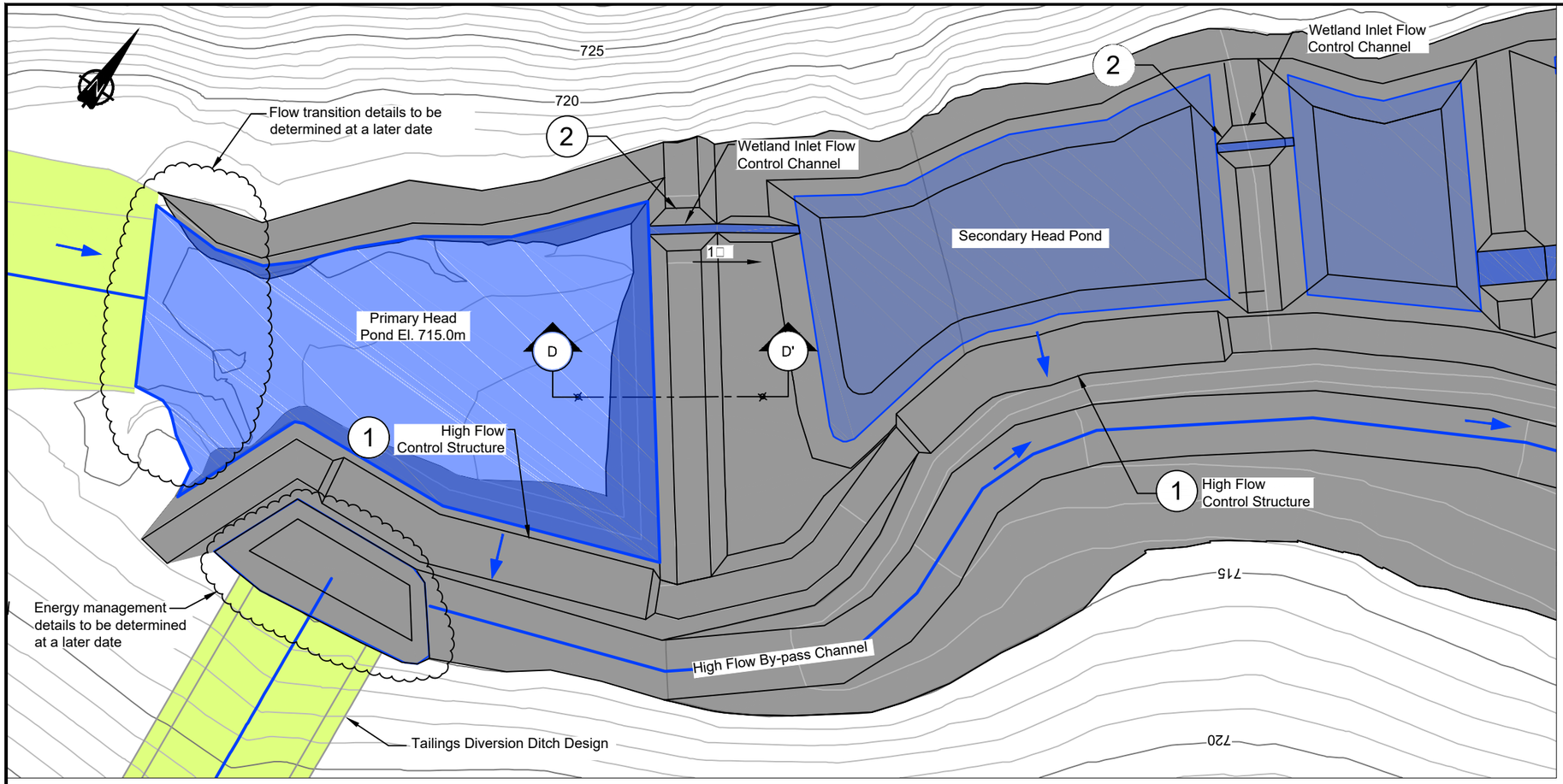



## LEGEND

- Wetland Foundation Fill Material
- Rip Rap
- Constructed Wetlands Design
- Designed Infrastructure (Not Constructed)
- Geomembrane
- Flow Direction

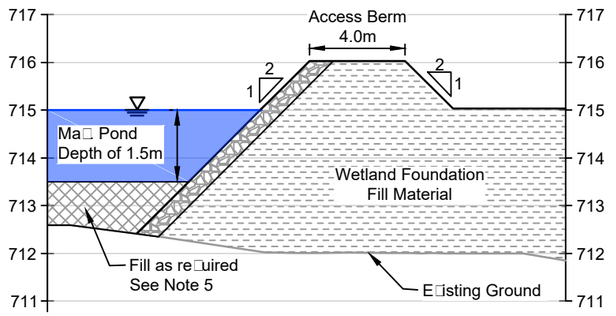
## NOTES

1. The Wetland Intake structure is designed to convey the design flow rate from the Primary Head Pond to the Secondary Head Pond. Flows exceeding this rate enter the high-flow bypass channel.
2. Wetland intake structure to be designed at later stages of design to convey 3000 m3/day into the wetland.
3. High Flow By-Pass flow control structure to be designed at later stages of design.
4. High Flow By-Pass Channel and Stilling Basin designed by SRK Closure Conveyance Channel Design Report 2016.
5. Pond to be filled to avoid structures classified as dams

## PRIMARY AND SECONDARY HEAD POND PLAN VIEW

0 10 20 30

Scale in Metres

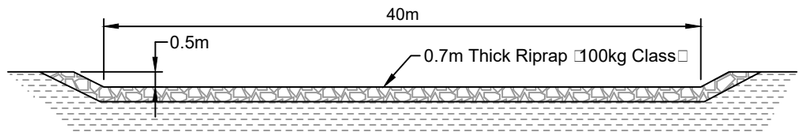



## SECTION D - D'

D

0 2 4 6 8 10

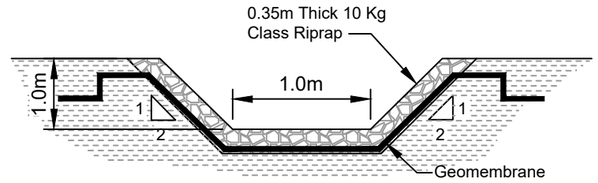
Horizontal Scale in Metres
Vertical Exaggeration 2X




## DETAIL 1 - TYPICAL HIGH FLOW CONTROL STRUCTURE

1

NTS




## DETAIL 2 - TYPICAL WETLAND INLET FLOW CONTROL CHANNEL

2

NTS

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Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: Head Pond Area Layout

| DRAWING NO. | SHEET | REVISION NO. |
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| CW-03 | 4 OF 5 | A |

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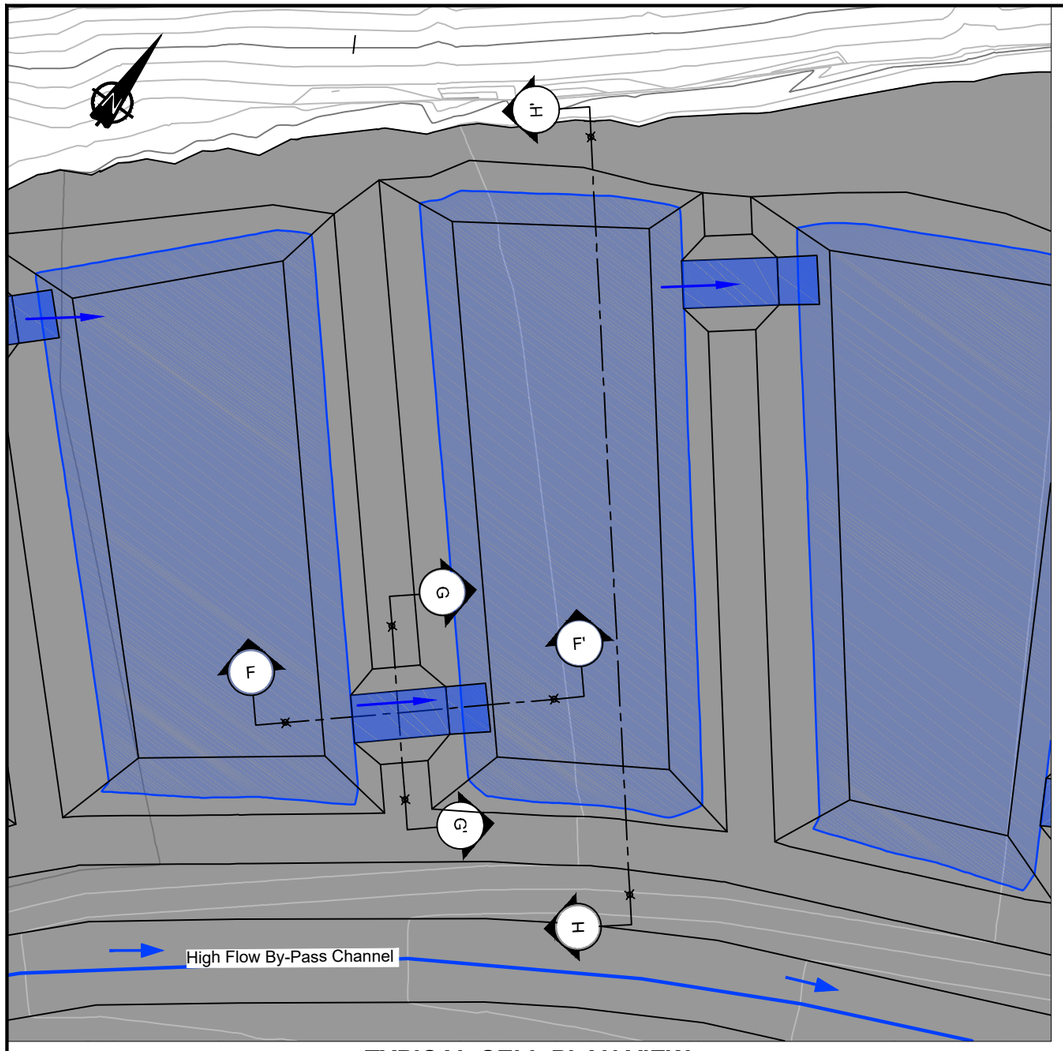
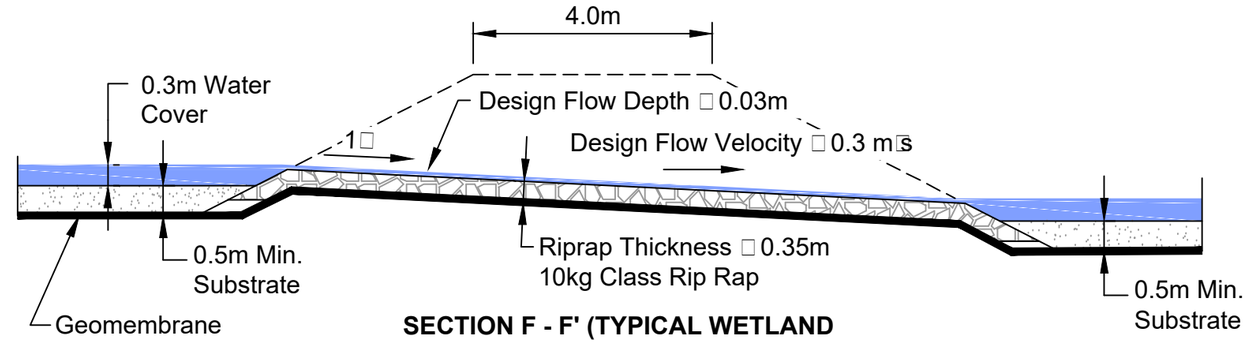



## TYPICAL CELL PLAN VIEW

0 5 10 15 20 25

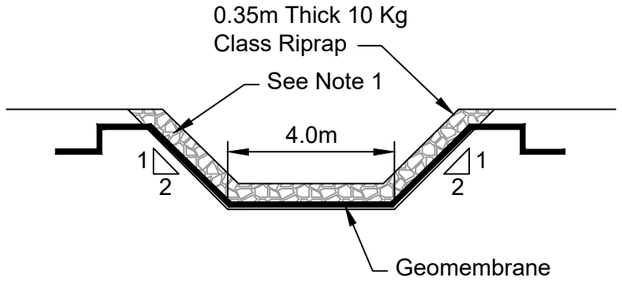
Scale in Metres




## SECTION F - F' (TYPICAL WETLAND CELL CONVEYANCE CHANNEL)

F

NTS




## SECTION G - G' (TYPICAL WETLAND CELL CONVEYANCE CHANNEL)

G

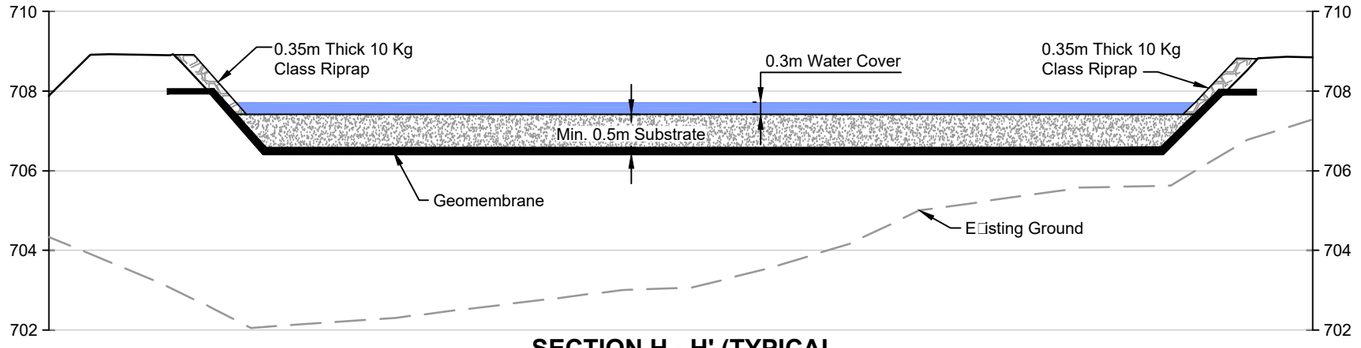
NTS

**10kg CLASS - RIP RAP**

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 300 |
| $D_{85}$ | 280 |
| $D_{50}$ | 200 |
| $D_{15}$ | 90 |
| Layer Thickness | 350 |

**100 kg CLASS - RIP RAP**

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 680 |
| $D_{85}$ | 610 |
| $D_{50}$ | 450 |
| $D_{15}$ | 200 |
| Layer Thickness | 700 |




## SECTION H - H' (TYPICAL CONSTRUCTED WETLAND)

H

0 2 4 6 8 10

Horizontal Scale in Metres
Vertical Exaggeration 2

## LEGEND

- Rip Rap
- Constructed Wetlands Design
- Geomembrane
- Flow Direction

## NOTES

1. Cell Conveyance Channel requires a minimum 350 mm layer of rock rip-rap having an average diameter of greater than 200 mm to mitigate erosion.
2. Typical 4.0 m wide berms to be constructed to provide access for Construction and monitoring and maintenance.

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Preliminary Infrastructure Minto Creek Constructed Wetlands

DRAWING TITLE: Typical Cell and Cell Spillway Layout

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CW-04 | 5 OF 5 | A |

# Closure Water Conveyance System Design Update Report, Minto Mine

**Prepared for**

Minto Explorations Ltd.



**Prepared by**

SRK Consulting (Canada) Inc.
1CM002.042
February 2018

# Closure Water Conveyance System Design Update Report, Minto Mine

February 2018


**Prepared for**

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Project No: 1CM002.042

File Name: Minto_ClosureConveyanceDesign_1CM002-042_20180201_spb_VM_dbm


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# Appendices

Appendix A – Conveyance System Drawings

Appendix B – Site-Specific Hydrology Review

Appendix C – Climate Change Analysis

Appendix D – Channel Routing Options Evaluation

Appendix E – Integrating Vegetation Erosion Protection

# 1 Introduction

SRK Consulting (Canada) Inc. has prepared this updated post-closure water conveyance system design report for the Minto Mine located in Yukon, Canada, and operated by Minto Explorations Ltd. The updated designs are intended to form a part of Minto's January 2018 update of the mine's Reclamation and Closure Plan (RCP 2018-01).

The designs of the post-closure water conveyance system described herein are updates to those developed for the previous version of the RCP (RCP 2016-01). The updated designs account for the following:

- Updated as-built details of the current ground surface;
- Updated as-built and design details for the Main Pit Dump;
- Redesign of the ultimate Area 2 Stage 3 Pit; and
- Refinements based on outcomes of the 2017 Failure Modes and Effects Assessment (AEG 2018).

Because of the above revisions, the existing post-closure designs for the water conveyance network and related infrastructure required updates. Included in this report is the preliminary design level of the post-closure water network. Secondary and tertiary drainage features are not included in the preliminary engineering design for the conveyance network; however, the accompanying cover designs address local drainage networks as part of managing surface runoff and limiting erosion for covered facilities (SRK 2018).

The post-closure conveyance system is a network of channels, erosion protection features, and energy dissipation structures that convey surface water from and through the mine site to Minto Creek, which itself discharges into the Yukon River. This design report focuses on the primary arterial network of conveyance channels within the mine footprint. The network of channels is designed to collect, intercept, and convey water through the mine in its closed state. To support the conveyance system designs and methodology summarized in this report, the following technical memos are provided in the appendices:

- Appendix A – Conveyance System Drawings,
- Appendix B – Site-Specific Hydrology Review,
- Appendix C – Climate Change Analysis,
- Appendix D – Routing Flow Closure Evaluation, and
- Appendix E – Integrating Vegetation Erosion Protection.

# 2 Water Management Review

To support the water conveyance designs, SRK has reviewed and updated the site-wide hydrology analysis to reflect climate change, modified watershed catchment areas and assessed

options of alignments for conveyance channels. The results of this review are summarized below. Further details are provided in the technical memos (Appendices B, C and D).

## 2.1 Hydrology Review

This section summarizes the background and results of the site wide hydrology review which is included with this report in Appendix B.

The hydrology analysis was updated to estimate the summer probable maximum precipitation (PMP), the probable maximum flood (PMF), and 1:200-year peak flows for the design of the conveyance channels and erosion protection required for the Reclamation and Closure Plan (RCP).

The maximum instantaneous 200-year peak flow and PMF were calculated using a rainfall-runoff methodology where maximum average daily snowmelt was modelled as baseflow. The Soil Conservation Service method was used to determine runoff based on catchment area characteristics such as: lag time, area, and curve number coefficients. The Soil Conservation Service Type I rainfall distribution was selected for use in the HEC-HMS (2013) model. The Type I distribution approximates an intense, short-duration storm event typical of storms in the Yukon and nearby Alaskan interior. A HEC-HMS model was developed for the post-closure conveyance network, to determine the 1:200 year return-period peak flows and the PMF along the post-closure conveyance channels.

The PMP for a 24-hour duration event was evaluated to be 159 mm of precipitation based on observed data from 20 regional meteorological stations. Additional details of the hydrology and evaluation of the PMP are presented in Appendix B.

## 2.2 Climate Change Analysis

This section summarizes the background and results of the climate change study which is included in Appendix D of this report.

The International Panel on Climate Change (IPCC) projects a 5°C to 6°C increase in the ambient temperature in Northern Canada for year 2100 relative to the 1980 to 1999 temperatures (IPCC 2007). Evaluating the climate change models relative to Minto Mine, the mean annual air temperature has the potential to increase 3.3°C over the next century. Trending forward in time, the mean annual air temperatures may reach −0.8°C, 0.2°C, and 1.1°C in the 2020s, 2050s, and 2080s, respectively.

According to the climate change model, the total precipitation at Minto is forecasted to increase 67.9 mm (15%) during the closure and post-closure periods (2011 to 2040) and 199.3 mm (44%) by 2100. Heavy rainfall, which is the fraction of annual precipitation greater than the 95th percentile, is predicted to increase by 96% over the next century at Minto. Similarly, the number of days with more than 10 mm of rainfall is forecasted to increase by 140%. This trending increase in annual precipitation was accounted for in the sizing and specifications of conveyance structures (Section 3).

The monthly average snow depth at Minto is expected to increase over the next century. Forecasts suggest that freshet will occur in April, and maximum daily snowmelt will increase over the next century.

## 2.3 Channel Routing Options Evaluation

This section summarizes the results of an alternative assessment for the channel alignment around the Main Pit and Area 2 Stage 3 Pit. Channel alignments and flood routing through the pits were evaluated for a range of design storms including the PMF.

Two flood routing alternatives for the Area 2 Stage 3 Pit were considered:

- Option 1 – Area 2 Stage 3 Pit upstream flow is routed into the pit through Channel B. From the pit, flows are discharged to Channel D.
- Option 2 – Area 2 Stage 3 Pit upstream flow is routed around the pit through Channel B. Channel B and Channel C both report to Channel E.

The results of the two routing options illustrate a minimal difference in the magnitude of the PMF in downstream channels for Options 1 and 2. Furthermore, the Option 2 of diverting flows around the Area 2 Stage 3 Pit does not result in any measurable difference in the timing of the peak flow into lower Minto Creek.

A total of three geometric channel configurations were evaluated for the pit outlet channels to assess hydraulic design requirements (i.e. channel depth and erosion protection):

- Case 1 – Minimum spillway width (2 m).
- Case 2 – Constructible spillway width, based on dozer sizing (7 m).
- Case 3 – Maximum spillway width, based on topography (22 m for Main Pit, 15 m for Area 2 Pit).

Based on the routing alternatives and channel geometry assessment, it is recommended that channel alignments flow into the Main Pit and Area 2 Stage 3 Pit.

Based on the constructability methods and costs of using a dozer, it is recommended that channel widths be sized to a minimum of a dozer blade (i.e. Case 2). Given that there is no benefit to route flows around the pits, it is recommended that channel alignments flow into the pits and should be sized to have a minimum bottom width of a dozer blade (i.e. 7 m). More detail of this analysis is included in Appendix D.

# 3 Design Basis

The design basis of the closure water conveyance system is to collect upstream surface runoff and convey flows through the mine site to downstream Minto Creek.

The conveyance system should be designed in a manner that constructed water management features are robust and durable post-closure. Key design criteria considered in the design include:

- Rip rap erosion protection and integration of vegetation,
- Robust geometry that reduces the risk of overtopping and erosion,
- Allowance for future climate change conditions and discharge requirements, and
- Utilization of pit lakes for mixing, energy dissipation, and sediment deposition.

## 3.1 Summary of the Channel Alignments

The conveyance channel system is composed of seven primary conveyance channels, the Stilling Basin, and the Primary Head Pond (Drawing CC-01; Appendix A). These channel alignments were selected based on four design considerations:

- Ability to convey surface runoff generated from upstream catchment areas,
- Minimization of channel slopes and excavation volumes (while maintaining alignments that are robust against excess flows and negative effects of long term thaw consolidation of foundation materials),
- Utilization of pit lakes established in the Main Pit and Area 2 Stage 3 Pit to dissipate energy and settle sediments, and
- Convey flows generated on site to the Minto Creek channel upstream of the W3 monitoring station downstream of all mine disturbances.

The following section provides a summary of the function of each conveyance structure at closure.

- **Conveyance Channel A:** Located southwest of the Main Pit, downgradient of the Main Waste Dump (MWD) and the Southwest Waste Dump (SWD). This channel will convey surface water from the W15 tributary across the South Wall Buttress into the Main Pit lake. The channel alignment will incorporate a light vehicle swale crossing at its inlet to maintain access to the upgradient catchment areas.
- **Conveyance Channel B:** Located east of the Area 2 Stage 3 Pit. This channel collects flow from the Airport Road Ditch and from the W35A tributary and conveys into the Area 2 Stage 3 Pit. The channel is cut into the pit wall and incorporates erosion protection. The upstream channel alignment incorporates a light vehicle swale crossing to maintain access to the underground portal to the west of the channel (South Portal).
- **Conveyance Channel C:** Channel C conveys discharge water from the Main Pit to a downstream confluence with Channel D, where the two combine to form the upstream segment of Channel E. Additionally, a constructed access road is required to maintain access to Channel C and to the Main Pit for post-closure monitoring and maintenance.

- **Conveyance Channel D:** Channel D conveys the discharge water from the Area 2 Stage 3 Pit to the confluence with Channel C. The confluence of flows from Channel C and D requires additional design attention to ensure flow transitions don't result in channel erosion. Similar to Channel C, the channel design also includes a parallel access road for post-closure monitoring and maintenance.

- **Conveyance Channel E:** Channel E has been subdivided into a system of three sequential channels: E1, E2, and E3. Channel E ultimately conveys water from the Main and Area 2 Stage 3 open pits into the Constructed Wetland Treatment System (CWTS). Flows in excess of the design of the CWTS flow rate are directed into a high-flow bypass channel (Channel G).

  Channel E1 commences at the confluence between channels C and D and conveys water in a constructed channel at a slope grade of 1% to the existing alignment of the site access road. Channel E2 and E3 is constructed on the alignment of the existing access road with grades ranging from 1.5% to 20%. Downstream of Channel E3, high velocity flows are transitioned into the Stilling Basin located upstream of the Primary Head Pond.

- **Conveyance Channel F:** Conveyance Channel F has been subdivided into two channels. Channel F1 represents the existing Tailings Diversion Ditch and Channel F2 represents the downstream segment of the diversion to convey flows upstream of the Dry Stack Tailings Storage Facility to Channel G (High Flow Bypass Channel).

- **Conveyance Channel G:** The High Flow Bypass Channel conveys flows from the Primary and Secondary Head Ponds through the High Flow Control Structures around the CWTS to lower Minto Creek. Flows that are diverted around the wetland are those that are in excess of the design flow rate for the CWTS or which enter the channel via Channel F (SRK 2016 and Contango 2016).

- **Stilling Basin:** Downslope of Channel E3, high velocity water is received by a Stilling Basin which is designed to dissipate energy and contain the development of a hydraulic jump within the protected stilling basin surface. Water passes from the Stilling Basin into the Primary Head Pond.

- **Primary Head Pond:** The Primary Head Pond moderates turbulent flows that exit the Stilling Basin before water is directed into the CWTS or the High Flow Bypass Channel by flow control structures on the south side of each head pond. The dual head pond system is designed to step down the flow rate discharging the Channel E3 to essentially separate the wetland design flow from the remainder of the water discharging the site. A design layout for the Primary and Secondary head ponds are illustrated in the Minto Creek Constructed Wetland: Physical Infrastructure Preliminary Design report (SRK 2016).

## 3.2 Design Criteria

### 3.2.1 Channel Design Criteria

All closure conveyance channels are designed to be lined with riprap for erosion protection for flows up to a 24-hour, 200-year return period. Evaluation of the suitability of using vegetation as a stand-alone protection will be considered at a later stage of design. Further details on the selection of vegetation species and biotechnical techniques are included in Appendix E. Given that over time, vegetation will naturally establish within the conveyance system, channels were sized to convey the 200-year peak flow with vegetation growth.

For channels with cross-slope alignments that have a risk of overtopping during a return period greater than the 200-year event and causing significant downstream effect (i.e. Channel B), channels were designed to convey the PMF. Table 3-1 provides a summary of the design criteria applied for the erosion and conveyance (i.e. channel sizing).

**Table 3-1: Channel Design Criteria Summary**

| Channel | Design Criteria | | Description |
|---|---|---|---|
| | Erosion Protection | Conveyance | |
| A | 200-year | PMF | Risk of overtopping onto Main Pit Dump and causing erosion. Channel sized to contain PMF. |
| B | | PMF | Risk of overtopping onto Dry Stack Tailings Storage Facility and causing erosion. Channel sized to contain PMF. |
| C | | 200-year + freeboard | Surrounding topography provides adequate relief to convey PMF. |
| D | | 200-year + freeboard | Surrounding topography provides adequate relief to convey PMF. |
| E1 | | 200-year + freeboard | Surrounding area graded to form valley-bottom to convey PMF to Channel E2. |
| E2 | | 200-year + freeboard | Surrounding area graded to form valley-bottom to convey PMF to Channel E3. |
| E3 | | 200-year + freeboard | Surrounding area graded to form valley-bottom to convey PMF to Stilling Basin. |
| F1 | | PMF | Risk of overtopping onto Dry Stack Tailings Storage Facility and causing erosion. Channel sized to contain PMF. |
| F2 | | 200-year + freeboard | Surrounding topography provides adequate relief to convey PMF (PMF contained within natural gulley). |
| G | | 200-year + freeboard | PMF contained in the valley-bottom to downstream Minto Creek. Overtopping of wetland infrastructure will occur under flows that exceed channel capacity. |

All closure conveyance channels are designed with a typical geometry that reflects the size and capability of the heavy equipment used on site. All channels were designed to have a minimum base width of 7 m (D11 dozer blade width), side slopes of 2:1 and a minimum freeboard of 0.3 m.

The base of the channel will be graded to create a thalweg in the center of the channel instead of incorporating a pilot channel as a design element. During low flow events, flows will be conveyed along the thalweg.

Excavated depths are variable due to channel grade and riprap sizes and each channel is divided into segments that relate to a typical riprap classification. A summary of required channel depths and rip rap specifications are provided in the drawing package (Appendix A).

The closure conveyance channels are designed to be lined with riprap for erosion protection and geotextile to prevent sediment migration and erosion of the channel side slopes. Sediment migration and erosion of the base material beneath the riprap protection may not warrant any geotextile along the proposed alignments, however geotextile has been incorporated at this stage of design. A geotextile element may not ultimately be necessary because the excavated material from which the channel alignments are constructed consists of either heavily compacted fills from existing haul roads or coarse rock fills generated during mine development. The need for geotextile will be considered further during later design.

Seepage losses from Channel E2 would ultimately report to the Stilling Basin, and are therefore expected to not represent a risk to closure performance. Seepage volumes are expected to be low, in part due to the highly compacted nature of the mine access road that forms the base of the post-closure channel. As such, no additional low permeability element has been incorporated into the design.

### 3.2.2 Stilling Basin Design Criteria

This structure is designed and protected to convey up to the PMF. Channel E3 enters the Stilling Basin at the western (upstream) end; Channel E2 has a maximum slope of 20% followed by a slope of 0.5% in the Stilling Basin itself. This abrupt slope change is anticipated to produce a hydraulic jump under design flows, and that hydraulic jump will provide energy dissipation. To improve the energy reduction, the channel width is increased from 7 to 20 m.

### 3.2.3 Primary Head Pond

The design criteria developed for the management of the passive treatment wetlands is to portion 3000 $m^3$/day of water from the discharge of E3 and the Stilling Basin and convey it into the wetlands (Contango 2016). To moderate the flows entering the CWTS and to direct excess flows to the High Flow Bypass Channel, a sequence of inlet flow control structures and outlet overflow structures are required.

The second component to the CWTS flow conveyance system is required to bypass the flows that exceed the design flow capacity of the CWTS. The High Flow Bypass Channel is designed to convey excess flow from the two head ponds around the wetland system, as well as to keep the discharge from the Tailings Diversion Ditch separate from the wetlands and route that water to lower Minto Creek. Downstream, wetland passive treatment discharge flows will join with the bypass flow and enter Minto Creek.

# 4 Methodology

## 4.1 Design Flow Estimates

Conveyance channel design flows were determined based on the site-wide hydrology and climate change reviews that were prepared by SRK (see Appendix B and C).

A rainfall-runoff approach was used to model peak flows. Rainfall was applied to a 24-hour distribution curve and was then converted to runoff based on catchment characteristics, including curve number, lag time, and total area, using the Soil Conservation Service (SCS) Method. A HEC-HMS model was developed to evaluate the peak 200-year and PMF to design the riprap protection and channel size of each conveyance channel.

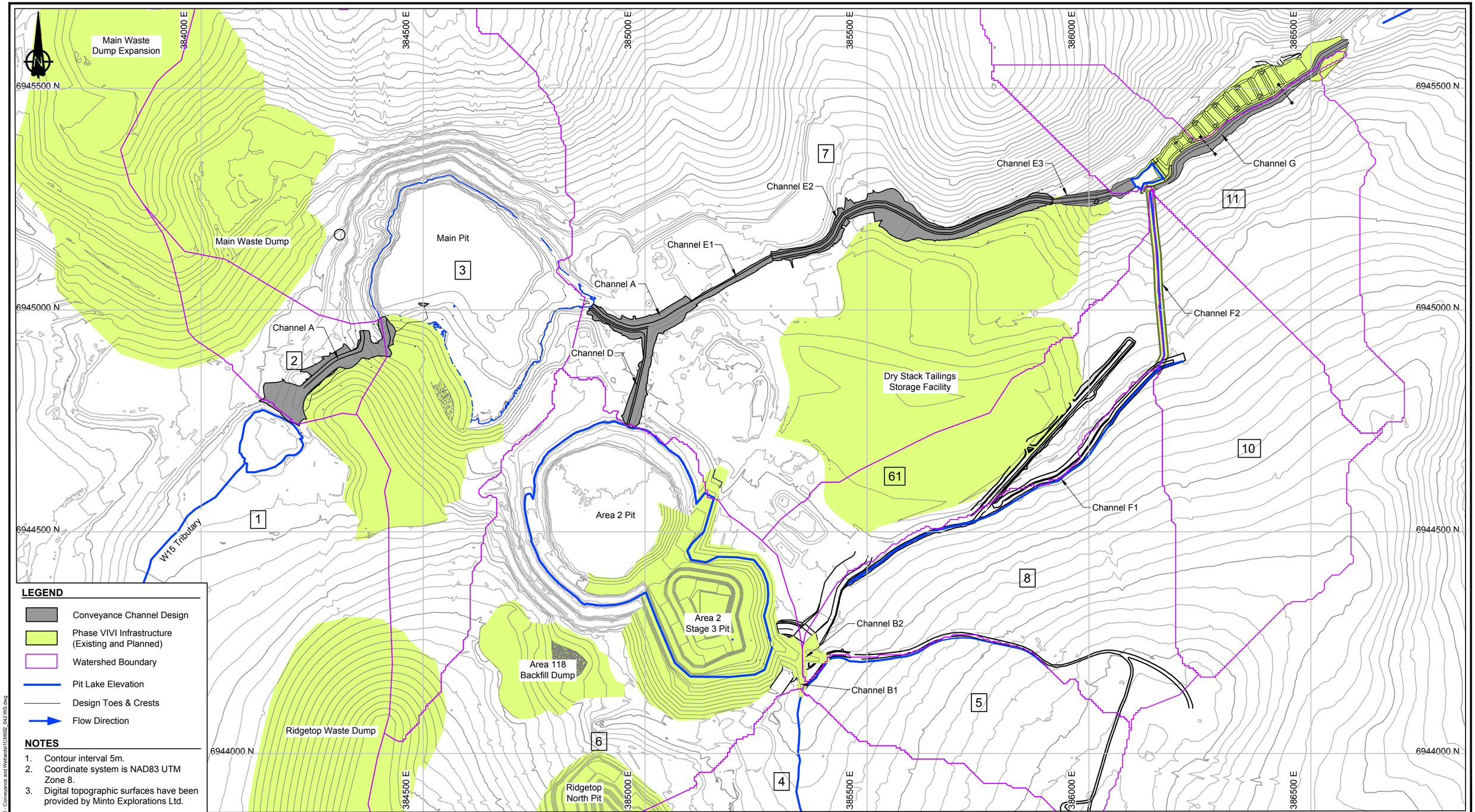
Figure 4-1 illustrates the catchment delineation for each channel and Table 4-1 summarizes the model inputs and Table 4-2 presents the 200-year and PMF flows for each channel. Appendix B provides additional details of the model inputs and validation.

**Table 4-1: Summary of Hydrology Model Inputs**

| Catchment | Area (km²) | Lag Time (min) | Baseflow (m³/s) |
|---|---|---|---|
| 1 | 3.46 | 27 | 0.92 |
| 2 | 0.10 | 6 | 0.03 |
| 3 | 0.86 | 6 | 0.23 |
| 4 | 1.87 | 21 | 0.50 |
| 5 | 0.17 | 9 | 0.05 |
| 6 | 0.64 | 7 | 0.17 |
| 7 | 1.81 | 17 | 0.33 |
| 8 | 0.32 | 18 | 0.09 |
| 9 | 0.21 | 19 | 0.06 |
| 10 | 0.32 | 12 | 0.09 |
| 11 | 0.29 | 12 | 0.08 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

Note: CN number applied to upstream watershed = 83




**LEGEND**

- Conveyance Channel Design
- Phase VIVI Infrastructure (Existing and Planned)
- Watershed Boundary
- Pit Lake Elevation
- Design Toes & Crests
- Flow Direction

**NOTES**

1. Contour interval 5m.
2. Coordinate system is NAD83 UTM Zone 8.
3. Digital topographic surfaces have been provided by Minto Explorations Ltd.

**NOT FOR CONSTRUCTION**

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srk consulting

capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.

MINTO EXPLORATIONS Ltd.

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| FILE NAME: 1CM002_042-WS.dwg | | SRK JOB NO.: 1CM002.042 |

Closure Conveyance Design

DRAWING TITLE:

Watershed Delineation

DRAWING NO.

4.1

**Table 4-2: Summary of Peak Flows**

| Channel | 200-year ($m^3/s$) | Probable Maximum Flood ($m^3/s$) |
|---|---|---|
| A | 11.5 | 42.6 |
| B | 7.6 | 28.2 |
| C | 13.1 | 47.7 |
| D | 9.7 | 36.6 |
| E1 | 28.9 | 110.1 |
| E2 | 28.9 | 110.1 |
| E3 | 28.9 | 110.1 |
| F1 | 1.3 | 4.8 |
| F2 | 2.3 | 8.6 |
| G | 31.5 | 121.3 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\CatchmentSummary_Minto_Closure_2018_spb_rev01.xlsm

## 4.2 Hydraulic Analysis (Channel Dimension and Erosion Protection)

The hydraulic analysis and sizing of channels were determined using Manning's Equation under a steady state normal depth condition. As described in Section 3.2.1, rip rap was sized for the 200-year peak flow and channels were sized for either the 200-year peak flow or PMF depending on the downstream risk (see Table 3-1) and the assumption that post-closure vegetation will be established. The Manning's roughness coefficient for a channel with vegetation in literature is determined to be 0.1 (Bedient et al, 2008). Studies of willows in channel have also been completed where it was found that the Manning's roughness coefficient for Sandbar Willows ranged from 0.04 to 0.08 depending of the channel depth (Chen et al. 2009). For the sizing of the conveyance channels at Minto a roughness coefficient of 0.1 was applied for channels with vegetation. The procedure to evaluate the Manning's coefficient for the rip rap is an iterative process between water depth, Manning's roughness and rip rap size.

Riprap sizing and Manning's roughness values were derived through model iterations. The Manning's equation was evaluated using initial roughness values, and the results were extracted at each channel segment of different longitudinal slope. For each interval, the $D_{50}$ of the riprap was calculated based on the velocity in the channel, and the corresponding Manning's roughness value was calculated based on the riprap sizing. This process was repeated until similar *n* values were obtained between model iterations.

### 4.2.1 Riprap Calculations

#### Closure Conveyance Channels

Riprap sizing for the closure conveyance channels was estimated using three expressions: Isbash (USACE 1991), Robinson et al. (1998), and Khan and Ahmad (2011). To be conservative, the maximum of the three estimates was used in the conveyance channel design.

Equation 2 presents the Isbash expression.

$$D_{50} = \frac{V^2}{C^2 2g(\frac{\gamma_s - \gamma_w}{\gamma_w})}$$ Eq. [2]

Where *V* is the average velocity (ft/s), *g* is gravitational acceleration (ft/s²), $\gamma_s$ is the unit weight of riprap (lb/ft³), $\gamma_w$ is the unit weight of water (lb/ft³), $D_{50}$ is the median riprap size (ft), and C is the Isbach coefficient. The Isbach coefficient was set to 1.2 for low turbulence or bank protection.

Equations 3 and 4 present the Robinson et al (1998) expressions, which are based on the channel slope.

$$D_{50} = (\frac{Q}{9.76x10^{-7} * S^{-1.50}})^{\frac{1}{1.89}} \qquad S < 0.10$$ Eq. [3]

$$D_{50} = (\frac{Q}{8.07x10^{-6} * S^{-0.58}})^{\frac{1}{1.89}} \qquad 0.10 \leq S \leq 0.40$$ Eq. [4]

Where *Q* is the unit peak flow rate (m³/s/m), $D_{50}$ is the median riprap size (m), and *S* is the slope (m/m).

Equation 5 presents the Khan and Ahmad (2011) expression.

$$D_{50} = 0.66\, x\, t^{0.58}\, x\, S^{0.22}\, x\, {C_u}^{-0.45}\, x\, {Q_f}^{0.22}$$ Eq. [5]

Where *t* is the riprap thickness (m), *S* is the channel slope (m/m), $C_u$ is the coefficient of uniformity, and $Q_f$ is the critical unit discharge (m³/s/m).

**Stilling Basin and Head Pond**

The erosion protection of the Stilling Basin and Head Pond were designed to be protected to convey the PMF resulting in large peak flows. The above three rip rap sizing expressions were complemented with Wittler and Abt, Mishra, and LaGasse et al. (Abt et al. 2013), which are expressions that are more suitable for evaluating larger sized riprap.

Because of the variability of the rip rap results, the riprap selected for the Stilling Basin and Head Pond was based on the average of these all six expressions (i.e. Isbash, Robinson et al., Khan and Ahmad, Wittler and Abt, Mishra, and LaGasse et al.), where the minimum and maximum values were removed from the average.

### 4.2.2 Manning's Roughness Estimation

Given a riprap size estimate, a Manning's roughness value (n) was then calculated based on three relationships by Strickler, Anderson, and Abt et al. (1988). The average *n* value obtained from the three expressions was selected. A smaller *n* value corresponds to a higher velocity and lower flow depth and vice versa; the average provides a conservative velocity and depth for the design.

Equation 6 presents the Strickler expression.

$$n = 0.0385{K_s}^{1/6} \quad \text{Eq. [6]}$$

Where *n* is the Manning's roughness value, and $K_s$ is the particle diameter of the largest 15% of the riprap grain size distribution (ft).

Equation 7 presents the Abt et al. (1988) expression.

$$n = 0.0456(D_{50}\ x\ S)^{0.159} \quad \text{Eq. [7]}$$

Where *n* is the Manning's roughness value, S is the channel slope (ft/ft), and $D_{50\ is}$ the average riprap diameter (inches).

Equation 8 presents the Anderson expression.

$$n = 0.0395{D_{50}}^{1/6} \quad \text{Eq. [8]}$$

Where *n* is the Manning's roughness value, and $D_{50}$ is the average riprap diameter (ft).

### 4.2.3 Riprap Classification and Gradation for Conveyance Channels

The riprap classifications (Table 4-3) were developed based on MOT BC (2006) to follow the design rationale described in this section for the closure channel segments. As stated before, the conveyance channels are composed of channel segments that have a typical profile, slope, and velocity profile. Each segment was assigned a riprap class and a layer thickness. The layer thickness is an aggregate of rock diameter types. Details pertaining to the riprap specifications for each segment are provided in the drawing package (Appendix A).

**Table 4-3: Riprap Class Gradation**

| Class of Riprap [kg] | Riprap Thickness [mm] | Rock Gradation Percentage Larger than Given Rock Mass [kg] | | | Rock Gradation Percentage Smaller than Given Rock Diameter [mm] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 85% | 50% | 15% | $D_{15}$ | $D_{30}$ | $D_{50}$ | $D_{85}$ | $D_{100}$ |
| 10 | 400 | 1 | 10 | 30 | 90 | 140 | 200 | 280 | 300 |
| 25 | 600 | 2.5 | 25 | 75 | 130 | 200 | 300 | 380 | 450 |
| 100 | 900 | 10 | 100 | 300 | 200 | 300 | 450 | 610 | 680 |
| 250 | 1200 | 25 | 250 | 750 | 270 | 400 | 600 | 820 | 900 |
| 500 | 1600 | 50 | 500 | 1500 | 340 | 540 | 800 | 1030 | 1200 |
| 1000 | 2000 | 100 | 1000 | 3000 | 420 | 670 | 1000 | 1300 | 1500 |

# 5 Closure Conveyance Channel Design

This section summarizes the closure conveyance channel design parameters. Channel depths are variable and related to the depth of water being conveyed. Specification tables for the channel geometry, flow depths and riprap are provided in Appendix A. All conveyance channel alignments are selected to avoid sharp bends to minimize the risk of scour and erosion and ultimately long-term maintenance requirements. Additional design elements that are specific to each channel are provided in the following sections and in the drawing package included in Appendix A. Drawing CC-01 (Appendix A) illustrates the general post-closure arrangement of the primary water conveyance network.

The following designs are prepared as an interim surface water conveyance design for closure which is based on the as-built configuration of the August 2017 surface. The closure design will need to be reviewed and updated based on future changes to mining and closure concepts.

## 5.1 Channel A

The closure design concept of Channel A is to collect and convey surface water from the W15 tributary to the Main Pit lake. Surface water from the W15 tributary is designed to enter Channel A through an intake transition section. This section will be designed to a detail level upon the completion mining, using the final surface as-built details.

The alignment, profile and typical cross-sections for Channel A are illustrated in Drawing CC-02. Table 5-1 summarizes the hydraulic design for Channel A where the maximum slope is 35%. The channel was sized to convey the PMF (42 $m^3/s$) and rip rap protection was sized for the 200-year peak flow (11 $m^3/s$).

**Table 5-1: Design Summary for Closure Conveyance Channel A**

| Segment ID | Length [m] | Slope [%] | Channel Base Width (m) | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|---|---|
| | | | | | | D50 (mm) | Class (kg) |
| 1 | 83 | 0.091 | 10 | 1.50 | 0.55 | 300 | 25 |
| 2 | 159 | 0.040 | 10 | 1.50 | 0.70 | 200 | 10 |
| 3 | 107 | 0.353 | 10 | 1.00 | 0.37 | 450 | 100 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.2 Channel B

Currently routine flows from the W35A Tributary and Airport Diversion Ditch flow through a pipe crossing to the Tailings Diversion Ditch (Channel F). Flows in excess are routed through a spillway into the Area 2 Stage 3 Pit. The proposed closure concept for Channel B is to reroute all flows from W35A tributary and Airport Diversion Ditch to the Area 2 Stage 3 pit through a new alignment cut into the pit wall and sloped back at a 16% grade. The channel will be protected against erosion with rip rap and provide a thermal layer to reduce permafrost degradation.

The closure conveyance channel design will plug and backfill the entrance to the existing pipe crossing and regrade the current spillway to convey flows to the Channel B at closure. Surface water from the W35A tributary and the Airport Diversion Ditch is designed to enter Channel B through an intake transition section. These sections will be designed to a detail level upon the completion of final closure mine plan and will include rock riprap erosion protection and compacted earth berms that direct flows from the W35A tributary and the Airport Diversion Ditch into Channel B.

Drawings CC-03 illustrate the alignment, profile and typical cross-sections. The Table 5-2 summarizes the closure conveyance hydraulic design Channel B. The channel was sized to convey the PMF (28 $m^3/s$) and rip rap protection was sized for the 200-year peak flow (8 $m^3/s$).

**Table 5-2: Design Summary for Closure Conveyance Channel B**

| Segment ID | Length [m] | Slope [%] | Channel Base Width (m) | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|---|---|
| | | | | | | D50 (mm) | Class (kg) |
| 1 | 72 | 0.046 | 7 | 1.35 | 0.64 | 200 | 10 |
| 2 | 52 | 0.064 | 7 | 1.23 | 0.59 | 300 | 25 |
| 3 | 83 | 0.162 | 7 | 1.00 | 0.45 | 450 | 100 |
| 4 | 56 | 0.162 | 7 | 1.00 | 0.45 | 450 | 100 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.3 Channel C

The closure design concept for Channel C is to convey discharge water from the Main Pit water cover at elevation 786 m to the downstream confluence of Channel C (Area 2 Stage 3 Pit outlet channel). The intake structure in the Main Pit of Channel C will be designed to a detail level upon the completion of final closure plan.

Parallel to Channel C, a 4-m wide light vehicle access road will be designed. This road will provide post-closure access for monitoring and maintenance of the conveyance channel. The traffic surface of the access road is sloped towards the conveyance channel for drainage and to minimize excavation.

Drawings CC-04 illustrate the alignment, profile and typical cross-section for Channel C. Table 5-3 summarizes the closure conveyance hydraulic design for Channel C where a minimum channel slope of 1% was applied. The riprap erosion protection and channel was sized to convey the 200-year peak flow (13 $m^3/s$). Given the large cut, and parallel access road, it is also able to convey the PMF (48 $m^3/s$).

**Table 5-3: Design Summary for Closure Conveyance Channel C**

| Segment ID | Length [m] | Slope [%] | Channel Base Width (m) | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|---|---|
| | | | | | | D50 (mm) | Class (kg) |
| 1 | 182 | 0.010 | 7 | 1.70 | 1.35 | 200 | 10 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.4 Channel D

The closure design concept for Channel D is to convey discharge water from the Area 2 Stage 3 Pit at an elevation of 799 m to the downstream confluence of Channel C. The intake structure in from the Area 2 Stage 3 Pit to Channel D will be designed to a detail level upon the completion of final closure plan. A flow contraction transition structure constructed from overburden backfill and coarse oversize rock riprap is recommended for consideration to reduce permafrost degradation and direct the pit discharge into Channel D.

Drawings CC-05 illustrate the alignment, profile and typical cross-section for Channel D. Table 5-4 summarizes the closure conveyance hydraulic design. The riprap erosion protection and channel was sized to convey the 200-year peak flow (10 $m^3/s$). Given the large cut, and parallel access road, it is also able to convey the PMF (37 $m^3/s$).

**Table 5-4: Design Summary for Closure Conveyance Channel D**

| Segment ID | Length [m] | Slope [%] | Channel Base Width (m) | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|---|---|
| | | | | | | D50 (mm) | Class (kg) |
| 1 | 160 | 0.023 | 7 | 2.10 | 1.80 | 200 | 10 |
| 2 | 78 | 0.137 | 7 | 1.40 | 1.10 | 450 | 100 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.5 Channel E

Channel C and D converge to form Channel E. This confluence location was selected based on existing topography and the chosen channel grades for Channel C and D. The confluence will be designed to a detail level upon the completion of the final closure plan and will require an apron sufficiently large enough to protect against an increase in water depth and high velocities due to the development of a hydraulic jump. Channel E is composed of three sequential subsections E1, E2, and E3 and conveys flows from the mine site (i.e. Main Pit, Area 2 Stage 3 Pit and Dry Stack Tailings Storage Facility to the CWTS).

Channel E1 starts at the confluence of channels C and D and conveys flows originating from the Main Pit and from the Area 2 Stage 3 Pit and transitions into Channel E2 and E3 along the existing access and discharges into a stilling basin prior to flowing into the CWTS.

The Channel E alignment is designed to overlay the current mine access road. A light vehicle access road is designed parallel to the alignment. The existing road surface was chosen for construction of a channel because the roadway has undergone traffic compaction over the life of mine and is expected to experience minimal long-term settlement and minimal seepage interception from the Dry Stack Tailings Storage Facility. At future stages of closure design, the need for seepage management along Channel E2 should be evaluated and, if found necessary, may require additional design details to address the need to further limit seepage interception into the channel. This potential additional design requirement could be addressed through lining the channel or components of the channel with low conductivity geomembranes. At this stage of the design, the compacted road material of the existing site access road is accepted to have sufficient low permeability.

Drawings CC-06, CC-07 and CC-08 illustrate the alignment, profile and typical cross-sections for Channel E1, E2 and E3 respectively. Channel E1 and E1 have segments with slopes ranging from 1% to 8%. Channel E3 is designed as a high velocity conveyance channel with a slope of 20% into the Stilling Basin.

Table 5-5 summarizes the hydraulic design for Channel E. The riprap erosion protection and channel was sized to convey the 200-year peak flow (29 $m^3/s$). The mine site will be graded to create a valley bottom to direct all flows from the site into Channel E and ultimately the Stilling Basin. As such, the Channel E valley-bottom can convey the PMF (110 $m^3/s$).

**Table 5-5: Design Summary for Closure Conveyance Channel E**

| Segment ID | Length [m] | Slope [m/m] | Channel Base Width (m) | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|---|---|
| | | | | | | D50 (mm) | Class (kg) |
| 1 | 278 | 0.011 | 7 | 2.00 | 1.82 | 200 | 10 |
| 2 | 260 | 0.062 | 7 | 2.00 | 1.26 | 450 | 100 |
| 3 | 98 | 0.014 | 7 | 2.00 | 1.89 | 450 | 100 |
| 4 | 92 | 0.058 | 7 | 2.00 | 1.28 | 450 | 100 |
| 5 | 92 | 0.063 | 7 | 2.00 | 1.26 | 450 | 100 |
| 6 | 105 | 0.041 | 7 | 2.00 | 1.41 | 450 | 100 |
| 7 | 33 | 0.076 | 7 | 2.00 | 1.19 | 600 | 250 |
| 8 | 46 | 0.051 | 7 | 2.00 | 1.33 | 450 | 100 |
| 9 | 150 | 0.207 | 7 | 2.00 | 0.90 | 1000 | 1000 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.6 Stilling Basin

Downslope of the E3 channel is the Stilling Basin which is designed to contain the development of a hydraulic jump within the protected stilling basin surface. The Stilling Basin geometry consists of a 20 m wide basin channel with 2H:1V side slopes constructed from riprap. Outflow from the Stilling Basin transitions into the Primary Head Pond which has a surface elevation of 715 m.

Table 5-6 summarizes the hydraulic design for the Stilling Basin.

**Table 5-6: Design Summary for the Stilling Basin**

| Segment ID | Length [m] | Slope [m/m] | Channel Base Width (m) | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|---|---|
| | | | | | | D50 (mm) | Class (kg) |
| 10 | 40 | 0.005 | 20 | 3.30 | 1.50 | 450 | 100 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.7 Channel F (Tailings Diversion Ditch)

Channel F is composed of two sequential subsections. Channel F1 illustrates the existing Tailings Diversion Ditch (TDD) constructed to divert flows around the Dry Stack Tailings Storage Facility and transitions to Channel F2 down an existing natural gulley down to the High Flow Bypass Channel (Channel G).

The grade along the existing TDD (Channel F1) range from 0.8% to 7% and the channel dimensions fluctuate along the alignment. Drawings CC-09 illustrates the alignment, profile and a cross-section of Channel F1. This cross-section was chosen to illustrate the most critical section (i.e. flattest slope and shallow channel depth) along the alignment. Channel F1 has sufficient capacity to convey the post-closure 200-year peak flow (1.3 $m^3/s$) with a Manning's coefficient of 0.1 assuming vegetation will be established within the channel section. The flattest segment of Channel F1 (0.8%) has the capacity to convey the PMF (4.8 $m^3/s$) at a maximum channel depth of 1.4 m.

Channel F2 is aligned in an existing natural gulley with grades ranging from 8% to 30% near the outlet into Channel G. Drawing CC-10 illustrates the alignment, profile and a typical cross-section of the Channel F2 design. Channel F2 has a v-shaped cross-section with a 12% side-slope and a minimum channel depth of 0.8 m to convey the 200-year peak flow under post-closure conditions (i.e. with vegetation established within the channel). The riprap protection was designed for the 200-year peak flow. Table 5-7 summarizes the hydraulic design for Channel F2. Given that the alignment follows natural topography, the PMF (8.6 $m^3/s$) will not create a new flow path. Some long-term settlement along the channel is expected due to thawing of the underlying permafrost; however, as the channel follows an existing natural channel with a steep gradient, any differential settlement is not likely to result in a change in flow path.

**Table 5-7: Design Summary for Closure Conveyance Channel F2**

| Segment ID | Slope [m/m] | Minimum Channel Depth [m] | 1:200 year Water Depth[1] [m] | Riprap | |
|---|---|---|---|---|---|
| | | | | D50 (mm) | Class (kg) |
| 1 | 0.078 | 0.8 | 0.50 | 800 | 500 |
| 2 | 0.121 | 0.8 | 0.46 | 800 | 500 |
| 3 | 0.159 | 0.8 | 0.44 | 800 | 500 |
| 4 | 0.092 | 0.8 | 0.49 | 800 | 500 |
| 5 | 0.163 | 0.8 | 0.44 | 800 | 500 |
| 6 | 0.168 | 0.8 | 0.43 | 800 | 500 |
| 7 | 0.174 | 0.8 | 0.43 | 800 | 500 |
| 8 | 0.284 | 0.8 | 0.39 | 800 | 500 |
| 9 | 0.270 | 0.8 | 0.40 | 800 | 500 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.8 Channel G (High Flow Bypass Channel)

The High Flow Bypass Channel conveys flows from Channel F and excess flows the Head Pond of the CWTS. Excess flows from the head pond flow through a 40 m wide and 0.5 m deep spillway. Flows that are diverted around the CWTS are those that are in excess of the design flow rate that can be managed by the wetlands (SRK 2016 and Contango 2016).

Drawing CC-11 illustrates the alignment, profile and typical cross-sections for Channel F. Table 5-8 summarizes the hydraulic design for Channel G. The channel slope ranges from 1% to 5%. The riprap protection and channel was sized to convey the 200-year peak flow (32 $m^3/s$). The 200-year water depth post closure with vegetation established in the channel will vary along the alignment depending on topography. During the PMF event, water levels will rise and flow into the CWTS and ultimately downstream to Minto Creek.

**Table 5-8: Design Summary for Closure Conveyance Channel G**

| Segment ID | Length [m] | Slope [m/m] | Channel Base Width (m) | Minimum Channel Depth [m] | Riprap | |
|---|---|---|---|---|---|---|
| | | | | | D50 (mm) | Class (kg) |
| 1 | 28 | 0.01 | 7 | 2.5 | 300 | 25 |
| 2 | 62 | 0.05 | 7 | 2.0 | 300 | 25 |
| 3 | 61 | 0.02 | 7 | 2.0 | 300 | 25 |
| 4 | 84 | 0.03 | 7 | 2.0 | 300 | 25 |
| 5 | 334 | 0.03 | 7 | 2.0 | 300 | 25 |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.042_ClosureConveyance\FMEA_2017\Minto - Channel_SPB.xlsm

**Notes:**

[1] Water depths represent the water depth for the 200-year peak flow with vegetation established post-closure in the channel.

## 5.9 Primary Head Pond

The Primary Head Pond moderates turbulent flows that exit the Stilling Basin before water is directed into a secondary head pond of the CWTS or Channel G by two flow control structures (CC-11).

The dual head pond system is designed to step down the flow rate discharging from the E Conveyance Channel to protect the constructed wetland treatment system from excess flows.

Design details for the CWTS and the head pond flow control structures can be found in *Minto Creek Constructed Wetland: Physical Infrastructure Preliminary Design* (SRK 2016).

# 6 Information Required to Advance the Channel Design

To further develop the closure conveyance channel design towards a final closure design plan, the following data requirements and project developments are required:

- The final post-mining as-built surfaces (such as as-built waste rock, pit, and general mine area surfaces) will be required to update and optimize the conveyance channel design.
- Review site wide closure progress and closure designs for other site components. This will allow determination of design gaps or redundancies in the closure conveyance channel design and will permit identification of opportunities for optimization and integration.
- In conjunction with review of site-wide closure designs, surficial drainage features from adjacent areas will need to be incorporated into the conveyance system. Designed drainage features include elements in the final cover designs, landform grading on waste rock dumps and tailings covers, and mine elements (e.g. haul roads, pit shells, and the underground portal).
- Design elements for the planned constructed wetland treatment system within the current WSP footprint will need to be integrated.
- Include an as-built design of the Tailings Diversion Ditch upon its completion to finalize the design of the High Flow Bypass Channel and related wetland infrastructure.
- Final post closure road layout design will be required to ensure integration of the road and channel networks.
- It is expected that the channels will have limited seepage losses and that there is no requirement for incorporation of low permeability elements in the channel designs. This should be confirmed during final design.
- At future stages of closure design, details of the specific hydraulic design of the Main and Area 2 Stage 3 open pit outlets and the energy dissipation aprons will need to be developed.

This report, "Closure Water Conveyance System Design Update Report, Minto Mine", was prepared by

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2/6/2018

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Date 2/6/2018
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.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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# Appendix A – Conveyance System Drawings

# Engineering Drawings for the Closure Conveyance Design, Minto Mine, Yukon, Canada

## ACTIVE DRAWING STATUS

| DWG NUMBER | DRAWING TITLE | REVISION | DATE | STATUS | REPLACED REVISIONS |
|---|---|---|---|---|---|
| CC-00 | Engineering Drawings for the Closure Conveyance Design, Minto Mine, Yukon, Canada | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-01 | Post-Closure General Arrangement | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-02 | Channel A | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-03 | Channel B | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-04 | Channel C | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-05 | Channel D | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-06 | Channel E1 | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-07 | Channel E2 | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-08 | Channel E3 AND STILLING BASIN | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |
| CC-09 | Channel F1 Existing Tailings Diversion Ditch | F | Jan. 16, 2018 | Issued For Review | |
| CC-10 | Channel F2 | F | Jan. 16, 2018 | Issued For Review | |
| CC-11 | Channel G High Flow By-Pass | B | Jan. 16, 2018 | Issued For Review | July 27, 2016; Rev A IFR |

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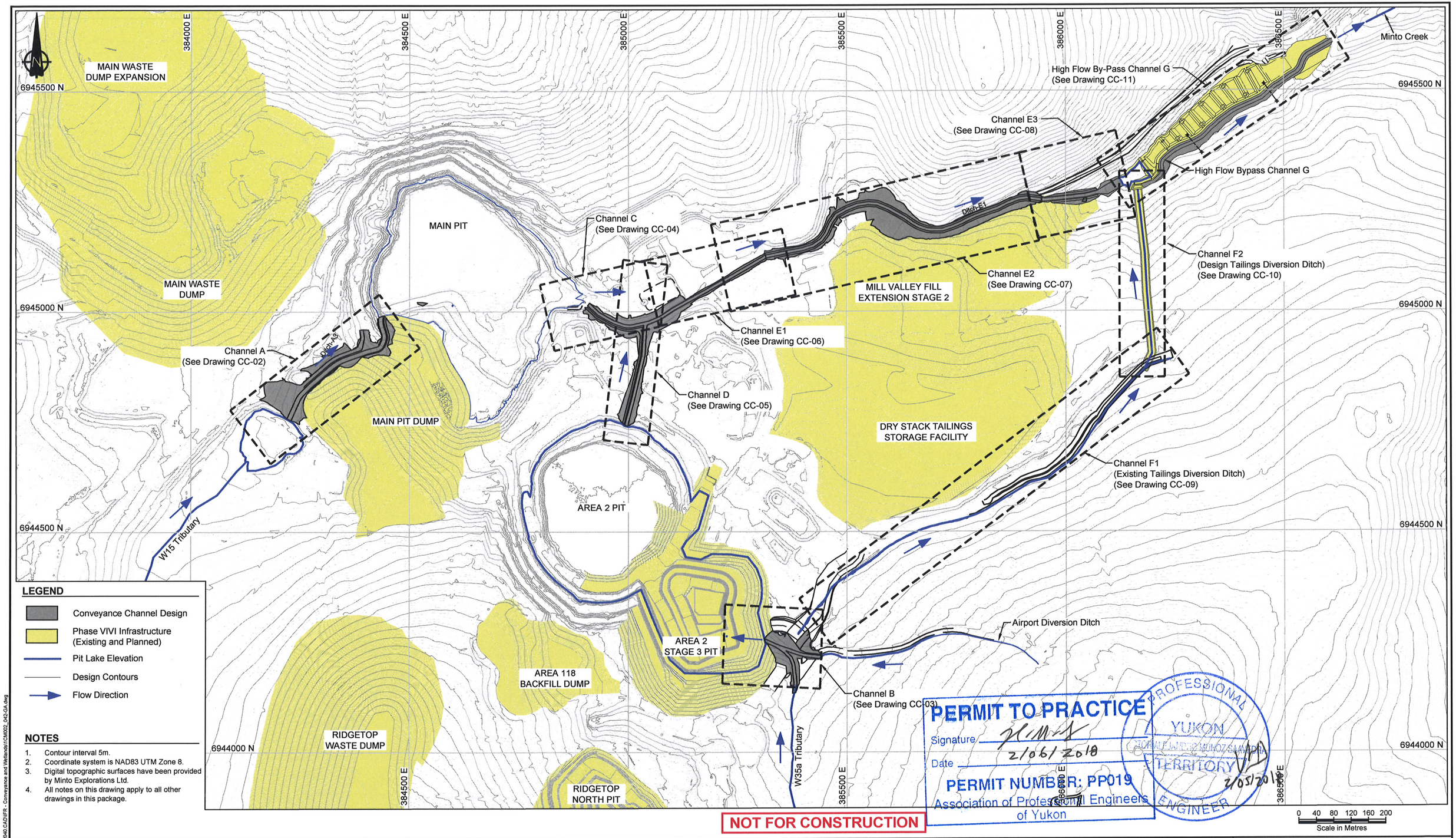
Revision B - Issued for Review
January 16, 2018
Drawing CC-00




**LEGEND**

- Conveyance Channel Design
- Phase VIVI Infrastructure (Existing and Planned)
- Pit Lake Elevation
- Design Contours
- Flow Direction

**NOTES**

1. Contour interval 5m.
2. Coordinate system is NAD83 UTM Zone 8.
3. Digital topographic surfaces have been provided by Minto Explorations Ltd.
4. All notes on this drawing apply to all other drawings in this package.

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|---|---|---|---|

REFERENCE DRAWINGS

| NO. | DESCRIPTION | CHK'D | APP'D | DATE |
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| B | Issued for Review | SP | VM | 16Jan18 |
| A | Issued for Review | SM | VM | 15Jul16 |

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Closure Conveyance Design

DRAWING TITLE: Post-Closure General Arrangement

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CC-01 | 1 OF 12 | B |

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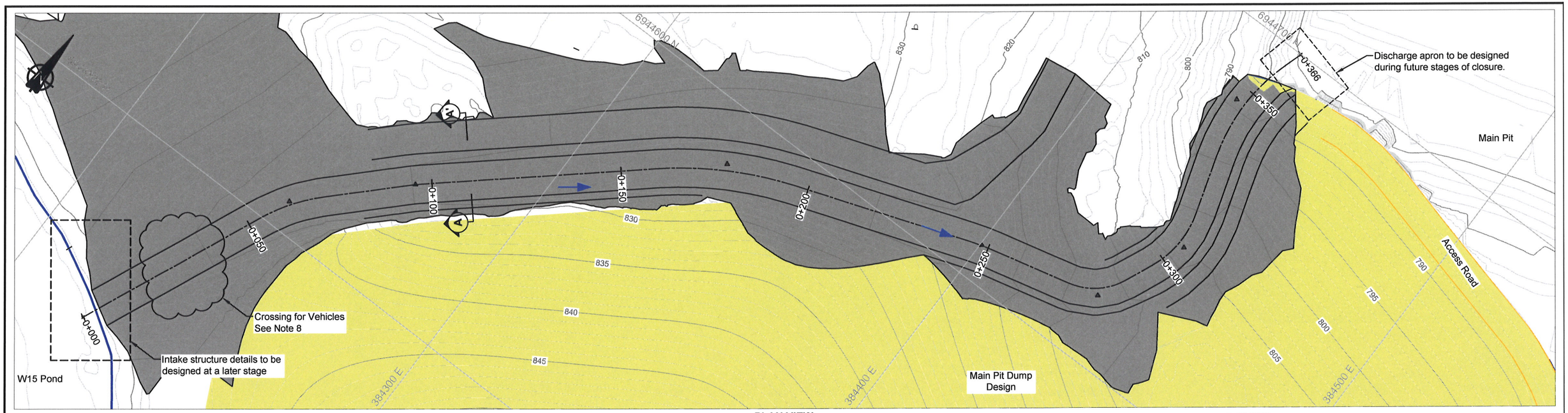


**PLAN VIEW**
**A CONVEYANCE CHANNEL**

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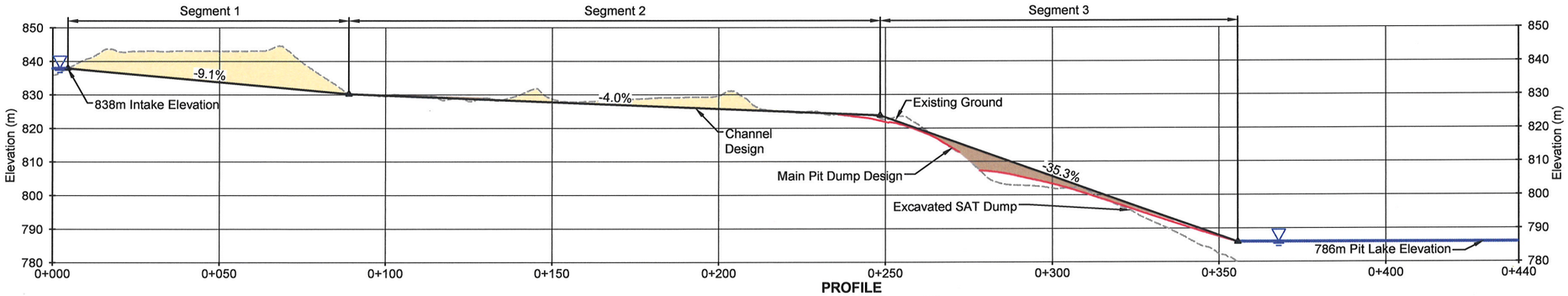
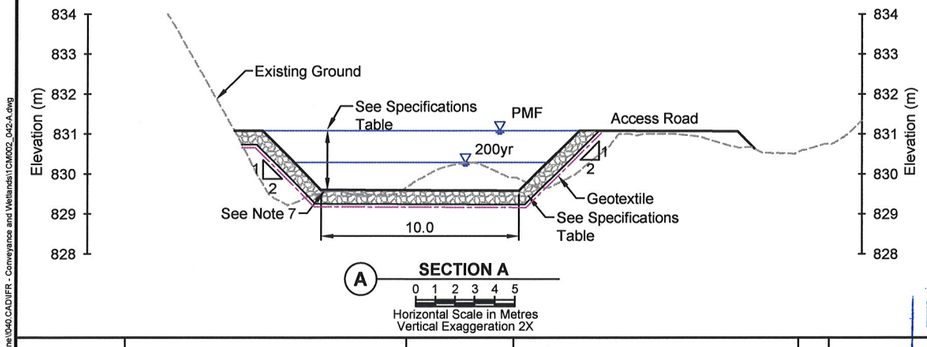
Scale in Metres




**PROFILE**
**A CONVEYANCE CHANNEL**

0 5 10 15 20 25
Scale in Metres

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YUKON
ALEJANDRO MUNOZ SAAVEDRA
TERRITORY
2/05/2018

**LEGEND**

- Conveyance Channel Design
- Channel Fill
- Channel Excavation
- Phase VIVI Infrastructure (Existing and Planned)
- Pit Lake Elevation
- Design Toes and Crests
- Flow Direction

**NOTES**

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Topographic surfaces shown are comprised of existing and designed surfaces.
4. Constructed channel specifications are provided in the specifications table as per each channel segment.
5. Rip Rap classification gradation tables are provided in Drawing CC-06.
6. Future mining activities may alter the topography of the channel alignment. SRK recommends that at future stages of closure design channel alignment and grades be re-assessed.
7. The base of the channel will be graded to create a thalweg in the centerline.
8. A light vehicle crossing is to be designed into the closure conveyance channel upon the completion of the channel construction. A swale crossing with 5:1 side slopes should be considered during detailed design and alignment selection.

**CHANNEL A SPECIFICATIONS:**

| Segment | Length (m) | Slope (%) | Minimum Channel Depth (m) | Channel Bottom Width (m) | Water Depth for 1:200 yrs (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 83 | -9.1 | 1.5 | 10.0 | 0.55 | 25 | 600 | 300 |
| 2 | 159 | -4.0 | 1.5 | 10.0 | 0.70 | 10 | 400 | 200 |
| 3 | 107 | -35.3 | 1.0 | 10.0 | 0.37 | 100 | 900 | 450 |

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| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE | NO. | DESCRIPTION | CHKD | APP'D | DATE | PROFESSIONAL ENGINEERS STAMP | |
| | | | | B | Issued for Review | SM | VM | 15JUN18 | | |
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| SM | VM | 2018/01/16 |

FILE NAME: 1CM002_042-A.dwg

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MINTO EXPLORATIONS Ltd.

SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE: Channel A

DRAWING NO. CC-02 | SHEET 3 OF 12 | REVISION NO. B

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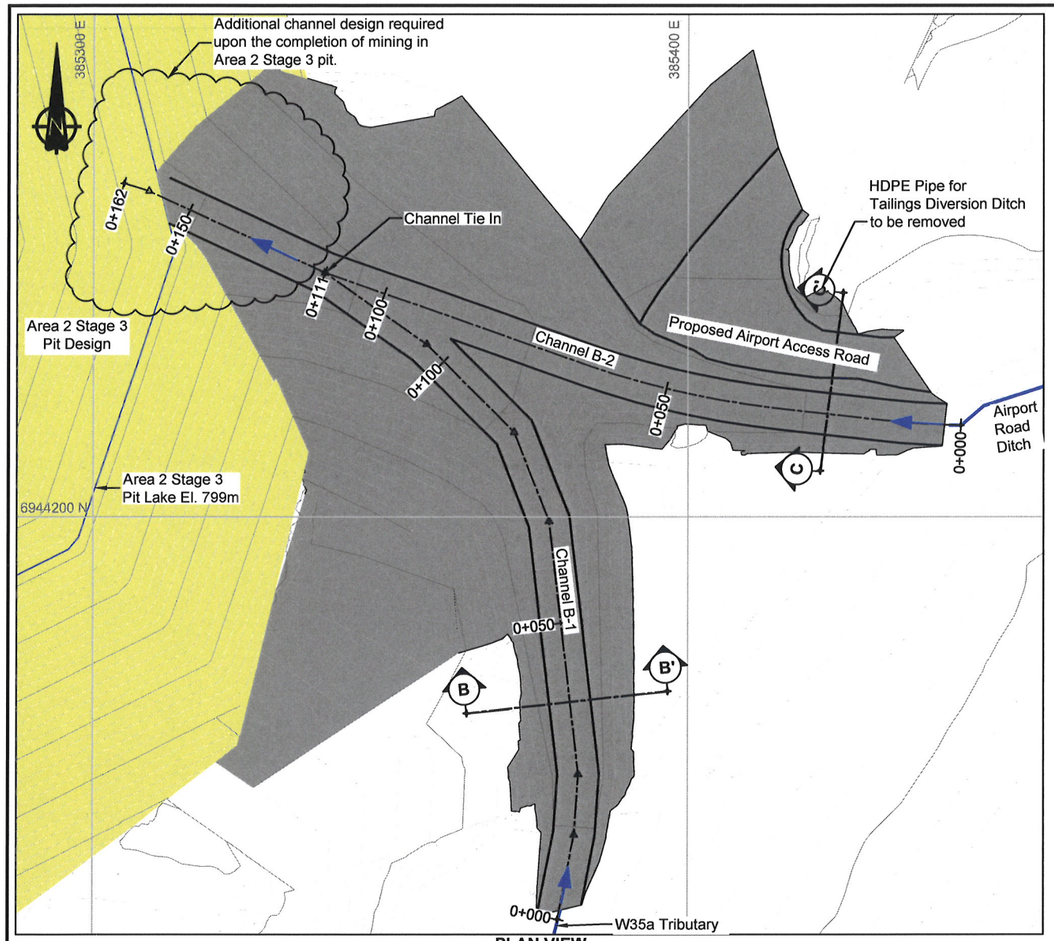



**PLAN VIEW**
**B CONVEYANCE CHANNEL**

0 5 10 15 20 25
Scale in Metres

## LEGEND

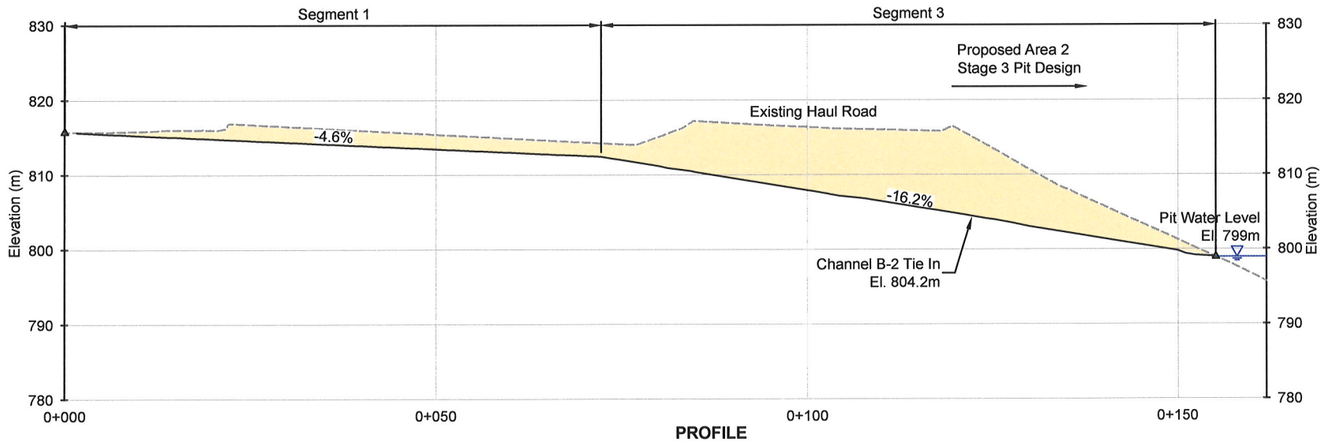
- Conveyance Channel Design
- Channel Fill
- Channel Excavation
- Phase VIVI Infrastructure (Existing and Planned)
- Pit Lake Elevation
- Access Roads, Design Toes & Crests
- Flow Direction

## NOTES

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Topographic surfaces are comprised of existing and designed surfaces.
4. Swale crossing design for light vehicle access to be designed later.
5. Rip Rap classification gradation tables are provided in Drawing CC-06.
6. The base of the channel will be graded to create a thalweg in the centerline.

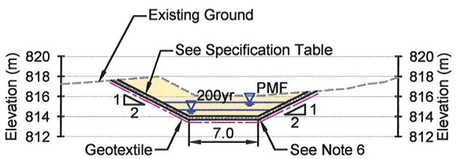
## CHANNEL B SPECIFICATIONS:

| Segment | Length (m) | Slope (%) | Minimum Channel Depth (m) | Channel Bottom Width (m) | Water Depth for 1:200 yrs (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 72 | -4.6 | 1.35 | 7.00 | 0.64 | 10 | 400 | 200 |
| 2 | 52 | -6.4 | 1.23 | 7.00 | 0.59 | 25 | 600 | 300 |
| 3 | 83 | -16.2 | 1.00 | 7.00 | 0.45 | 100 | 900 | 450 |
| 4 | 56 | -16.2 | 1.00 | 7.00 | 0.45 | 100 | 900 | 450 |



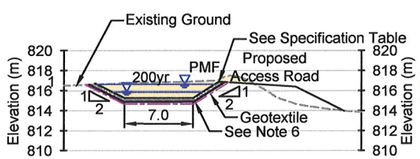

**PROFILE**
**B-1 CONVEYANCE CHANNEL**

0 4 8 12 16 20
Scale in Metres



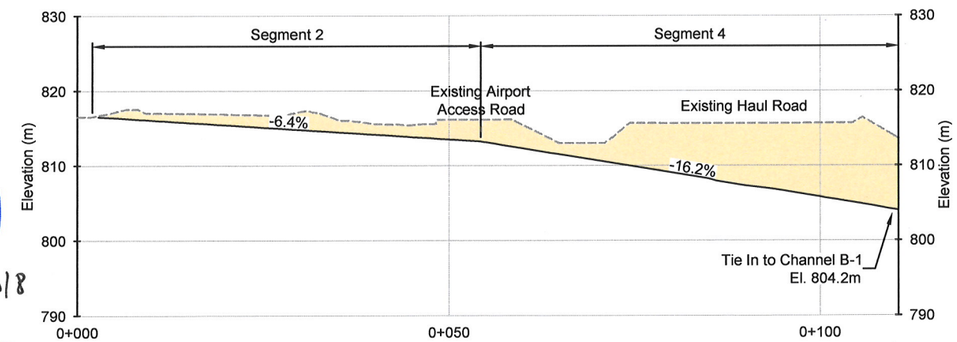

**SECTION B**
**TYPICAL SECTION**

0 2 4 6 8 10
Horizontal Scale in Metres




**SECTION C**
**TYPICAL SECTION**

0 2 4 6 8 10
Horizontal Scale in Metres




**PROFILE**
**B-2 CONVEYANCE CHANNEL**

0 4 8 12 16 20
Scale in Metres

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Date 2/06/2018
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| SM | VM | 2018/01/16 |

FILE NAME: 1CM002_042-A&B.dwg

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SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE: Channel B

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CC-03 | 4 OF 12 | B |

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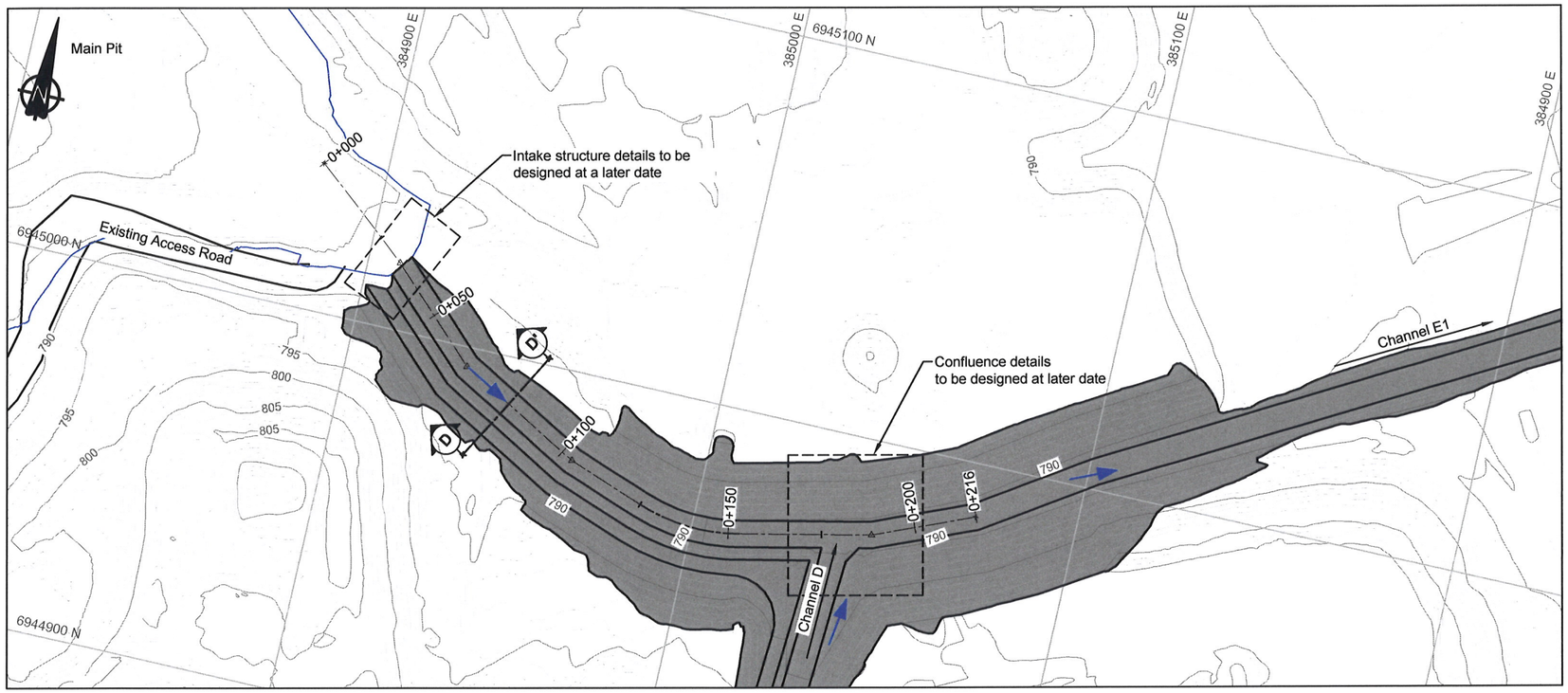



**LEGEND**

- Conveyance Channel Design
- Channel Fill
- Channel Excavation
- Water Elevation
- Design Toes & Crests
- Flow Direction

**NOTES**

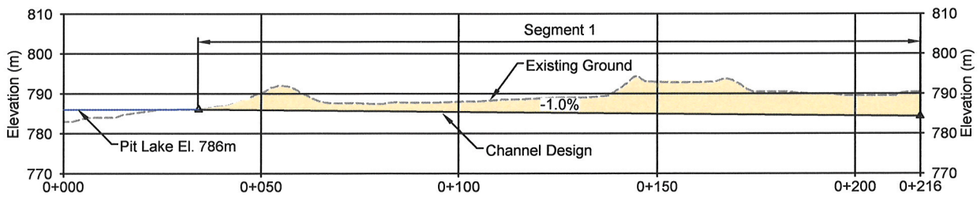
1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. The base of the channel will be graded to create a thalweg in the centerline.

**PLAN VIEW CHANNEL C**

0 5 10 15 20 25
Scale in Metres

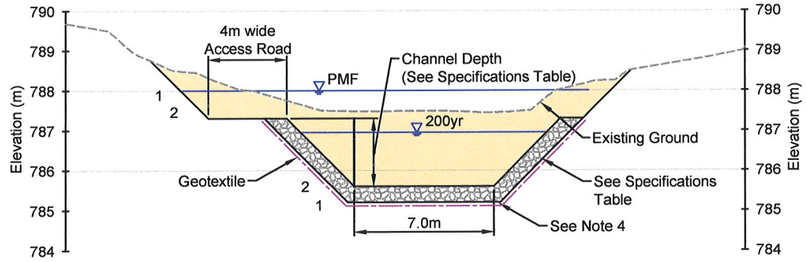
**CHANNEL C SPECIFICATIONS:**

| Segment | Length (m) | Slope (%) | Minimum Channel Depth (m) | Channel Bottom Width (m) | Water Depth for 1:200 yrs (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 182 | -1.0 | 1.70 | 7.00 | 1.35 | 10 | 400 | 200 |




**PROFILE CHANNEL C**

0 5 10 15 20 25
Scale in Metres




**SECTION D TYPICAL SECTION**

0 1 2 3 4 5
Horizontal Scale in Metres
Vertical Exaggeration 2X

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Date 2/06/2018
PERMIT NUMBER: PP019
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SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE: Channel C

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CC-04 | 5 OF 12 | B |

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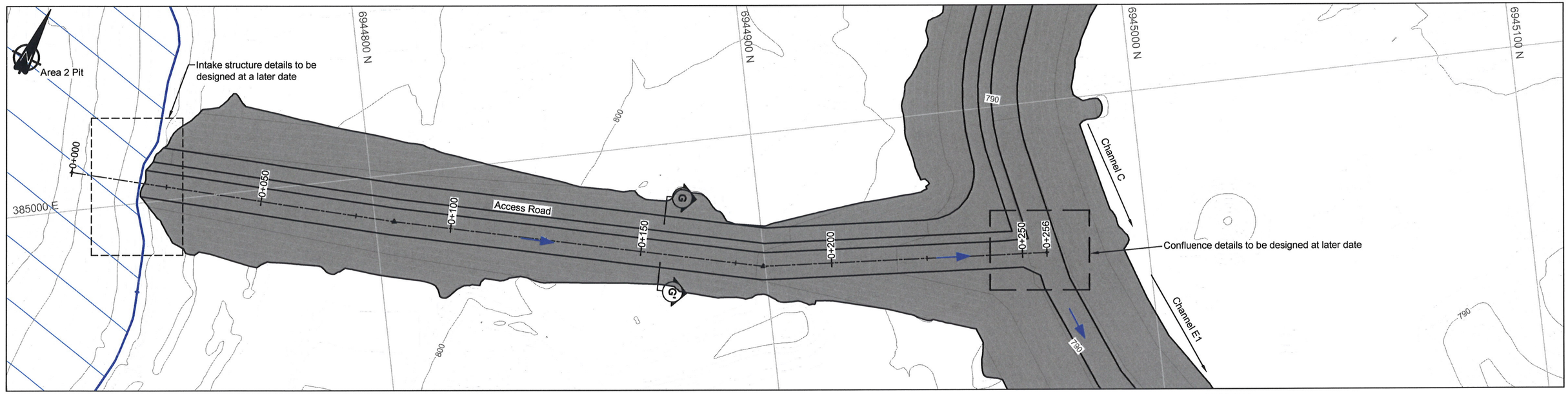
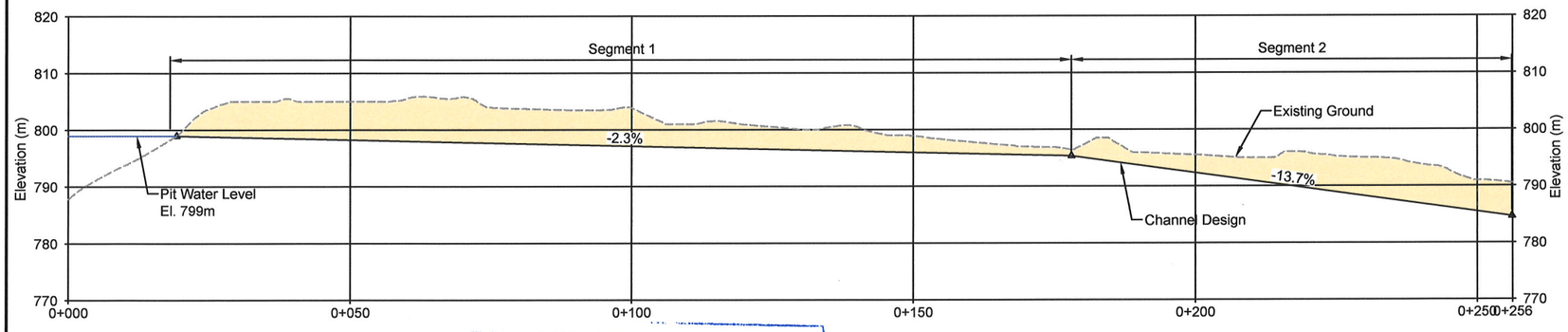



## PLAN VIEW CHANNEL D

0 5 10 15 20 25
Scale in Metres




## PROFILE CHANNEL D

0 5 10 15 20 25
Scale in Metres

**CHANNEL D SPECIFICATIONS:**

| Segment | Length (m) | Slope (%) | Minimum Channel Depth (m) | Channel Bottom Width (m) | Water Depth for 1:200 yrs (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 160 | -2.3 | 2.10 | 7.00 | 1.80 | 10 | 400 | 200 |
| 2 | 78 | -13.70 | 1.40 | 7.00 | 1.10 | 100 | 900 | 450 |

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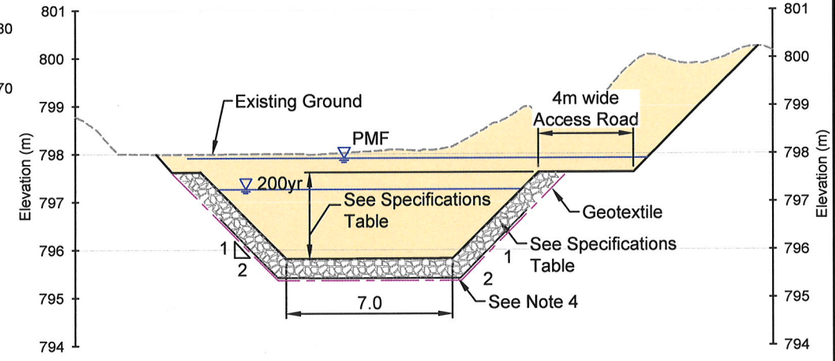
## LEGEND

- Conveyance Channel Design
- Channel Fill
- Channel Excavation
- Pit Lake Elevation
- Design Toes & Crests
- Flow Direction

## NOTES

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Access road paralleling channel to be connected with the site wide access roads for mine closure.
4. Rip Rap classification gradation tables are provided in Drawing CC-06.
5. The base of the channel will be graded to create a thalweg in the centerline.




G SECTION G

0m 1 2 3 4 5
Horizontal Scale in Metres
Vertical Exaggeration 2X

| DRAWING NO. | DRAWING TITLE | DRAWING NO. | DRAWING TITLE |
|---|---|---|---|

REFERENCE DRAWINGS

| NO. | DESCRIPTION | CHKD | APPD | DATE |
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SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE: Channel D

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CC-05 | 6 OF 12 | B |

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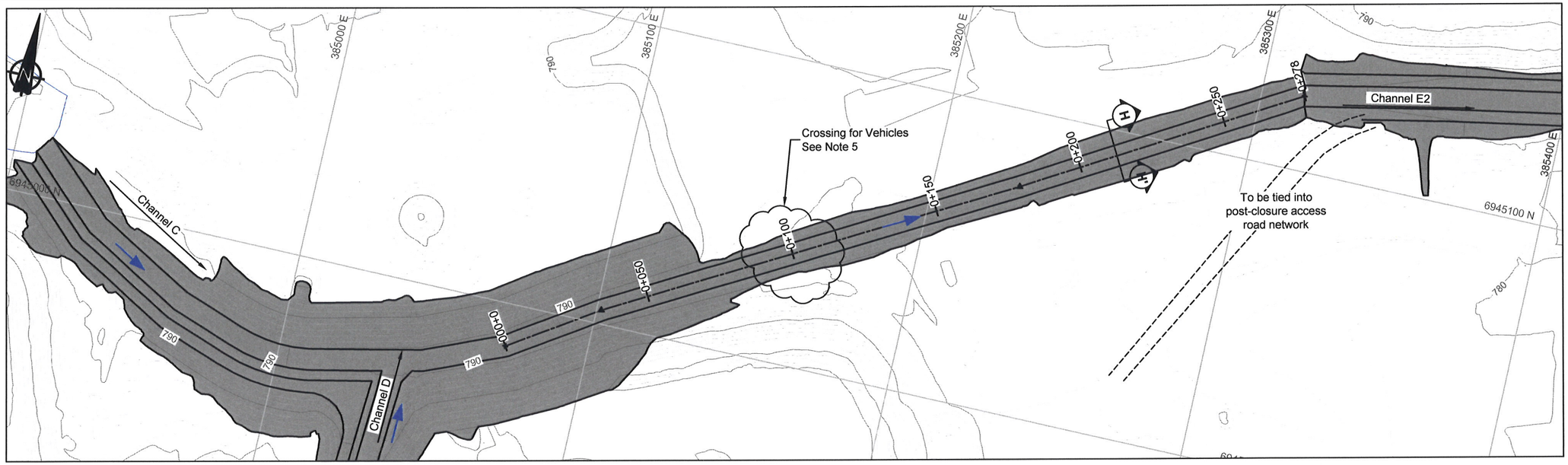



## LEGEND

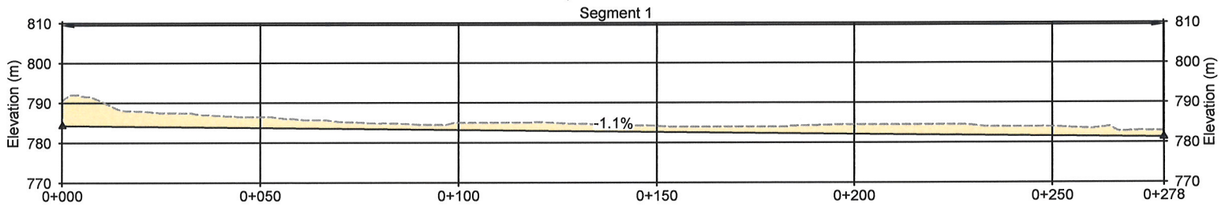
- Conveyance Channel Design
- Channel Excavation
- Design Toes & Crests
- Flow Direction

## NOTES

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Channel E is constructed as a typical channel. The base of the channel will be graded to create a thalweg in the centerline.
4. A light vehicle crossing is to be designed into the closure conveyance channel upon the completion of the channel construction. A swale crossing with 5:1 side slopes should be considered during design and alignment selection.
5. Surrounding area along Channel E1 graded to create a valley bottom. PMF will be conveyed downstream to Channel E2.
6. Segment 1 and Segment 3 set to a minimum freeboard of 10cm because of topographical constraint.

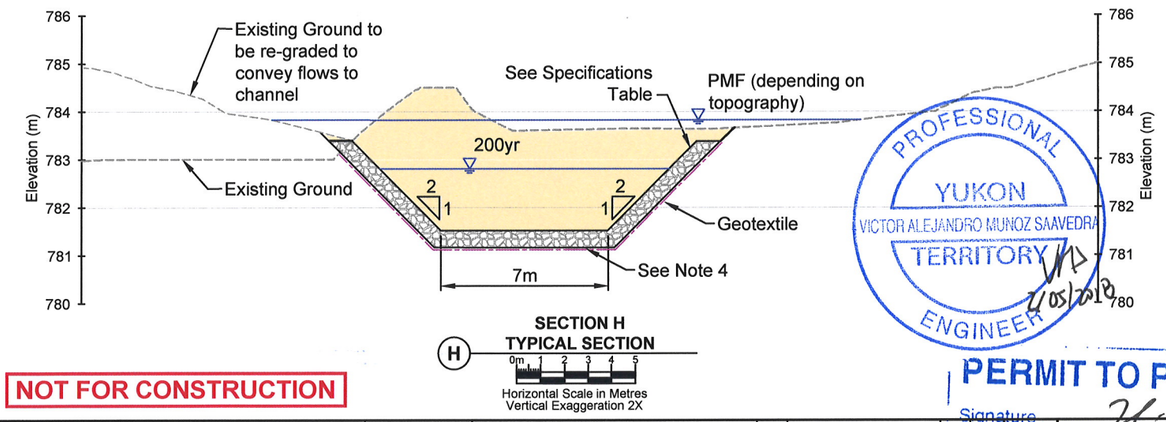
## PLAN VIEW CHANNEL E1

0 5 10 15 20 25
Scale in Metres




## PROFILE CHANNEL E1

0 5 10 15 20 25
Scale in Metres




## SECTION H
## TYPICAL SECTION

Horizontal Scale in Metres
Vertical Exaggeration 2X

### 10 kg CLASS - RIP RAP

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 300 |
| $D_{85}$ | 280 |
| $D_{50}$ | 200 |
| $D_{15}$ | 90 |
| Layer Thickness | 400 |

### 25kg CLASS - RIP RAP

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 450 |
| $D_{85}$ | 380 |
| $D_{50}$ | 300 |
| $D_{15}$ | 130 |
| Layer Thickness | 600 |

### 100 kg CLASS - RIP RAP

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 680 |
| $D_{85}$ | 610 |
| $D_{50}$ | 450 |
| $D_{15}$ | 200 |
| Layer Thickness | 900 |

### 250kg CLASS - RIP RAP

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 900 |
| $D_{85}$ | 820 |
| $D_{50}$ | 600 |
| $D_{15}$ | 270 |
| Layer Thickness | 1200 |

### 500kg CLASS - RIP RAP

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 1200 |
| $D_{85}$ | 1030 |
| $D_{50}$ | 800 |
| $D_{15}$ | 340 |
| Layer Thickness | 1600 |

### 1000kg CLASS - RIP RAP

| Material Type | Rip Rap Dia. (mm) |
|---|---|
| $D_{100}$ | 1500 |
| $D_{85}$ | 1300 |
| $D_{50}$ | 1000 |
| $D_{15}$ | 420 |
| Layer Thickness | 2000 |

## CHANNEL E SPECIFICATIONS:

| Segment | Length (m) | Slope (%) | Minimum Channel Depth (m) | Channel Bottom Width (m) | Water Depth for 1:200 yrs (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 278 | -1.1 | 2.0 | 7.0 | 1.82 | 10 | 400 | 450 |
| 2 | 260 | -6.2 | 2.0 | 7.0 | 1.26 | 100 | 900 | 450 |
| 3 | 98 | -1.4 | 2.0 | 7.0 | 1.89 | 100 | 900 | 450 |
| 4 | 92 | -5.8 | 2.0 | 7.0 | 1.28 | 100 | 900 | 450 |
| 5 | 92 | -6.3 | 2.0 | 7.0 | 1.26 | 100 | 900 | 450 |
| 6 | 105 | -4.1 | 2.0 | 7.0 | 1.41 | 100 | 900 | 450 |
| 7 | 33 | -7.6 | 2.0 | 7.0 | 1.19 | 250 | 1200 | 600 |
| 8 | 46 | -5.1 | 2.0 | 7.0 | 1.33 | 100 | 900 | 450 |
| 9 | 150 | -20.7 | 2.0 | 7.0 | 0.90 | 1000 | 2000 | 1000 |
| 10 | 40 | -0.05 | 3.3 | 20.0 | 1.50 | 100 | 900 | 300 |

PROFESSIONAL ENGINEER
YUKON TERRITORY
VICTOR ALEJANDRO MUNOZ SAAVEDRA
4/05/2018

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SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE: Channel E1

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CC-06 | 7 OF 12 | B |

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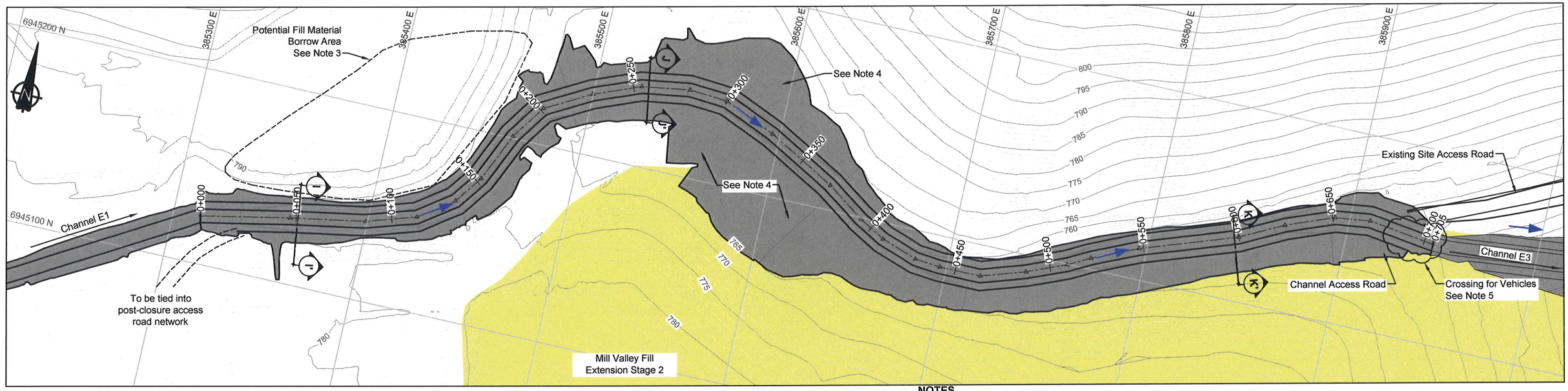



**LEGEND**

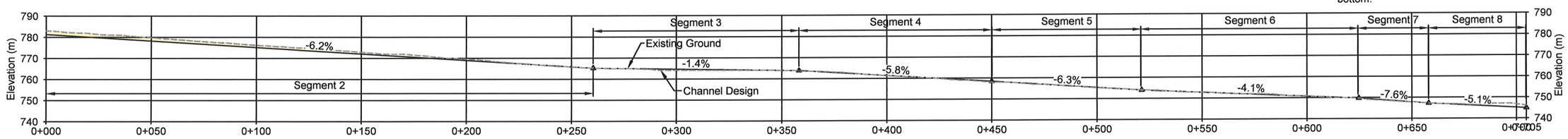
- Conveyance Channel Design
- Phase VIVI Infrastructure (Existing and Planned)
- Channel Excavation
- Design Toes & Crests
- Flow Direction

**PLAN VIEW CHANNEL E2**

0 10 20 30 40 50
Scale in Metres

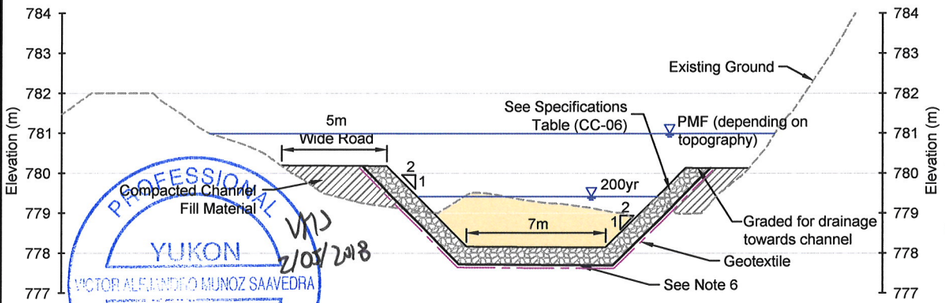
**NOTES**

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Extents and depth of the potential fill material borrow area has not be defined for this stage of design. Area identified as a potential source due to overburden / fill thickness.
4. Backfill and regrade required to convey surface water to conveyance channel
5. A light vehicle crossing is to be designed into the closure conveyance channel upon the completion of channel construction. A swale crossing with 5:1 side slopes should be considered during design and alignment selection.
6. The base of the channel will be graded to create a thalweg in the centerline
7. Surrounding area along Channel E2 to be graded to create a valley bottom.



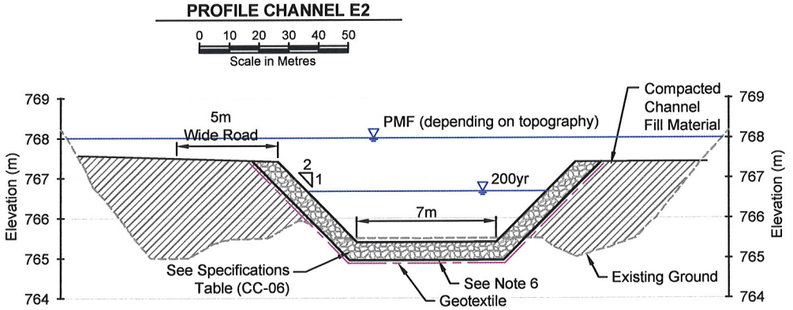

**PROFILE CHANNEL E2**

0 10 20 30 40 50
Scale in Metres



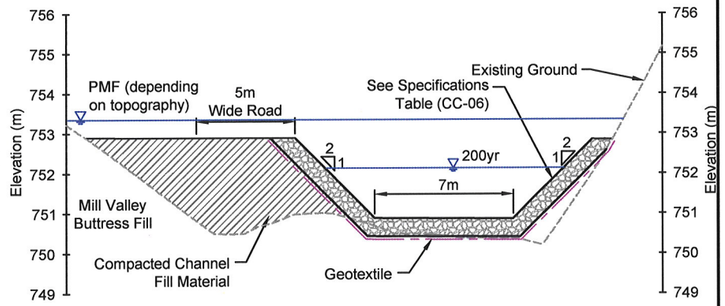

**SECTION I**

0 2 4 6 8 10
Horizontal Scale in Metres
Vertical Exaggeration 2X




**SECTION J**

0 2 4 6 8 10
Horizontal Scale in Metres
Vertical Exaggeration 2X




**SECTION K**

0 2 4 6 8 10
Horizontal Scale in Metres
Vertical Exaggeration 2X

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|---|---|---|---|
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| CHECKED: SM | APPROVED: VM | DATE: 2018/01/16 |

FILE NAME: 1CM002_042-1.dwg

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MINTO EXPLORATIONS Ltd.

SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE: Channel E2

| DRAWING NO. | SHEET | REVISION NO. |
|---|---|---|
| CC-07 | 8 OF 12 | B |

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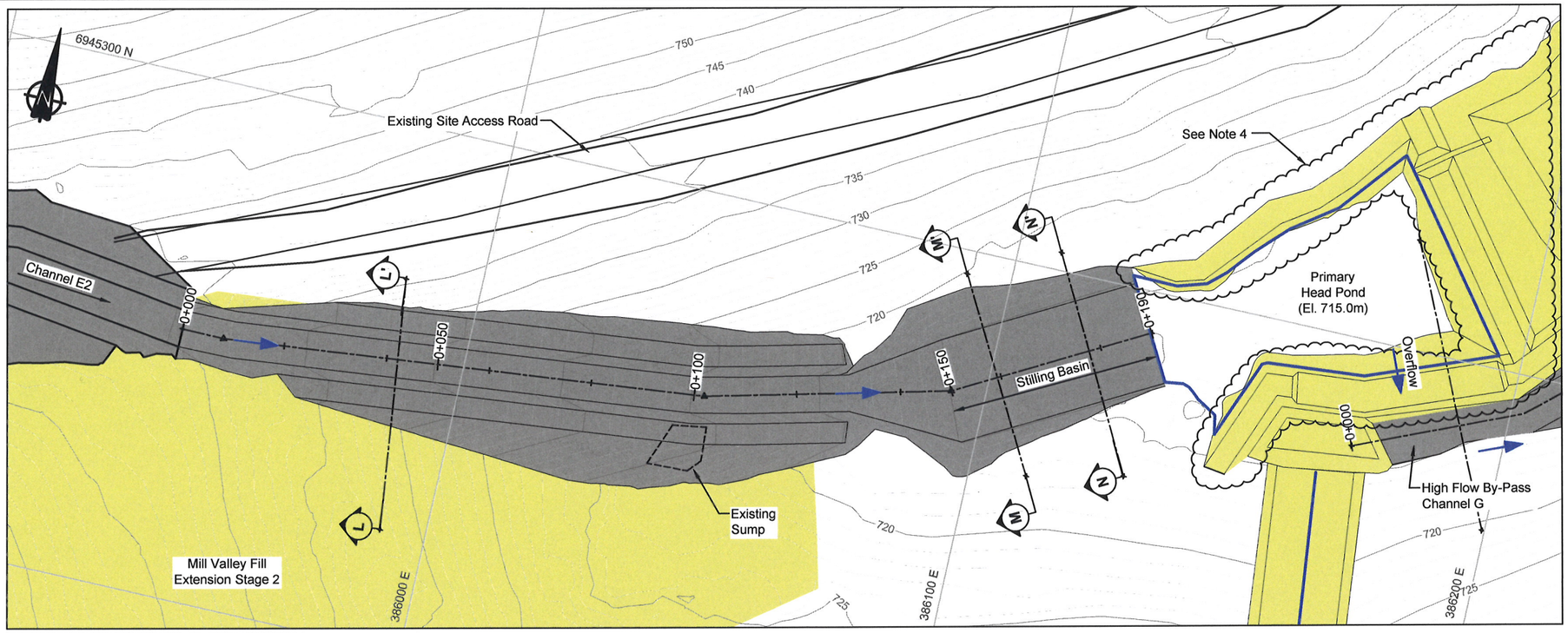
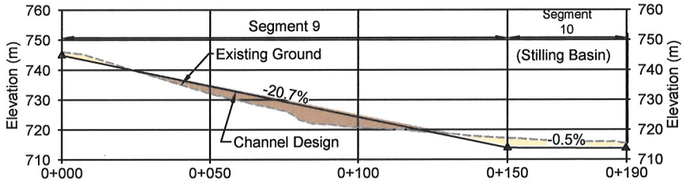



## LEGEND

- Conveyance Channel Design
- Channel Foundation Fill
- Channel Excavation
- Phase VIVI Infrastructure (Existing and Planned)
- Design Toes & Crests
- Flow Direction

## NOTES

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Stilling basin design rip rap specifications are located in the specifications tables in Drawing CC-06.
4. Wetland Infrastructure Design prepared by SRK. Refer to Wetland Infrastructure Design Report (SRK 2016).
5. The base of the channel will be graded to create a thalweg in the centerline
6. Surrounding area along Channel E3 graded to create a valley bottom. PMF will be conveyed downstream to the stilling basin.




**PROFILE CHANNEL E3**

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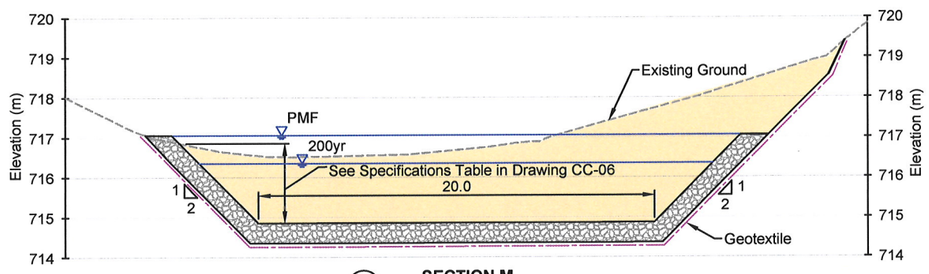
Scale in Metres

**PLAN VIEW CHANNEL E3**

0 5 10 15 20 25
Scale in Metres




**M SECTION M**

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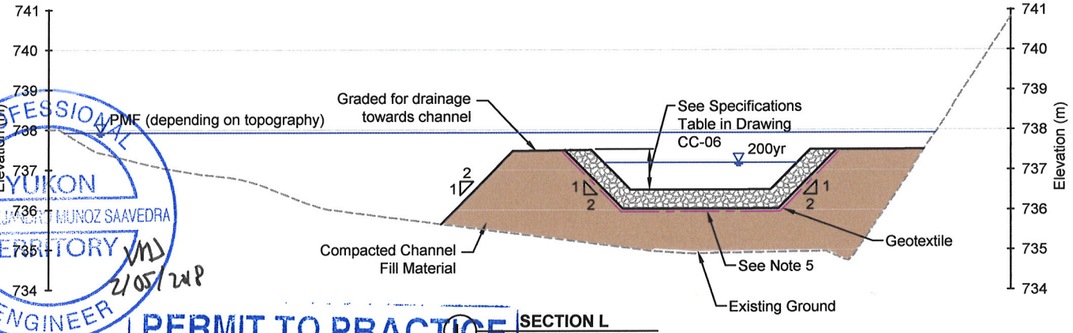
Horizontal Scale in Metres
Vertical Exaggeration 2X




**L SECTION L**

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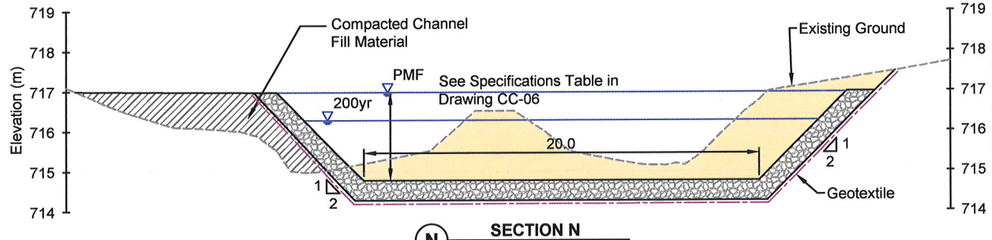
Horizontal Scale in Metres
Vertical Exaggeration 2X




**N SECTION N**

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Horizontal Scale in Metres
Vertical Exaggeration 2X

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FILE NAME: 1CM002_042-1.dwg

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SRK JOB NO.: 1CM002.042

Closure Conveyance Design

DRAWING TITLE:
Channel E3
and Stilling Basin

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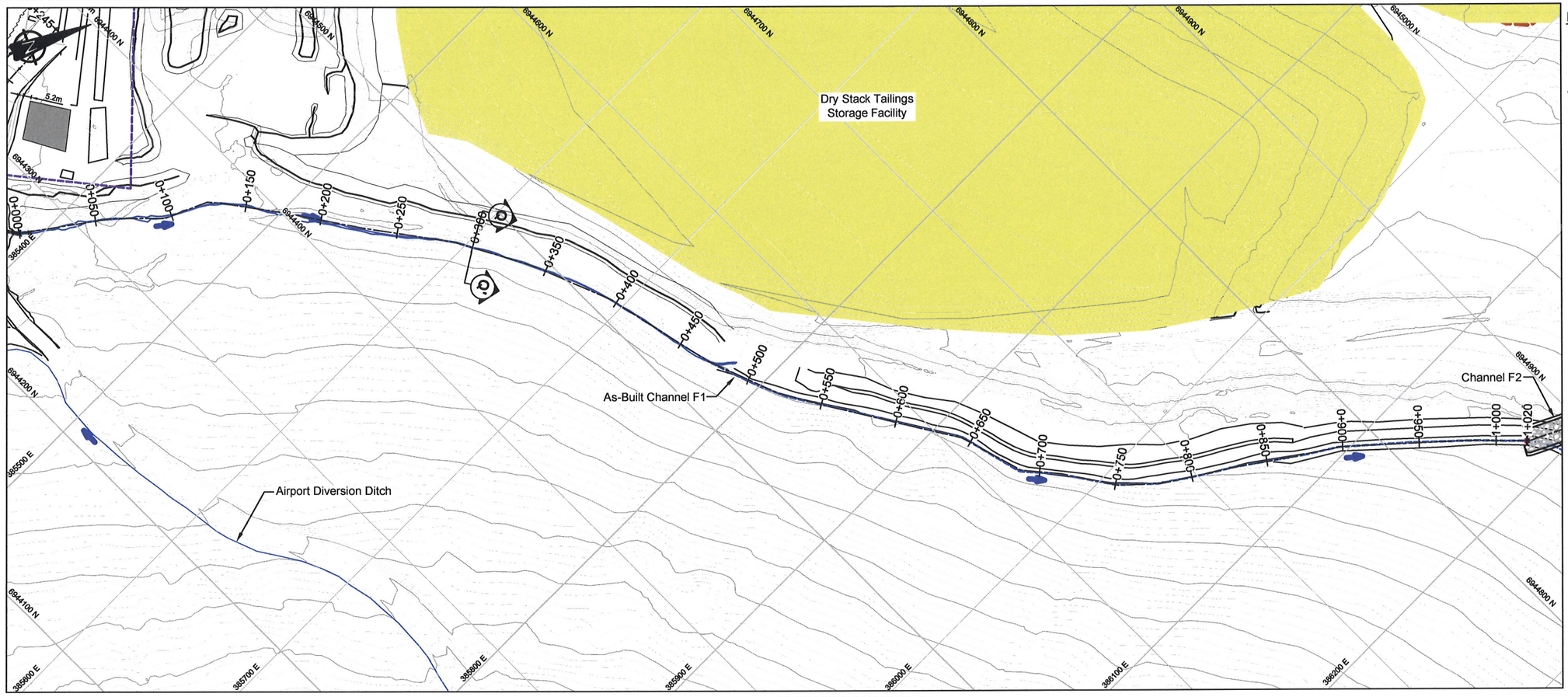


**PLAN VIEW CHANNEL F1**

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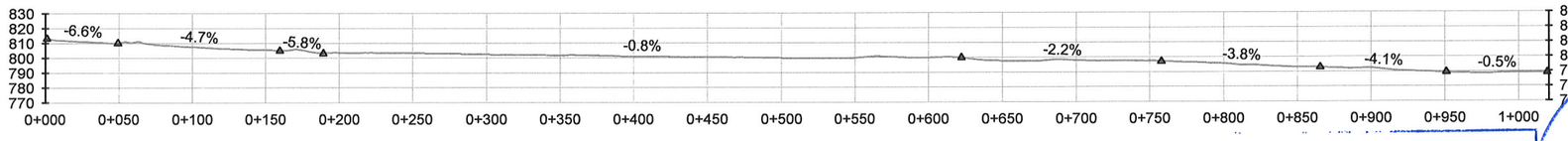


**AS-BUILT PROFILE CHANNEL F1**

0m 20 40 60 80

## LEGEND

- Existing Major Contour
- Existing Minor Contour
- Diversion Channel (existing)
- Diversion Channel (design by others)
- Excavation Limits
- Water Flow Direction
- Phase VIVI Infrastructure (Existing and Planned)

## NOTES

1. Existing topographic contours provided by Minto dated August 2017.
2. Contour interval is 1m.

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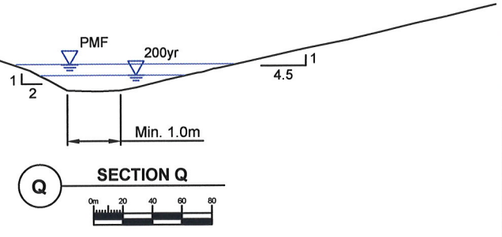
2/05/2018




**SECTION Q**

0m 20 40 60 80

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| B | Issued for Discussion | - | - | 7Aug13 |
| A | Issued for Review | - | - | 6Jun13 |

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Closure Conveyance Design

DRAWING TITLE:
Channel F1
Existing Tailings Diversion Ditch

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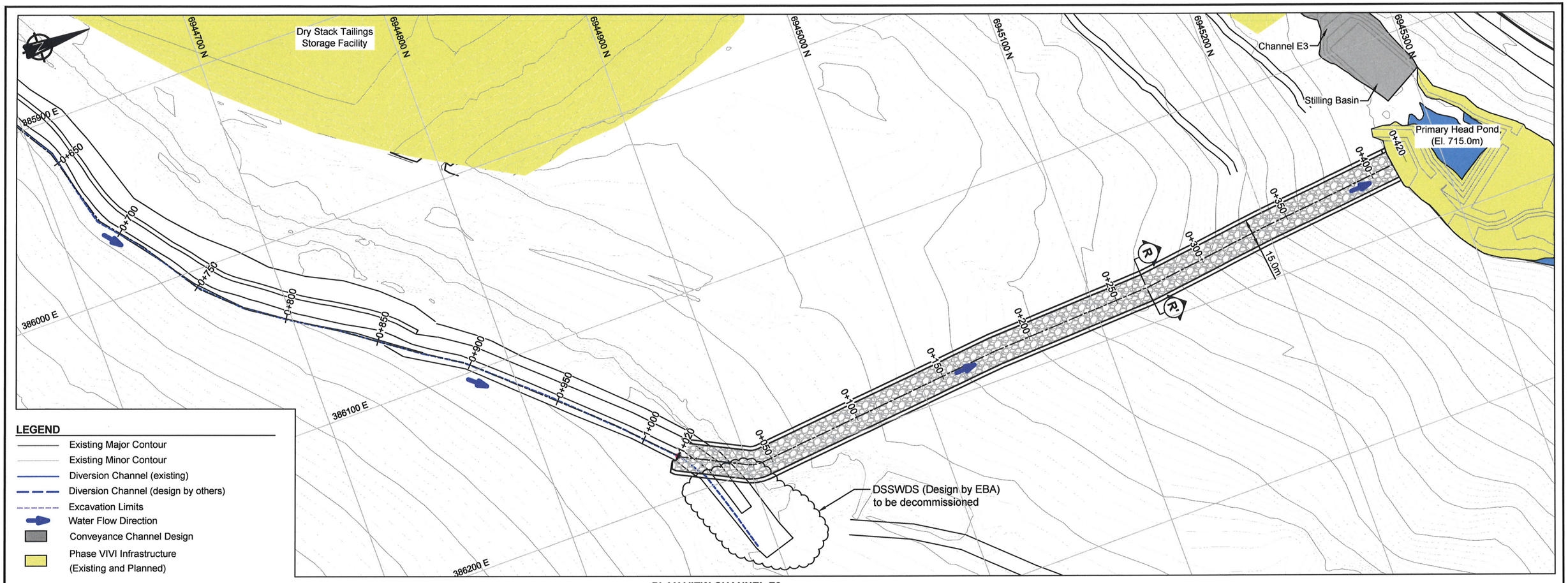
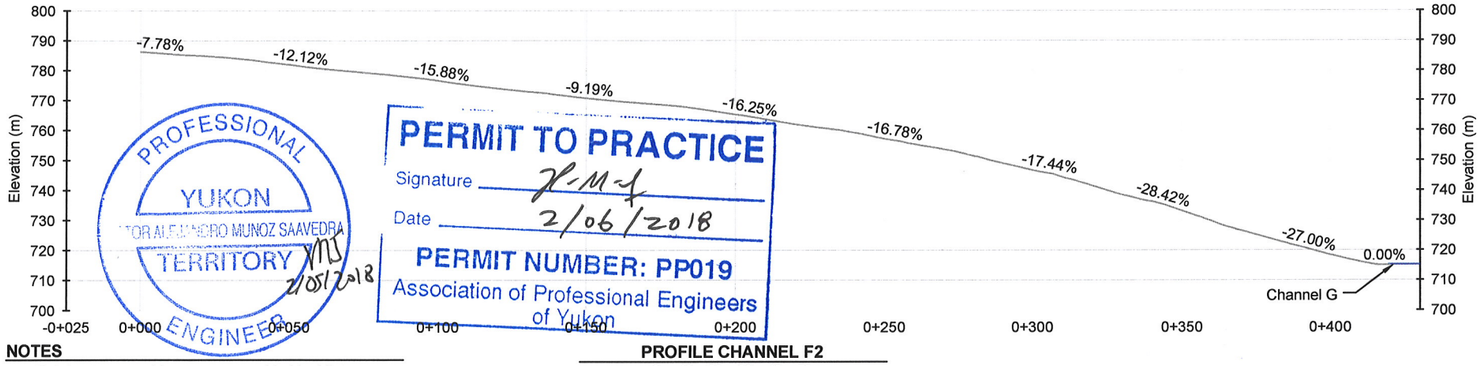



**LEGEND**

- Existing Major Contour
- Existing Minor Contour
- Diversion Channel (existing)
- Diversion Channel (design by others)
- Excavation Limits
- Water Flow Direction
- Conveyance Channel Design
- Phase VIVI Infrastructure (Existing and Planned)

**PLAN VIEW CHANNEL F2**

0 10 20 30 40 50
Scale in Metres




**PROFILE CHANNEL F2**

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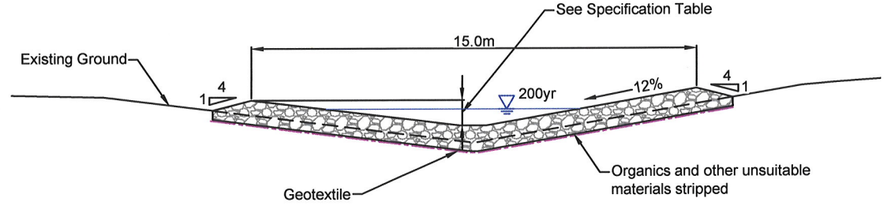
Scale in Metres




**SECTION R**

0 10 20 30 40 50
Scale in Metres

**CHANNEL F SPECIFICATIONS:**

| Length (m) | Minimum Channel Depth (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|
| 420 | 0.8 | 500 | 1600 | 800 |

**NOTES**

1. Existing topographic contours provided by Minto dated January 2014.
2. Contour interval is 1m.
3. Rip-rap sized for steepest grade (28.42%)

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Date 2/06/2018
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| D | Issued for Discussion | - | - | 28Jul14 |
| C | Issued for Discussion | - | - | 1Nov13 |
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DRAWING TITLE: Channel F2

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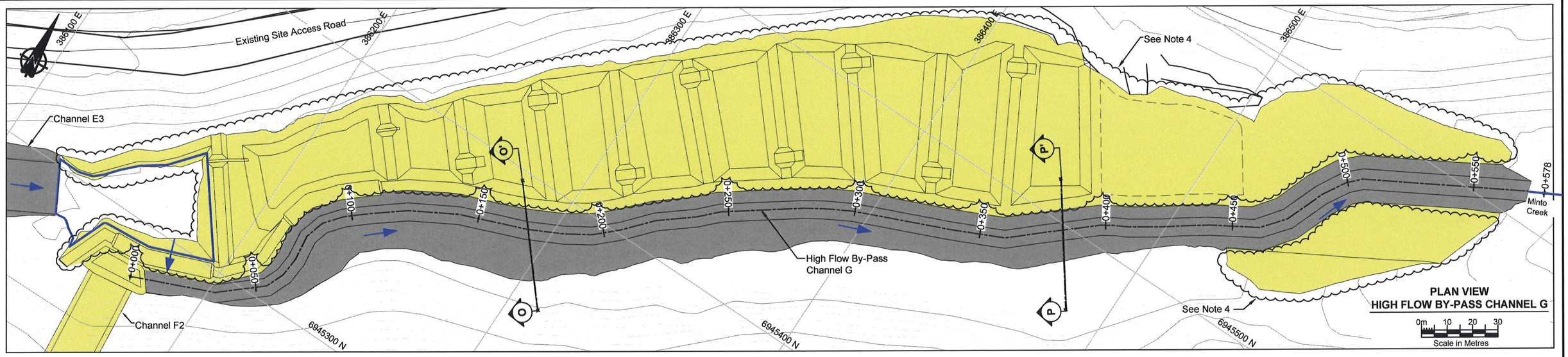
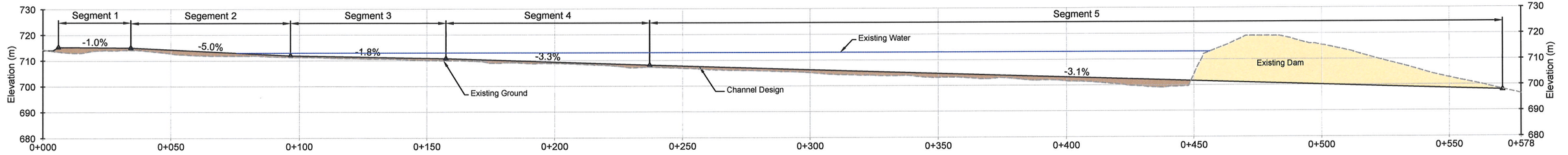


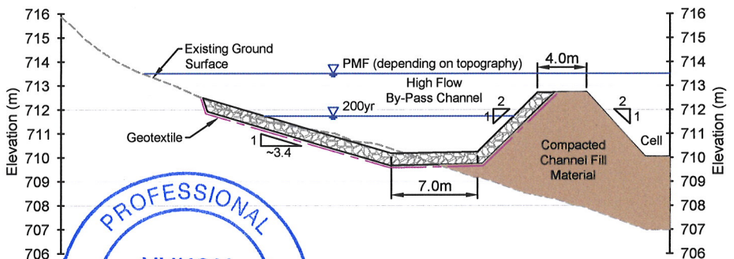

PLAN VIEW
HIGH FLOW BY-PASS CHANNEL G

0m 10 20 30
Scale in Metres



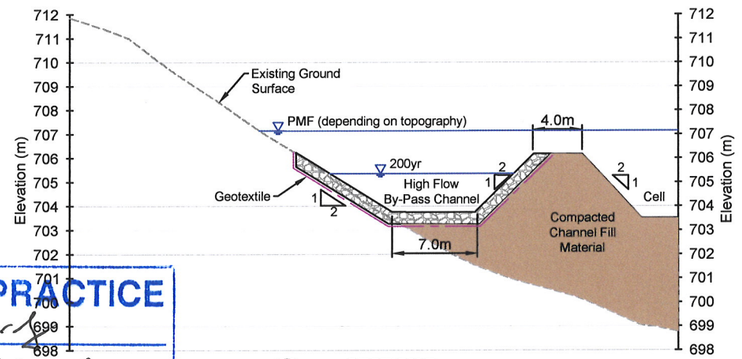

CENTRELINE PROFILE
HIGH FLOW BY-PASS CHANNEL G

0m 10 20 30
Scale in Metres




SECTION O

0 2 4 6 8 10
Scale in Metres




SECTION P

0 2 4 6 8 10
Scale in Metres
Horizontal Scale in Metres
Vertical Exaggeration 2X

## LEGEND

- Conveyance Channel Design
- Channel Foundation Fill
- Channel Excavation
- Designed Infrastructure (Not Constructed)
- Design Toes & Crests

## NOTES

1. Contour interval 1m.
2. Digital topographic surfaces have been provided by Minto Explorations Ltd.
3. Wetland Infrastructure Design prepared by SRK. Refer to Wetland Infrastructure Design Report (SRK 2016).
4. 200 year channel depth along channel varies depending on topography.

## CHANNEL HIGH FLOW BY-PASS CHANNEL SPECIFICATIONS:

| Segment | Length (m) | Slope (%) | Minimum Channel Depth (m) | Channel Bottom Width (m) | Rip-rap Class (kg) | Rip-rap Thickness (mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 28 | -1.0 | 2.5 | 7.0 | 25 | 600 | 300 |
| 2 | 62 | -5.0 | 2.0 | 7.0 | 25 | 600 | 300 |
| 3 | 61 | -1.8 | 2.0 | 7.0 | 25 | 600 | 300 |
| 4 | 84 | -3.3 | 2.0 | 7.0 | 25 | 600 | 300 |
| 5 | 334 | -3.1 | 2.0 | 7.0 | 25 | 600 | 300 |

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YUKON TERRITORY
VICTOR ALEJANDRO MUNOZ SAAVEDRA
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Closure Conveyance Design

DRAWING TITLE:
High Flow By-Pass Channel G

DRAWING NO. CC-11 | SHEET 12 OF 12 | REVISION NO. B

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# Appendix B – Site-Specific Hydrology Review

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www.srk.com

# Memo

| | | | |
|---|---|---|---|
| **To:** | Ryan Herbert, Minto Explorations Ltd. | **Client:** | Minto Explorations Ltd. |
| **From:** | Samantha Barnes<br>Victor Muñoz S.<br>Francis Smith | **Project No:** | 1CM002.042 |
| **Cc:** | Dylan MacGregor, SRK | **Date:** | August 3, 2016 |
| **Subject:** | Site-Specific Hydrology Review, Minto Mine, Yukon | | |

# 1 Introduction

SRK Consulting (Canada) Inc. has prepared an updated closure water conveyance plan design report for Minto Mine (Minto) located in Yukon, Canada, and operated by Minto Explorations Ltd. In support of the updates to the conveyance designs, SRK reviewed and updated site-wide hydrology models to include potential influences resulting from future climate change and alterations to watershed catchment areas. Inputs to the modelling are listed as follows:

- Rainfall depths for short duration storms for return periods ranging from the 1:2 through the 1:200 year precipitation event
- Maximum snowmelt depth expected over a 24-hour period
- Probable maximum precipitation (PMP) over a 24-hour period
- Hydrological curve number calibrated for regional catchment
- Hydrologic modelling approach to estimate peak flows for each structure

This memorandum outlines the formulation of inputs required for the closure conveyance designs.

# 2 Supporting Information from Public Databases

Regional historic precipitation data was obtained from the Meteorological Service of Canada (MSC) division of Environment Canada (EC 2015a). Regional stations were included in the studies for short duration rainfall, mean annual precipitation (MAP) and probable maximum precipitation (PMP).

Regional daily hydrometric data was obtained from the Water Survey of Canada (WSC) within an approximate 300 km radius surrounding the site for the unit peak flow analysis (EC 2015b).

Precipitation intensity–duration-frequency (IDF) estimation was derived utilizing short-duration rainfall IDF statistics obtained from the Government of Canada's Engineering Climate Dataset (Government of Canada 2016).

# 3 Precipitation

## 3.1 Mean Annual Precipitation

Regional regression analyses were performed using the 20 nearest MSC meteorological stations. RStudio® software (version 3.2.3; i386 - w64) was used to calculate mean annual precipitation for each station. Table 3-1 presents the station locations, distance relative to the site and their respective MAP estimates.

**Table 3-1: Regional Meteorological Stations and MAP**

| Station Name | Longitude | Latitude | MAP [mm] | Elevation | Distance |
|---|---|---|---|---|---|
| PELLY RANCH | −137.4 | 62.8 | 309 | 454 | 23 |
| CARMACKS | −136.3 | 62.1 | 282 | 525 | 75 |
| STEWART CROSSING | −136.7 | 63.4 | 332 | 480 | 89 |
| MCQUESTEN | −137.5 | 63.6 | 349 | 458 | 109 |
| MAYO A | −135.9 | 63.6 | 304 | 504 | 131 |
| STEWART RIVER | −139.4 | 63.3 | 294 | 358 | 136 |
| DRURY CREEK | −134.4 | 62.2 | 373 | 609 | 154 |
| SNAG A | −140.4 | 62.4 | 366 | 587 | 165 |
| ELSA | −135.5 | 63.9 | 430 | 814 | 170 |
| KENO HILL | −135.2 | 63.9 | 585 | 1473 | 178 |
| DAWSON A | −139.1 | 64.0 | 323 | 370 | 184 |
| BEAVER CREEK A | −140.9 | 62.4 | 413 | 649 | 188 |
| BEAVER CREEK YTG | −140.9 | 62.4 | 414 | 663 | 189 |
| ANVIL | −133.4 | 62.4 | 389 | 1158 | 200 |
| FARO A | −133.4 | 62.2 | 318 | 716 | 205 |
| KLONDIKE | −138.2 | 64.5 | 468 | 973 | 210 |
| CLINTON CREEK | −140.7 | 64.5 | 344 | 576 | 269 |
| OGILVIE RIVER | −138.3 | 65.4 | 340 | 597 | 310 |

Figure 3-1 includes a location map of the stations used in the MAP analysis. It also presents the subsequent regression analysis for MAP against elevation and the monthly precipitation distributions.

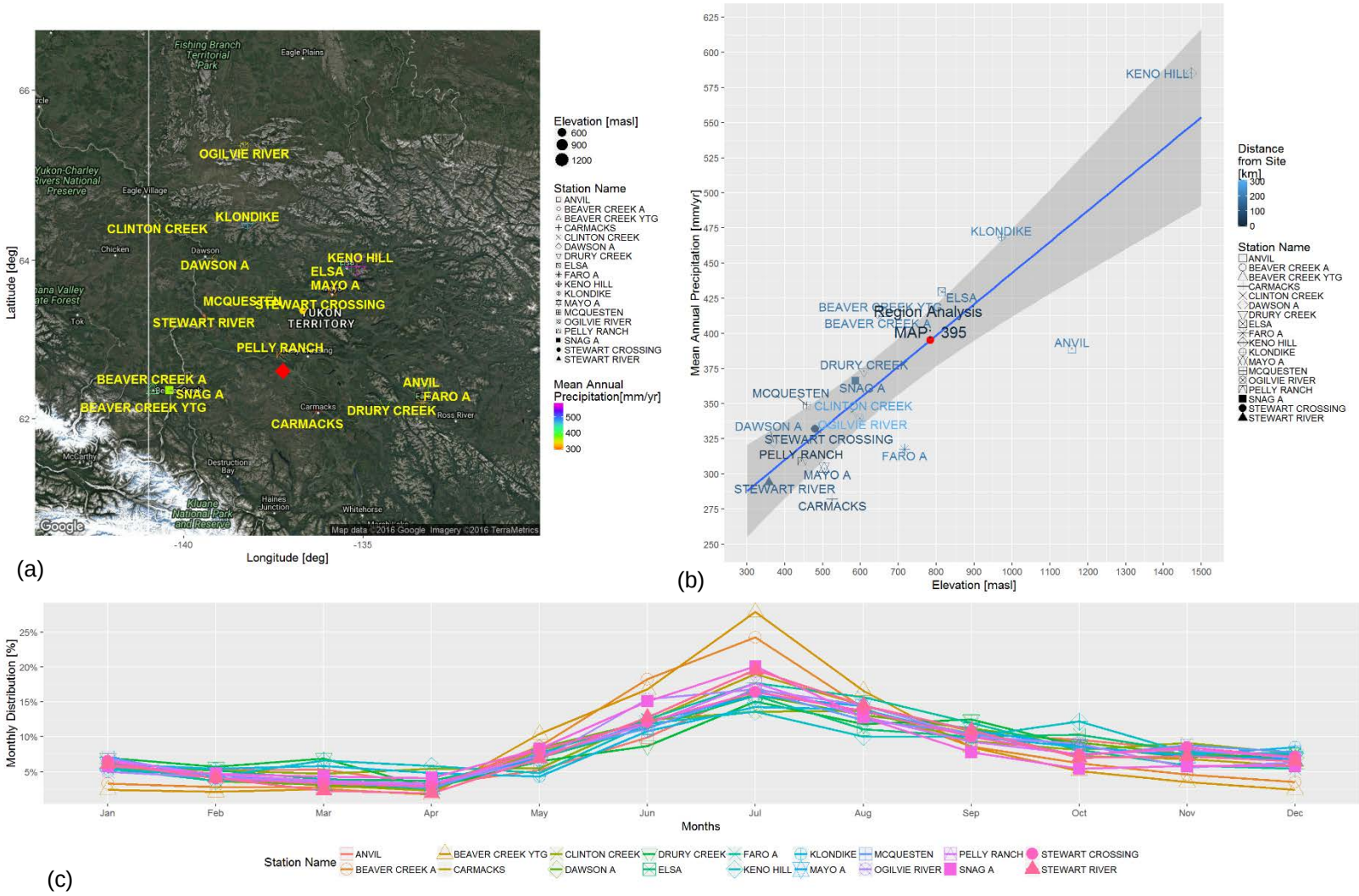


**Figure 3-1: MAP Analysis Station Locations (a), Regional Regression Analysis (b), and Monthly Precipitation Distributions (c)**

Based on the MAP versus elevation regression analysis and an average site elevation of 784 meters above sea level (masl), the MAP for Minto is estimated to be 395 mm.

## 3.2 Precipitation-Duration-Frequency Analysis

Short-duration storm analyses provide an estimation of the amount of precipitation expected for a storm return period ranging from 2 to 200 years with durations ranging from 5 minutes to 24 hours. A regional analysis was performed in order to understand the relationships between return period, duration, and rainfall for stations within close proximity to the site.

Using the results of the regional analysis, the precipitation-duration-frequency (PDF) data for the site was established using the following equation:

$$\text{Equation 1: } Pp_{Duration\ hrs.}^{Frequency\ years} = Pp_{24hrs.}^{10yrs} \cdot FF_{(Frequency)} \cdot DF_{(Duration)}$$

Where,

$Pp$ is the precipitation as a function of storm frequency and duration;

$Pp_{24hrs.}^{10yrs}$ is the precipitation in 24 hours with a return period of 10 years;

$FF$ are frequency factors, which correspond to the rate between precipitation associated with a defined frequency and the return period of 10 years; and

$DF$ are duration factors, which correspond to the rate between the defined storm duration and a storm duration of 24 hours.

Duration and frequency factors for a 1:10 year, 24-hour precipitation event were established from the regional analysis. The following sections discuss how the design precipitation event was developed using the frequency factors.

### 3.2.1 One-in-Ten Year 24-hour Precipitation Event

This analysis was performed using the RStudio software, and was conducted using data obtained from the Environment Canada meteorological stations (Environment Canada 2015a) located throughout the Yukon (Figure 3-1). Frequency analyses were performed for each station to estimate the 1:10 year, 24-hour–duration precipitation depth. These values were then correlated with elevation, latitude, and longitude. The strongest correlation was with longitude, which was used to establish the 1:10 year precipitation for the site (Figure 3-2).

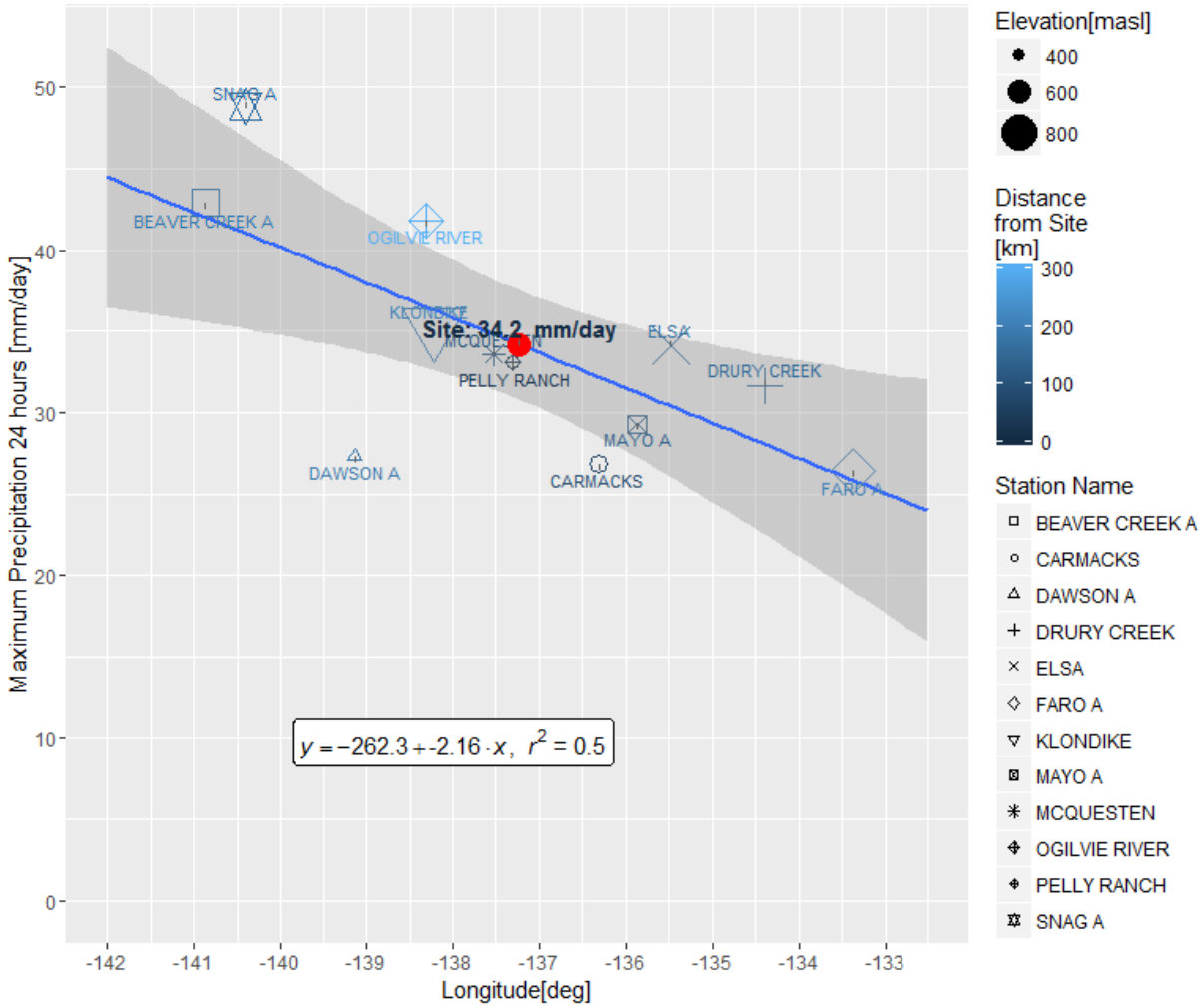


**Figure 3-2: Regional Analysis for the 1:10 Year 24-hour Duration Rainfall Event**

Based on the site longitude of −137.2 degrees, the 1:10 year 24-hour rainfall event is 34.2 mm.

### 3.2.2 Regional Intensity-Duration-Frequency Relationships

Five meteorological stations with IDF statistics all within 185 km of the site were located and are summarized in Table 3-2.

**Table 3-2: Summary of Meteorological Stations Used for Short Duration Storm Event Analysis**

| Station Name | Latitude | Longitude | Elevation | Years of Data |
|---|---|---|---|---|
| Mayo A | −135.9 | 63.6 | 503.8 | 22 |
| Pelly Ranch | −137.4 | 62.8 | 454.2 | 32 |
| Dawson A | −139.1 | 64.0 | 370.3 | 26 |
| Carmacks | −136.3 | 62.1 | 524.9 | 15 |
| Burwash A | −139.1 | 61.4 | 806.2 | 13 |

The frequency analyses were prepared considering the following probabilistic distributions: Normal, Log Normal, GEV, Gumbel, Pearson III, and Log Pearson III. The selection of the distribution parameters was prepared with the L-moments methodology.

The L-moments approach provides a more robust estimation to outliers when compared with typical estimations. The selection of the best-fit distribution was prepared based on four criteria: Akaike Information Criterion, Corrected Akaike Information Criterion, Anderson-Darling Criterion, and Bayesian Information Criterion, as described by (Laio, Di Baldassarre, and Montanari 2009). These best-fit distributions were implemented using RStudio.

The results from the frequency analyses were compiled into an IDF table for each station. Duration and frequency factors for each regional station were calculated using an iterative optimization process, such that the product of the two factors and the 1:10 year, 24-hour precipitation depth would equal the rainfall depth for a given duration and frequency, based on Equation 1. The results were then compared regionally to determine the appropriate factors to be applied to the site.

### Regional Trends in Duration Factors

The duration factors for each station were plotted against return period (Figure 3-3). The Burwash A station was found to behave differently from the other four stations, as shown in Figure 3-3. The Pearson distribution was used to determine whether the duration factors for each duration were related to the elevation, latitude, or longitude of the meteorological station. Regional analysis suggests this is likely due to the stations high elevation and geographic position within a valley immediately on the leeward side of the Saint Elias Mountains, with a greater orographic influence than the other stations and the project area, which are located further east within the lower elevation interior of Yukon. Consequently, the longitude of the site, −137.2 degrees, was used to establish the duration factors for each return period at site. Table 3-3 and Figure 3-3 present the duration factors established for each regional station and for the site.

**Table 3-3: Regional Analysis of Duration Factors**

| Station ID | Long. | Lat. | Elev. masl | Dist, km | Storm Duration | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 6 min | 10 min | 30 min | 1 hr | 2 hr | 3 hr | 6 hr | 12 hr | 24 hr |
| Mayo A | -135.87 | 63.62 | 503.80 | 131.10 | 0.20 | 0.26 | 0.29 | 0.34 | 0.37 | 0.45 | 0.61 | 0.78 | 1.00 |
| Pelly Ranch | -137.37 | 62.82 | 454.20 | 23.45 | 0.23 | 0.32 | 0.40 | 0.48 | 0.58 | 0.66 | 0.75 | 0.85 | 1.00 |
| Dawson A | -139.13 | 64.04 | 370.30 | 184.33 | 0.30 | 0.38 | 0.42 | 0.51 | 0.57 | 0.65 | 0.72 | 0.87 | 1.00 |
| Carmacks | -136.30 | 62.10 | 524.90 | 75.35 | 0.24 | 0.34 | 0.40 | 0.47 | 0.52 | 0.60 | 0.72 | 0.89 | 1.00 |
| Burwash A | -139.05 | 61.37 | 806.20 | 168.10 | 0.09 | 0.13 | 0.16 | 0.21 | 0.28 | 0.34 | 0.65 | 0.77 | 1.00 |
| Site Estimated | -137.22 | 62.62 | 784.45 | n/a | 0.24 | 0.32 | 0.38 | 0.45 | 0.52 | 0.59 | 0.70 | 0.85 | 1.00 |

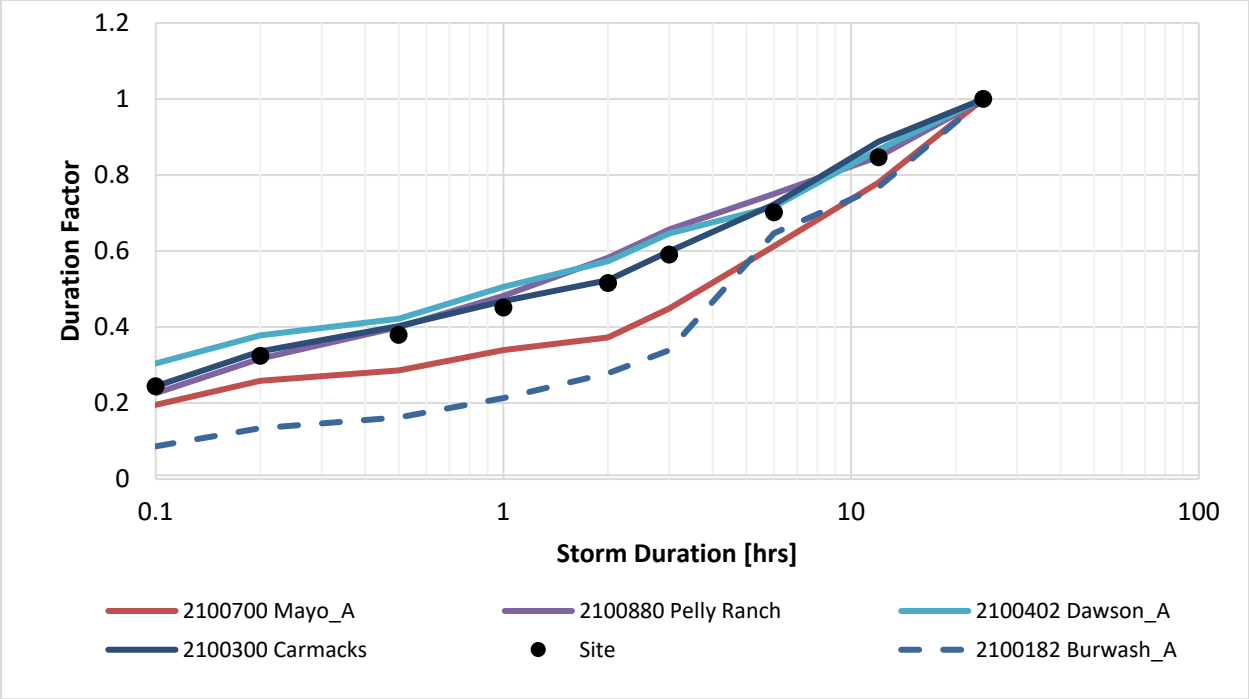


**Figure 3-3: Regional and Site-Specific Duration Factors**

### Regional Trends in Frequency Factors

Similarly to the duration factors, the Pearson distribution was used to determine whether the frequency factors for each return period were related to the elevation, latitude, or longitude of the meteorological station. The best relationship was found to be with elevation; however, the difference in frequency factors across the region was minimal, and the site elevation was within the range of the stations analyzed. Therefore, the average from the regional frequency factors was applied to the site. Table 3-4 and Figure 3-4 present the duration factors established for each regional station and for the site.

**Table 3-4: Regional Analysis of Frequency Factors**

| Station ID | Long. [degrees] | Lat. [degrees] | Elevation [masl] | Distance [km] | Return Period [years] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 | 5 | 10 | 25 | 50 | 100 |
| Mayo A | −135.87 | 63.62 | 503.80 | 131.10 | 0.70 | 0.88 | 1.00 | 1.15 | 1.26 | 1.37 |
| Pelly Ranch | −137.37 | 62.82 | 454.20 | 23.45 | 0.58 | 0.83 | 1.00 | 1.19 | 1.34 | 1.49 |
| Dawson A | −139.13 | 64.04 | 370.30 | 184.33 | 0.65 | 0.85 | 1.00 | 1.15 | 1.28 | 1.40 |
| Carmacks | −136.30 | 62.10 | 524.90 | 75.35 | 0.64 | 0.85 | 1.00 | 1.17 | 1.30 | 1.43 |
| Burwash A | −139.05 | 61.37 | 806.20 | 168.10 | 0.71 | 0.89 | 1.00 | 1.15 | 1.26 | 1.36 |
| Site (Estimated) | −137.22 | 62.62 | 784.45 | n/a | 0.66 | 0.86 | 1.00 | 1.16 | 1.29 | 1.41 |

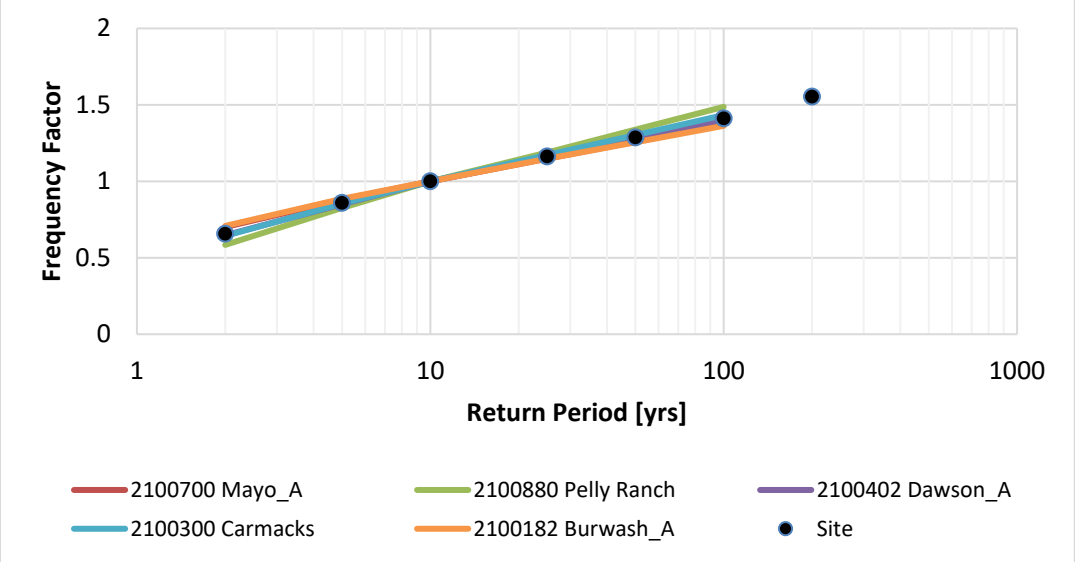


**Figure 3-4: Regional and Site-Specific Frequency Factors**

### 3.2.3 Site-Specific Intensity-Duration-Frequency Table

The results of site-specific frequency and duration factors and the 1:10 year, 24-hour duration rainfall of 34.2 mm were converted to an IDF table using Equation 1. In addition, the 1:200 year rainfall depth was extrapolated for each duration using a linear extrapolation of the duration factors and frequency factors. Results are presented in Table 3-5.

**Table 3-5: Site-Specific IDF Table**

| Storm Duration | | Return Period [years] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Minutes** | **Hours** | **2** | **5** | **10** | **25** | **50** | **100** | **200** |
| 5 | 0.08 | 5.5 | 7.2 | 8.3 | 9.7 | 10.7 | 11.8 | 13.0 |
| 10 | 0.17 | 7.3 | 9.5 | 11.1 | 12.9 | 14.3 | 15.6 | 17.2 |
| 15 | 0.25 | 8.5 | 11.2 | 13.0 | 15.1 | 16.7 | 18.3 | 20.2 |
| 30 | 0.5 | 10.1 | 13.3 | 15.4 | 17.9 | 19.9 | 21.8 | 24.0 |
| 60 | 1 | 11.6 | 15.2 | 17.6 | 20.5 | 22.7 | 24.9 | 27.4 |
| 120 | 2 | 13.3 | 17.4 | 20.2 | 23.5 | 26.0 | 28.5 | 31.4 |
| 360 | 6 | 15.8 | 20.6 | 24.0 | 27.9 | 30.9 | 33.9 | 37.3 |
| 720 | 12 | 19.0 | 24.9 | 29.0 | 33.6 | 37.3 | 40.9 | 45.0 |
| 1440 | 24 | 23.5 | 30.0 | 34.2 | 39.3 | 42.9 | 46.6 | 47.6 |

### 3.2.4 Climate Change and IDF Results

The values for the respective return periods and durations were increased by 44% to reflect the forecasted increase resulting from the effects of future climate change (SRK 2016). Adjusted IDF values are presented in Table 3-6.

**Table 3-6: Site-Specific IDF Table Adjusted for Total Precipitation Increase by 2100**

| Storm Duration | | Return Periods [years] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Minutes** | **Hours** | **2** | **5** | **10** | **25** | **50** | **100** | **200** |
| 5 | 0.08 | 7.9 | 10.3 | 12.0 | 14.0 | 15.5 | 17.0 | 18.7 |
| 10 | 0.17 | 10.5 | 13.7 | 16.0 | 18.5 | 20.5 | 22.5 | 24.8 |
| 15 | 0.25 | 12.3 | 16.1 | 18.7 | 21.7 | 24.0 | 26.4 | 29.0 |
| 30 | 0.5 | 14.6 | 19.1 | 22.2 | 25.8 | 28.6 | 31.4 | 34.5 |
| 60 | 1 | 16.7 | 21.8 | 25.4 | 29.5 | 32.7 | 35.8 | 39.5 |
| 120 | 2 | 19.1 | 25.0 | 29.1 | 33.8 | 37.4 | 41.1 | 45.2 |
| 360 | 6 | 22.7 | 29.7 | 34.6 | 40.2 | 44.5 | 48.8 | 53.7 |
| 720 | 12 | 27.4 | 35.8 | 41.7 | 48.5 | 53.7 | 58.9 | 64.8 |
| 1440 | 24 | 33.8 | 43.2 | 49.2 | 56.6 | 61.8 | 67.1 | 68.5 |

## 3.3 Snowmelt

Snowmelt estimation was performed in RStudio software using a daily snowmelt-energy model. This model incorporates daily meteorological parameters including daily maximum and minimum temperatures, wind speed, and total precipitation. Daily values for each parameter were obtained using the ERA-Interim reanalysis tool with daily information from 1979 to 2015 (ECMWF 2015).

Using the energy-based model (Walter 2005), the snow-water equivalent, potential snowmelt, and snowpack depth were calculated at each time step. The maximum daily snowmelt for each month of the simulated record from ERA-Interim was calculated, and the 50$^{th}$ percentile of maximum daily snowmelt was determined to be 23 mm/day (SRK 2016). This value can be applied as a baseflow on top of the design storm to estimate true peak flows for each catchment.

## 3.4 Probable Maximum Precipitation

The PMP for a 24-hour duration event was evaluated using the Hershfield method (World Meteorological Organization (WMO), 2009), for the same 20 regional meteorological stations used in the analysis for MAP. The Hershfield methodology requires the daily maximum 24 hour precipitation for at least 10 years of record. The analysis was performed in RStudio software, generating a PMP estimate for each of the 20 regional stations. A regression analysis was performed against longitude, which was found to have a better correlation than latitude or elevation. The results are presented in Figure 3-5, which presents a 24-hour PMP for the site of 159 mm.

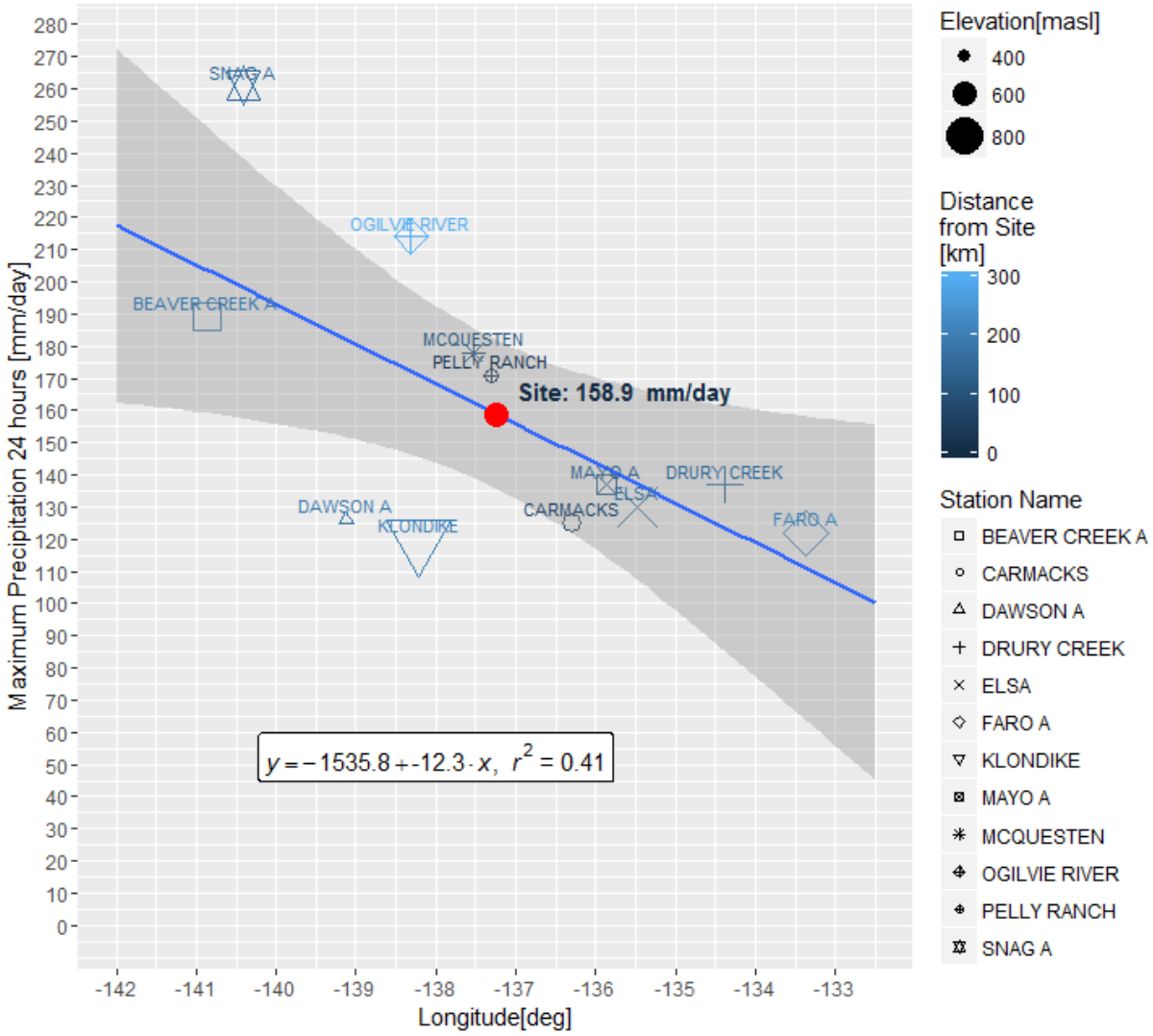


**Figure 3-5: Regional Analysis for PMP**

# 4 Peak Flows

A rainfall-runoff approach can be used to model peak flows at the site. Rainfall is applied to 24-hour distribution curve and is then converted to runoff based on catchment characteristics, including curve number, lag time, and total area, using the Soil Conservation Service (SCS) Method.

The following section summarizes the methodology to evaluate peak flows for the mine site.

## 4.1 Frequency-based Hypothetical Storm

The depth and temporal distribution of the storm hyetograph are defined using synthetic 24-hour rainfall distributions developed by National Resource Conservation Service (NRCS) (Chow et al. 1988), with a Type 1 rainfall distribution. This was selected due to the Pacific maritime climate with wet winters and dry summers observed in the Yukon, which closely mirrors the climate within Alaska for which a Type 1 distribution is typical (Chow et al. 1988). This distribution approximates an intense, short-duration storm event.

## 4.2 Initial loss

The SCS curve number model is used to estimate precipitation excess as a function of cumulative precipitation, soil cover, land use and antecedent moisture using the following equation:

$$P_e = \frac{(P - I_a)}{P - I_a + S}$$

Where,

$P_e$ = accumulated precipitation excess at time *t*,

$P$ = accumulated rainfall depth at time *t*,

$I_a$ = the initial abstraction (initial loss), and

$S$= potential maximum retention, a measure of the ability of a watershed to abstract and retain storm precipitation.

An empirical relationship between $I_a$ and $S$ was developed by the SCS as:

$$I_a = 0.2S$$

The maximum retention, $S$, and watershed characteristics related through an intermediate parameter, the curve number was developed as:

$$S = \frac{25400 - 254\ CN}{CN}$$

Incremental excess for a time interval is computed as the difference between the accumulated excess at the end of and beginning of the period.

## 4.3 Hydrological Transformations

The SCS Unit Hydrograph method is used to transform precipitation excess into an outflow hydrograph for each sub-area. A HEC-HMS (2013) model can be used to evaluate peak flows. HEC-HMS uses a single input parameter, the lag time ($T_{lag}$), defined as the time between the centroid of precipitation mass to the peak for the resulting hydrograph. The lag time for each

catchment was calculated using the NRCS transformation from time of concentration. The NRCS transformation is $T_{lag}$ = 0.6*Tc. Time of concentration and resulting lag times are relatively short (<15 minutes), resulting in a flashy response with peak discharge timing almost coincident with the timing of the precipitation peak. The time of concentration was estimated with the methods cited in (Li *et al*. 2008) where a minimum time of concentration of 10 minutes was applied.

## 4.4 Curve Number

The SCS curve number is utilized for the calculation of precipitation excess and the transformation of runoff within the watershed (NRCS 1986). The curve number for a watershed can be estimated as a function of land use, soil type, and antecedent watershed moisture, using tables published by the SCS and refined using calibration methods.

Once the closure period begins, the active mining areas will be decommissioned, and the land use is assumed to return to natural conditions. Based on this assumption, the curve number for the site can be validated using a regional catchment with known peak flows, a rainfall depth, and catchment characteristics including lag time and area.

A suitable regional catchment was selected using a regional analysis, comparing unit peak flows for eight nearby WSC hydrometric stations (EC 2015b). The stations are summarized in Table 4-1 (EC 2015b) and were compiled in RStudio software.

**Table 4-1: Summary of Water Survey of Canada Stations used in Regional Analysis of Peak Flows**

| Station Name | Lat. [degrees] | Long [degrees] | Area [km$^2$] | Distance from Site [km] | Years with Info. |
|---|---|---|---|---|---|
| DRURY CREEK AT KM 469 ROBERT CAMPBELL HIGHWAY | 62.2 | -134.4 | 552 | 154 | 15 |
| LITTLE SOUTH KLONDIKE RIVER BELOW ROSS CREEK | 64.0 | -137.6 | 860 | 154 | 13 |
| GILTANA CREEK NEAR THE MOUTH | 61.2 | -137.0 | 190 | 159 | 27 |
| SOUTH BIG SALMON RIVER BELOW LIVINGSTONE CREEK | 61.4 | -134.4 | 515 | 203 | 14 |
| IBEX RIVER NEAR WHITEHORSE | 60.7 | -135.5 | 648 | 230 | 23 |
| SIDNEY CREEK AT KILOMETRE 46 SOUTH CANOL ROAD | 60.8 | -133.1 | 372 | 301 | 12 |
| WHEATON RIVER NEAR CARCROSS | 60.1 | -134.9 | 864 | 304 | 48 |
| SOUTH MACMILLAN RIVER AT KILOMETRE 407 CANOL ROAD | 62.9 | -130.5 | 997 | 343 | 22 |
| PINE CREEK NEAR ATLIN | 59.6 | -133.7 | 697 | 391 | 11 |

Peak and unit peak flows were calculated for return periods between the 1:2 year and 1:200 year events, where the unit peak flow is equal to the peak flow divided by the catchment area. Relationships were developed for unit peak flows of each return period and longitude, elevation and latitude. The best correlation was found to be with latitude, and the results of the regression analyses are presented in Figure 4-3.

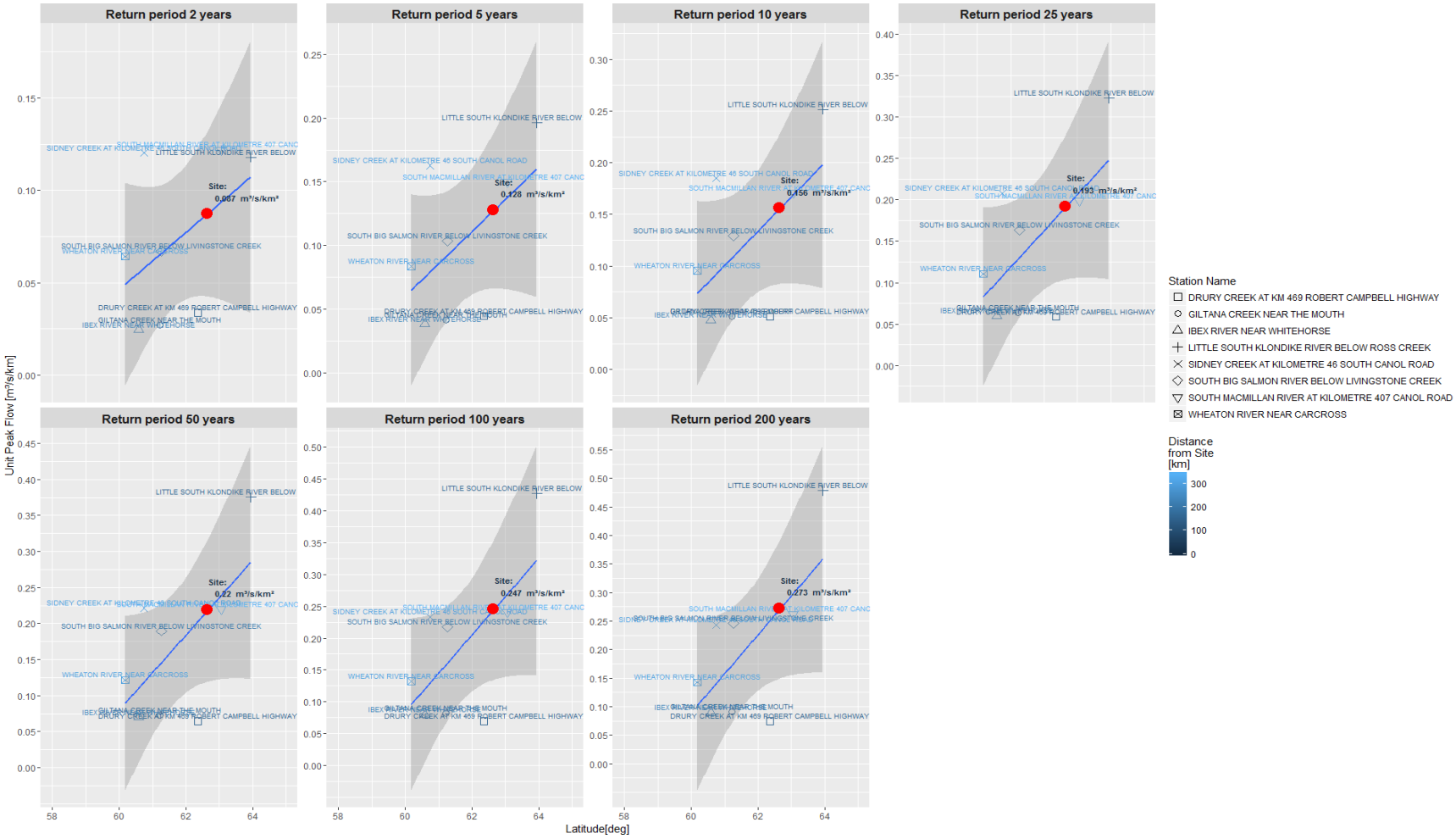


**Figure 4-1: Regional Unit Peak Flows**

For return periods greater than the 1:5 year event, 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 curve number calibration purposes to generate a conservatively high estimate.

The lag time for Little South Klondike River below Ross Creek was calculated to be 137 minutes, using the methodology described in Section 4.3 and was modelled in HEC-HMS (2013) along with the catchment area. Rainfall depths from the IDF results in Table 3-5 prior to climate change impacts were modelled for the 1:200 year event and the 1:10 year event, which form the design criteria for the closure conveyance structures. The curve number value was adjusted until the modelled peak flows matched the historically estimated peak flows. The results of the calibration are presented in Table 4-2, and include varying the curve number value from 70 to 84.

**Table 4-2: Curve Number Calibration Results**

| Return Period [years] | Historic Rainfall Depth [mm] | Historic Peak Flow [$m^3/s$] | Curve Number | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 70 | 75 | 80 | 82 | 83 | 84 |
| 200 | 47.6 | 411.7 | 91.4 | 172.1 | 311.3 | 385.2 | 425.6 | 468.6 |
| 10 | 34.2 | 216.3 | 27.8 | 53 | 111.4 | 151 | 175.1 | 201.6 |

The 1:200 year return period was best matched using a curve number value of 83. The peak flow for the 1:10 year event using this curve number value is underestimated. However this return period is only used for the sizing of pilot channels within larger floodplain channels, ensuring that any overtopping of the pilot channel as a result of slightly underestimated flows will be captured. The curve number value of 83 was applied to all site catchments for closure conditions.

# 5 Summary

For the purpose of the post-closure water conveyance analysis, a hydrologic study was completed. The study used regional meteorological stations to generate expected precipitation estimates for the site that can be used for the design of the required conveyance infrastructure.

The following is a summary of the hydrology analysis for conveyance channels:

- Mean annual precipitation of 395 mm;
- The intensity-duration-frequency results are adjusted for potential impacts due to climate change, for a range of storm durations and frequencies (Table 3-6)
  - 1:200 year 24-hour rainfall depth of 68.5 mm,
  - 1:10 year 24-hour rainfall depth of 49.2 mm;
- Maximum expected 24-hour snowmelt depth of 23 mm including the impacts of climate change;

- 24-hour probable maximum precipitation (PMP) of 159 mm;
- Calibrated regional curve number for natural catchments is a value of 83.

SRK Consulting (Canada) Inc.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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# Appendix C – Climate Change Analysis

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# Memo

| | | | |
|---|---|---|---|
| **To:** | Ryan Herbert, Minto Explorations Ltd. | **Client:** | Minto Explorations Ltd. |
| **From:** | Victor Munoz Saavedra<br>Tia Shapka-Fels | **Project No:** | 1CM002.042 |
| **Cc:** | Dylan McGregor, SRK | **Date:** | August 3, 2016 |
| **Subject:** | Climate Change Analysis, Minto Mine, Yukon | | |

# 1 Introduction

SRK Consulting (Canada) Inc. has prepared an updated closure water conveyance plan design report for Minto Mine (Minto) located in the Yukon, Canada, and operated by Minto Exploration Ltd.

There is agreement within the engineering community that climate change is occurring and that climate change needs to be integrated into engineering designs. Engineers Canada (2013) encourages its members to keep themselves informed about the changing climate and consider potential impacts on their professional activities. Design integration of climate change analysis results looks to the long term performance of mine closure designs such as conveyance channels and waste rock cover systems. Mine closure infrastructure designed using average daily temperatures and precipitation values during mines operation may not be adequate for infrastructures that support the mine site in the future when the climate has changed.

This memo presents climate change projections of key climatic and hydrological parameters which may be experienced at the mine site in the future. Parameters include, but are not limited to, projections for changes in temperature, rain and snowfall precipitation. This memo further discusses how the climate change projections for the Minto site are then integrated into the closure conveyance channel design.

# 2 Method

Climate change analysis includes collating and evaluating baseline climate data, querying available climate change prediction models, and making forecasting climate trends. This analysis produced a graphical summary of results (Section 5). The summaries presented in Section 5 are a probabilistic expected change in the climatic with respect to baseline conditions at the Minto mine site.

The analysis required three steps as outlined in Section 2.1 to 2.3.

## 2.1 Step 1: Data Retrieval

The first step of the analysis was to identify the availability of the climate change models for each required climate parameter. Environment Canada provides access to monthly climate change modeling predictions for any location in the World from the following climate change assessment reports:

- Canadian Regional Climate Model (CRCM), also called First Assessment Report (AR1) (EC 2015)
- Second Assessment Report (AR2) (IPCC 1995)
- Third Assessment Report (AR3) (IPCC 2001)
- Fourth Assessment Report (AR4) (IPCC 2007)
- Fifth Assessment Report (AR5) (IPCC 2014)

Information for the first four assessment reports is available from 1960, with predictions out to 2100 for the meteorological variables listed in Table 2.1; however, there are significant gaps depending on the assessment report, scenario evaluated, and variable assessed. Information for the fifth assessment report is available for 1900 to 2100, but only includes mean temperature and total precipitation.

As part of the procedure, data from the five assessment reports are downloaded from Environment Canada for the site being evaluated based on latitude and longitude. This process is automated through a purpose built script developed using R programming language (CRAN 2015).

The meteorological parameters covered in the assessment reports are used, though application of empirical models, to calculate climate change design parameters for other parameters such as intensity-duration–frequency (IDF) curves (i.e. extreme storm events), snowpack thickness, evaporation, etc.

**Table 2.1: Metrological Parameters Listed in AR1 through AR4**

| Parameter | Base Parameter | Details |
|---|---|---|
| Air Temperature | Temperature | Mean ($T_{mean}$), Mean Max ($T_{max}$), Mean Minimum ($T_{min}$), and Extreme Range at 2 m above ground surface |
| Heat Wave Duration Index | Temperature | Maximum period >5 consecutive days with $T_{max}$ >5°C above the baseline $T_{max}$ normal |
| Frost Days | Temperature | Total number of frost days (days with absolute minimum temperature <0°C) |
| Growing Season Length (GSL) | Temperature | Growing season length is defined as the time period each year between when $T_{mean}$ >5°C for more than 5 days and when $T_{mean}$ <5°C for more than 5 days |
| Air Temp. Extreme Range | Temperature | Intra-annual extreme temperature range is the difference between the highest temperature and lowest temperature of the same calendar year |

| Parameter | Base Parameter | Details |
|---|---|---|
| Total Precipitation | Precipitation | Total precipitation including rainfall and snowfall as snow water equivalent |
| Days with rain >10 mm | Precipitation | Days with rain greater than or equal to 10 mm/day |
| Simple Daily Intensity Index | Precipitation | Annual total precipitation divided by the number of precipitation days greater than or equal to 1 mm/day |
| Dry Days | Precipitation | Max amount of consecutives dry days (precipitation <1 mm) |
| Fraction of total annual precipitation >95$^{th}$ percentile | Precipitation | Annual precipitation >95th percentile |
| Wind Speed | Wind Speed | Mean, Meridional, and Zonal wind speed at 10 m above ground surface |
| Solar Radiation | Radiation | Shortwave surface down-welling |
| Humidity | Humidity | Relative and specific humidity at 2 m above ground surface |
| Sea Level Pressure | Air Pressure | Mean sea level pressure |

## 2.2 Step 2: Baseline Analysis (Outcome 1)

Climate change models presented in the assessment reports assume application of radiative forces (energy flux) through different anthropogenic sources that results in discharge of varying concentrations of atmospheric greenhouse gases. These radiative forces are not constant through time, as they are based on global anthropogenic behavior such as environmental policies, population growth, economic growth, energy sources, land use, hydrocarbon usage, etc. Each individual climate change model presented in the assessment reports represent these non-linear radiative forces differently and thus present a different climate change scenario, underscored by its own model assumptions and boundary conditions.

None of these individual models are inherently superior or inferior to others, and likewise, the newer generation of assessment reports are not necessarily more reliable than older versions, but rather represent more detailed consideration of global anthropogenic forces. Therefore, the user is forced to make a judgement call on which individual model or generation of models are the most suitable to use in design, which invariably leads to bias. This method of analysis is specifically aimed at eliminating this bias by analysing all the available climate change models with equal weight and presenting a single climate change design parameter based on a rational statistical evaluation of the overall cumulative results.

Using each and every climate change model available in the five assessment reports, the projected change with respect to a set baseline condition can be calculated using Equation 2.1.

**Equation 2.1**

$$\textbf{\textit{Change with respect to set baseline condition}}\ [\%] = \frac{\textbf{\textit{Projection}} - \textbf{\textit{Baseline}}}{\textbf{\textit{Baseline}}}$$

In Equation 2.1, the *Baseline* and *Projection* periods have a minimum timeframe of 30 years, which is generally recognized as being the minimum acceptable period length of record that is statistically significant (WMO 2007). These periods can be defined as follows:

- *Baseline* is the time frame associated with the past (i.e. estimation of the climate data based on the climate change models). For the purpose of this analysis, this period is fixed from 1975 to 2005, which coincides with the baseline adopted for AR5.
- *Projection* is the future time frame where climate change models are applied, reflecting climate change predictions. Three *Projection* periods are applied from 2011 to 2040, 2041 to 2070, and 2071 to 2100. These 30-year periods are based on convention as stipulated in WMO (2007).

Climate change model predictions are currently presented up to the year 2100 (IPCC 2014), which is deemed that maximum reasonable timeframe to extend predictions to. As a result, this is the maximum timeframe for which this analysis method applies.

Equation 2.1 is automatically processed using a script developed in R. An example result is presented in Figure 2.1, which represents the outcome at a hypothetical site for the meteorological parameter mean air temperature. For this example, the *Projection* period is representative of 2041 to 2070.

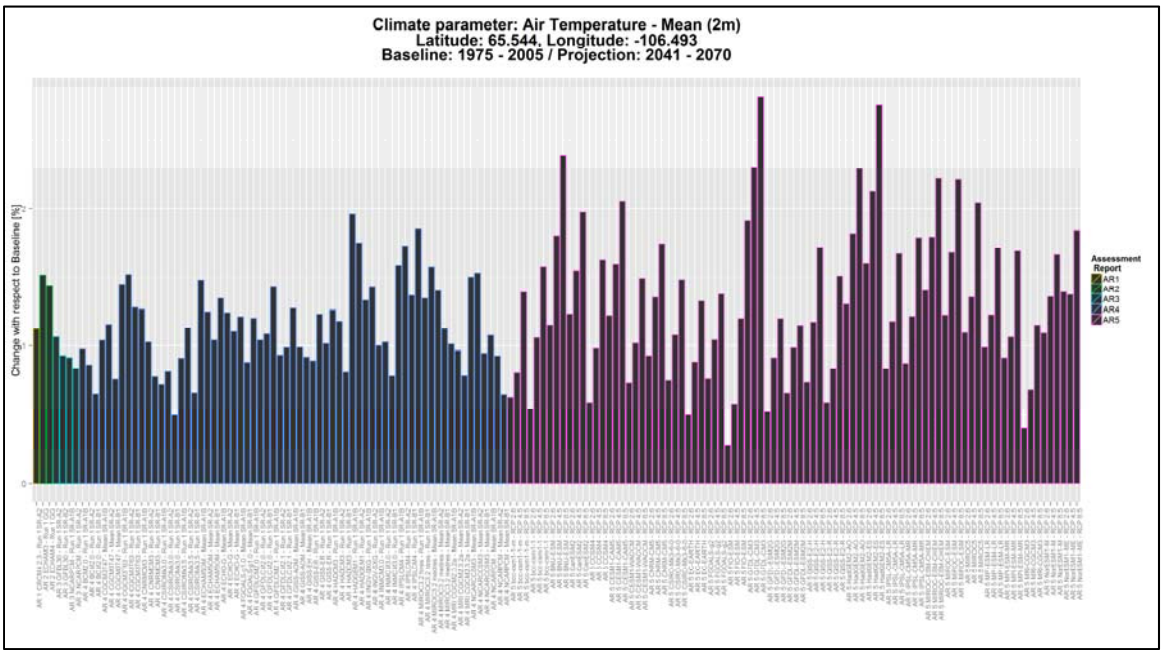


**Figure 2.1: Example outcome for hypothetical site showing results of change to baseline conditions for individual climate change models associated with each of the five assessment reports for a projection period from 2041 to 2070**

The analysis presented in Figure 2.1 can be presented as a box-whisker plot as illustrated in Figure 2.2. The change with respect to baseline conditions for each individual Assessment Report is summarized, together with an overall summary representing all the assessment reports combined. The centerline of the box represents the median value, while the upper and lower box borders represent the first and third quartile values, respectively. The limits whiskers will extend to the maximum and minimum of 1.5 times the total range of the box (i.e. the third quartile minus first quartile). If values exist outside the whisker limits (i.e. outliers), then they are presented as dots.

The results in Figure 2.2 can also be presented as a cumulative probabilistic curve as illustrated in Figure 2.3. To weigh all climate change models equally, only the cumulative probabilistic curve associated with combined data from all assessment reports was considered in this analysis. The overall spread of results as presented by the collection of box-whisker plots in Figure 2.2 illustrates why this is deemed appropriate.

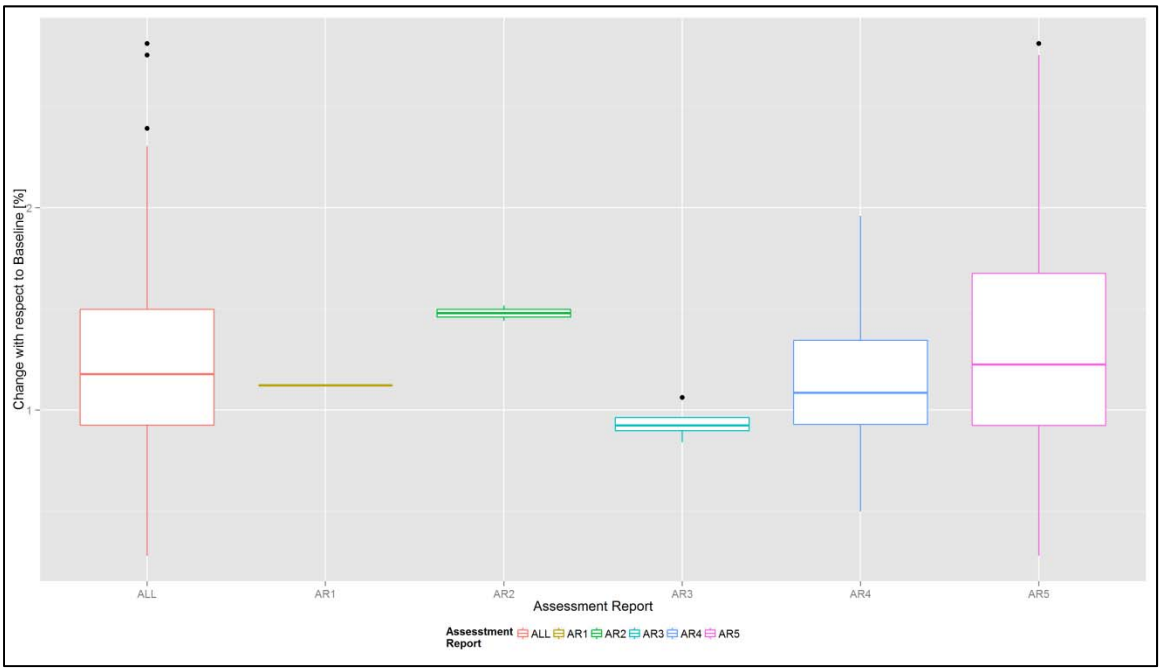


**Figure 2.2: Combined box-whisker plot of change to baseline conditions for the individual climate change models presented in the Figure 2.1 example**

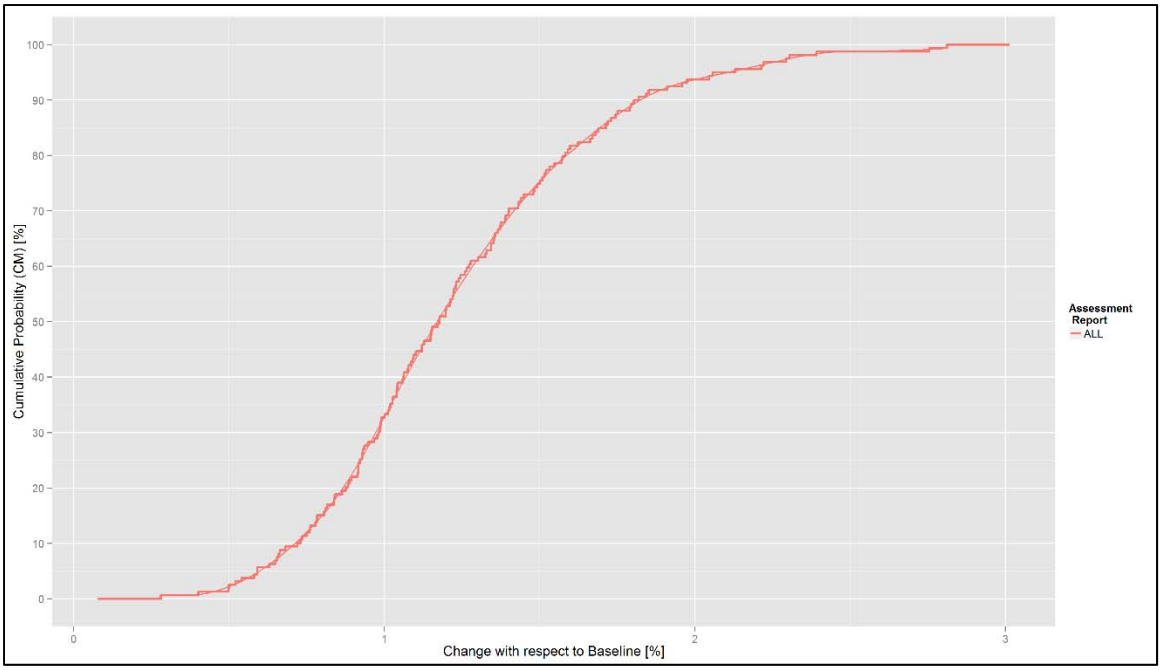


**Figure 2.3: Cumulative probability curve of climate change prediction models from all assessment reports expressed as a percentage of change against baseline conditions**

## 2.3 Step 3: Trend Analysis (Outcome 2)

As discussed in Section 2.2, climate change models consider global anthropogenic forces that are not constant in time. Irrespective of such forces, the science of hydrology estimates and predicts future meteorological conditions through consideration of historic trends. Therefore, to facilitate selection of climate change parameters for design, a trend analysis approach is used as a reality check.

To best represent the historical trend, a global climatic model reanalysis approach is used, rather than relying on regional meteorological stations for historic data, since the availability and timespan of records vary greatly. Reanalysis combines satellite information, land records, and numerical models that simulate the earth's climatic conditions. Typically, reanalysis extends for several decades and covers the entire planet. State-of-the-art publically available reanalysis data from ERA-Interim produced by the European Center for Medium-Range Weather Forecast (ECMWF 2015) was used in this analysis. ERA-Interim includes twice daily data from 1979 to 2015 for the entire world, based on a 0.75 degree latitude by 0.75 degree longitude grid.

The ERA-Interim data trend analysis entailed two parts: first, identification of the trend, and second, estimation of the statistical significance of the trend. Five different trend analysis methodologies were considered:

- Ordinary least square (Maidment 1993)
- Quantile regression (Koenker and Bassett 1978)

- Mann-Kendall and Theil Sen (Mann 1945 and Sen 1968)
- Zhang (Zhang 2000)
- Yue and Pilon (Yue et al 2002)

Figure 2.4 presents the outcome of the reanalysis for the hypothetical example site presented in Figure 2.1 through Figure 2.3. Each regression method has a statistical significance value over 95%; however, this may not always be the case and the meaning of that is described further in next section.

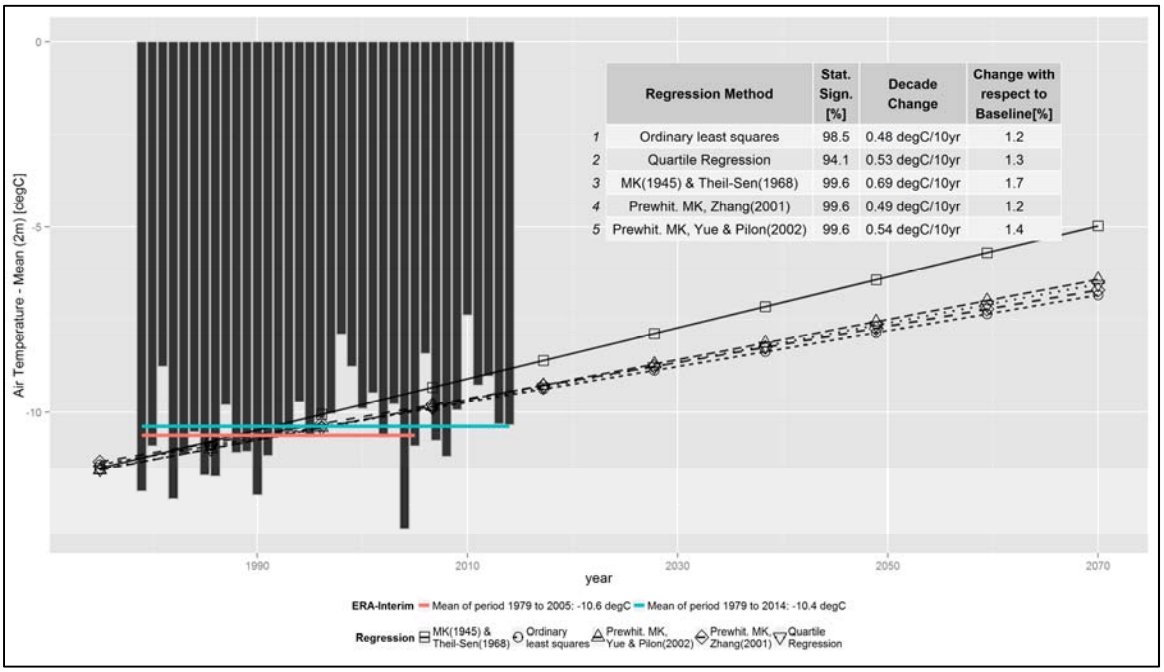


**Figure 2.4: Trend analysis outcome based on reanalysis evaluation for hypothetical site presented in Figure 2.1**

## 2.4 Recommended Climate Change Design Parameter

Following completion of the previously described procedure, a design recommendation for each identified climate change parameter is presented. The previous procedure produces two outcomes as follows:

- Outcome 1 is a cumulative probability curve representing change relative to baseline conditions based on the Step 2 analysis; this is also represented by Figure 2.3.
- Outcome 2 is the five separate regression analysis results from the Step 3 trend analysis, again representing change relative to baseline conditions represented by Figure 2.4. The statistical significance of each regression analysis is calculated during this step and must yield a value greater than 95% to be deemed statistically significant.

If the trend analysis shows no regression of statistical significance (i.e. greater than 95%), the climate change design parameter is the 50% cumulative probability value based on the Step 2 baseline analysis. If on the other hand, one or more of the trend analyses suggest trends of statistical significance, the climate change parameter is the maximum of either the 50% cumulative probability value based on the Step 2 baseline analysis, or the mean of all the trend analysis values with statistical significance. Equation 2.2 provides an expression for this criteria.

**Equation 2.2**

$$Recommended\ Climate\ Change\ Design\ Parameter = \text{Maximum}(50\%\ Cumulative\ Probability,\ Mean\ \{Regression_{Stat.\ Sign \geq 95\%}\})$$

# 3 Climate Change Projections

## 3.1 Long Term Temperature Trends

The mean annual air temperature at Minto is expected to increase by about 3.3°C over the next century (Table 3.1), with mean annual air temperatures of −0.8°C, 0.2°C, and 1.1°C in the 2020s, 2050s and 2080s, respectively. These predictions compare well with those presented by other studies. The International Panel on Climate Change (IPCC) projects a 5°C to 6°C increase in the temperature in Northern Canada for 2100 relative to the 1980 to 1999 temperatures (IPCC 2007).

Table 3.1 though Table 3.8 present additional temperature related climate forecasts for the Minto area. These tables predict longer periods with high temperatures and consequently shorter periods with lower temperatures and less inter-annual temperature variation.

**Table 3.1: Mean Annual Air Temperature at Minto**

| Timeline | Context | Value (°C) | Change Over Baseline (°C) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | -2.12 | - | - |
| 1979-2014 | Current Reality | -2.29 | -0.17 | -0.06% |
| 2011-2040 | 2020s | -0.82 | 1.30 | 0.48% |
| 2041-2070 | 2050s | 0.24 | 2.36 | 0.87% |
| 2071-2100 | 2080s | 1.13 | 3.25 | 1.20% |

**Table 3.2: Mean Maximum Air Temperature at Minto**

| Timeline | Context | Value (°C) | Change Over Baseline (°C) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 1.39 | - | - |
| 1979-2014 | Current Reality | 1.26 | -0.13 | -0.05% |
| 2011-2040 | 2020s | 1.40 | 0.01 | 0.36% |
| 2041-2070 | 2050s | 1.40 | 0.01 | 0.69% |
| 2071-2100 | 2080s | 1.41 | 0.02 | 1.10% |

**Table 3.3: Mean Minimum Air Temperature at Minto**

| Timeline | Context | Value (°C) | Change Over Baseline (°C) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | -5.46 | - | - |
| 1979-2014 | Current Reality | -5.68 | -0.22 | -0.08% |
| 2011-2040 | 2020s | -5.49 | -0.03 | 0.48% |
| 2041-2070 | 2050s | -5.51 | -0.05 | 0.93% |
| 2071-2100 | 2080s | -5.54 | -0.08 | 1.40% |

**Table 3.4: Intra-Annual Temperature Range at Minto(1)**

| Timeline | Context | Value (°C) | Change Over Baseline (°C) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 61.3 | - | - |
| 1979-2014 | Current Reality | 62.2 | 0.9 | 0.27% |
| 2011-2040 | 2020s | 59.8 | -1.5 | -0.45% |
| 2041-2070 | 2050s | 58.6 | -2.7 | -0.81% |
| 2071-2100 | 2080s | 57.6 | -3.7 | -1.10% |

**Note(s):**

(1) The difference between the highest temperature of the year and the lowest temperature of the year.

**Table 3.5: Daily Minimum Air Temperature, 90th Percentile at Minto**

| Timeline | Context | Value (%) | Change Over Baseline (%) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 10.0 | - | - |
| 1979-2014 | Current Reality | 10.2 | 0.2 | 2.0% |
| 2011-2040 | 2020s | 14.6 | 4.6 | 46.0% |
| 2041-2070 | 2050s | 21.0 | 11.0 | 110.0% |
| 2071-2100 | 2080s | 31.0 | 21.0 | 210.0% |

**Table 3.6: Growing Season Length(1) at Minto**

| Timeline | Context | Value (days) | Change Over Baseline (days) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 93 | - | - |
| 1979-2014 | Current Reality | 95.9 | 2.9 | 3% |
| 2011-2040 | 2020s | 115.3 | 22.3 | 24% |
| 2041-2070 | 2050s | 136.7 | 43.7 | 47% |
| 2071-2100 | 2080s | 147.9 | 54.9 | 59% |

**Note(s):**

(1) Growing season length is the number of days between the first five consecutive days of the year with a mean air temperature above 5°C, and the last five such days of the year.

**Table 3.7: Heat Wave Duration Index(1) at Minto**

| Timeline | Context | Value (days) | Change Over Baseline (days) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 108 | - | - |
| 1979-2014 | Current Reality | 110 | 2.0 | 2% |
| 2011-2040 | 2020s | 143 | 34.6 | 32% |
| 2041-2070 | 2050s | 185 | 76.7 | 71% |
| 2071-2100 | 2080s | 270 | 162.0 | 150% |

**Note(s):**

(1) The maximum period for the year of at least five consecutive days with the maximum air temperature at least 5°C warmer than the daily climatology baseline.

**Table 3.8: Frost Days(1) at Minto**

| Timeline | Context | Value (days) | Change Over Baseline (days) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 225 | - | - |
| 1979-2014 | Current Reality | 225 | 0.0 | 0.0% |
| 2011-2040 | 2020s | 216 | -9.5 | -4.2% |
| 2041-2070 | 2050s | 207 | -18.5 | -8.2% |
| 2071-2100 | 2080s | 196 | -29.3 | -13.0% |

**Note(s):**

(1) Total number of days with an absolute minimum temperature less than 0°C.

## 3.2 Long Term Precipitation Trends

The total precipitation at Minto is forecasted to increase 67.9 mm (15%) during the mine life (2011 to 2040) and 199.3 mm (44%) by 2100 (Table 3.9).

**Table 3.9: Total Precipitation at Minto**

| Timeline | Context | Value (mm) | Change Over Baseline (mm) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 453 | - | - |
| 1979-2014 | Current Reality | 469 | 16.0 | 4% |
| 2011-2040 | 2020s | 521 | 67.9 | 15% |
| 2041-2070 | 2050s | 584 | 131.4 | 29% |
| 2071-2100 | 2080s | 652 | 199.3 | 44% |

## 3.3 Frequency of Drought

Climate change model suggests that consecutive dry days will decrease by up to 13% by 2100 (Table 3.10).The clear mean annual temperature increase trend (Table 3.1) along with the increasing precipitation trend (Table 3.9) and decreasing consecutive dry day trend (Table 3.10) suggest that the frequency of drought should be decreasing.

**Table 3.10: Consecutive Dry Days(1) at Minto**

| Timeline | Context | Value (days) | Change Over Baseline (days) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 17.1 | - | - |
| 1979-2014 | Current Reality | 17.8 | 0.7 | 4.1% |
| 2011-2040 | 2020s | 16.0 | -1.1 | -6.4% |
| 2041-2070 | 2050s | 15.2 | -1.9 | -11.0% |
| 2071-2100 | 2080s | 14.9 | -2.2 | -13.0% |

**Note(s):**

(1) Maximum number of consecutive dry day is a year. Days with less than 1 mm of precipitation are considered dry days.

## 3.4 Frequency of Rainfall

The simple daily precipitation intensity index is the mean annual precipitation divided by the total number of wet days. Therefore, the total number of wet days can be estimated from the simple daily precipitation intensity index values and the total precipitation.

The simple daily precipitation intensity index at Minto is forecasted to increase by 6.6% during the mine life and by 25% in the next century (Table 3.11).

Table 3.12 presents the estimated number of wet days. The total estimated number of wet days is forecasted to increase by a similar amount with a 7.9% increase during the mine life and a 15.2% increase during the next century.

**Table 3.11: Simple Daily Precipitation Intensity Index(1) at Minto**

| Timeline | Context | Value (mm/year) | Change Over Baseline (mm/year) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 3.9 | - | - |
| 1979-2014 | Current Reality | 3.95 | 0.05 | 1.28% |
| 2011-2040 | 2020s | 4.16 | 0.26 | 6.60% |
| 2041-2070 | 2050s | 4.41 | 0.51 | 13.00% |
| 2071-2100 | 2080s | 4.88 | 0.98 | 25.00% |

**Note(s):**

(1) The total annual precipitation divided by the total number of wet days in a year

**Table 3.12: Estimated Total Number of Wet Days(1) at Minto**

| Timeline | Context | Value (days) | Change Over Baseline (days) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 116.2 | - | - |
| 1979-2014 | Current Reality | 118.7 | 2.6 | 2.2% |
| 2011-2040 | 2020s | 125.3 | 9.2 | 7.9% |
| 2041-2070 | 2050s | 132.6 | 16.4 | 14.2% |
| 2071-2100 | 2080s | 133.8 | 17.7 | 15.2% |

**Note(s):**

(1) The total number of wet days is not directly developed from the R analysis, but rather calculated based on the values in Table 3.9 and Table 3.11.

## 3.5 Long Duration Rainfall

Long duration rainfall, fraction of annual precipitation greater than 95th percentile, is predicted to increase by 96% over the next century at Minto (Table 3.13). The number of days with more than 10 mm of rainfall is forecasted to increase by 140% (Table 3.14).

The change in days with more than 10 mm of rain is forecasted to be 58% respectively during mine life (2011 to 2040). Similarly the maximum total precipitation for a five day period will increase by 20% over the next century and 7.8% over the mine life (2011 to 2040) as shown in

Table 3.15. Therefore, the volume and frequency of high precipitation events will tend to increase over the century.

**Table 3.13: Fraction of Annual Precipitation >95th Percentile(1) at Minto**

| Timeline | Context | Value (%) | Change Over Baseline (%) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 5.01 | - | - |
| 1979-2014 | Current Reality | 5.29 | 0.28 | 5.59% |
| 2011-2040 | 2020s | 7.01 | 2.00 | 40.00% |
| 2041-2070 | 2050s | 7.52 | 2.51 | 50.00% |
| 2071-2100 | 2080s | 9.82 | 4.81 | 96.00% |

**Note(s):**

(1) Percentage of days with precipitation greater than the 95th percentile calculated for wet days from the baseline period.

**Table 3.14: Days with Precipitation Greater Than or Equal to 10 mm at Minto**

| Timeline | Context | Value (days) | Change Over Baseline (days) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 3.88 | - | - |
| 1979-2014 | Current Reality | 4.3 | 0.38 | 9.79% |
| 2011-2040 | 2020s | 6.1 | 2.25 | 58.00% |
| 2041-2070 | 2050s | 7.7 | 3.84 | 99.00% |
| 2071-2100 | 2080s | 9.3 | 5.43 | 140.00% |

**Table 3.15: Greatest Five Days Total Rainfall at Minto**

| Timeline | Context | Value (mm) | Change Over Baseline (mm) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 38.9 | - | - |
| 1979-2014 | Current Reality | 40.2 | 1.3 | 3.3% |
| 2011-2040 | 2020s | 41.9 | 3.0 | 7.8% |
| 2041-2070 | 2050s | 43.6 | 4.7 | 12.0% |
| 2071-2100 | 2080s | 46.7 | 7.8 | 20.0% |

## 3.6 Short Duration Rainfall

Based on an evaluation of the predicted values for greatest five-day total precipitation, consecutive dry days, simple daily intensity index, days with rain greater than 10 mm, and fraction of total annual precipitation greater than the 95th percentile, the IDF for Minto was adjusted, where the total precipitation increase is forecasted to increase by 44% in 2100. Using the current reality, the values for the respective return periods and durations were increased by 44% to reflect the forecasted increase

**Table 3.16: IDF Adjusted for Total Precipitation Increase by 2100**

| Duration | | Return Periods [years] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Minutes | Hours | 2 | 5 | 10 | 25 | 50 | 100 | 200 |
| 5 | 0.08 | 7.9 | 10.3 | 12.0 | 14.0 | 15.5 | 17.0 | 18.7 |
| 10 | 0.17 | 10.5 | 13.7 | 16.0 | 18.5 | 20.5 | 22.5 | 24.8 |
| 15 | 0.25 | 12.3 | 16.1 | 18.7 | 21.7 | 24.0 | 26.4 | 29.0 |
| 30 | 0.5 | 14.6 | 19.1 | 22.2 | 25.8 | 28.6 | 31.4 | 34.5 |
| 60 | 1 | 16.7 | 21.8 | 25.4 | 29.5 | 32.7 | 35.8 | 39.5 |
| 120 | 2 | 19.1 | 25.0 | 29.1 | 33.8 | 37.4 | 41.1 | 45.2 |
| 360 | 6 | 22.7 | 29.7 | 34.6 | 40.2 | 44.5 | 48.8 | 53.7 |
| 720 | 12 | 27.4 | 35.8 | 41.7 | 48.5 | 53.7 | 58.9 | 64.8 |
| 1440 | 24 | 33.8 | 43.2 | 49.2 | 56.6 | 61.8 | 67.1 | 68.5 |

## 3.7 Snow Accumulation

Estimations of snow accumulation were developed by coupling the climate change model predictions for precipitation, temperature, and wind speed with the energy snowmelt model by Walter et al. (2005).

To estimate snowmelt, a subroutine from the EcoHydRolody library in R, called SnowMelt was used to analyze snow melt from an energy-based model. This program function forecasts the future daily snowmelt using energy--based model posed by Walter et al. (2005). This hydrological

model is based on typical meteorological parameters (e.g. daily maximum, minimum temperature, wind speed, and total precipitation).

These inputs were obtained on a sub-daily and daily scale from the reanalysis source ERA-Interim from 1979 to 2015. As a terrain source, the model required latitude and longitude of the site, topographical slope, and aspect of the terrain. These last two parameters were obtained from the topographical information GTopo30. This source provides a worldwide topographical information with a spacing of 30 arc-sec which is approximately equal to 1 km.

The result of the model is a daily snowmelt model including parameters such as snowfall water equivalent, snowmelt, snowpack depth, and snow water equivalent of snowpack.

The monthly average snow depth at Minto is expected to increase from over the next century (Table 3.17). In the time periods 1979 to 2005 and 1979 to 2014, the snowpack depth will tend to increase with the time to a maximum in the 2100s. These snowpack values should be taken as a reference as snowmelt model should be calibrated with site information.

**Table 3.17: Monthly Average Snowpack at Minto**

| Timeline | Snow Depth (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1979-2005 | 230 | 260 | 240 | 220 | 30 | 0 | 0 | 10 | 30 | 100 | 160 | 180 |
| 1979-2014 | 240 | 260 | 260 | 230 | 40 | 0 | 0 | 10 | 30 | 110 | 170 | 210 |
| 2011-2040 | 270 | 280 | 280 | 230 | 30 | 0 | 0 | 0 | 20 | 100 | 180 | 230 |
| 2041-2070 | 290 | 300 | 280 | 210 | 20 | 0 | 0 | 0 | 10 | 90 | 190 | 240 |
| 2071-2100 | 330 | 330 | 300 | 200 | 10 | 0 | 0 | 0 | 10 | 90 | 210 | 280 |

## 3.8 Snowmelt

The daily maximum snowmelt in an average year at Minto can be seen in Table 3.18, the month in which these maximum values are obtained from can be seen in Table 3.19. These predictions forecast freshet in April, and slightly increasing maximum daily snowmelt over the next century. The predicted maximum daily snowmelt in 2071 to 2100 is similar that of the snowmelt 1979 to 2005 (Table 3.18).

**Table 3.18: Maximum Daily Snowmelt in Average Year at Minto**

| Timeline | Daily Maximum Snowmelt (mm/day) |
|---|---|
| 1979-2005 | 20 |
| 1979-2014 | 20 |
| 2011-2040 | 22 |
| 2041-2070 | 23 |
| 2071-2100 | 22 |

**Table 3.19: Daily Maximum Snowmelt per Month at Minto**

| Timeline | Snow Melt (mm/day) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1979-2005 | 4 | 4 | 6 | 20 | 0 | 0 | 0 | 0 | 1 | 6 | 4 | 4 |
| 1979-2014 | 3 | 4 | 6 | 20 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 4 |
| 2011-2040 | 4 | 6 | 9 | 22 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 4 |
| 2041-2070 | 5 | 7 | 13 | 23 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 5 |
| 2071-2100 | 5 | 9 | 16 | 22 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 6 |

## 3.9 Wind Speed

The mean annual wind speed at Minto is predicted to increase by 2.4% over the next century (Table 3.20).

**Table 3.20: Mean Wind Speed at Minto**

| Timeline | Context | Value (m/s) | Change Over Baseline (m/s) | Change [%] |
|---|---|---|---|---|
| 1979-2005 | Baseline | 2.56 | - | - |
| 1979-2014 | Current Reality | 2.55 | -0.01 | -0.39% |
| 2011-2040 | 2020s | 2.56 | 0.00 | 0.01% |
| 2041-2070 | 2050s | 2.58 | 0.02 | 0.87% |
| 2071-2100 | 2080s | 2.62 | 0.06 | 2.40% |

# 4 Benchmarking

The climate change projections were benchmarked against the following reports with climate projections:

- **Yukon Climate Change Indicators and Key Findings 2015** (NCEC 2015). The report is designed to provide an overview of the trends in temperature, precipitation, fire severity, and sea ice extent/volume for decision makers in the province. The temperature and precipitation trends can be used as a comparative for the climate change value evaluated in this report.

- **Coffee Gold Project, Climate Change Projection for Coffee Creek Region, Yukon** (Lorax 2015). The report is designed to address climate projections and their potential impacts on the project. They address temperature, precipitation and freeze and thaw dates, which can be used as a comparative for the climate change projections evaluated in this report.

Projected mean annual temperature, precipitation and freezing days all exhibit similar values. The NCEC report uses historical trends to predict the future outcomes. Coffee Gold's report uses global climate models, while this report uses both. Lorax (2015) in the Coffee Gold report uses five downscaled model averages climate change models. SRK's methodology does not use downscaled climatic model models, instead considered gridded information for all the available climate change models and compared those results applied to the site with historical trends from Reanalysis ERA-Interim.

The expected mean annual temperature presents similar trend in all of three reports. Freezing-day estimations are also quite similar in Coffee Gold's report and to SRK's. MAP shows an increasing trend in all reports; SRK's report presents a greater increase than either of the two benchmark reports. However, the magnitude seems reasonable compared with the benchmarked reports. Table 4.1 presents an overall synthesis of the climate change results in the area.

**Table 4.1: Climate Change Benchmarks – Meteorological Parameters**

| Projected Parameter | Period [years] | NCEC Yukon, 2015 | Lorax -Coffee Gold, 2015 | SRK – Minto, 2016 |
|---|---|---|---|---|
| Mean Annual Temperature | 2060's | >+2 ˚C | | +2.4 ˚C[1] |
| | 2100's | | +3-5 ˚C | +3.3 ˚C |
| Mean Annual Precipitation | 2060's | +10-20% | | + 29% [1] |
| | 2100's | | +20% | +44% |
| Freezing Days | 2060's | N/A | | -18.5 Days[1] |
| | 2100's | | -30 Days | -29 Days |

**Note(s):**

(1) Value defined for 2050s.

For IDF benchmarking the site IDF was compared with Simonovic et al's (Western University – London, ON) IDF CC tool (2016). They provide a web evaluation of all the IDF curves in Canada under different time frames and for a wide variety of climate change scenarios. The IDF information from the closest EC meteorological station of Pelly Ranch located 25 km north of the site was used from this web page as a comparison to the site IDF.

The climate change timeframe used in all of the scenarios is 2071 to 2100. Simonovic et al. (2016) provide IDF values for three representative concentration pathway (RCP) scenarios: RCP 2.6, RCP 4.5 and RCP 8.5. Table 4.2 provides a summary of the IDF changes for the Site (SRK) versus Pelly Ranch (Simonovic et. al., 2016) based on baseline conditions. The table shows that the SRK value falls within the higher range of the values presented by Simonovic et al. However, the value is within a reasonable range considering the uncertainty associated to these climate change models.

**Table 4.2: Climate Change Benchmarks – Intensity Duration Frequency Curves**

| Source | RCP 2.6 (2071-2100) | RCP 4.5 (2071-2100) | RCP 8.5 (2071-2100) | Compiled (2071-2100) |
|---|---|---|---|---|
| IDF CC Tool – Pelly Ranch, 2016 | +20% | +26% | +47% | |
| SRK – Minto, 2016 | | | | +44% |

# 5 Summary of Overall Climate Change Trends

Climate change effects develop over very long timescales relative to the project life. As such the trends listed in Table 5.1 will manifest as minimal increases and decrease over the length of the Project.

**Table 5.1: Overall Climate Change Trends**

| Climate Factor | Trend | Justification |
|---|---|---|
| Mean Annual Temperature | Increasing | The mean annual temperature should increase in total 3.3 degrees Celsius for the period 2100's. |
| Frequency of Extreme Temperatures | Reduction of variability | The intra-annual temperature range will decrease with the time, range between extreme maximum and minimum temperatures. |
| Frequency of Rainfall | Increasing | The IDF will increase in 44% for the period 2100s. This is also complemented with an increase in the amount of wet days in a year. |
| Total Rainfall | Increasing | Increase in total precipitation of 199.3 mm (44%) by 2100's. |
| Snow Accumulation | Increasing | Snow depth appears to be increasing between December and March mainly by years 2100s. |
| Snowmelt | Unknown | There is a predicted increase in the daily maximum snowmelt, however the values are not monotonically increasing with the time; and the variation magnitude is close to 10%, which suggest some uncertainty. |
| Floods and Storms | Unknown, likely Increasing | Increasing temperature, precipitation, long duration rainfall and storm intensities in the trends to 2100 suggest that storms and freshet are increasing. Therefore it is likely reasonable to assume that storms and floods will increase by the period of 2100's. |

# 6 Effects of Climate Change on Closure Design Criteria

The climate change projections discussed in this memo and specifically summarized in Section 5 contribute to develop a long-term design criteria for engineered closure designs and infrastructure. For closure conveyance channel designs the predicted increase in precipitation and in the frequency of storms play a considerable role in engineering channel geometries and riprap specifications. According to the climate change study, channels which are designed on the present day discharges are projected to more water in the form of a greater peak flow, greater and more frequent storm runoffs, and even freshets flow.

SRK Consulting (Canada) Inc.

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# Appendix D – Channel Routing Options Evaluation

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# Memo

| | | | |
|---|---|---|---|
| **To:** | Ryan Herbert, Minto Explorations Ltd | **Client:** | Minto Explorations Ltd. |
| **From:** | Samantha Barnes, SRK | **Project No:** | 1CM002.042 |
| **Cc:** | Dylan McGregor, SRK | **Date:** | August 3, 2016 |
| **Subject:** | Minto Channel Routing Options Evaluation | | |

# 1 Introduction

This memo summarizes the impacts of routing runoff through the pit versus diverting it around the pit. The Minto routing flow closure evaluation assessed channel design options for surface water flow received by the Main and Area 2 open pits.

Flow routing alternatives include two options for the Area 2 Pit:

- Option 1 – Area 2 Pit upstream flow are routed into Area 2 Pit through Channel B (Ditch B Phase V/VI Design). From the pit, the flows are discharged through channel width, which becomes Channel D.
- Option 2 – Area 2 Pit catchment is diverted into Channel B (Ditch B), which by-passes the Area 2 Pit.

Three 24 hours precipitation return period models were applied to three geometric channel configurations for the Main Pit and options 1 and 2 for the Area 2 Pit.

# 2 Hydraulic – Hydrologic Model

Three 24 hours precipitation return period events were modelled to test the change in resultant peak flow and flow depth in the discharge channel design: a 2-year peak flow, a 200-year peak flow, and a probable maximum flood (PMF). Three geometries were assessed for discharge channels from both open pits as follows:

- Case 1 – Minimum channel width (2 m)
- Case 2 – Constructible channel width, based on dozer sizing (7 m)
- Case 3 – Maximum channel width, based on topography (22 m for Main Pit, 15 m for Area 2 Pit)

Geometric models of each routing alternative and each channel width alternative were compared using HEC-HMS developed by US Army Corps of Engineers (2000).

# 3 Results

## 3.1 Routing Options – Hydrologic Results

Figure 1 shows the complete hydrograph for Option 1 and Option 2. The blue solid line is the routing and channel width alternative (Option 1). The red dashed line is the diversion alternative (Option 2). Figure 2 shows a close-up of this variation in peak flow under both scenarios. The difference between the two routing options is approximately 30 m³/s for the PMF event.

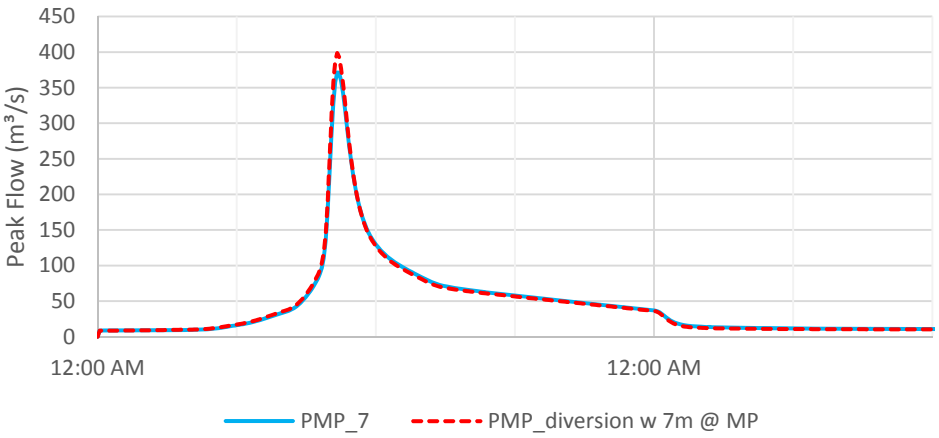


**Figure 1: Routing Option Comparison for the PMF**

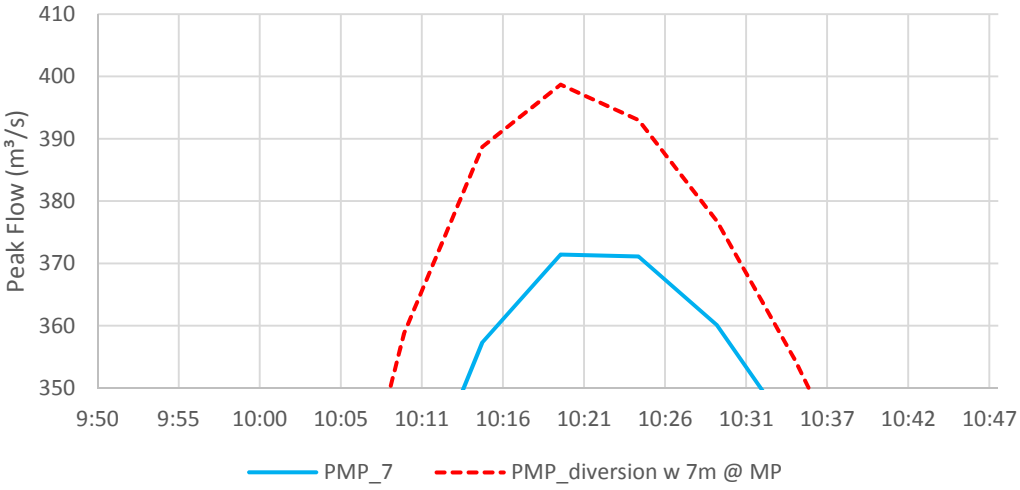


**Figure 2: Routing Option Comparison for the PMF (Flow Peak Close-up)**

## 3.2 Geometric Cases – Hydraulic Results

The results for the three channel width cases are presented in Table 1 where the design peak flow events are assumed to be the PMP. The riprap was sized based on the Isbash method (Garcia 2007).

**Table 1: Probable Maximum Flood Results**

| Channel Width Scenario | Area 2 Pit | | | Main Pit | | |
|---|---|---|---|---|---|---|
| | Peak Flow ($m^3/s$) | Flow Depth (m) | Riprap D50 (m) | Peak Flow ($m^3/s$) | Flow Depth (m) | Riprap D50 (m) |
| Case 1 (2m) | 5.8 | 0.99 | 0.08 | 17.4 | 1.71 | 0.30 |
| Case 2 (7m) | 9.7 | 0.79 | 0.09 | 23 | 1.31 | 0.32 |
| Case 3 (max) | 14 | 0.64 | 0.07 | 31.9 | 0.86 | 0.17 |

# 4 Discussion and Recommendations

The results of the two routing options illustrate a minimal difference in impact from diverting runoff around the Area 2 Pit as opposed to through the pit. Furthermore, the diversion Option 2 does not result in a difference in the magnitude of peak flow or the period of time when the peak is presented when compared to routing flows through the pit. For the channel width options to minimize the size of riprap required, Case 2 is recommended for both open pit channel widths.

Based on the analyses presented and considering future construction riprap needs, it is recommended that the Option 1 channel alignment and the Case 2 channel width option be implemented. Option 1 represents the routine option with the lowest flows and it is paired with the channel geometry that requires the most conservative riprap sizing.

SRK Consulting (Canada) Inc.

*Original Signed By*

Samantha Barnes, EIT
Consultant

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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# Appendix E – Integrating Vegetation Erosion Protection

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# Memo

| | | | |
|---|---|---|---|
| **To:** | Ryan Herbert, Minto Explorations Ltd. | **Client:** | Minto Explorations Ltd. |
| **From:** | Stuart McPhee, EIT | **Project No:** | 1CM002.042 |
| **Cc:** | Dylan MacGregor, SRK | **Date:** | August 3, 2016 |
| **Subject:** | Integrating Vegetation Erosion Protection | | |

This memo discusses the use of vegetation to assist channel stabilization and erosion reinforcement of disturbed soils for the Minto Project. Best management practices (BMPs) are provided in the Yukon Revegetation Manual for Practical Approaches and Methods (Matheus 2013) and the Government of Alberta's Transportation Erosion and Sediment Control Manual (2011). These BMP's provide guidelines for analysis, design selection, construction, and maintenance of erosion, and sediment control structures and site-specific selection of vegetation and establishing plant communities.

A commonly employed reclamation practice is to use live vegetation for channel protection and erosion control of disturbed soils. The use of biotechnical techniques do not replace the need for rock riprap, but can complement and improve channel stabilization designs during construction (e.g. regraded slopes and rock riprap). These techniques also improve soil reinforcement on disturbed slopes and regraded areas and ultimately assist in establishing vegetation, riparian zones, and develop soils.

The vegetation proposed for channel stabilization and erosion control focus on the use of coarse woody, grass and legume, and wetland species of vegetation. These species are widely used in industrial site reclamation design, construction, and maintenance to mitigate erosion, and sedimentation. The Yukon Revegetation Manual summarizes common plant species that are established by seeding. Common seeding practices for reclamation include hydroseeding and broadcast seeding. Appended to this memo are the summary tables prepared in the Yukon Revegetation Manual *Chapter 5: Revegetation Scenarios and Seed Recommendations*. Included in the appended tables are both Non-Native (Agronomical) and Locally-Collected (Native) seeds and the reclamation scenario's that they are suited for.

Methods to improve existing and proposed infrastructure (e.g. conveyance channels, covers and disturbed erodible slopes) include:

- establish vegetation and restorative self-sustaining plant communities;
- increase slope and channel stability due to root reinforcement, interlock, and soil draining;
- provide protection against wind, water, and surface erosion and rock fall;

- provide shade to regulate temperature and humidity close to surface that promotes further vegetation growth of volunteer species;
- provide improvement to the soil water regime through interception, evapotranspiration, and storage;
- improve soil development and the formation of organic soils;
- improve habitat provisions for animals;
- may reduce construction and maintenance costs (compared to other designs); and
- establish post closure landscapes that are often more appealing due to their more natural features.

At this stage of closure design, a preliminary assessment of common biotechnical reclamation practices has identified that there is a future opportunity to integrate vegetation erosion protection into the closure conveyance channel design and the disturbed soils adjacent to the channels.

There are three main components to the design and construction of the closure conveyance channels that would benefit from biotechnical stabilization BMPs:

- Disturbed and excavated slopes
- Establishing riparian vegetation
- Channel erosion and protection

Closure designs for conveyance channels will require sections of channels to have excavated alignments through erodible materials. The excavated slopes within these materials will typically have slopes graded towards the channel. It is expected that if these disturbed slopes are left, they will erode and even transport sediment into the channels. If the slopes contain weak fine grained erodible soils, then the slopes may be subject to sloughing and larger scale transportation of materials, which may block the conveyance channels.

Immediately after construction the closure conveyance channels will lack riparian vegetation. Biotechnical techniques can assist with slope stabilization and establishing riparian vegetation. Techniques for stabilizing these slopes are recommended to be a combination of BMPs provided in the Government of Alberta's Transportation Erosion and Sediment Control Manual (2011) as listed in Table 1. The BMP figure for live staking method is attached to this memo as an example.

**Table 1: Selected Closure BMPs from Alberta Transportation Erosion and Sediment Control Manual**

| BMP ID | BMP Name | Disturbed and Excavated Slopes | Riparian Vegetation Development | Channel Erosion Protection |
|---|---|---|---|---|
| 13b | Rolled Erosion Control Products | ✓ | | |
| 14a,b | Riprap Armouring | ✓ | | ✓ |
| 19a,b | Slope Drains | ✓ | ✓ | |
| 24a | Hydroseeding | ✓ | ✓ | |

| BMP ID | BMP Name | Disturbed and Excavated Slopes | Riparian Vegetation Development | Channel Erosion Protection |
|---|---|---|---|---|
| 27a | Live Staking | ✓ | ✓ | ✓ |
| 27b1,2,3 | Brush Layering | ✓ | ✓ | ✓ |
| 28 | Wattle (Live Fascine) | ✓ | ✓ | |
| 34a | Surface Roughening | ✓ | ✓ | |
| 34c | Slope Benching | ✓ | | |
| 38a,b,c | Coir/Straw Rolls with Brush Layers | ✓ | ✓ | |
| 39 | Brush Mattress | ✓ | ✓ | |
| 40 | Live Siltation | | ✓ | ✓ |
| 41 | Willow Post and Pole | ✓ | ✓ | ✓ |
| 44 | Vegetated MSE | ✓ | ✓ | ✓ |
| 45a,b,c,d | Vegetated Riprap | ✓ | ✓ | ✓ |

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

# 1 References

Government of Alberta. 2011. Erosion and Sediment Control Manual. AB. Recovered July 28, 2016 from http://www.transportation.alberta.ca/Content/docType372/Production/ErosionControlManual.pdf

Matheus P, and Omtzigt T. 2013. Yukon Revegetation Manual – Practical Approaches and Methods. Recovered July 28, 2016 from: http://www.yukonrevegetationmanual.ca/.

# Attachment 1: Revegetation Scenarios and Seed Recommendations

## Summary of Recommended Species

Table 5.27

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS) AND APPLICABLE SCENARIOS

| SCENARIO | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** (cultivar) | **# OF SEEDS/KG** | LOW SLOPE, LOW-MID ELEVATION SITES | STEEP SLOPES | WET SITES | HIGHWAY RIGHT-OF-WAYS | DISTURBED PERMAFROST SITES | ARCTIC TUNDRA AND STABLE PERMAFROST SITES | ALPINE AND SUBALPINE SITES |
| **Rocky Mountain fescue**<br>*Festuca saximontana*<br>(common) | **1,430,000** | x | x | | x | x | | x |
| **Violet wheatgrass**<br>*Elymus alaskanus*<br>(common) | **330,000** | x | x | | x | | x | x |
| **Glaucous bluegrass**<br>*Poa glauca*<br>(Tundra or common) | **2,904,000** | x | x | | x | | x | x |
| **Slender wheatgrass**<br>*Elymus trachycaulus*<br>(Revenue, Adanac, Highlander or common) | **349,800** | x | x | | x | | | |
| **Ticklegrass**<br>*Agrostis scabra*<br>(common) | **11,000,000** | x | | | | x | | x |
| **Tufted hairgrass**<br>*Deschampsia caespitosa*<br>(Nortran or common) | **3,300,000** | x | | x | x | x | x | x |
| **Fowl bluegrass**<br>*Poa palustris*<br>(common) | **4,840,000** | x | | x | x | x | | |
| **Spike trisetum**<br>*Trisetum spicatum*<br>(common) | **5,500,000** | | | | | | x | x |
| **Bluejoint reedgrass**<br>*Calamagrostis Canadensis*<br>(Sourdough or common) | **8,442,438** | x | | x | | x | | |
| **Polargrass**<br>*Arctagrostis latifolia*<br>(Alyeska or common) | **3,960,000** | | | x | | x | x | |
| **American sloughgrass**<br>*Beckmannia syzigachne*<br>(Egan or common) | **2,723,600** | | | x | | x | | |
| **Alpine bluegrass**<br>*Poa alpina*<br>(Gruening or common) | **2,353,826** | | | | | | x | x |

## Summary of Recommended Species

Table 5.28

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS) AND APPLICABLE SCENARIOS

| SCENARIO | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** (cultivar) | **# OF SEEDS/KG** | LOW SLOPE, LOW-MID ELEVATION SITES | STEEP SLOPES | WET SITES | HIGHWAY RIGHT-OF-WAYS | DISTURBED LOWLAND PERMAFROST SITES | ARCTIC TUNDRA AND STABLE PERMAFROST SITES | ALPINE AND SUBALPINE SITES |
| **Kentucky bluegrass** *Poa pratensis* (Nugget) | **3,057,648** | | | x | | | x | |
| **Creeping red fescue** *Festuca rubra* (Arctared for northern Yukon, Boreal for southern Yukon) | **539,407** | x | x | | x | x | x | x |
| **Canada bluegrass** *Poa compressa* (Reubens or common) | **5,264,204** | x | x | x | x | x | | |
| **Streambank wheatgrass** *Elymus lanceolatus* (Sodar) | **336,600** | x | x | x | x | x | x | |
| **Meadow foxtail** *Alopecurus pratensis* (common) | **895,136** | x | x | x | x | x | x | |
| **Red top** *Agrostis gigantea* (common) | **10,672,640** | x | | x | | | | |
| **Timothy** *Phleum pratense* (Climax, Engmo) | **2,559,400** | | | x | | x | x | |
| **Alfalfa** *Medicago sativa* (Rangelander, Rambler or Peace) | **498,960** | | x | | | | | |
| **Sheep fescue** *Festuca ovina* (common) | **1,100,000** | x | | | x | x | x | x |
| **Annual rye** *Lolium multiflorum* | **477,400** | | x | | | x | | |
| **Barley** *Hordeum vulgare* | **29,920** | | x | | | x | x | x |

## Summary of Recommended Species

Table 5.29

LOCALLY-COLLECTED NATIVE HERBACEOUS SPECIES (SEEDS) AND APPLICABLE SCENARIO

| SCENARIO | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| SPECIES | # OF SEEDS/KG | LOW SLOPE, LOW-MID ELEVATION SITES | STEEP SLOPES | WET SITES | HIGHWAY RIGHT-OF-WAYS | DISTURBED LOWLAND PERMAFROST SITES | ARCTIC TUNDRA AND STABLE PERMAFROST SITES | ALPINE AND SUBALPINE SITES |
| **Northern rough fescue** *Festuca altaica* | 451,854 | x | x | x | x | x | x | |
| **Yukon wheatgrass** *Elymus calderi* | — | x | | | | | | |
| **Macrourum's wheatgrass** *Elymus macrourus* | 374,782 | x | x | | | | | |
| **Northern brome** *Bromus pumpellianus* | 202,400 | x | x | | x | | | |
| **Sweetgrass** *Hierochloë hirta* (formerly *H. odorata*) | 242,000 | x | x | | x | | | |
| **Alpine sweetgrass** *Hierochloë alpina* | — | | | | | | x | x |
| **Mountain timothy** *Phleum alpinum* (formerly *P. commutatum*) | — | | | | | x | | x |
| **Northern bluegrass** *Poa alpigena/Poa pratensis* | 3,057,648 | | | x | | x | x | x |
| **Arctic bluegrass** *Poa arctica* | 3,250,553 | | | | | | x | |
| **Nuttall's alkaligrass** *Puccinellia nuttalliana* | 4,648,140 | x | x | x | x | x | x | x |
| **Yellow locoweed** *Oxytropis campestris* | 521,400 | x | | | x | | | |
| **Showy locoweed** *Oxytropis splendens* | 1,548,800 | x | | | x | | | |
| **Bear root** *Hedysarum alpinum* | 154,000 | x | | | | | | |
| **Mackenzie's hedysarum** *Hedysarum Mackenzii* | 101,889 | x | | | | | | |
| **Yarrow** *Achillea millefolium* and *Achillea sibirica* | 6,274,426 | x | | | x | | | |
| **Mountain avens** *Dryas* spp. | — | x | | | x | x | x | x |
| **Arctic lupine** *Lupinus arcticus* | 22,733 | x | | x | x | x | x | x |
| **Wormwood/sage** *Artemesia* spp. | — | x | x | | x | | x | x |

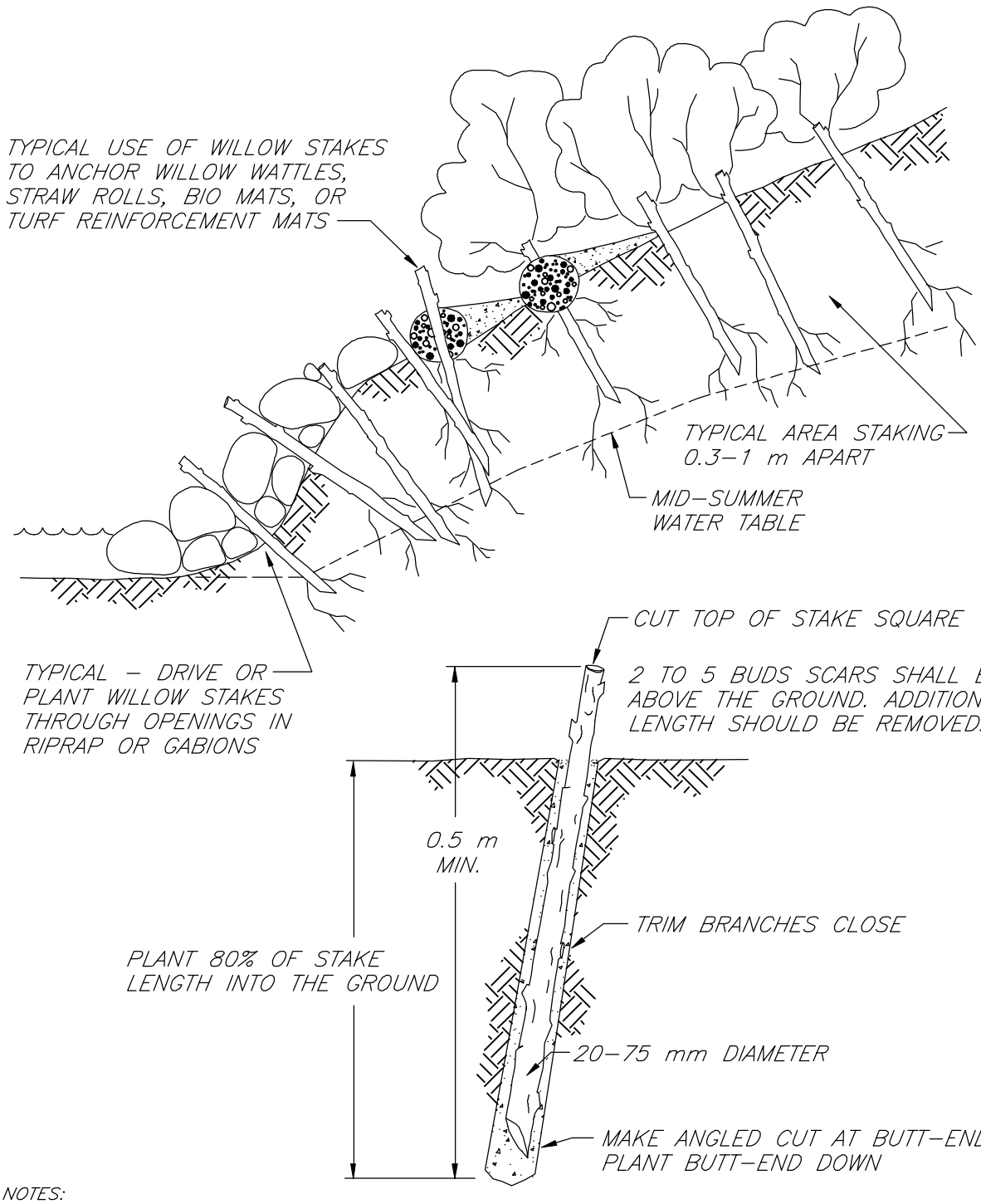
# Summary of Recommended Species

Table 5.30

## LOCALLY-COLLECTED WOODY SPECIES AND APPLICABLE SCENARIOS

| SCENARIO | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **LOCAL WOODY SPECIES** | LOW SLOPE, LOW-MID ELEVATION SITES | STEEP SLOPES | WET SITES | HIGHWAY RIGHT-OF-WAYS | DISTURBED LOWLAND PERMAFROST SITES | ARCTIC TUNDRA AND STABLE PERMAFROST SITES | ALPINE AND SUBALPINE SITES |
| **Willow**<br>*Salix alaxensis, S. pulchra, S. planifolia, S. richardsonii, S. hastate, S. arbusuloides, S. lucida, S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*) | x | | x | | x | x | x |
| **Poplar**<br>*Populus balsamifera* | x | | x | | | | |
| **Shrub birch**<br>*Betula glandulosa* | x | | x | | | x | x |
| **Dwarf birch**<br>*Betula nana* | | | | | | x | |
| **Green alder**<br>*Alnus crispa* | x | | x | | | x | x |
| **Grey alder**<br>*Alnus tenuifolia* | x | | x | | | | |

Attachment 2: Live Staking BMP Technique




NOTES:
1. HARVEST AND PLANT STAKES DURING THE DORMANT SEASON.
2. USE HEALTHY, STRAIGHT AND LIVE WOOD AT LEAST 1 YEAR OLD.
3. MAKE CLEAN CUTS AND DO NOT DAMAGE STAKES OR SPLIT ENDS DURING INSTALLATION, USE A PILOT BAR IN FIRM SOILS.
4. SOAK CUTTINGS FOR 24 HOURS (MIN.) PRIOR TO INSTALLATION.
5. TAMP THE SOIL AROUND THE STAKE.
6. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

NOT TO SCALE

# LIVE STAKING

FILE: LIVESTK

From: Salix–Applied Earthcare – EROSION DRAW 3.0
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# Site Characterization Plan

January 2018

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# 1 INTRODUCTION

As a requirement for Capstone Mining Corp's Quartz Mining Licence, a Site Characterization Plan has been developed. The Plan will outline the existing condition at the Minto Mine. Table 1-1 shows how sections of this plan correspond to the Plan Requirements Guidance for Quartz Mining Projects.

**Table 1-1: Concordance with Plan Requirements**

| Section in Guidance Document | | Corresponding Section(s) in this Plan | |
|---|---|---|---|
| 4.1 | Introduction | 1 | Introduction |
| 4.2 | Geology | 2 | Geology |
| 4.3 | Climate and Hydrology | 3<br>4 | Meteorology<br>Hydrology |
| 4.4 | Surface Water | 5 | Surface Water Quality |
| 4.5 | Groundwater | 6 | Groundwater |
| 4.6 | Vegetation and Wildlife | 7<br>8<br>9 | Wildlife<br>Aquatic Resources<br>Vegetation |
| 4.7 | Soils and Bedrock | 2 | Geology |
| 4.8 | Seismicity | 2 | Geology |
| 4.9 | Geochemistry and Geotechnical Information | 10 | Geochemistry and Geotechnical Information |

The Plan Requirements Guidance for Quartz Mining Projects references a concordance table outlining applicable proponent commitments and decision document conditions. As this plan describes the existing site conditions, none of the commitments made in the YESAB process or the conditions in the decision document are relevant to the understanding of this plan. Capstone's commitments and the conditions contained in the decision document are addressed in the appropriate documents that evaluate the potential environmental effects of the project and the issues raised in the evaluation process.

## 1.1 SITE OVERVIEW

The Minto Mine is located on the west side of the Yukon River, approximately 240 km northwest of Whitehorse, Yukon (Figure 1-1) and is centered at 62°37'N latitude and 137°15'W longitude (NAD 83, UTM Zone 8 coordinates 6945000N, 384000E). Highway 2 (North Klondike Highway) is located on the east side of the Yukon River; the mine can be accessed in the summer by barge crossing or in winter by the ice bridge crossing at Minto Landing.

Environmental conditions are summarized in Table 1-2 below.

**Table 1-2: Summary of Environmental Conditions in the Minto Mine Area.**

| Project Area Attribute Description | Project Area Attribute Description |
|---|---|
| Region: | Yukon |
| Topographic map sheet: | NTS 115 I/10, 115 I/11 |
| Geographic location name code: | Minto Project |
| Latitude: | 62° 36' N |
| Longitude: | 137° 15' W |
| Drainage region: | Yukon River |
| Watersheds: | Yukon River, Big Creek, Wolverine Creek, Dark Creek, McGinty Creek, and Minto Creek. |
| Ecoregion: | Yukon Plateau (Central) - Pelly River ecoregion. |
| Study area elevation: | Rolling hills above mine site at 1131 to 600 m at the Yukon River Valley bottom. |
| Site climate: | Temperature ranges from –43.2°C (November 2006) to 30.3°C (July 2009). Mean annual temperature of –1.8°C. Mean annual rainfall is 174mm. |
| Vegetation communities: | Riparian, black spruce, white spruce, paper birch, lodgepole pine, buck brush/willow and ericaceous shrubs, feather moss, sedge, sagewort, grassland, mixed forest (aspen, balsam, and sub-alpine). Discontinuous permafrost is present on site. Site has been subject to recent forest fires. |
| Wildlife species: | Moose, caribou, Dall sheep, mule deer, grizzly and black bear, varying hare, beaver, lynx, marten, ermine, deer mouse, fox, mink, wolverine, least weasel, wolf, squirrel, porcupine coyote, muskrat, otter and wood frog. Bird species include: spruce, blue, ruffed, and sharp-tail grouse, waterfowl, raptors, and a variety of smaller birds. |
| Fish species: | In the Yukon River, Chinook, Coho, and chum salmon, rainbow trout, lake trout, least cisco, Bering cisco, round whitefish, lake whitefish, inconnu, Arctic grayling, northern pike, burbot, longnose sucker and slimy sculpin; In Big Creek, Chinook and chum salmon, Arctic grayling and whitefish species; In Wolverine Creek, Chinook salmon, Arctic grayling, and slimy sculpin; In Minto Creek (lower reaches only), Chinook salmon, slimy sculpin, round whitefish, Arctic grayling, longnose sucker, burbot; In McGinty Creek (lower reaches only), slimy sculpin, Arctic grayling |

The Minto Mine property lies in the eastern portion of the Dawson Range, which is part of the Klondike Plateau Physiographic Region, an uplifted surface that has been dissected by erosion. The area was largely unglaciated during the last ice age and topography consists of deep and narrow valleys, rounded rolling hills, and ridges with relief of up to 600 m (2,000 ft.). The highest elevation on the property is 975 m (3,200 ft.) above sea level, compared to lower elevations in the region with elevations of 460 m (1,500 ft.) along the Yukon River.

The Minto Mine is near the height of land with relatively gentle slopes and smooth ridges that often have spines of bedrock outcrops (tors) at their crests left from long periods of weathering. Broad ridges are typically mantled with felsenmeer (fields of angular, frost-heaved, in situ rock fragments). Below the ridge crests, bedrock exposures are limited or negligible. The Project area lies in a zone of extensive discontinuous (50–90%) permafrost and is included in the western portion of the Yukon plateau central ecozone. North-facing slopes in the area are commonly underlain by permafrost. Valley-bottom deposits and upland soils usually contain ice-rich horizons. Well-drained uplands may have permafrost-free soils.

As the ecoregion is largely unglaciated, the dominant parent materials are stony residual materials along ridge tops and summits, coarse colluvium on upper slopes, and silty colluvium and loess, rich in organic matter, on lower slopes and floors of main valleys. Muck is usually capped with peat and underlain by

permafrost. In the Minto Mine area, much of the colluvium on ridge slopes is coarse sand derived from decomposition of the largely granitic bedrock in the area. Overburden of relic soils that predate the last glaciation includes lacustrine deposits overlain by colluvium and organic silt in some upper valleys, some of which was exposed during excavation on the south side of the pit.

The mine development area is in the transition from the forested to non-forested (alpine) zone. Below the treeline (elev. ~1,000 m) the vegetation patterns reflect the discontinuous distribution of permafrost with stunted black spruce woodlands on cold, north-facing sites and mixed (aspen, white spruce, minor birch) forests on warm, south-facing slopes. The area has been burned over by several wild fires, the latest of which was in 2010 (Minto Landing to lower Minto Creek area). Many of the burnt trees have blown down and natural regeneration of pine and alder is occurring over much of the property and the Project area.

The climate of the region is continental with short, warm summers and very cold winters. Annual precipitation ranges from 300 to 500 mm. Mean annual temperatures are near –5°C with mean mid-winter temperatures of –23°C to –32°C, in July from +10°C to +15°C and extremes in the lower valleys ranging from –60°C to +35°C.

The area is drained by tributaries of the Yukon River. The rate of runoff is controlled by almost total vegetation ground cover and moderate slope gradients. Infiltration rate is expected to be high in areas of thicker colluvium. However, permafrost and seasonally frozen soils inhibit vertical percolation.

Topography in the Dawson Range is moderate and the active geomorphological processes in the study area are typically limited to include slow mass movement (solifluction) and some minor gully erosion. Although there are no reports of large-scale active natural landslides in the Minto Project area, smaller scale instabilities have recently been documented in the Minto Creek catchment area, downstream of the mine site. Substantial sediment loading in lower Minto Creek in the absence of effluent discharge from the site was observed throughout the open water months of 2011 (Appendix 1-3, *Minto Creek Water Quality Characterization*). This prompted a targeted water quality survey and an aerial investigation of the creek and tributaries in spring of 2012 in an attempt to identify the source(s) of the sediment. Two areas were identified in tributaries on the southern side of the Minto Creek catchment, below the area of control of the mine, where soil materials had slumped and transported a significant amount of material into the creek channel. Although ground investigations were not conducted, it is suspected that these instances may be related to thawing of frozen ground conditions, or may simply be small-scale instability of fine textured (lacustrine) soils.

## 1.2 SITE DESCRIPTION

The Minto Mine is a high grade copper mine located within Selkirk First Nation (SFN) Category A Settlement Land Parcel R-6A approximately 240 km northwest of Whitehorse, Yukon Territory (Figure 1-1). It is owned and operated by the Minto Explorations Ltd. a wholly owned subsidiary of Capstone Mining Corporation. Development of the mine was initiated in 1997, commercial operations started in October 2007, and the currently anticipated operating life is to 2020 with permitted resources to 2022. The Minto Mine is permitted

to conduct open pit and underground mining, and to mill the copper/gold/silver ore at a rate of 4,200 tonnes of per day. In 2016 (the most recent year of record), the Minto Mine produced 69.3 million pounds of copper from milling approximately 1.49 million tones or ore.

In addition to open pit mines, underground mines, and the mill, the Minto Mine site includes a number of waste rock dumps, a concentrate storage shed, a dry stack tailings storage facility (DSTSF), a water retention dam with a water storage pond (WSP), a water treatment plant, administrative offices, an airstrip, and a camp (Figure 1-2). Mill tailings are stored in the DSTSF and in mined-out open pits. Mine-impacted seepage from the DSTSF and under the Mill Valley Fill (MVF) is collected at the toe of the MVF in sump W62 and is pumped to the Main Pit (Figure 1-2). Non-impacted water and treated mine-impacted water are collected in the WSP (Figure 1-2). Effluent from the WSP is periodically discharged to Minto Creek under conditions specified in Water Use Licence (WUL) QZ14-031 (August 2015). Minto Creek, in turn, discharges to the Yukon River approximately 7.7 km south-east of the WSP (Figure 1-2).






capstone
MINTO MINE

ALEXCO ENVIRONMENTAL GROUP

**MINTO MINE**
**CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN**

# FIGURE 1-1
# PROJECT LOCATION

**JANUARY 2018**

D:\Project\AllProjects\Minto\gis\mxd\Overview_Maps\01-Project Location\Project_Location_MASTER_ESRI_Layers_20170802.mxd (*Last edited by: amatlashevska; 05/01/2018/13:21 PM*)




# MINTO MINE

## CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN

## FIGURE 1-2

## MINE SITE LAYOUT

JANUARY 2018

capstone MINTO MINE

1:13,500 *when printed on 11 x 17 inch paper*

0 50 100 200 300 400 500 Meters

ALEXCO ENVIRONMENTAL GROUP

Aerial imagery obtained from Challenger Geomatics. Imagery acquired August 9rd 2017

Datum: NAD 83 Projection: UTM Zone 8N

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D:\Project\All Projects\Minto\gis\mxd\Overview_Maps\05-Project Development\Year_0_Overview_20171220.mxd
(*Last edited by: amatlashevska;12/01/2018/13:39 PM*)

# 2 GEOLOGY

## 2.1 PHYSIOGRAPHY

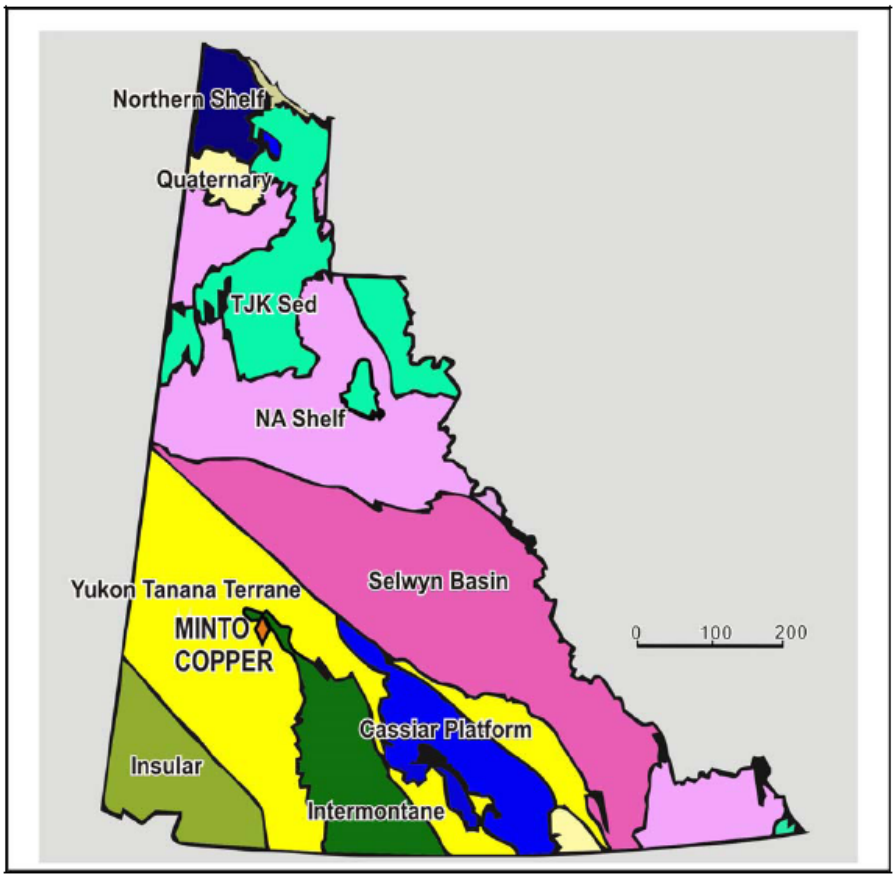
The property lies in the Dawson Range, part of the Klondike Plateau, an uplifted surface that has been dissected by erosion. Local topography consists of rounded rolling hills and ridges and broad valleys. The highest elevation on the property is approximately 1,000 m above sea level, compared to elevations of 460 m along the Yukon River. Slopes on the property are relatively gentle and do not present accessibility problems. Bedrock outcrops can often be found at the tops of hills and ridges. There are no risks of avalanche on the property.

Overburden is colluvium primarily comprised of granite-based sand from weathering of the granitic bedrock in the area and is generally thin but pervasive. It can reach plus 50 m in depth. Seams of clay and ice lenses are also present sporadically. South-facing slopes generally provide well-drained, sound foundation for buildings and roads. North-facing slopes in the area typically contain permafrost.

Vegetation in the area is sub-Arctic boreal forest made up of largely spruce and poplar trees. The area has experienced several wildfires over the years, the latest in 2010, and has no old-growth trees remaining. The fire in 2010 led to the partial evacuation of the camp and a short stoppage in production.

## 2.2 BEDROCK GEOLOGY

The Minto Project is found in the north-northwest trending Carmacks Copper Belt along the eastern margin of the Yukon-Tanana Composite Terrain, which is comprised of several metamorphic assemblages and batholiths (). The Belt is host to several intrusion-related Cu-Au mineralized hydrothermal systems. The Yukon-Tanana Composite Terrain is the easternmost and largest of the pericratonic terrains accreted to the Paleozoic northwestern margin of North America (e.g., Colpron *et al.*, 2005). It is regarded to be the product of a continental arc and back-arc system, preserving meta-igneous and metasedimentary rocks of Permian age on top of a pre-Late Devonian metasedimentary basement (e.g., Piercey *et al*. 2002).




*From: Yukon Geologic Survey "Maps Yukon" website (www.geology.gov.yk.ca)*

**Figure 2-1: Yukon Geology (from Yukon Geologic Survey "Maps Yukon" website (www.geology.gov.yk.ca).**

The Minto Property and surrounding area are underlain by plutonic rocks of the Granite Mountain Batholith (Early Mesozoic Age) (Figure 2-2: Regional Geology) that have intruded into the Yukon-Tanana Composite Terrain. They vary in composition from quartz diorite and granodiorite to quartz monzonite. The batholith is unconformably overlain by clastic sedimentary rocks thought to be the Tantalus Formation and andesitic to basaltic volcanic rocks of the Carmacks Group, both of which are assigned a Late Cretaceous age. Immediately flanking the Granite Mountain Batholith, to the east, is a package of undated mafic volcanic rocks, outcropping on the shores of the Yukon River. The structural relationship between the batholith and the undated mafic volcanics is poorly understood because the contact zone is not exposed

Geobarometry and geothermometry data (Tafti and Mortensen, 2004) suggests that the Granite Mountain Batholith was emplaced at a depth of at least 9 km, while the presence of euhedral to subhedral epidote, interpreted by Tafti and Mortensen as magmatic in origin, suggests a deeper emplacement depth in the order of 18 to 20 km.

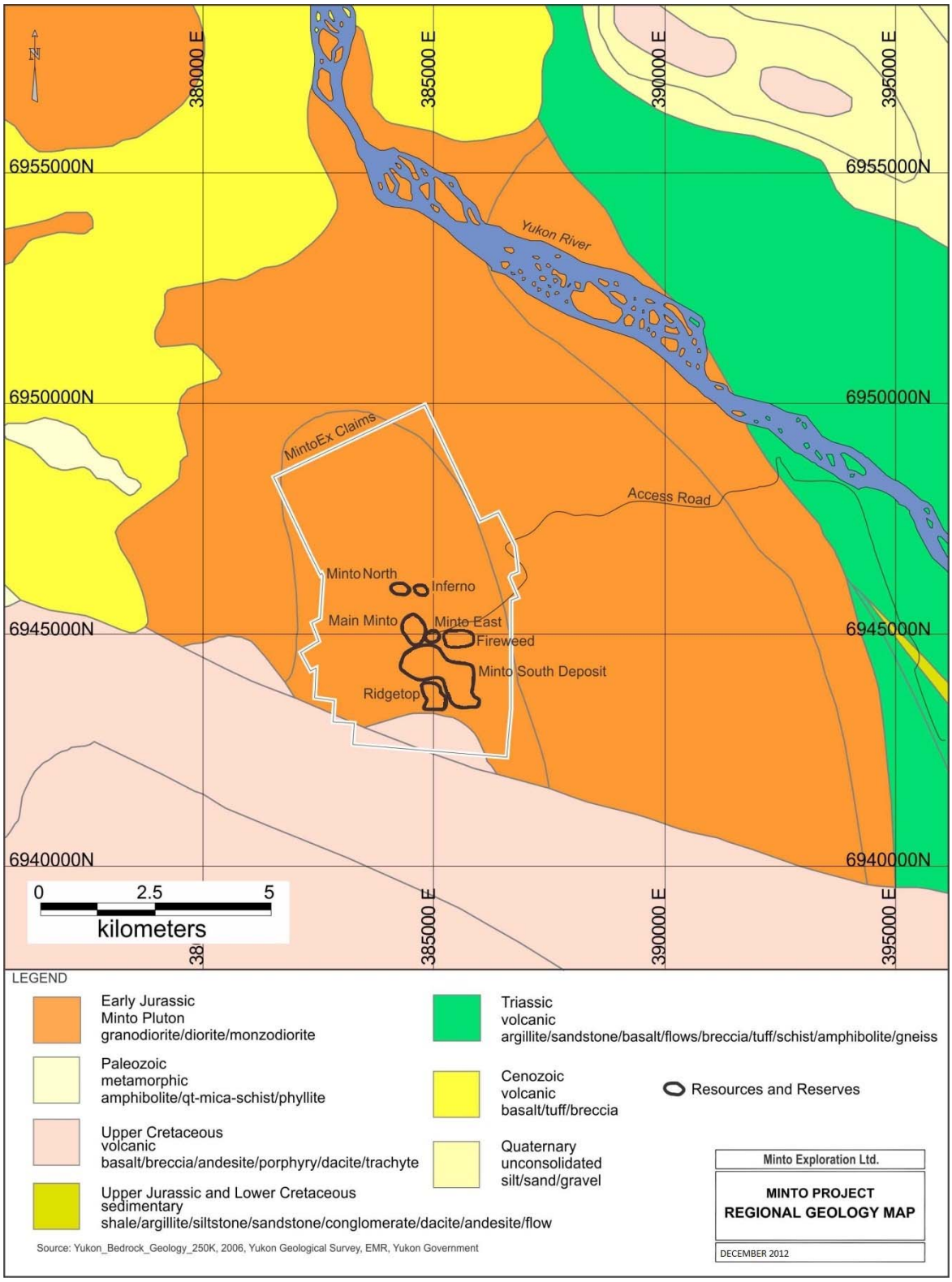



**Figure 2-2: Regional Geology.**

## 2.3 PROPERTY GEOLOGY AND LITHOLOGICAL DESCRIPTION

Much of the geological understanding of the rock around the Minto deposits is based on observations from diamond drill core and extrapolation from regional observations. The reason for this is poor outcrop exposure (less than 5% coverage), as well as the deep weathering and oxidation of any existing exposed outcrop. The terrain was not glaciated during the last ice age event.

Five additional deposits of mineralization are reported in this document outside of the Minto Main Deposit; Minto South Deposit, Ridgetop, Minto North, Inferno, Fireweed, and Minto East (). For the purpose of this report Area 2, Area 118, Copper Keel, and Wildfire resource sub-domains are now considered continuous and reported as one deposit, namely Minto South Deposit (MSD) located immediately south of Main Minto. Names of these resource sub-domains are retained for ease of discussion when discussing regions within MSD. The Ridgetop deposit is located just over 300 m south of the Area 2/118 resource sub-domain, the Minto North and Inferno deposits are located about 700 m north of the Main Deposit, the Fireweed deposit is located just over 500m east of the south end of the Minto Main deposit, the Minto East deposit is located about 200 m east of the south end of the Minto Main deposit, while the Copper Keel and Wildfire sub-domains form a southeast extension from Area 2/118. Each of these deposits closely shares a similar style of mineralization of shallow dipping copper sulphide mineralized zones. The Main Minto deposit was exposed in the dormant open pit mine; similarly, this flat geometry is currently exposed in the Minto South Deposit (Area 2 resource sub-domain) starter pit. In addition to these mineral deposits which have NI 43-101 compliant mineral resources there are several significant mineral prospects. These deposits and prospects define a general north-northwest trend.

The hypogene copper sulphide mineralization at Minto is hosted wholly within the Minto pluton, which intrudes near the boundary between the Stikinia and Yukon-Tanana terrains, however since the contact is not exposed it is unclear if the pluton stitches the two terrains. The Minto pluton is predominantly of granodiorite composition. Hood *et al*. (2008) distinguish three varieties of the intrusive rocks in the pluton. The first variety is a megacrystic K-feldspar granodiorite. It gradually ranges in mineralogy to quartz diorite and rarely to quartz monzonite or granite, typically maintaining a massive igneous texture. An exception occurs locally where weakly to strongly foliated granodiorite is seen in distinct sub-parallel zones several meters to tens of meters thick.

A second variety of igneous rock is quartzofeldspathic gneiss with centimeter-thick compositional layering and folded by centimetre to decimetre-scale disharmonic, gentle to isoclinal folds (Hood et al., 2008). The third variety of intrusive is a biotite-rich gneiss. MintoEx geologists consider all units to be similar in origin and are variably deformed equivalents of the same intrusion.

Copper sulphide mineralization is found in the rocks that have a structurally imposed fabric, ranging from a weak foliation to strongly developed gneissic banding. For this reason, all core logging by the past and present operators separates the foliated to gneissic textured granodiorite as a distinctly discernible unit. It is generally believed by MintoEx geologists that the foliated granodiorite is just variably strained equivalents of the two primary granodiorite textures and not a separate lithology.

While this interpretation, based upon detailed observations from logging of tens of kilometers of drill core is highly likely but it still needs to be conclusively proven. Tafti & Mortensen (2004) noted that the relatively massive plutonic rocks have similar mineral and chemical composition as the foliated rocks. Research in collaboration with the Mineral Deposits Research Unit ("MDRU") of the University of British Columbia is on-going.

The contact relationship between the foliated deformation zones and the massive phases of granodiorite is generally very sharp. These contacts do not exhibit chilled margins and are considered by MintoEx geologists to be structural in nature, separating the variably strained equivalents of the same rock type. Tafti and Mortensen (2004) had interpreted the sharp contacts to be zones of deformed rock within the unfoliated rock (i.e. rafts or roof pendants). Supergene mineralization occurs proximal to near-surface extension of the primary mineralization and beneath the Cretaceous conglomerate.

Conglomerate and volcanic flows have been logged in drill core by past operators. New drilling has confirmed the presence of conglomerate, but not the volcanic flows. The latter cannot be confirmed by the authors as the drill core from historic campaigns was largely destroyed in forest fires and no new drilling has intersected such rocks. However, undated volcanic rocks are mapped by Hood, near the southwest margin of the property, south of a fault that is inferred from geophysics to separate them from the Jurassic Age intrusive rocks. The conglomerate has been dated (unpublished date pers. com. Dr. Maurice Colpron - Yukon Geological Survey) as Cretaceous Age. It is now recognized as an outcrop within a borrow pit exposure located west of the airstrip as well as in numerous recent drill holes. Observations of foliated and even copper mineralized cobbles in drilling indicate that "Minto-type" mineralization was exposed, eroded and reincorporated in sedimentary deposits by the Cretaceous Age.

Other rock types, albeit volumetrically insignificant, include dykes of simple quartz-feldspar pegmatite, aplite; and an aphanitic textured intermediate composition rock. Bodies of all of these units are relatively thin and rarely exceed the one meter core intersections. These dykes are relatively late, and observed contact relationships suggest they generally postdate the peak ductile deformation event; however some pegmatite and aplite bodies observed in a rock cut located north of the mill complex are openly folded.

It is unclear if this folding is contemporaneous with foliation development in the deformed rocks or post-dates the foliation development. Observations from drill core and open cut benches in the mine show examples where the foliation and the pegmatitic/aplitic intrusions are both folded, as well as examples where the intrusions are not folded, suggesting two populations of minor dykes.

## 2.4 SEISMIC HAZARD

The tectonics and seismicity of southwestern Yukon are influenced primarily by the Pacific and North American lithospheric plate margins. In Yukon's St. Elias region, northwest British Columbia and southeast Alaska, the boundary of the two lithospheric plates changes from right lateral transform to subductive. Instead of sliding past each other, the Pacific Plate is forced beneath the stable North American plate resulting in the St. Elias region being uplifted. This transfer of force along the fault into uplift or mountain

building dissipates tectonic energy, reducing seismic effects on the region northeast of and across the fault (SRK, 2013).

An assessment of peak ground acceleration was performed for the Minto project area using the 2015 National Building Code Seismic Hazard Calculation, and is shown in  below. Additional details can be found in Appendix 1-1 Seismic Hazard Assessment for Minto, YT.

## 2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

July 31, 2016

Site: 62.618 N, 137.241 W  User File Reference: Minto Mine

Requested by: , Minto Explorations Ltd.

**National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)**

| Sa(0.05) | Sa(0.1) | **Sa(0.2)** | Sa(0.3) | **Sa(0.5)** | **Sa(1.0)** | **Sa(2.0)** | **Sa(5.0)** | **Sa(10.0)** | PGA (g) | PGV (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.154 | 0.229 | **0.269** | 0.246 | **0.207** | **0.146** | **0.083** | **0.030** | **0.012** | **0.125** | **0.156** |

**Notes.** Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s$^2$). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

| Probability of exceedance per annum | 0.010 | 0.0021 | 0.001 |
|---|---|---|---|
| Probability of exceedance in 50 years | 40% | 10% | 5% |
| Sa(0.05) | 0.025 | 0.060 | 0.091 |
| Sa(0.1) | 0.034 | 0.086 | 0.134 |
| Sa(0.2) | 0.052 | 0.114 | 0.166 |
| Sa(0.3) | 0.060 | 0.118 | 0.163 |
| Sa(0.5) | 0.058 | 0.110 | 0.146 |
| Sa(1.0) | 0.047 | 0.085 | 0.109 |
| Sa(2.0) | 0.028 | 0.049 | 0.063 |
| Sa(5.0) | 0.0098 | 0.018 | 0.023 |
| Sa(10.0) | 0.0039 | 0.0068 | 0.0089 |
| PGA | 0.022 | 0.050 | 0.075 |
| PGV | 0.046 | 0.087 | 0.114 |

**Figure 2-3: 2015 National Building Code Seismic Hazard Calculation for the Minto Mine**

# 3 METEOROLOGY

The existing meteorology of the Project area and the climate trends and projections of the Minto region of Yukon were first described in detail in EBA's report *Minto Mine – 2010 Climate Baseline Report* and subsequently in Access Consulting Group's (ACG) *Minto Climate Baseline Report* (2012) and Alexco Environmental Group's (AEG) *Minto Mine Site Characterization – Hydrometeorology* (2017) (Appendix 1-2). The meteorological data contained in the above reports were recorded by two on-site meteorological stations over a period of about twelve years. Snow depth and water equivalent data were provided from annual on-site snow surveys since 1994. Data used in climate trend analyses were sourced from regional monthly and annual records provided by the Meteorological Service of Canada and applied to the Project area. Future temperature and precipitation scenarios for the Minto Mine areas were obtained from a probabilistic analysis conducted by SRK (2016). Details of the data collection program and the procedures used for analysis are provided in the 2017 *Hydrometeorology Site Characterization Report* (Appendix 1-2).

The climate in the Minto region is subarctic continental characterized by long, cold winters and short, cool summers. The area experiences moderate precipitation in the form of rain and snow and a large range of temperatures on a yearly basis with a mean annual temperature below 0°C.

## 3.1 SUMMARY OF SITE METEOROLOGICAL CONDITIONS (2005-2016)

Two meteorological stations installed at the property have recorded wind speed and direction, air temperature, relative humidity, barometric pressure, solar radiation and rainfall in one-hour intervals since September 7, 2005 for the HOBO and October 15, 2010 for the Campbell Scientific station. The Campbell Scientific weather station has been shown to provide more reliable data and as such, the HOBO station was decommissioned in the summer of 2014.

### 3.1.1 Wind

The HOBO anemometer was installed at a height of 3 meters and got damaged by strong winds in 2010. Based on data from the Campbell Scientific anemometer, which is installed at a height of 10 meters and is much less prone to icing than the HOBO anemometer, dominant winds at site originate from the South, Southeast and Northwest, with an average speed of 2.8 m/s and gusts up to 26.8 m/s.

### 3.1.2 Air Temperature

Summer is characterized by temperatures in the range of 10°C to 20°C. Winter is characterized by a much larger day-to-day variation in temperatures, typically between –10°C and –30°C. Diurnal variation in air temperatures tends to be less during the winter period than during the summer period. The transitions between winter and summer are characterized by a quick rise or fall in air temperatures. July has been the warmest month on average (14.5°C) while the coldest has been December (–17.7°C). The mean annual

temperature for the period of record is -1.9°C for the HOBO station and -0.9°C for the Campbell Scientific station. Extremes ranged from -43.2°C to 30.3°C.

### 3.1.3 Relative Humidity

Relative humidity (RH) is highest during the winter months (typically in the range of 75% to 95%) and lowest during the spring and early summer, typically in the range of 40% to 60%. Relative humidity has a much larger day-to-day variability during the summer. The lowest recorded %RH was 10.25%. The highest was 100%. Annually, mean relative humidity is 70%.

### 3.1.4 Solar Radiation

As would be expected at a latitude of 62.6°N, a strong seasonal pattern is evident in solar radiation, with a maximum being received near the summer solstice in late June (daily maximums on the order of 750 $W/m^2$), and daily maximums slightly above zero around the winter solstice when the site experiences only about 3 hours of direct sunlight per day. Large fluctuations from the general trend during the summer are due to cloud cover. Mean annual solar radiation is 108 $W/m^2$ (averaged over the two meteorological stations).

On July 20, 2016, a second pyranometer was installed at the Campbell Scientific station to measure outgoing radiation. Data from August 2016 to December 2016 range from 5 $w/m^2$ to 34 $W/m^2$.

### 3.1.1 Barometric Pressure

Barometric pressure recorded on-site at 885 m elevation is converted into a meteorological standard sea level equivalent. Barometric pressure is slightly higher on average between May and August (above 1009 hPa), and lowest between September and April (below 1008 hPa). Mean annual sea-level equivalent barometric pressure is 1006.5 hPa (average of both meteorological stations).

### 3.1.2 Precipitation

#### *3.1.2.1 Rainfall*

The Minto Mine HOBO meteorological station has been recording rainfall on site since its installation in September 2005 until decommissioning in June 2014. Based on a cumulative of average monthly rainfall, 192.8 mm of rain is expected on average at site in a single year (AEG, 2017). August is the rainiest month with an average rainfall of 46.2 mm. The largest monthly rainfall total was 100.6 mm (August 2008). Rainfall has been recorded in every month of the year. Based on regional data, about 64% of total annual precipitation falls as rain (average proportion over the period of record for four regional stations). Applying

this ratio to the average annual rainfall of 192.8 mm measured at the Minto Mine HOBO station would result in a total annual precipitation value of 303.2 mm.

#### *3.1.2.2 Total Precipitation*

The Campbell Scientific station was recording rainfall only from time of commissioning until October 14, 2011, when a snowfall conversion adaptor was installed on the tipping bucket to allow for measurement of total precipitation. On November 18, 2014, a Geonor T-200B vibrating wire all weather precipitation gauge was installed in addition to the existing tipping bucket and rainfall adaptor to improve accuracy and validate total precipitation measurements. Average annual total precipitation is 277.6 mm with the tipping bucket and snowfall adaptor and 248.5 mm with the total precipitation gauge. Both values are less than the estimated total of 303.2 mm based on the HOBO rainfall measurements and regional data. This could indicate potential undercatch of both the snowfall adaptor and total precipitation gauge, however, other factors such as wind or snow pillow formation can also play a role. More years of total precipitation data will allow a more meaningful comparison.

### 3.1.3 Snowpack

Annual snow surveys have been conducted in 1994, 1995, 1998, and annually from 2006 to 2016, at three locations in the Minto Creek catchment area and a fourth station was added in 2016. Based on the ten years of snow surveys, the average water-equivalent snow depth remaining on the first day of March and April is 86.3 mm and 86.7 mm, respectively. In four of the seven May surveys, the snowpack had melted entirely by May 1. In the three years where snow remained on the ground on May 1 (1995, 2006, and 2008), the mean snowpack had reduced to 10%, 27%, and 20%, respectively, of the peak measured snowpack in that year. The data indicates that the majority of runoff due to snowmelt occurs in April.

### 3.1.4 Evaporation

No evaporation records are available for the Minto Mine site. An evaporation pan was deployed on site during the summer of 2016, however, due to a system error, data are invalid. Starting in August 2012, the Campbell Scientific datalogger program incorporated an instruction for the calculation of potential evapotranspiration (PET) using the American Society of Civil Engineers (ASCE) standardized reference evapotranspiration equation (Penman-Monteith). The PET instruction uses temperature, relative humidity, wind speed, solar radiation, latitude, longitude and altitude to calculate an evaporation rate for a short grass crop. This provides an approximation of actual evaporation, which varies locally depending on surface type and micro topography. The average total annual PET is 428 mm which is similar to the estimated mean evaporation value of 400 mm/year based on regional data.

## 3.2 REGIONAL CLIMATE TRENDS

Long-term trends were evaluated by reviewing long-term records from stations in the region (regional analysis). Environment Canada meteorological stations used for this regional analysis were selected based on location/proximity and data availability.

### 3.2.1 Temperature

#### *3.2.1.1 Past Trends*

The annual mean temperature has been increasing at Pelly Ranch by 0.07°C per year on average over the 57-year period corresponding to a total average increase of 4.2°C from 1957 to 2014. For Carmacks, the average rate of increase of the annual mean temperature is slightly less at 0.05°C per year, resulting in an average increase of 2.5°C for the 52-year period. It is also important to note that the average annual minimum temperature has been increasing at a faster rate than the average annual maximum temperature at both stations, thus implying that the average diurnal range has also been decreasing. With respect to seasonality, January (winter) mean temperatures have experienced much higher rates of increase (0.15°C per year at Pelly Ranch and 0.22°C per year at Carmacks) than July (summer) mean temperatures (0.03°C per year at Pelly Ranch and 0.02°C per year at Carmacks). A close correlation between monthly average temperatures recorded at Minto and at Pelly ranch and Carmacks, as well as the proximity of the stations to the property, suggests that the long term trends would also be applicable to the Minto property. Winter temperatures at Minto however are approximately 3°C to 5°C higher due to a predominant Yukon winter temperature inversion of +8°C/ km up to an elevation of 1200 m (EBA, 2010).

#### *3.2.1.2 Future Trends*

Based on a probabilistic analysis conducted by SRK (2016), the mean annual temperature at Minto is expected to increase by about 3.3°C over the next century, with mean annual temperatures of -0.8°C, 0.2°C and 1.1°C in the 2020s, 2050s and 2080s, respectively. The intra-annual range between extreme maximum and extreme minimum temperatures is expected to decrease with time (SRK, 2016).

### 3.2.2 Precipitation

#### *3.2.2.1 Past Trends*

Environment Canada monthly precipitation records at Pelly Ranch and Carmacks show an increasing trend in total annual precipitation over the period of record, however the correlation is weak. The proportion of total

precipitation falling as rain also displays an increasing trend over the period of record, but again, the correlation is weak.

#### *3.2.2.2 Future Trends*

Based on a probabilistic analysis conducted by SRK (2016), The total precipitation at Minto is forecasted to increase 67.9 mm (15%) during the mine life (2011 to 2040) and 199.3 mm (44%) by 2100 the total precipitation at Minto is forecasted to increase 67.9 mm (15%) during the mine life (2011 to 2040) and 199.3 mm (44%) by 2100. The simple daily precipitation intensity index (mean annual precipitation divided by the total number of wet days) is forecasted to increase by 6.6% during the mine life and by 25% in the next century. Snow accumulation appears to be increasing between December and March mainly by years 2100s.

# 4 SURFACE WATER HYDROLOGY

The baseline surface water hydrology of the Minto Creek watershed prior to mining activity was detailed in Clearwater Consultants Ltd. Memorandum CCL-MC6 *Minto Copper Project—Surface Water Hydrology Conditions* (CCL, 2010). CCL-MC6 also covered conditions during Mine Operations until 2009. A subsequent report was prepared by ACG to update CCL-MC6 by presenting those previous data, and data gathered since then until the end of the 2012 open water season (ACG, 2013). Additionally, this report included data since 2009 gathered in McGinty Creek, a catchment of similar size to Minto Creek, also draining into the Yukon River and located directly north of the Minto Creek catchment (Figure 4-1). An updated *Minto Mine Site Characterization – Hydrometeorology* report prepared by Alexco Environmental Group (2017) is presented in Appendix 1-2.

Hydrological data have been gathered by either ACG or Minto representatives. Data coverage from year to year varies, depending on when in situ dataloggers were installed and removed, and when instantaneous discharge measurements were taken. Instantaneous discharge is measured using the velocity-area method and a current meter. Solinst Water Leveloggers are used to collect continuous stage readings which are then corrected based on physical staff gauge measurements. The records are processed into continuous discharge based on the stage-discharge relationship. This relationship (stage and discharge) is established each season through rating measurements obtained during regular field visits to the sites.

The locations for which the greatest amount of data have been collected are stations W1, Minto Creek near the mouth (catchment area of 42 $km^2$); and W3, Minto Creek downstream of water storage pond dam (catchment area of 10.4 $km^2$ area). In 2010, another continuously monitored hydrometric site called MC1 was added, approximately 2 km upstream of W1. In 2011, data collection did not allow for processing of stage records into continuous discharge; however, improved monitoring allowed for successful processing in 2012.

In addition to Minto Creek, the catchment to the north has been monitored since 2009 to support development of the Minto North deposit, and is referred to as McGinty Creek. There are five stations on McGinty Creek at which discharge is measured. In 2009, four stations were established including MN-4.5, MN-2.5, MN-1.5 and MN-0.5; in 2011 a fifth site, MN-0.2, was added (Figure 4-1). Continuous hydrometric data has been collected at MN-4.5 since 2009, and additional continuous logging instruments were added to stations MN-2.5 and MN-0.5 in late 2012.

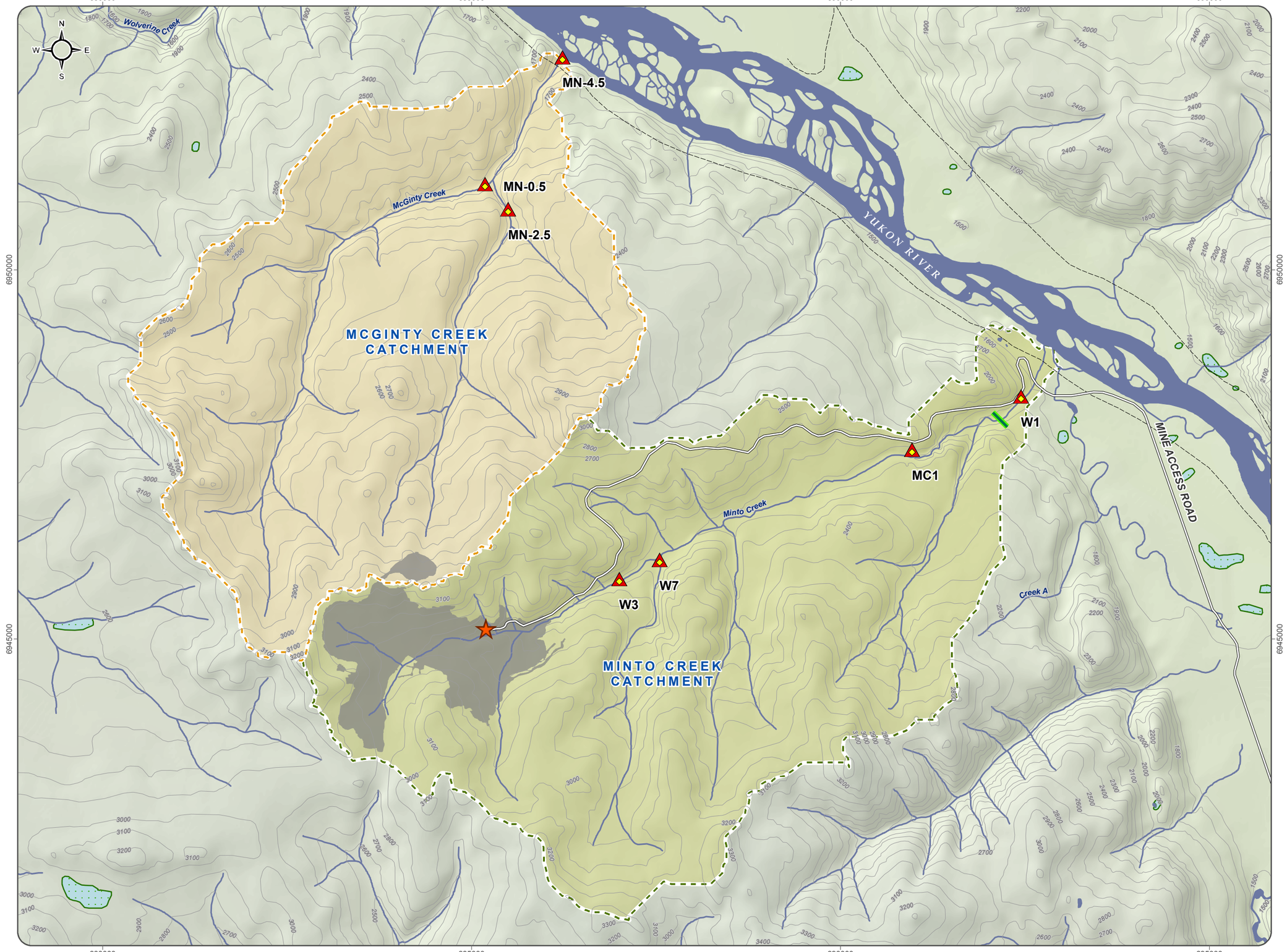
# MINTO MINE

## CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN

**FIGURE 4-1**

**MINTO AND MCGINTY CREEK HYDROMETRIC MONITORING NETWORK AND CATCHMENT AREAS**

JANUARY 2018




- Water Quality and Hydrometric Monitoring Station
- Observed Fish Barrier - Minto Creek
- Mine Footprint
- McGinty Creek Catchment
- Minto Creek Catchment
- Wetland
- Minto Access Road
- Contours (100ft)

**1:50,000** *when printed on 11 x 17 inch paper*

0 500 1,000 1,500 2,000 Meters

Alexco Environmental Group

National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced underlicense from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

Datum: NAD 83 Projection: UTM Zone 8N

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(*Last edited by: amatlashevska;12/01/2018/11:24 AM*)

## 4.1 MINTO CREEK

Monitoring of hydrological parameters on Minto Creek began in 1993 and has continued intermittently at sites W1 and W3 (Figure 4-1). Monitoring has been more intensive since mine commissioning in 2007. W3 is an in-stream trapezoidal flume with a manufacturer-specified stage-discharge relationship. Both discharge and stage are read on an integrated gauge in the throat of the flume. A Solinst Levelogger record is calibrated with these field observations to process a continuous discharge record at this site. Flows at W3 are impacted by storage within, and discharge from the Water Storage Pond. Sites MC-1 and W1 are natural stream channels where manual velocity measurements are taken across the channel and discharge is calculated using the velocity area method. Continuous water levels from Solinst Leveloggers are processed into continuous discharge using these rating measurements. Updated mean monthly flows for W1 and W3 are presented in Table 4-1 and Table 4-2, respectively.

**Table 4-1: Mean Monthly Discharge ($m^3/s$) on Minto Creek at Station W1.**

| | Apr | May | Jun | Jul | Aug | Sep | Oct |
|---|---|---|---|---|---|---|---|
| 1993 | | | | | | 0.069 | |
| 1994 | | 0.312 | 0.058 | 0.095 | 0.007 | 0.073 | |
| 1995 | | 0.027 | 0.001 | 0.091 | | 0.133 | |
| 1996 | | 0.031 | 0.024 | 0.324 | | 0.146 | |
| 1997 | | 1.447 | | | 0.265 | | |
| 1998 | | 0.161 | | | 0.003 | | |
| 1999 | | | | | 0.033 | | |
| 2000 | | 1.004 | | | | | |
| 2001 | | 0.467 | | | | | |
| 2002 | | | | | | | |
| 2003 | | | | | 0.129 | | |
| 2004 | | | | 0.118 | | | |
| 2005 | | 0.097 | 0.012 | 0.127 | 0.209 | 0.219 | 0.134 |
| 2006 | 0.203 | 0.354 | 0.15 | 0.02 | 0.0068 | | 0.031 |
| 2007 | 0.645 | 0.175 | 0.053 | 0.061 | 0.025 | 0.034 | 0.035 |
| 2008 | | 0.117 | 0.015 | 0.026 | 0.184 | 0.184 | 0.026 |
| 2009 | | 0.868 | 0.351 | 0.249 | 0.139 | 0.026 | |
| 2010 | 0.560 | 0.081 | 0.038 | 0.106 | 0.118 | 0.125 | 0.092 |
| 2011 | | | 0.229 | 0.200 | 0.200 | 0.082 | |
| 2012 | | 0.269 | 0.073 | 0.052 | 0.051 | 0.078 | 0.056 [2] |
| 2013 | | 0.485 [1] | 0.064 | 0.065 | 0.044 | 0.085 | 0.059 [2] |
| 2014 | | 0.138 [1] | 0.022 | 0.020 | 0.014 | 0.031 | 0.025 [2] |
| 2015 | | 0.117 | 0.010 | 0.010 | 0.030 | 0.024 | 0.020 [1] |
| 2016 | 0.252 [1] | 0.047 | 0.020 | 0.017 | 0.024 | 0.043 | 0.026 |
| **Mean** | | | | | | | |
| **Pre-Mine 1993 to 2006** | 0.203 | 0.433 | 0.049 | 0.129 | 0.093 | 0.128 | 0.083 |
| **Mining Period 2007 to 2016** | 0.486 | 0.255 | 0.088 | 0.081 | 0.083 | 0.071 | 0.042 |
| **All Data 1993 to 2016** | 0.415 | 0.344 | 0.075 | 0.099 | 0.087 | 0.090 | 0.050 |

*Notes: [1] Based on incomplete or derived data*

*[2] Based on multiple discrete measurements*

**Table 4-2: Mean Monthly[1] Discharge ($m^3/s$) on Minto Creek at Station W3.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | | | | | | | | | 0.028 | | | |
| 1994 | | | | | 0.101 | 0.028 | 0.039 | 0.011 | 0.028 | | | |
| 1995 | | | | | | 0.004 | 0.017 | | 0.027 | 0.008 | | |
| 1996 | | | | | 0.013 | | 0.087 | | 0.021 | | | |
| 1997 | | | | | 0.554 | | | | | | | |
| 1998 | | | | | | | | 0.006 | | | | |
| 1999 | | | | | | | | 0.006 | | | | |
| 2000 | | | | | | | | | | | | |
| 2001 | | | | | 0.160 | | | | | | | |
| 2002 | | | | | | | | | | | | |
| 2003 | | | | | | | | 0.037 | | | | |
| 2004 | | | | | | | 0.026 | | | | | |
| 2005 | | | | | 0.046 | 0.008 | 0.014 | 0.017 | 0.022 | 0.020 | | |
| 2006 | | | | 0.018 | 0.128 | 0.042 | 0.006 | 0.015 | 0.009 | 0.010 | | |
| 2007 | | | | 0.001 | 0.012 | 0.009 | 0.006 | | | | | |
| 2008 | | | | | | | | 0.064[2] | 0.122[2] | 0.003 | | |
| 2009 | | | | | | 0.026[2] | 0.106[2] | 0.092[2] | 0.124[2] | 0.110 | | |
| 2010 | | | | 0.002 | 0.004 | 0.005 | 0.034 | 0.071 | 0.086 | 0.070 | | |
| 2011 | | | | | | 0.005 | 0.005 | 0.006 | 0.005 | | | |
| 2012 | | | | 0.004 | 0.020 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | | |
| 2013 | | | | | | <0.001 | <0.001 | 0.002 | 0.003 | 0.003 | 0.003 | 0.006 |
| 2014 | 0.003 | 0.006 | 0.006 | 0.057 | 0.086 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.006 |
| 2015 | 0.004 | 0.002 | 0.001 | 0.075 | 0.052 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 |
| 2016 | | | | 0.022 | 0.052 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 |
| **Mean** | | | | | | | | | | | | |
| **Pre-Mine 1993 to 2006** | -[3] | -[3] | -[3] | -[3] | 0.167 | 0.02 | 0.032 | 0.015 | 0.023 | 0.013 | -[3] | -[3] |
| **Mining Period 2007 to 2016** | 0.004 | 0.004 | 0.004 | 0.027 | 0.038 | 0.007 | 0.021 | 0.028 | 0.040 | 0.025 | 0.004 | 0.005 |
| **All Data 1993 to 2016** | 0.004 | 0.004 | 0.004 | 0.026 | 0.102 | 0.012 | 0.025 | 0.023 | 0.033 | 0.022 | 0.004 | 0.005 |

[1]Monthly flows calculated by averaging all available flow data for a given month. Average flow in months with only a single spot flow measurement assumed equal to the spot flow measurement.

[2]Flows impacted by storage within, and emergency releases from, the Water Storage Pond in August and September 2008 and in June through October 2009.

[3]Insufficient data for calculation.

Table 4-3 shows the discharge data gathered to date at station MC-1 and Table 4-4 shows data available at station W7. Appendix 1-2 contains the associated baseline report and the available hydrographs from 2007-2012 for stations W1, W3, W7 and MC-1.

**Table 4-3: Mean monthly discharge ($m^3/s$), Minto Creek at MC-1.**

| | Month | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** |
| **2011** | | | | | 0.118 | 0.093 |
| **2012** | 0.179 | 0.065 | 0.052 | 0.041 | 0.108 | - |
| **2013** | 0.358 | 0.085 | 0.103 | 0.044 | 0.089 | 0.064 [2] |
| **2014** | 0.187 | 0.028 | 0.031 | 0.036 | 0.028 | 0.033 [2] |
| **2015** | 0.862 [2] | 0.014 | 0.028 | 0.042 | 0.035 | 0.031 [1] |
| **2016** | - | 0.029 [1] | 0.036 | 0.048 | 0.076 | - |
| **Mean** | **0.397** | **0.044** | **0.050** | **0.042** | **0.076** | **0.055** |

*Notes: [1] Based on incomplete or derived data*
*[2] Based on multiple discrete measurements*

**Table 4-4: Mean monthly discharge ($m^3/s$), Minto Creek at W7.**

| | Month | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** |
| **2013** | | | 0.013 | 0.031 | 0.019 | 0.006 |
| **2014** | 0.112 | | | | | |
| **2015** | | 0.006 | 0.004 | 0.011 | 0.011 | 0.029 |
| **2016** | | 0.006 | 0.010 | 0.010 | 0.013 | 0.010 |

*Notes: Based on discrete measurements only*

## 4.2 McGinty Creek

McGinty Creek has two main sub-catchments that each have two water quality monitoring stations, one just above the confluence and one near the headwaters. MN-4.5 is located on the main stem below the confluence of the tributaries near the mouth; just above the Yukon River (Figure 4-1). MN-0.5 and MN-0.2 are the lower and upper stations on the west tributary, respectively. MN-2.5 and MN-1.5 are the lower and upper stations on the east tributary, respectively. Stations MN-0.2 and MN-1.5 are not set up with continuous loggers and generally exhibit very low flows. As such they are not included in the discussion below.

**Table 4-5: Mean monthly discharge ($m^3/s$), McGinty Creek at MN-4.5.**

| | Month | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** |
| **2009** | - | 0.018 [1] | 0.033 | 0.019 | 0.031 | 0.016 | 0.013 [1] |
| **2010** | - | 0.028 [1] | 0.051 | 0.079 | 0.047 | 0.034 | - |
| **2011** | - | 0.444 | 0.093 | 0.125 | 0.134 | 0.068 | 0.045 [1] |

| | Month | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** |
| **2012** | 0.212 [1] | 0.230 | 0.180 | 0.082 | 0.053 | 0.109 | - |
| **2013** | - | - | 0.054 [1] | 0.103 | 0.093 | 0.116 | - |
| **2014** | - | 0.230 [1] | 0.041 | 0.037 | 0.026 | 0.046 [1] | - |
| **2015** | - | - | 0.013 | 0.046 | 0.049 | 0.029 | 0.029 [1] |
| **2016** | - | 0.017 [1] | 0.015 | 0.026 | 0.028 | 0.028 | 0.010 [1] |

*Notes: [1] Based on incomplete or derived data*

**Table 4-6: Mean monthly discharge ($m^3/s$), McGinty Creek at MN-2.5.**

| | Month | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** |
| **2014 [1]** | - | 0.032 | - | - | - | - | - |
| **2015 [1]** | - | 0.015 | 0.003 | 0.011 | 0.038 | 0.010 | 0.010 |
| **2016 [1]** | 0.034 | 0.008 | - | - | 0.009 | 0.014 | 0.003 |

*Notes: [1] Based on incomplete or derived data*

**Table 4-7: Mean monthly discharge ($m^3/s$), McGinty Creek at MN-0.5.**

| | Month | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** |
| **2014 [1]** | - | 0.045 | - | - | - | - | - |
| **2015 [1]** | - | 0.035 | 0.013 | 0.054 | 0.098 | 0.029 | 0.025 |
| **2016 [1]** | - | 0.028 | 0.016 | 0.010 | 0.016 | 0.035 | 0.018 |

*Notes: [1] Based on incomplete or derived data*

Hydrographs from 2009–2016 at MN-4.5, MN-2.5 and MN-0.5 are shown in the *Minto Mine Site Characterization – Hydrometeorology* report (Appendix 1-2).

# 5 SURFACE WATER QUALITY

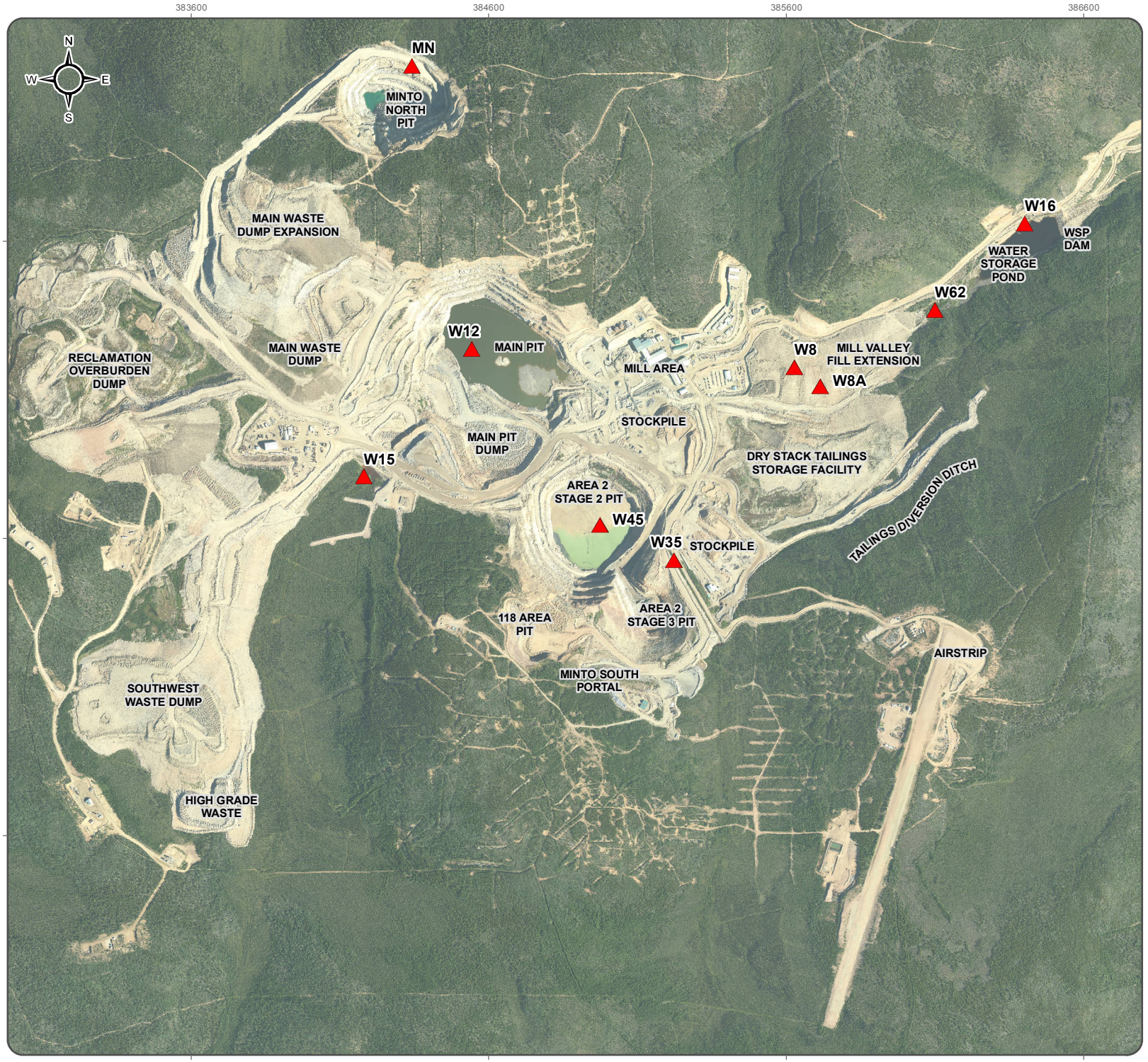
Surface water quality is a key consideration in the evaluation of potential effects of mining and mineral development projects. Effects from mining activities can be observed for significant distances downstream and changes to water quality parameters have the potential to impact aquatic resources and to affect human use of water resources. Both Minto and McGinty Creeks are receiving environments for Minto Mine and have been monitored for water quality conditions, with more intensity and duration of sampling in Minto Creek as part of the initial baseline and more recently the intensive operational monitoring under the mine water quality monitoring programs (licenced and otherwise). A characterization report for water quality in these two watersheds has been developed with the intention of presenting either baseline or existing water quality conditions as the foundation of assessing potential effects from proposed mine expansion activities. Minto Creek and McGinty Creek have both been previously characterized in numerous reports. The *Minto and McGinty Creeks Water Quality Characterization report* (AEG, 2017) included as Appendix 1-3 provides updates to the water quality characterization of both Minto and McGinty Creek stations and for key mine site water management and monitoring stations, and includes monitoring results to December 2016. Key findings from the characterization report are included below.

## 5.1 MINTO MINE SITE

The water quality for ten monitoring stations around the Minto Mine Site including W8, W8A, W12, W15, W16, W35, W35A, W35B, W45 and W62 is summarized in this section. For ease of discussion and presentation of results, these stations are divided into two groupings: the “upper mine site” and “lower mine site”. The Minto Mine Site stations and groupings are described in Table 5-1 and shown in Figure 5-1. Water quality is monitored at many more locations on the Minto site, but these ten stations are the most critical with respect to decisions regarding the conveyance, storage and treatment of site water.

**Table 5-1: Minto Mine Monitoring Station Locations.**

| Station | Description / Location |
|---|---|
| **Upper Mine Site** | |
| W12 | Main Pit |
| W15 | Minto Creek, d/s of Southwest Waste Rock Dump |
| W35 | South Diversion Ditch |
| W35A | North End of South Diversion Ditch |
| W35B | South End of South Diversion Ditch |
| W45 | Area 2 Pit |
| **Lower Mine Site** | |
| W8 | Dry Stack Tailings Storage Facility drainage, west |
| W8A | Dry Stack Tailings Storage Facility drainage, east |
| W16 | Water Storage Pond |
| W62 | Sump at toe of Mill Valley Fill Extension |




# MINTO MINE

**CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN**

**FIGURE 5-1**

## MINE SITE MONITORING STATION LOCATIONS

JANUARY 2018

capstone MINTO MINE

▲ Surface Water Surveillance Program Monitoring Station Locations

**1:18,000** ***when printed on 8x11 inch paper***

0 100 200 300 400 500 Meters

ALEXCO ENVIRONMENTAL GROUP

Aerial imagery obtained from Challenger Geomatics. Imagery acquired August 3rd th 2017.

Datum: NAD 83 Projection: UTM Zone 8N

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The characteristics, trends and patterns associated with the geochemistry of surface waters at the Minto Mine Site are summarized below, while more details are available in *Minto and McGinty Creeks Water Quality Characterization report* (AEG, 2017) included as Appendix 1-3.

- The pH of the waters was predominantly circumneutral to slightly alkaline;
- Although typically well oxygenated, lower levels of dissolved oxygen were often observed during winter, particularly for the pit lake locations, where ice cover limited the oxygenation of underlying waters;
- Nitrogen species concentrations were generally highest in the pit lake and DSTSF drainage sites, reflecting leaching of nitrogen residue from blasting activity. Nitrate-N levels showed marked seasonality at both the Minto Creek mine site location (W15) and the DSTSF drainage (W8 and W8A), but with different patterns. In Minto Creek, nitrate-N levels were highest in winter and lowest over summer, responding to nitrogen uptake demand by primary producers, whereas the opposite trend was noted in the DSTSF drainage;
- DOC concentrations were highest during spring snowmelt, likely due to snowmelt flushing the surrounding soils of labile organic matter that had accumulated through the previous summer and fall;
- Dissolved hardness concentrations were typically lowest in spring at the flowing water sites due to snowmelt dilution, and increased through the year, peaking in winter, suggestive of a marked groundwater component to hardness levels;
- Concentrations of dissolved iron, and to a lesser extent dissolved aluminum, often appeared higher than may be expected from equilibrium with their oxyhydroxide minerals under the prevalent oxidizing, circumneutral pH conditions. Complexation with dissolved organic matter likely maintains these elevated dissolved iron and aluminum levels;
- Dissolved copper concentrations were highest in the DSTSF drainage and tended to peak with freshet, suggestive of some association with DOC; and
- Dissolved concentrations of both selenium and molybdenum increased approximately four-fold in the pit lake sites over the past two to three years, alongside sulphate. Dissolved selenium exhibited strong seasonal cycling in both Minto Creek (W15) and the DSTSF drainage (W8A), but with offset patterns. In Minto Creek, selenium concentrations were lowest at freshet, then rose through the year, peaking in winter, suggestive of a strong groundwater contribution. The opposite pattern was observed at site W8A, where selenium levels oscillated on an annual basis between summer peaks and winter troughs.

## 5.2 MINTO NORTH PIT

The Minto North Pit is located at the northernmost tip of the mine site (Figure 5-1). Station MN was established with the initiation of the mining activities in the Minto North Pit (August 2015), and the monitoring results presented in the report for this station are all 'operational' results. Water quality data from the Minto North Pit are considered in isolation since the pit does not discharge at present and is not anticipated to discharge during the operational period.

The characteristics, trends and patterns associated with the geochemistry of Minto North Pit are summarized below, while more details are available in *Minto and McGinty Creeks Water Quality Characterization report* (AEG, 2017) included as Appendix 1-3.

- Minto North Pit waters were circumneutral to mildly alkaline and well oxygenated over the one year of data collected to date;
- Field-measured conductivity and hardness were relatively high and showed no seasonal trends;
- Nitrogen species were very high in the Minto North Pit, likely due to nitrogen residue from blasting activities;
- Minto North Pit waters generally contained elevated dissolved copper, molybdenum, and selenium concentrations;
- The majority of dissolved silver and zinc measurements were below detection; and
- Dissolved aluminum, arsenic, cadmium, nickel, and iron concentrations were unremarkable although some sporadic spikes in iron levels were an order of magnitude higher than the median dissolved iron concentration.

## 5.3 MINTO CREEK

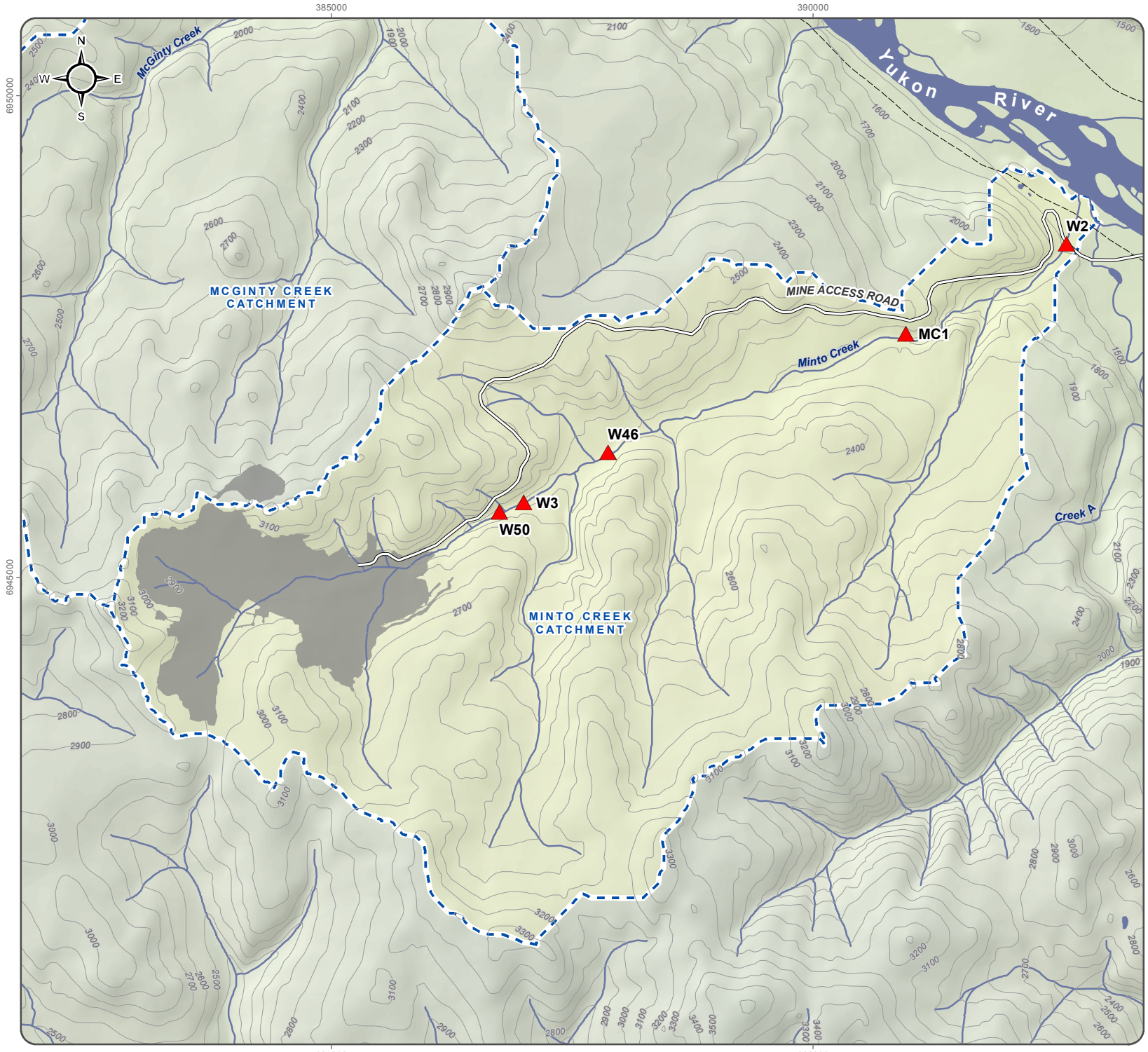
Several water quality stations are monitored on Minto Creek during the operational period. Data from four of these monitoring stations are provided in this report: W50, W3, MC1, and W2. These stations are described in Table 5-2 and their location shown in Figure 5-2. These stations are all on the 'mainstem' of Minto Creek.

**Table 5-2: Minto Creek Monitoring Station Locations**

| Station | Description / Location |
|---|---|
| W50 | Minto Creek, approximately 50m downstream of toe of WSP dam |
| W3 | Downstream of Water Storage Pond dam, MMER Final Discharge Point (Flume) – Effluent |
| MC1 | Receiving Environment station upstream of the canyon fish barrier on Minto Creek. |
| W2 | Lower Minto-Creek at Road Crossing – Receiving Environment station in reach with documented fisheries usage. |

W50 is located downstream of the inflow of the effluent discharge and is a point of compliance for effluent quality standards (EQSs) as outlined in WUL QZ14-031 (August 5th, 2015). EQSs are presented and discussed in further detail in Section 3.3 of Appendix 1-3 *Minto and McGinty Creeks Water Quality Characterization report* (AEG, 2017). Station W3—located downstream of the Water Storage Pond dam—is the mine effluent monitoring and compliance point per the Metal Mining Effluent Regulations (MMER). Station W2 is the lowermost Minto Creek receiving environment monitoring location before the confluence with the Yukon River, and is the "WQO Station" designated in the Water Use Licence QZ94-031 during the period when flow is encountered at stations W15 and W35. Both W2 and W3 have been monitored regularly since 2005. Station MC1 in Minto Canyon serves as a comparison monitoring point between W3 and W2 and began regular monitoring in 2010.

Four additional stations (W6, W7, C4 and C10) situated on tributaries to Minto Creek are monitored regularly or semi-regularly. The data for these stations are not included in this reporting update as they were a component of the Minto Creek background water quality evaluation in 2016, and are included in Minnow Environmental Inc. (2016) (Appendix A of Appendix 1-3).




# MINTO MINE

## CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN

## FIGURE 5-2

## MINTO CREEK MONITORING STATION LOCATIONS

JANUARY 2018

capstone MINTO MINE

- Surface Water Surveillance Program Monitoring Station Locations
- Catchment
- Mine Footprint
- Minto Access Road
- Trail

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### 5.3.1 Background Water Quality

In 2009, to support the redevelopment of the mine Water Management Plan, Minnow Environmental compiled Minto Creek water quality monitoring data into a pooled data set that reflected background (unimpacted by development activities) conditions. The mine water-quality monitoring program has continued to monitor stations within the operational area, downstream stations which are exposed to the influence of mine effluent discharge, and downstream stations which are not exposed to effluent. Data from these non-exposed stations are relevant the background water quality condition in Minto Creek, and were therefore added to the pre-existing 2009 background data set. New background data sets were developed for periods up to the end of 2010 and to the end of 2012. The background water quality data are also used in the water quality prediction work as the 'unimpacted' source term for undisturbed catchment areas.

### 5.3.2 Mainstem Minto Creek Water Quality

The characteristics, trends and patterns associated with the geochemistry of surface waters at the Minto Creek stations is summarized below, while more details are available in *Minto and McGinty Creeks Water Quality Characterization report* (AEG, 2017) included as Appendix 1-3.

- The Minto Creek waters were typically circumneutral to slightly alkaline pH and well-oxygenated;
- Nitrogen species concentrations were generally higher during and following periods of mine discharge, likely due to blasting activity within the mine site. Aside from discharge periods, seasonal trends were observed, particularly for nitrate-N, with lower nitrate-N concentrations typically observed in summer months when primary producers that uptake nitrogen species would be most active;
- Concentrations of DOC at W3 were typically higher during April/May likely due to high flows caused by spring meltwater mobilizing organic carbon that had accumulated over the previous year. DOC concentrations also appeared to be higher during mine discharge periods, but as many of these periods occurred in early spring it is difficult to discern the effects of mine discharge on DOC. At downstream stations MC1 and W2, DOC concentrations were higher in mid to late summer and were generally lower in spring and winter;
- Hardness was often lowest in April and May and increased through the summer and fall suggesting dilution in spring, followed by a higher proportional contribution of groundwater to Minto Creek flow through summer, fall, and winter. This trend was more marked at W50 and downstream stations MC1 and W2, whereas W3 returned higher hardness concentrations with less seasonality;

- Dissolved aluminum concentrations were higher in the spring and decreased through the year, likely due to mobilization by high flows from spring meltwater and possibly complexation by DOC, which also peaked in spring;

- Dissolved arsenic and iron concentrations were typically higher at downstream stations MC1 and W2 than upstream stations and were highest in mid to late summer. A reasonable correlation with DOC concentrations suggests DOC likely enhances iron solubility at MC1 and W2;

- Since 2010, dissolved chromium, lead, silver and zinc has generally been closer to or below detection levels with and without mine discharge;

- Dissolved copper, molybdenum and selenium concentrations were higher during and following periods of mine discharge. Dissolved copper concentrations also appeared to vary seasonally with higher concentrations observed in the spring with higher flows from meltwater and were correlated with DOC concentrations. Dissolved molybdenum concentrations were consistently higher at W3 than W2 in pre-operations and during non-discharge periods.

## 5.4 McGinty Creek

McGinty Creek water quality was monitored monthly by ACG from May 2009 until July 2012 and has since been monitored monthly by Minto Mine Environment Department staff.

Water quality is monitored at five stations in the McGinty Creek watershed, described in  and shown in . Water quality results for McGinty Creek stations are presented and discussed in two groups:

1. East arm of McGinty Creek (MN-1.5 and MN-2.5) and MN-4.5; and

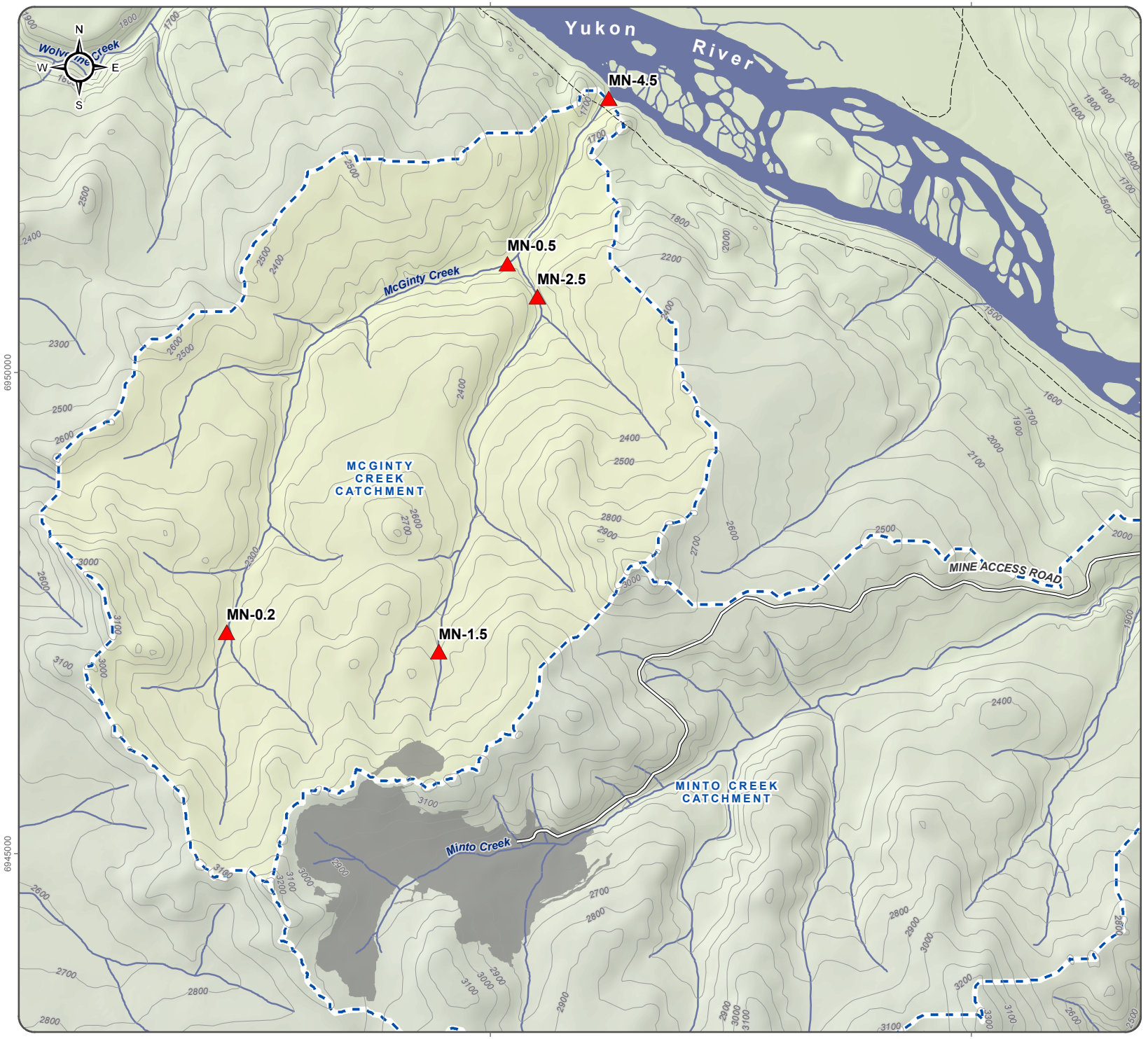
2. West arm of McGinty Creek (MN-0.2 and MN-0.5).

The east arm of McGinty Creek is considered the ‘exposure tributary’ as it originates downgradient of the Minto North deposit where the Minto North pit is located, while the west arm of McGinty Creek is considered the ‘reference tributary’.

**Table 5-3: McGinty Creek Monitoring Station Locations.**

| Station | Description / Location |
|---|---|
| **East Arm of McGinty Creek** | |
| MN-1.5 | Upper east arm of McGinty Creek downstream of the Minto North deposit |
| MN-2.5 | East arm of McGinty Creek just upstream of confluence with the west arm |
| MN-4.5 | Lower mainstem McGinty Creek near confluence with Yukon River |
| **West Arm of McGinty Creek (Reference Stations)** | |
| MN-0.2 | Upper west arm of McGinty Creek |
| MN-0.5 | West arm of McGinty Creek just upstream of the confluence with the east arm |

Monitoring at the upper reference station MN-0.2 was suspended between June 2009 and April 2011, which explains in part the lower total number of samples collected at this station. Similar to Minto Creek, McGinty Creek typically freezes in the winter months with little to no flow observed at all monitoring stations.




**MINTO MINE**

**RECLAMATION AND CLOSURE PLAN**

## FIGURE 4-4

## MCGINTY CREEK WATER QUALITY MONITORING STATION LOCATIONS

JANUARY 2018

capstone MINTO MINE

- Surface Water Surveillance Program Monitoring Station Locations
- Catchment
- Mine Footprint

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The characteristics, trends and patterns associated with the geochemistry of surface waters at the and McGinty Creek stations is summarized below, while more details are available in *Minto and McGinty Creeks Water Quality Characterization report* (AEG, 2017) included as Appendix 1-3.

- Field pH was generally circumneutral to slightly alkaline and increased farther downstream in both arms of McGinty Creek;
- The waters were fairly well-oxygenated with occasional troughs of dissolved oxygen measured in winter months when ice cover likely inhibited ingress of oxygen to McGinty Creek;
- Nitrate-N concentrations were typically lower in April/May due likely to dilution from meltwater and higher values were typically observed in the winter when uptake by primary producers would have been lowest. Nitrite-N was predominantly below detection level in McGinty Creek;
- Concentrations of DOC were typically higher during April/May likely due to mobilization by high flows caused by spring meltwater. Higher concentrations were also commonly observed in mid to late summer;
- Dissolved hardness concentrations increased farther downstream and varied seasonally with lowest concentrations in the spring and increasing concentrations through to the winter, suggesting a significant proportion of hardness from baseflow that is diluted by spring meltwater;
- Dissolved aluminum concentrations were higher in the upstream stations of the east and west arms of McGinty Creek and were erratic, perhaps varying with precipitation events as concentrations were typically higher in April and May when higher flows caused by spring meltwater could mobilize aluminum. Complexation by DOC, which was highest during spring, may also have maintained elevated dissolved aluminum concentrations at this time;
- Dissolved arsenic and iron concentrations were higher in upstream stations of the east and west arm of McGinty Creek and often peaked in August or September. A negative correlation between iron and ORP suggests the presence of a groundwater seep with reducing conditions that could have provided elevated concentrations of iron to McGinty Creek. DOC could also be a factor in maintaining higher iron concentrations in solution;
- Dissolved cadmium and zinc concentrations appeared to decrease from 2010 to 2013 and have been fairly low throughout all McGinty Creek stations post-2013;
- Dissolved chromium concentrations were higher in upstream stations of the east and west arms of McGinty Creek;
- The upstream-most stations – MN-1.5 (east arm) and MN-0.2 (west arm reference tributary) – consistently returned higher dissolved copper concentrations in McGinty Creek. Generally,

concentrations were higher in April/May likely due to mobilization by the elevated DOC levels observed at this time of the year;

- Dissolved molybdenum concentrations typically increased moving downstream in McGinty Creek and varied seasonally such that lower concentrations were observed in the spring and higher concentrations were observed in the winter, suggestive of dilution of baseflow providing the bulk of molybdenum to McGinty Creek in the spring;

- Dissolved lead and silver concentrations have generally been close to or below their respective detection levels in McGinty Creek;

- Dissolved selenium concentrations in McGinty Creek were generally highest in the west arm (reference tributary) at MN-0.5, suggesting a significant proportion of loading occurs from the west arm to McGinty Creek downstream of MN-2.5 and upstream of MN-4.5.

# 6 GROUNDWATER

Current groundwater conditions for the Minto Mine are presented in multiple reports. Groundwater conditions at the Minto site are monitored as part of the Minto Mine Groundwater Monitoring Plan (GMP, 2016-02), with monitoring data reviewed as part of the Operational Adaptive Management Plan (OAMP, 2017-02). The *Groundwater Characterization and Conceptual Model Update Report* (SRK 2018a) includes an assessment of data collected from groundwater wells in the area, results from the environmental tracer study and an assessment of potential transport of mine contact water across the site (see Appendix 1-4a). Updated conceptual models are presented for both the Minto Creek and McGinty Creek catchments. SRK (2018b) presents a summary of groundwater quality at OAMP monitoring stations that has reached thresholds defined in the OAMP (see Appendix 1-4b). The sum of this information is the basis for this section.

In the Minto Creek catchment, groundwater is fracture-controlled and, at the largest scale, groundwater flow follows topography, except where influenced by the Main and Area 2 open pits, and the Minto South Underground. These mine components create localized hydraulic sinks that overprint the topographic flow system. Locally, permafrost impedes downward infiltration of water from reaching the deeper groundwater system. Groundwater that does flow out of the mine footprint will move towards the Minto Creek valley and the Yukon River. Most of groundwater from the mine is expected to discharge to surface water by or within the Water Storage Pond. Any groundwater that does bypass the Water Storage Pond would be assumed to discharge to Minto Creek by surface water station MC1.

Seepage of contact groundwater from the open pits is interpreted to have remained within the mine footprint. OAMP events for groundwater quality are limited to $SO_4$, As, Cd and Se; other parameters have remained stable or not shown consistent changes sufficient to trigger the OAMP. As and Cd events have been inconsistent and, as of the last 2017 sampling round, did not exceed thresholds. Se exceedances have also been inconsistent and do not show consistent trends. $SO_4$ exceedances in groundwater at the mine property boundary are interpreted to not be related to mine seepage (Appendix 1-4a).

In the McGinty Creek catchment, the only current mine component is the Minto North open pit and related roadwork. In this catchment, groundwater is fracture-controlled and flow follows topography, with the Minto North open pit acting as a hydraulic sink; the open pit has not filled with water. Groundwater in this catchment that does not report to the open pit will move towards the Yukon River and is assumed to discharge to McGinty Creek.

There is interpreted to be no seepage of contact groundwater from the Minto North open pit as the pit is acting as a hydraulic sink. OAMP events for groundwater quality have occurred for As, Zn, Cd, $NO_3$ and $SO_4$. Zn and Cd events have been inconsistent. As and NO3 exceedances in groundwater have been consistent but are interpreted to be related to flushing of non-PAG haul road rock via precipitation. $SO_4$ exceedances of baseline concentrations have been ongoing, but concentrations are very low (<5 mg/L) and not considered significant.

# 7 WILDLIFE

Wildlife assessments were completed within, or near, the Project area between 1994 and 2017. This section summarizes the results of wildlife surveys conducted in the area to date, identifies species of concern, and lists ongoing and/or near-future surveys to be completed. The last update on the number and types of wildlife studies that have been conducted in the Minto Mine area was in a comprehensive 2010 report produced by EBA Engineering Consultants Ltd (EBA), titled *Minto Mine, Environment Baseline Report – Wildlife*.

## 7.1 ENVIRONMENTAL SETTING

The Minto Mine is located within the Boreal Cordillera ecozone and in the western part of Yukon Plateau Central ecoregion (Smith et al., 2004). The Minto Mine is situated in the far western part of the Yukon Plateau-Central ecoregion near the Dawson Range and adjacent to the Klondike Plateau ecoregion in the west. The area was part of the eastern extent of Beringia, which remained ice-free approximately twenty to fifteen thousand years ago during the last maximum glacial period (Smith et al., 2004).

The Minto Mine is in the eastern part of the Dawson Range the local elevation ranges from 700 m to 950 m; the general landscape is composed of rounded mountains intersected by broad valleys and drainages that flow into the Yukon River. The access road starts on the western side of the Yukon River, at the barge landing site, continues north along the Yukon River and then turns southwest up the Minto Creek valley for 12 km to reach the Minto Mine site.

Forest fires are frequent in this region as less than 300 mm of precipitation falls per year due to the rain shadow formed by the St. Elias-Coast Mountains in the west. As a result, the study area around Minto Mine has experienced numerous fires over the last thirty years, rendering it into a complex mosaic of plant communities at various stages of succession. The oldest pertinent fire burned approximately 7,236 ha in 1980, the second and more extensive fire occurred in 1995 and burned approximately 55,521 ha (GYWFM, 2012). The 1995 burn occurred along the access road by the Yukon River barge landing and just west of the airstrip as shown in . The most recent fires occurred in 2010 and 2011, these small fires only consumed 17 hectares within the Minto claims, southeast of the airstrip.

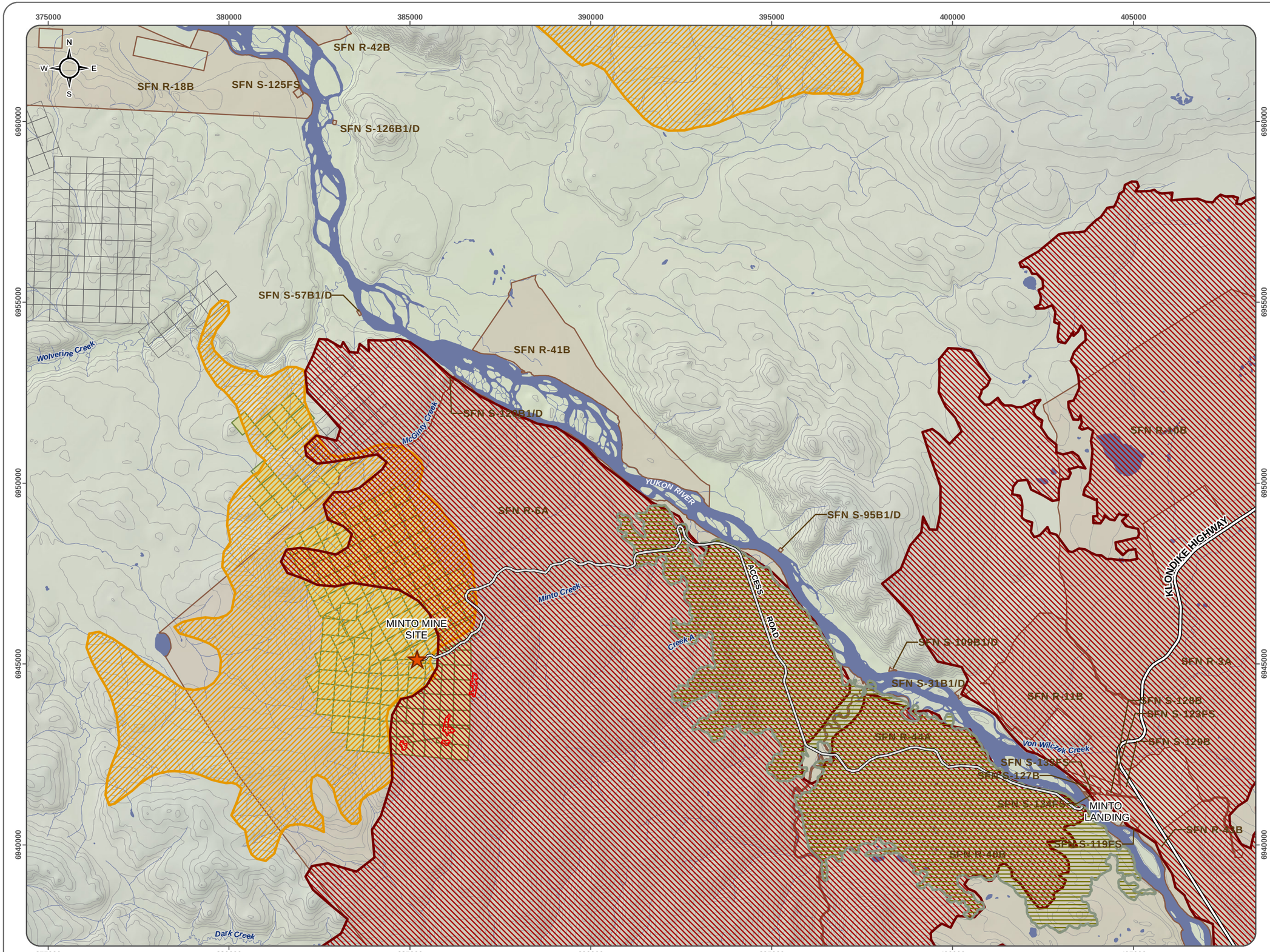
The fire-disturbed areas are now regenerating and young forest or shrub ecosystems dominate the Minto area (Oswald and Brown, 1990). Willows (*Salix sp*.) and trembling aspen (*Populus tremuloides*) are the most represented species in crown cover at present. Lodge pole pine (*Pinus contorta latifolia*) is a later successional species and will gradually dominate well-drained mid and upper slopes. Shade-tolerant white spruce is the regenerating climax tree species currently found in the understory as seedlings. White spruce will eventually overgrow the pine and trembling aspen communities. Black spruce (*Picea mariana*) is also a climax species that is adapted to wetter, cooler sites, and is often the persistent species in white/black spruce-mixed areas along slope toes, valley bottoms and northern aspects. Small grasslands are scattered along dry crests and steep south-facing slopes, these locations do not retain enough moisture to sustain tree growth.

# MINTO MINE

## CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN

## FIGURE 7-1
## FIRE HISTORY

JANUARY 2018




Minto Mine Site

Control Burn 2010

1980 Fire

1995 Fire

2010 Fire

Selkirk First Nation Settlement Lands

MInto Exploration Ltd. Claims

Other Claims

Mine Access Road

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kelometres

First Nation Settlement land obtained from Natural Resource Canada. Quartz claim boundaires and ownership are current as of 12 January 2018. Data obtained from Mineral Resources Branch, Energy Mines and Resources Department, Government of Yukon.
Site hydrology data provided by Minto Explorations Ltd, May 2009.

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The diversity of vegetative communities and successional stages around the Minto Mine provides a variety of habitat niches that support approximately 46 species of mammal (insectivores, bats, lagomorphs, rodents, carnivores, and ungulates), 60 species of birds, and one species of amphibian, the wood frog (*Rana sylvatica*). The list of mammals and bird species known to exist in the Minto area and/or the Yukon Plateau-Central ecoregion is included in EBA's 2010 baseline report.

## 7.2 WILDLIFE BASELINE ASSESSMENTS

lists the wildlife surveys and studies that have been conducted since 1994 in the Minto Mine area.

**Table 7-1: Wildlife Surveys and Studies Undertaken in the Minto Project Area.**

| Dates | Type of Survey | Conducted By |
|---|---|---|
| Jan-March 2012 | Late Winter Ungulate Studies | EDI, Environment Yukon |
| Fall 2012 | Klaza Caribou Herd Study | Environment Yukon |
| March 2011 | Late Winter Ungulate Study | Environment Yukon and EDI (on behalf of Casino Mining Corporation) |
| July 2010 | Baseline Ecosystems and Vegetation Survey | Access Consulting Group |
| February 2010 | Late Winter Moose Survey (Aerial) | Access Consulting Group |
| December 2010 | Post-rut Moose Survey (Aerial) | Access Consulting Group |
| June 2009 | Dall Sheep Survey (Aerial) | Environment Yukon |
| 2007 | Moose Survey | Environment Yukon |
| 2003 | Klaza Caribou Herd Survey | Environment Yukon |
| 1994 | Spring Wildlife Survey<br>Spring Dall Sheep Survey<br>Summer Raptor Survey<br>Summer Wildlife Ground Pellet Survey | Hallam Knight Piesold Ltd. |

The three most recent wildlife baseline studies were led by the Yukon Government (YG) and were not designed specifically for the Minto Mine project. These studies encompassed the large Carmacks West Moose Management Unit and the Klaza caribou herd range, for a total area of 6,430 $km^2$ which overlapped the Minto Mine site. The results from the YG surveys, when released, will provide more statistically sound estimates of moose and caribou population levels, gender ratios and recruitment success for the overall region. These values can then be used as means of gaging how Minto Mine area resident ungulate populations are faring. Also, the locations of sightings when mapped show distribution and can help detect high value habitat that may require protection if mine and road development increases substantially beyond the current footprint (which is not currently anticipated).

The 2010 Baseline Ecosystems and Vegetation Study (Access Consulting Group (ACG), 2010) was not primarily focused on wildlife; however, general wildlife observations were made during the vegetation survey, recorded on plot data sheets and wildlife mitigation recommendations were included in the report.

A wildlife log is maintained on site to track the animal sightings, details and behaviour in the site vicinity, and to monitor any human-wildlife interactions.

## 7.3 WILDLIFE SPECIES OF CONSERVATION CONCERN IN YUKON

The Minto Mine area and surrounding environment provide habitat for several species considered at risk by both the federal and territorial governments. lists species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and/or the Yukon Government as needing special attention and protective legislation, so that remaining populations are not unduly stressed. The list consists of species whose range overlaps the Minto Mine area.

**Table 7-2: Wildlife Species of Conservation Concern in Yukon.**

| Species | Status* | Source |
|---|---|---|
| Little Brown Bat (*Myotis lucifugus)* | Endangered | COSEWIC (2012) |
| Common Nighthawk *(Chordeiles minor)* | Threatened | COSEWIC (2007) |
| Olive-sided Fly Catcher *(Contopus cooperi)* | Threatened | COSEWIC (2007) |
| Barn Swallow (*Hirundo rustica)* | Threatened | COSEWIC (2011) |
| Canada Warbler *(Wilsonia canadensis)* | Threatened | COSEWIC (2008) |
| Peregrine Falcon (*Falco peregrinus anatum - tundrius)* | Special concern | COSEWIC (2007), Yukon Wildlife Act (2002) |
| Short Eared Owl *(Asio flammeus)* | Special concern | COSEWIC (2008) |
| Wolverine *(Gulo gulo)* | Special concern | COSEWIC (2014) |
| Grizzly Bear *(Ursus arctos)* | Special concern | COSEWIC (2012) |
| Northern mountain population of woodlandCaribou *(Rangifer tarandus caribou)* | Special concern | COSEWIC (2014), SARA (2002) |
| Collared Pika *(Ochotona collaris)* | Special concern | COSEWIC (2011) |
| Rusty Blackbird *(Euphagus carolinus)* | Special concern | COSEWIC (2017) |
| Gyrfalcon (*Falco rusticolus)* | Specially protected | Yukon Wildlife Act (2002) |
| Trumpeter Swan *(Cygnus buccinator)* | Specially protected | Yukon Wildlife Act (2002) |
| Mule Deer *(Odocoileus hemionus)* | Specially protected | Yukon Wildlife Act (2002) |
| Cougar *(Puma concolor)* | Specially protected | Yukon Wildlife Act (2002) |
| Bank Swallow (*Riparia riparia*) | Conservation concern | Yukon Environment (2011) |
| Northern Shrike (Lanius excubitor) | Conservation concern | Yukon Environment (2011) |
| Mountain Goat *(Oreamnos americanus)* | Conservation concern | Yukon Environment (2011) |

* Status designations by COSEWIC are defined as:

Extinct - A wildlife species that no longer exists.

Extirpated - A wildlife species that no longer exists in the wild in Canada, but exists elsewhere.

Endangered - A wildlife species facing imminent extirpation or extinction.
Threatened - A wildlife species that may become endangered if factors leading to its extirpation or extinction are not reversed.
Special Concern - A wildlife species that may become threatened or endangered because of its biological characteristics combined with environmental impacts.
The Yukon wildlife Act provides more legal protection for those wildlife species recognized as Specially Protected. Yukon Environment wildlife species of Conservation Concern are populations that are decreasing and require more monitoring.

There are currently eleven wildlife species in Yukon rated (in 2017) as threatened or of special concern by COSEWIC, of which ten species have ranges that could possibly encroach upon the area around Minto Mine. These include: grizzly bear (*Ursus arctos*), northern mountain woodland caribou (*Rangifer tarandus caribou*), wolverine (*Gulo gulo*), collared pika (*Ochotona collaris*), bank swallow (*Riparia riparia*), barn swallow (*Hirundo rustica*), rusty blackbird (*Euphagus carolinus*), olive-sided fly catcher (*Contopus cooperi*), common nighthawk (*Chordeiles minor*), short-eared owl (*Asio flammeus*), and peregrine falcon (*Falco peregrines anatum*).

One species, the little brown bat (*Myotis lucifugus*), has been classified by COSEWIC as an endangered species, which means they are in immediate danger of extinction or extirpation. Populations of these mammals have been seriously affected by a fungal infection known as White Nose Syndrome. The Minto Mine is within the northern extent of the summer range of the Little Brown Bat, although their existence within the area has not been verified.

The following sections provide brief descriptions of the most recent wildlife surveys conducted locally for Minto and surveys conducted by the Yukon Government that were larger in scale and included the Minto Mine area.

### 7.3.1 Moose

Current information regarding moose in the area came from two aerial surveys conducted by Environment Yukon and Environmental Dynamics Inc. (EDI) that covered a survey area that included the Minto Mine site. The average density of moose in the Yukon typically ranges from 100 to 250 moose/1,000km$^2$ (Yukon Government, 2017a). Estimates of moose in the Minto Mine area have ranged from 20 to 127 moose/1,000km$^2$ (EDI, 2013).

#### *7.3.1.1 Aerial Moose Survey – Late Winter 2011/2012*

This late winter aerial survey covered 6,400 km$^2$ west and northwest of Carmacks. During this survey, a total of 311 moose were observed. The 2011 map shows a cluster of moose observation points around the Minto Mine and in the southeast highlands, indicating that this area has a high density of moose in the late winter as compared to most of the Regional Survey Area (G. Pelchat, pers. comm.). Minto Mine vicinity has been subjected to numerous fires in the last thirty years and the vegetation cover is dominated by tall shrubs, attractive habitat for moose with plenty of browse and cover.

In addition, the Yukon River is approximately 10 km to the east. This large river corridor has ample shoreline and islands for moose calving and post-calving habitat. The Ingersoll Islands, located in the Yukon River downstream of the project site, are known to be used for calving during the spring and as rearing habitat during the summer (Magrum, 1994). The old burn areas in the Minto Creek Valley, the banks of the Yukon River, and the swamp lands below Minto Creek are often used by moose during the spring and summer (EBA, 2010b).

#### *7.3.1.2 Aerial Moose Survey - Winter 2009/2010*

Aerial moose surveys were completed on December 15, 2009 (post-rut) and February 23, 2010 (late winter) by ACG (2010). The total area surveyed was 112 $km^2$, specifically concentrating on the area around the Minto Mine and nearby drainages, see . Moose density for the post-rut survey was estimated to be 125 moose per 1,000 $km^2$. The average population density for calf-to-cow ratio estimated from this data was 25 calves and no sub adults for every 100 adult cows, and the estimated adult sex ratio was 50 mature bulls for 100 cows, which is considered fair compared to territorial averages.

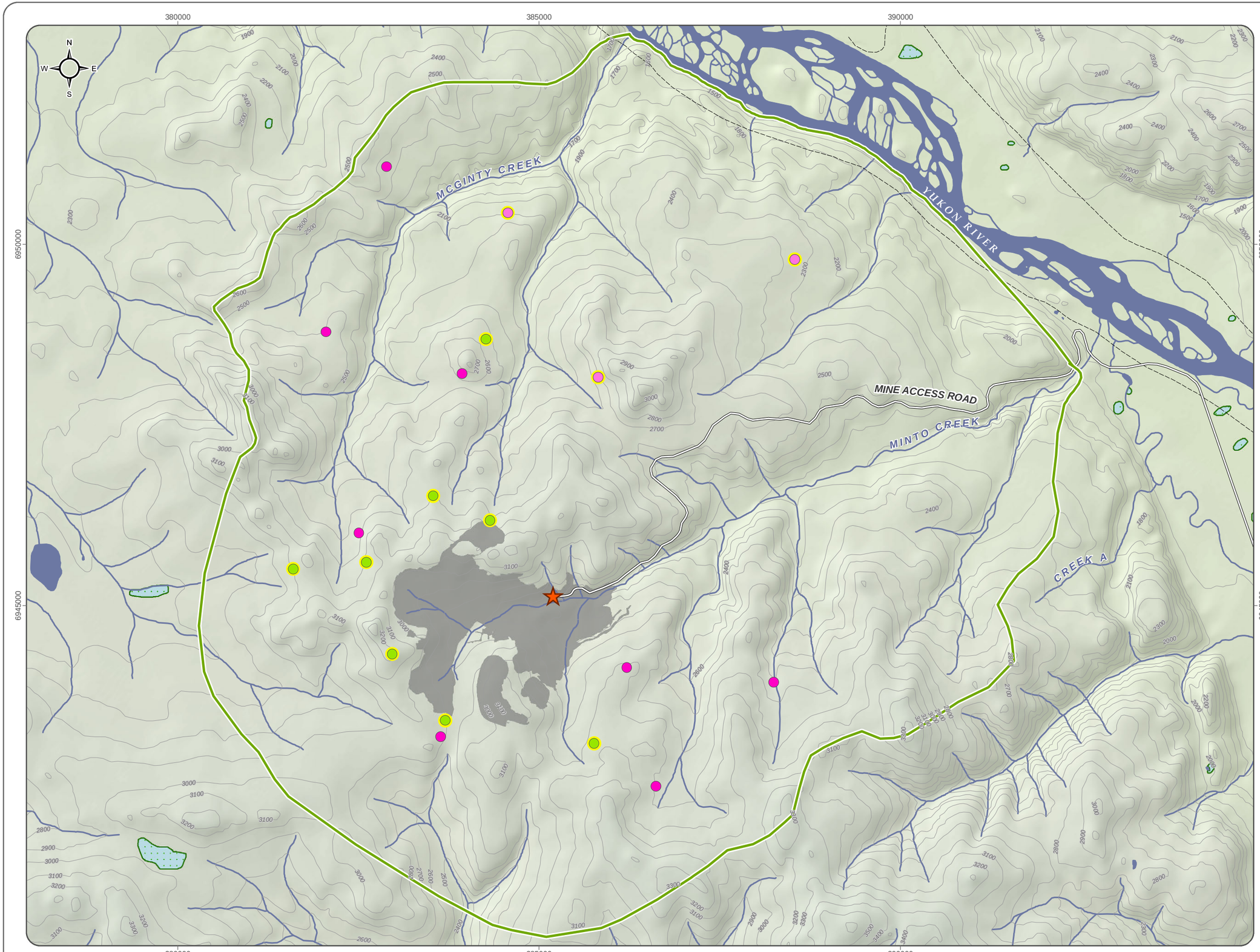
# MINTO MINE

## CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN

## FIGURE 7-2

## WINTER 2009/2010 AERIAL MOOSE SURVEY

JANUARY 2018




- Moose Observation (15-Dec-2009)
- Moose Observation (23-Feb-2010)
- Moose Tracks (23-Feb-2010)
- Winter 2009/2010 Survey Boundary
- Wetland
- Minto Access Road
- Contours (100ft)

**1:50,000** *when printed on 11 x 17 inch paper*

0 500 1,000 1,500 Meters

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Datum: NAD 83 Projection: UTM Zone 8N

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(Last edited by: amatlashevska,28/12/2017/11:07 AM)

### 7.3.2 2007 Early Winter Moose Survey

The early winter 2007 moose survey for the Carmacks West Moose Management Unit (MMU) was conducted by Yukon Department of Environment. The densities are comparable, as there are similar habitat types in the MMU and its boundaries overlap the Minto Mine. The calculated moose density was 124 moose per 1,000 $km^2$ for the survey area.

This survey covered a much larger study area than the surveys conducted by ACG during the winter of 2009/2010, which were specifically focused on the area surrounding the Minto Mine site. However, during this survey in 2007, a total of 208 moose were observed during the survey, with a total population estimate of 520 moose for the study area. Survival rates for calves and yearlings were relatively low. The sex ratio of 75 bulls per 100 cows is considered to be a healthy sex ratio. The average sex ratio for other areas surveyed within Yukon is 68 bulls per 100 cows (O'Donoghue et al., 2008).

### 7.3.3 1994 Late Winter Moose Survey

Wildlife Resources surveys conducted in January 1994 by the Yukon Government estimated a moose density of 40 moose per 1,000 $km^2$ in the Minto area, which was lower then the 100 to 250 per 1,000 $km^2$ Yukon average (Yukon Government, 2017).

### 7.3.4 Caribou

The closest Woodland caribou ranges to the Minto Mine belong to the Klaza and the Tatchun herds. The Klaza herd appears to be the more stable of the two, and is the larger herd. Below is a brief summary of the herds' interactions with the Minto Mine area.

In 2005, the Klaza herd population was estimated at 650 and predicted to increase (Yukon Environment, 2005a). There are concerns for this caribou herd, as an increase in exploration projects and road development may cause negative impacts to the health of the Klaza caribou. The Klaza caribou range is west of the Minto Mine. As the area around the Minto Mine has experienced numerous fires recently, the habitat is of minimal value for caribou (Hegel, pers. comm.). Caribou prefer mature open forests where arboreal and ground lichen are plentiful. A Wildlife Key Area (WKA) for woodland caribou winter range was identified approximately 9 km to the east-northeast of the project area (Yukon Environment, 2010a). A fall (rut) count of Klaza caribou herd was conducted by Environment Yukon, EDI and Little Salmon Carmacks First Nation members in 2012. The herd is currently estimated to be approximately 1,180 caribou and is considered stable (Francis et al., 2016).

The Tatchun Caribou herd range is to the east of the Yukon River and does not overlap with the Minto Mine. In 2012, the population estimate for the Tachun herd was 500 animals.

# MINTO MINE

## CAPSTONE MINTO MINE - SITE CHARACTERIZATION PLAN

## FIGURE 7-3

### WILDLIFE KEY AREAS

JANUARY 2018

capstone MINTO MINE

**WILDLIFE KEY AREAS**

- Golden Eagle
- Peregrine Falcon
- Bald Eagle
- Alpine Raptor
- Thinhorn Sheep
- Woodland Caribou

**OTHER MAP FEATURES**

- Minto Mine Site
- Mine Footprint
- Wetland
- Minto Access Road
- Contours (100ft)

1:85,000 *when printed on 11 x 17 inch paper*

0 1 2 3 4

Kilometers

Alexco Environmental Group

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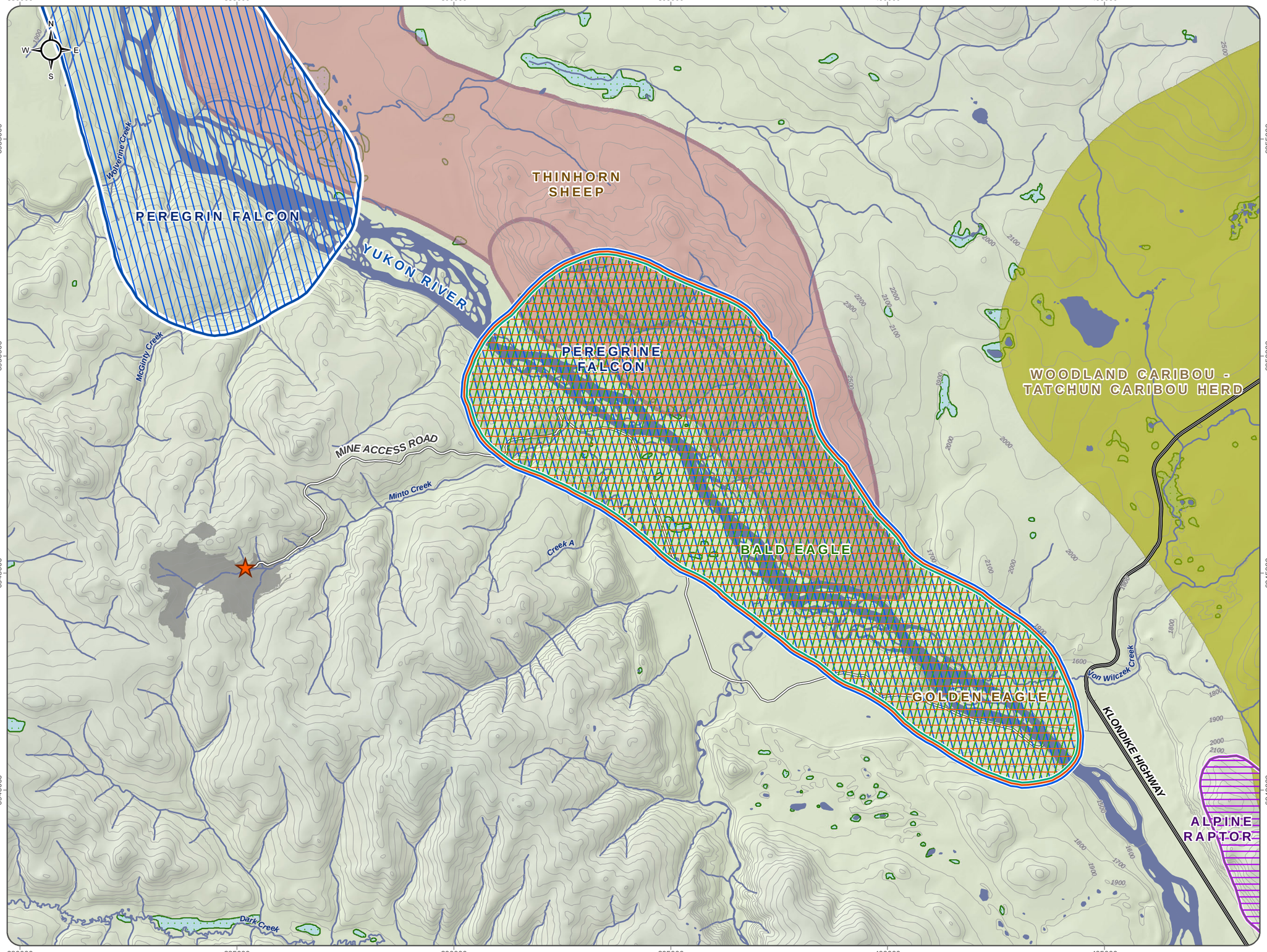
*(Last edited by: amatlashevska;28/12/2017(11:10 AM)*



### 7.3.5 Sheep

The Minto Bluffs along the Yukon River have been identified as an important Dall sheep area, see Figure 2, (O'Donoghue, 2009). Although the access road to the Minto Mine passes near sheep habitat, sheep habitat within the project area itself is limited and sheep are not expected to inhabit the project area for any extended length of time.

Between 2000 and 2017, sheep surveys of the Minto Bluffs resulted in observations of between 31 and 153 sheep annually, with the majority of observations being ewes, yearlings and lambs. During the 2016 survey, 153 sheep were observed, of which 59 were observed on the Minto Bluffs (which is located about 8 kilometres downstream and across the river from the Minto Mine site). This is the highest recorded observation for this area. Most sheep observed during these surveys have been located on the Minto Bluffs, Split Mountain, and Mount Hansen (O'Donoghue, 2009).

### 7.3.6 Carnivores, Fur Bearers and Small Mammals

Fur trapping and big game harvest statistics indicated the following species are expected to occur in the Minto Mine area: grizzly bear, black bear, coyote, gray wolf, red fox, wolverine, marten, least weasel, beaver, and lynx. Cougars may also have the potential to be found in the area as they are known to follow mule deer (Smith et al. 2004). Of the species listed above, the following species (or their sign) have been observed, on site: grizzly bear, black bear, gray wolf, lynx, river otter (HKP 1994, Capstone 2007-2008).

The territorial estimates for bear populations in Yukon are 6,000 to 7,000 grizzly bear and 10,000 black bear (Yukon Environment 2010b). The Yukon Government (2017b) has indicated that key habitat for black bears include seasonally concentrated feeding areas, such as south aspect slopes containing sagewort, bearberry, and grassland habitat. Summer and fall feeding habitats typically consist of those areas where berries grow. Black bears have been observed in the project area on many occasions (Wildlife log – Appendix 1-5).

Grizzly bears are known to use the Minto Mine area. Sightings and tracks were documented in the 2010 Baseline Ecosystems and Vegetation Report, and sightings have been reported by mine personnel (Appendix 1-5). Key habitat for grizzly bears includes areas where they concentrate seasonally, such as feeding areas, floodplains, and movement corridors. Important feeding habitat includes areas with profuse berries and areas where salmon spawn (Yukon Environment, 2017b). Although key habitat for grizzly bears has not been identified on site, they have been seen in the project area regularly since the commencement of mine operations. (ACG, 2010).

Wolverines have large territories where they hunt, scavenge and mate. While there is a moderate probability that they inhabit the area, because of their aversion to human activity and low population, they are not likely to be observed.

Small mammals common to the area include red squirrel, varying hare, fox, mink, weasel, vole, and shrew. The Minto Mine site is situated at the apex of five drainages that are part of the Yukon River watershed, so wildlife uses the area to access the valleys offering conduits from lowlands to highlands for seasonal foraging and hunting (ACG, 2010).

### 7.3.7 Birds

Five species of birds are considered to be of conservation concern: the peregrine falcon, short-eared owl, common nighthawk, olive-sided flycatcher, and rusty blackbird. Three of these species, the peregrine falcon, common nighthawk, and olive-sided flycatcher, have a moderate probability of occurrence at the Minto site. Suitable nesting habitat for the peregrine falcon is located in close proximity to the project site (see Figure 7-3), on the bluffs along the Yukon River (O'Donoghue, pers. comm.), and a historical record of nesting for this species was documented at the Pelly–Yukon River confluence (Mossop, pers. comm. as cited in HKP 1994). Common nighthawks are often found near open lodge pole pine forests, old burn areas and open mixed forests, and near wetlands or rivers (Sinclair et al., 2003) and many of these habitat types occur in the project area. The olive-sided flycatcher often occurs in black and white spruce, lodge pole pine, and mixed forests, from lowland areas to tree-line. The short-eared owl and rusty blackbird are considered to have a low probability of occurrence in the project area. The short-eared owl is often associated with open wetland and meadow, alpine, and alpine tundra habitat, which is limited within the project area. The rusty blackbird is also associated with wetland habitat (Sinclair et al., 2003), which is not abundant within the project area itself, but may occur along the margins of the Yukon River.

The rusty blackbird often nests at the edge of ponds/wetland complexes in boreal forests. They prefer lower elevations, but could feed and nest within the study area. Short-eared owls may travel through the area, but their typical habitat is in and near large meadows and agricultural fields and they may not be seen often because they are nocturnal. Peregrine falcons do not use the habitats in the Minto area; they nest and hunt near steep canyon walls along the Yukon River, approximately 20 km east.

#### *7.3.7.1 Raptors*

Although numerous raptor species have the potential to inhabit the project area, species that have been observed and documented in the Minto Mine area include the red-tailed hawk (HKP, 1994), peregrine falcon (Mossop, pers. comm. as cited in HKP 1994), and golden eagle (O'Donoghue, pers. comm.). It should be noted that only one aerial-based raptor survey was conducted as part of the Minto Mine baseline studies (HKP, 1994). High quality riparian cliff habitat for raptors exists along the Yukon River downstream of the Minto Mine access road. A WKA (wildlife key area) for golden eagle summer nesting habitat has been identified approximately 3 km to the east of the project area (Yukon Environment, 2010a) (Figure 7-3). This WKA is primarily associated with the steep bluffs along the Yukon River and includes a buffer area. No cliff-nesting raptor habitat has been identified within the Project area itself. The access road to

the Minto Mine, however, runs adjacent to potential nesting areas for cliff-nesting raptors, such as the golden eagle and peregrine falcon.

#### *7.3.7.2 Waterfowl*

Key habitat for waterfowl includes wetlands that are used as staging areas in the spring and fall, and for breeding and molting in the summer. As suitably-sized wetlands are not found near the Minto Mine, waterfowl are not known to be present in large numbers or for extended periods. A key habitat area, Lhatsaw wetlands, lies approximately 30 km east of the project site and is used for nesting and molting in the summer (Yukon Environment, 2016). Waterfowl that may occasionally use the Minto Creek drainage include Canada goose, mallard, northern pintail, green-winged teal and American widgeon.

#### *7.3.7.3 Game Species*

Game birds that have been observed or that have the potential to occur in the study area include grouse (spruce, ruffed, sharp-tailed) and ptarmigan (willow, white-tailed, and rock). Of the species of grouse that live in Yukon, the sharp-tailed grouse is currently the only species of management concern. Sharp-tailed grouse have a limited distribution in Yukon due to the lack of suitable habitat. Gravel outwashes with fairly stable aspen parkland habitat and wet sedge-hummock meadows after fire are considered suitable habitat for this species. Sharp-tailed grouse have been observed in the Project area.

#### *7.3.7.4 Amphibians*

Of the five amphibian species known to occur in Yukon and northern British Columbia, only the wood frog (*Rana sylvatica*) is known to occur in the project area. This species is restricted to wetland areas and has not been surveyed for at the Minto site, although there have been some anecdotal observations. No reptiles are known to occur in Yukon.

## 7.4 SUMMARY

The frequent and often large fires that have occurred around the Minto Mine have created high quality habitat for moose. The numerous moose sightings and signs found in the area indicate that it is attractive and well-used by resident moose. Local aerial surveys completed in early (December 2009) and late winter (February 2010) indicated that the moose population in the area was below territorial average and recruitment may be low. However, the population has increased since the initial local survey was done in 1994. Then, the population was estimated at 40 moose per 1,000 $km^2$ during a government-supported count. Winter surveys in 2007 indicated a population of 125 per 1,000 $km^2$.

The Klaza woodland caribou herd range is located approximately 10 km west of the Minto Mine, where there is better winter habitat and mature open forests with ample growth of arboreal and ground lichens. The Minto Mine area does not provide good habitat for caribou, but they may travel through occasionally.

Current wildlife population estimates for caribou and moose conducted by Environment Yukon biologists are done over large regional study areas. Average population statistics, especially for moose, may not accurately reflect local habitat usage or seasonal variations, but can serve as a background comparison.

Dall sheep habitat is found along the steeper hillsides within the Yukon River corridor; the Minto Mine area does not contain the steep escape topography nor grasslands needed by these animals. The nearest population of Dall sheep is found at the Minto Bluffs approximately 10 km further down the Yukon River. The nearest disturbance is the access road, which is still approximately 10 km from sheep habitat.

Raptor inventories have been concentrated along the Yukon River corridor where steep slopes and cliffs provide nesting and perches for peregrine and golden eagles. Bald eagles commonly use large trees for nesting and are closely associated with riparian systems. Forest-dependent raptors such as northern goshawk and red-tailed hawks are likely nesting around the Minto Mine in mature forest areas.

Black and grizzly bears are known to use the area and may be attracted to food smells emanating from the camp and garbage disposal area. A waste management plan is in place to reduce attracting bears to camp and operation areas.

Large mammals such as moose, mule deer, timber wolves, grizzly bears, and black bears were found to be using riparian corridors, secondary access roads, and exploration transects as migration routes throughout the Minto mine study area (ACG 2010).

There is a dearth of information on other animals existing in the vicinity of Minto such as wolves, lynx, mule deer and bears.

# 8 AQUATIC RESOURCES

## 8.1 OVERVIEW

A complete report on Aquatic Resources is presented in the *Minto Mine Site Characterization – Aquatic Resources (AEG and Minnow, 2017)* (Appendix 1-6), which constitutes an update to the 2013 Aquatic Resources Baseline Report which was compiled by Access Consulting Group (ACG) and Minnow Environmental as part of the Phase V/VI Yukon Environmental and Socio-Economic Assessment Board (YESAB) Project Proposal. A summary of the key findings of the 2017 report is presented in the sections below.

The Minto Mine region includes the Yukon River and its smaller tributaries, including 7 km upstream to Big Creek and 13 km downstream to Wolverine Creek. The local study area of the Minto Mine centres on four small drainages that drain directly into the Yukon River: Minto Creek, Big Creek, an unnamed creek (referred to as Creek A) and McGinty Creek. The primary drainage is that of Minto Creek, which flows northeast from the existing mine site over approximately 17 km to the Yukon River, and covers an area of roughly 41 $km^2$. Big Creek flows to the northeast over about 97 km and is crossed by the Minto Project access road. Creek A flows to the north over about 7 km near the lower end of Minto Creek, drains an area of roughly 9 $km^2$, and is crossed by the Minto Project access road. The fourth drainage is that of McGinty Creek (formerly referred to as Unnamed Creek B), which is located to the north of Minto Creek and flows north-northeast nearly 9.5 km to the Yukon River confluence, and covers an area of about 34 $km^2$. Operational data was collected for Minto Mine's Annual WUL and through 3 Cycles of EEM.

## 8.2 FISH AND FISH HABITAT

### 8.2.1 Regional Overview (Yukon River)

A variety of resident and migratory fish species inhabit the Yukon River near Minto Mine. These include Chinook, Coho and chum salmon, lake trout, least cisco, Bering cisco, round whitefish, lake whitefish, inconnu, Arctic grayling, northern pike, burbot, longnose sucker, and slimy sculpin.

Previous studies on the Yukon River within the vicinity of Minto Mine have identified both spawning and rearing areas for salmon. Spawning shoals are present in the Ingersoll Islands (downstream of the Project area) as well as around islands upstream of Minto Mine, near Big Creek. These offer an extensive network of side channels and sloughs which provide good spawning gravel.

This portion of the Yukon River also provides rearing habitat for Chinook salmon, as evidenced by past studies in the Project area. Juvenile Chinook salmon (JCS) generally spend up to 1.5 years feeding and growing in fresh water tributaries prior to out-migrating to the ocean, and feed or stage in various tributaries to the Yukon River during this slow out-migration. Usage of the Project area tributaries by JCS is outlined further below.

## 8.2.2 Local Fish Habitat Investigations

### *8.2.2.1 Minto Creek*

Fish and fish habitat studies of Minto Creek have been ongoing for many years, with contemporary studies including those from 1994 through to 2017 (see Table 8-1). A summary of effort and catches is presented in Table 8-2 while complete results can be found in Appendix 1-6. Generally, Minto Creek has been noted to provide only limited habitat to fish. Flows within the stream are quite variable on a yearly basis, with intermittent flows and extensive ice build-up during winter that limits the potential for overwintering habitat for fish. Also, the distribution of fish within Minto Creek has been observed to be limited to the lower 1.5 km of the watercourse, as there is a barrier and steep canyon upstream of that location. As noted above, Chinook salmon, slimy sculpin, Arctic grayling, longnose sucker, burbot, and round whitefish have been captured in Minto Creek; however, the latter have not been observed since the original baseline studies in 1994. Slimy sculpin have been observed consistently, but at a low density.

**Table 8-1: Summary of Key Fish and Fish Habitat Studies, Minto Mine.**

| Year | Firm and Study Name | Scope of Studies |
|---|---|---|
| 1994 | Hallam Knight Piesold (HKP) – IEE for Minto Project Area (HKP 1994) | • Fisheries investigations on Minto Creek and Creek A.<br>• Backpack electrofishing, minnow trapping.<br>• Reach definition and description, identification of barriers to fish passage. |
| 2006–2007 | Access Consulting Group (ACG), R&D Environmental – Various Fisheries Investigations for Minto Explorations Ltd. (Minnow/ACG, 2007) | • Fisheries investigations in Minto Creek to support the permitting of the Minto Mine.<br>• Backpack electrofishing, minnow trapping. |
| 2008 | ACG, Minnow Environmental – EEM Program, Cycle 1 (Minnow/ACG, 2009) | • Fisheries investigation of Minto Creek.<br>• Backpack electrofishing and minnow trapping. |
| 2009 | ACG – Fish Relocation Program (ACG, 2009) | • Minnow trapping in Minto Creek and transfer of fish to the Yukon River. |
| 2010 | ACG – Fish Mark and Recapture Program (ACG, 2010) | • Minnow trapping in Minto Creek and marking of captured fish (release back into Minto Creek). |
| 2009–2011 | ACG, Minnow Environmental – EEM Program, Cycle 2 (Minnow/ACG, 2012) | • Integrated assessment of effluent sub-lethal toxicity, water quality, benthic invertebrate community condition, and fish health (hatchery-based exposure study). |
| 2011–2012 | ACG – Minto Creek Fisheries Monitoring Program (ACG, 2012/ ACG, 2013) | • Minnow trapping in Minto Creek. |
| 2009–2011 | ACG – Fisheries Monitoring Program in McGinty Creek | • Fisheries Investigation of McGinty Creek through Minnow trapping. |
| 2012 | ACG- Fisheries Monitoring in Minto Creek and Big Creek | • Fisheries investigation of Minto Creek and Big Creek through minnow trapping and backpack electrofishing |
| 2013 | ACG- Fisheries Monitoring in Minto Creek and Big Creek, EEM Program Cycle 3 | • Fisheries investigation of Minto Creek and Big Creek through minnow trapping and backpack electrofishing |

| Year | Firm and Study Name | Scope of Studies |
|---|---|---|
| 2014 | ACG- Fisheries Monitoring in Minto Creek and Big Creek | • Fisheries investigation of Minto Creek and Big Creek through minnow trapping. |
| 2015 | ACG- Fisheries Monitoring in Minto Creek and Big Creek | • Fisheries investigation of Minto Creek and Big Creek through minnow trapping. |
| 2016 | Capstone- Fisheries Monitoring in Minto Creek and Big Creek | • Fisheries investigation of Minto Creek and Big Creek through minnow trapping. |

## Table 8-2: Summary of Fish captures in Minto Creek between 2008 and 2016.

| Year | Method | Effort | Summary Statistics | Units | Juvenile Chinook Salmon | All Other Species |
|---|---|---|---|---|---|---|
| 2008 | Backpack Electrofishing | 796 s | Catch | # | 1 | 0 |
| | | | CPUE | Fish/min | 0.075 | 0 |
| | Baited Gee Minnow Trapping | 28.6 days | Catch | # | 18 | 0 |
| | | | CPUE | Fish/day | 0.63 | 0 |
| 2009 | Baited Gee Minnow Trapping | 28.6 days | Catch | # | 136 | 142 |
| | | | CPUE | Fish/day | 4.76 | 4.97 |
| 2010 | Baited Gee Minnow Trapping | 145.9 days | Catch | # | 2293 | 2307 |
| | | | CPUE | Fish/day | 15.72 | 15.81 |
| 2011 | Baited Gee Minnow Trapping | 71 days | Catch | # | 12 | 29 |
| | | | CPUE | Fish/day | 0.17 | 0.41 |
| 2012 | Backpack Electrofishing | 1051 s | Catch | # | 0 | 4 |
| | | | CPUE | Fish/min | 0 | 0.23 |
| | Baited Gee Minnow Trapping | 43 days | Catch | # | 3 | 6 |
| | | | CPUE | Fish/day | 0.07 | 0.14 |
| 2013 | Backpack Electrofishing | 3402 s | Catch | # | 0 | 4 |
| | | | CPUE | Fish/min | 0 | 0.07 |
| | Baited Gee Minnow Trapping | 62.5 days | Catch | # | 121 | 7 |
| | | | CPUE | Fish/day | 1.94 | 0.11 |
| 2014 | Baited Gee Minnow Trapping | 70.2 days | Catch | # | 151 | 3 |
| | | | CPUE | Fish/day | 2.15 | 0.04 |
| 2015 | Baited Gee Minnow Trapping | 67.3 days | Catch | # | 6 | 0 |
| | | | CPUE | Fish/day | 0.089 | 0 |
| 2016 | Baited Gee Minnow Trapping | 69.4 days | Catch | # | 5 | 1 |
| | | | CPUE | Fish/day | 0.072 | 0.014 |

JCS presence in Minto creek was observed to be influenced by mine water discharge. During non-discharge periods, and prior to operations (baseline), numbers of JCS and other species of fish in the system were found to be very low. In contrast, during the two major discharge events (2009 and 2010), numbers of JCS were 20 to 30 times higher in the system (see Table 8-3 below), indicating that they may have been attracted into the system as a likely result of a more consistent temperature and flow regime associated with mine water discharge. Numbers of other species of fish during discharge events did not increase. It is important to note however that numbers of other species using the system has been consistently very low prior to mine development and during operations.

**Table 8-3: Maximum Catch per Unit Effort (CPUE) of Juvenile Chinook Salmon in Minto Creek using baited Minnow traps 1994-2016.**

| Year | Month | JCS – CPUE (#fish/trap-day)* | Minto Creek Conditions |
|---|---|---|---|
| 1994 | September | 0 | Pre-development – no discharge |
| 2008 | September | 0.9 | Operational – no discharge |
| 2009 | September/October | 20.0 | Discharge |
| 2010 | August | 30.0 | Discharge |
| 2011 | September | 0.43 | No discharge – high TSS contribution from tributary |
| 2012 | September | 0.19 | No discharge – high TSS contribution from tributary |
| 2013 | October | 5.01 | Operational – no discharge |
| 2014 | September | 5.05 | Operational – no discharge |
| 2015 | July | 0.30 | Operational – no discharge |
| 2016 | July | 0.301 | Operational – no discharge |

**CPUE calculated for actual 24-hr period (rather than nominal 24-hr period)*

Minto Creek does not provide preferred spawning habitat for fish because it completely freezes during winter months with no flow in lower Minto Creek. Accordingly, there is no evidence of spawning in Minto Creek (HKP 1994; R&D 2006, 2007), nor is there traditional knowledge indicating spawning occurring in the system (HKP 1994). Lower Minto Creek is also subject to low or zero flow conditions during periods in the summer when a portion (or all) of the flow sometimes infiltrates the ground, preventing the establishment of resident fish populations in this section of the stream. A natural barrier to fish passage exists at approximately km 1.2 upstream in Minto Creek from the Yukon River, therefore limiting fish use downstream of the barrier. This barrier is largely comprised of organic debris and can be considered temporary as it will likely degrade over time, although it has been consistently observed since it was first characterized in 2010. The canyon located upstream of the current barrier however is a permanent barrier to fish passage, due to its high gradient, thus limiting fish habitat to the lower 2.0 km of the system.

Water temperatures tend to remain cooler in Minto Creek than in the Yukon River until late June or early July. This likely deters fish, in particular JCS, from entering the system until creek temperatures equilibrate with the Yukon River. Minto Creek is subject to large diurnal fluctuations in temperature (up to 5°C or more) throughout the open water season. This daily variation is not ideal for fish and may limit their interest in using the creek for rearing.

Creek bottom substrate is comprised mostly of fines (silt/sand) with limited cobble/gravel sections which are more desirable for fish. In addition, significant input of suspended solids from a tributary in 2011 and 2012 may have further limited the use of the system by JCS during those years.

Bottom substrate at the mouth of Minto Creek and at the Yukon River confluence consists primarily of silt and mud which is not considered suitable substrate for salmonid spawning (grayling, salmon etc.). Aerial surveys for spawning fish were conducted in 2011, 2012, 2013 and 2014, and no adult fish were observed spawning in the vicinity of the Minto Creek/Yukon River confluence. No signs were present during the surveys that this area is used for spawning (such as redds or carcasses).

#### *8.2.2.2 Big Creek*

Starting in 2012, the compliance monitoring program included sampling efforts in Big Creek, which serves as a reference site. The same fish species as in Minto Creek were generally observed in Big Creek, and the CPUE has normally been slightly higher in Big Creek. Table 2-4 summarizes fish captures in Big Creek from 2012 to 2016.

**Table 8-4: Summary of Fish captures in Big Creek in 2012 to 2016.**

| Year | Method | Effort | Summary Statistics | Units | Juvenile Chinook Salmon | All Other Species |
|---|---|---|---|---|---|---|
| 2012 | Backpack Electrofishing | 273 s | Catch | # | 1 | 23 |
| | | | CPUE | Fish/min | 0.22 | 5.05 |
| | Baited Gee Minnow Trapping | 11.8 days | Catch | # | 7 | 2 |
| | | | CPUE | Fish/day | 0.59 | 0.17 |
| 2013 | Backpack Electrofishing | 911 s | Catch | # | 0 | 27 |
| | | | CPUE | Fish/min | 0 | 1.78 |
| | Baited Gee Minnow Trapping | 14.8 days | Catch | # | 19 | 2 |
| | | | CPUE | Fish/day | 1.28 | 0.14 |
| 2014 | Baited Gee Minnow Trapping | 16.4 days | Catch | # | 96 | 3 |
| | | | CPUE | Fish/day | 5.86 | 0.18 |
| 2015 | | 17.1 days | Catch | # | 58 | 3 |

| Year | Method | Effort | Summary Statistics | Units | Juvenile Chinook Salmon | All Other Species |
|---|---|---|---|---|---|---|
| | Baited Gee Minnow Trapping | | CPUE | Fish/day | 3.39 | 0.18 |
| 2016 | Baited Gee Minnow Trapping | 15.0 days | Catch | # | 51 | 9 |
| | | | CPUE | Fish/day | 3.40 | 0.60 |

#### *8.2.2.3 Creek A*

Creek A was investigated during the 1994 baseline study program at the Project site, at which time no fish were observed or captured (including a site at the road-crossing location). Creek A is not considered to offer high quality habitat for fish.

#### *8.2.2.4 McGinty Creek*

Arctic grayling and slimy sculpin were captured in McGinty Creek in 1994, through electrofishing and minnow trapping. Because substantial deadfall caused by a forest fire changed creek conditions, only minnow trapping was used in 2009–2011, yielding very low numbers of slimy sculpin. Since these captures were consistently made in close proximity to the Yukon River, these fish were presumed to be associated with the Yukon River, as opposed to McGinty Creek. These results are similar to those found in the 1994 survey, in that fish were only captured in close proximity to the Yukon River confluence. The physical nature of the McGinty Creek drainage is not conducive to a consistent year-round use by fish. Many factors, including gradient, discharge volume, depth, configuration, and paucity of an upstream reservoir, limit wintering habitat potential for fish. Also, several potential natural fish barriers were observed and documented in the lower reach of McGinty Creek.

## 8.2.3 Aquatic Environment and Habitat

### *8.2.3.1 Stream Sediments*

Stream sediments were studied for particle size and metal concentrations in 1994, and annually since 2006. Sediment particle size distribution was notably different when comparing earlier sampling years to more recent years. The change in distribution from 1994–2009 compared to 2010–2016 reflects methodological changes that were implemented in 2010. Sediment metal concentrations were also complicated by the change in methodology. With this qualification in mind, concentrations of arsenic, copper, and occasionally chromium exceeded the interim sediment quality guideline (ISQG) levels over the years but not greater than the probable effect level (PEL). Copper was the only metal that consistently exceeded guideline levels every year, including during baseline sampling in 1994. This could indicate that there are naturally high levels of copper at the exposure area. Due to the predominantly erosional habitat in upper Minto Creek, there are relatively few areas where sediment is deposited and then only in small quantities that likely wash away each year during freshet. Therefore, elevated sediment copper in the upper reaches of Minto Creek may be of limited importance in terms of exposure and potential toxicity to biota.

Two sediment toxicity tests, a 10-day *Chironomus dilutus* survival and growth, and a 14-day *Hyalella azteca* survival and growth test, were performed in 2011, 2015, and 2016. Lower Minto Creek sediment did not result in any effects to survival or growth of either test organism relative to the laboratory control or the field reference sediment (lower Wolverine Creek).

Additional detailed results for sediment physical and chemical parameters are available in Appendix 1-6.

### *8.2.3.2 Benthic Invertebrate Community*

Benthic macroinvertebrates (benthos) are non-backboned animals inhabiting the bottom substrates of aquatic habitats. The abundance, diversity, and taxonomic composition of benthos can be used as indicators of changing environmental conditions as their distribution and abundance can be influenced by a wide variety of physical parameters. Baseline and numerous other benthic invertebrate studies were undertaken in the Minto Mine area from 2006–2016.

Basic results of the 2008 and 2011 environmental effects monitoring (EEM) benthic analyses indicated that Minto Creek (treatment) had a significantly higher benthic invertebrate density and slightly lower number of taxa (not significant) compared to McGinty Creek (reference). The 2011 EEM benthic results show that Minto Creek had significantly higher number of taxa and higher density compared to both reference sites. Increased taxa, higher density, and lower evenness are indicative of a site that is experiencing nutrient enrichment. During the EEM investigation of cause (IOC) study (Phase 3), the benthic invertebrate community of the mine-exposed sites on upper Minto Creek was compared to the

reference condition (defined by 12 reference areas) for four primary EEM metrics: density, taxon richness, Simpson's evenness and Bray-Curtis (BC) distance. Results are summarized in Appendix 1-6.

Under the terms of Minto's Water Use License #QZ06-006, benthic macroinvertebrate communities are required to be annually monitored in Minto Creek. Benthic invertebrate density at lower Minto Creek in 2016 was lower than in 2014 and 2015 but higher than in 2013. Number of taxa at lower Minto Creek in 2016 was within the historical range from 2006 onwards, but moderately lower than in 1994. Lastly, Simpson's Evenness was within the historical range documented after methodological change in 2011. Over the 2012-2016 period benthic invertebrate community metrics parameters were stable, any differences between this time period and earlier sampling was more likely due to a change in mesh size of the Hess sampler, with 2012 used as a bridge.

#### *8.2.3.3 Periphyton*

Periphytic algae are simple aquatic plants which inhabit the substrate of water bodies. They can provide a valuable biological monitoring tool to assess potential impacts of nutrient enrichment and metal toxicity. Chlorophyll a is the primary photosynthetic pigment common to all algae. Determining chlorophyll a concentrations provides a measure of algae biomass and thus, the primary productivity of a given location. Periphyton was sampled in 1994 and 2011 to 2016, in Minto Creek (exposure) and Wolverine Creek (reference). Overall, the periphyton community of lower Minto Creek relative to lower Wolverine Creek had lower density and taxon richness. Temporal variability in periphyton community composition was evident among samples taken in 1994 and 2011-2016.

Concentrations of chlorophyll-a have been variable among areas over time. Significant differences between areas only occurred in 2014 and 2015. In 2016, concentrations were higher but as in previous years mean concentrations were below the British Columbia Water Quality Guideline (BCWQG) of 100 $mg/m^2$ for the protection of aquatic life (BCMOE 1985).

# 9 VEGETATION

The Minto Mine lies within the Boreal Cordillera ecozone and is situated in the far western part of the Yukon Plateau ecoregion, adjacent to the Klondike Plateau ecoregion in the west. This area was part of the eastern extent of Beringia, which remained ice-free approximately 15–20 thousand years ago. Endemic and rare plant species are associated with the Beringia area as it was a unique and isolated ecosystem. These remnant species are usually associated with grasslands and wetlands.

The Minto property lies within the eastern part of the Dawson Range, with elevations from 700 to 950 m; the landscape has rounded mountains intersected by broad valleys and drainages that are part of the Yukon River watershed. Discontinuous permafrost occurs on northern slopes and low-lying areas where sunlight is reduced.

Forest fires are frequent in this part of Yukon as it lies in the rain shadow of the St. Elias–Coast Mountains and receives less than 300mm of precipitation per year (Smith et al. 2004). As a result, the study area around Minto Mine has experienced numerous fires over the last forty years, rendering it a complex mosaic of plant communities at various stages of succession.

Capstone has characterized the baseline vegetation conditions for the project area by commissioning a vegetation survey and mapping project in 2010 and a vegetation metal uptake program in 2016. The following subsections summarize vegetation surveys conducted in the Project area. For further detail, please see the *Minto Mine Site Characterization – Vegetation* (AEG, 2017) in Appendix 1-7.

## 9.1 VEGETATION BASELINE SURVEY AND ECOSYSTEM MAPPING

A previous survey was conducted in 1994 by Hallam Knight Piesold (HKP), before any mine development had begun in the area. The 2010 baseline vegetation survey and mapping project was commissioned by Minto to capture the current biophysical conditions prior to expansion activities. The scope of the survey, mapping, and reporting includes classifying forest and vegetation types, identifying sensitive ecosystems, and compiling vegetation and some surficial soils information. In the intervening years between the 1994 and 2010 studies, the local landscape has been altered by the footprint of the current mine, further exploration and three major fires (See Fire History Map, of the *Minto Mine Site Characterization – Vegetation* (AEG, 2017*)*).

In the 2010 Vegetation Baseline Survey, different vegetation communities that exist within the study area were identified through aerial photo interpretation and delineated into polygons. Since most of the study area is regenerating from past fire disturbances, a mosaic of vegetation communities at different successional stages was delineated and classified. Thirty plots (23 of which are permanent plots) were visited to determine the accuracy of photo interpretation.

Most of the study area is regenerative young forest or shrub-dominated ecosystems where tree and shrub species are at a uniform height, as is common in fire disturbed areas (Oswald and Brown 1990). Willows

and trembling aspen are the most represented species in crown cover at the time of the survey. Lodgepole pine is a later successional species and will gradually dominate mid and upper slopes that are well drained. Shade-tolerant white spruce was often found in the understory as seedlings and is a climax species that will eventually overgrow the pine and trembling aspen communities on northern aspects. Black spruce is also a climax species that is adapted to wetter, cooler sites, and is often the persistent species in white/black spruce mixed areas along slope toes and valley bottoms. Small areas of grasslands are scattered along dry crests and steep south facing slopes as these locations do not retain enough moisture to sustain tree growth and are more likely to contain rare or uncommon plants.

Most of the planned expansion is along ridge tops and mid slopes. The main vegetation types in these areas are upland willow species, trembling aspen, lodgepole pine, and associated understory growth. The potentially impacted polygons were surveyed for rare and endemic plants; and while none were found at the time of survey, does not mean that none exist.

The ecosystem map (Appendix 1-7) was designed to be used as a land management and planning tool. As the mine expands its footprint, the map can be referred to for a quick assessment of which type of vegetation communities will be directly disturbed and how much area is involved. Sensitive areas that should be avoided, if possible, include: riparian corridors, bog/wetlands, mature forests, and grasslands.

### 9.1.1 Vegetation Types

Vegetation types are based on reoccurring patterns of plant associations dictated by site attributes such as: moisture and nutrient availability, aspect, and elevation. Polygons were delineated based on tree/shrub composition, cover, and structural stage. Plot descriptions are more detailed, but most polygons will fit in one of the following general forest types:

**Trembling Aspen/Lodgepole Pine**

This association is found in early successional forests originating after fire disturbance, on mesic to subxeric sites. Lodgepole pine (*Pinus contorta latifolia*) is more dominant than trembling aspen (*Populus tremuloides)* on well-drained south facing slopes and terraces. Coarse soils are often exposed, and lichens are well represented in the ground cover. Typically, these sites have low growing shrubs such as lingonberry (*Vaccinum vitis idaea*), kinnikinnick (*Arctostaphylos uva-ursi*), and prickly rose (*Rosa acicularis*).

**Black Spruce/Labrador Tea/Sphagnum**

Found in low lying areas and north facing slopes (cool sites), usually sparse to open forests (<50% crown cover), common shrubs in this ecosystem include Labrador tea, scrub birch, willow, and bog blueberry. Herbs present were sweet coltsfoot (*Petasites frigidus*), cloudberry (*Rubus chamaemorus*), and horsetail (*Equisetum sp.)* Sites are poorly drained (hydric to mesic) with peat horizons over mineral soils, often associated with permafrost.

**White/Black Spruce**

This association is typically located on south facing lower slopes with upland willow species and Labrador tea. A thick carpet of feather mosses and sphagnum covers the mineral soil. Ground cover shrubs include lingonberry, bog blueberry, and crowberry.

**Willow/Trembling Aspen**

This was the most common vegetation association in study area, indicative of regenerative growth (>10yrs) after a fire event. Most trees and shrubs are less than 5 m tall; cover can be open to closed as the canopy layer is of uniform height. Other species that may be present include: Alder (*Alnus crispa*) and Alaskan birch (*Betula neoalaskan*) on north facing slopes. Lodgepole pine and white spruce are also present in the understory and will eventually overtop other competing species to form the dominant canopy as the forest matures. The moisture regime ranges from subhygric to subxeric.

**Willow/Scrub Birch**

Willow (*Salix sp.)* and scrub birch (*Betula glandulosa*) occur in fluvial ecosystems adjacent to streams and fens. Other shrubs present are bog blueberry (*Vaccinum uliginosum*), Labrador tea (*Ledum groenlandicum*), and shrubby cinquefoil (*Potentilla fruticosa*). Associated graminoids include water sedge (*Carex aquatilis*), bluejoint grass (*Calamagrostis canadensis*), and rushes (*Juncus sp*.). Sphagnum, feather, and glow mosses are common.

**Trembling Aspen/Grassland**

This association features sparse to open cover of trembling aspen (*Populus tremuloides*), often with lodgepole pine (*Pinus contorta latifolia*) present as a minor component. Found on steep south and southwest facing slopes, its understory shrubs include prickly rose (*Rosa acicularis*), soapberry (*Shepherdia canadensis*), kinnikinnick (*Arctostaphylos uva-ursi*), purple reedgrass (*Calamagrostis purpurascens*), Glaucous bluegrass (Poa glauca), Threadleaf sedge (Carex filifolia), Death camas (*Zygadenus elegans*), common yarrow (*Acillea millefolium*), pussytoes (*Antennaria sp*.), and prickly saxifrage ( *Saxifraga tricuspidata*).

## 9.2 VEGETATION METAL UPTAKE

The main objectives of the vegetation metal uptake program were to utilize previously established or documented conditions, monitoring results or predictive efforts, where appropriate and possible; establish a network of plots for monitoring both soil and vegetation metal concentrations; and, allow for an ongoing evaluation of the extent and degree that metals from mining activity is affecting vegetation in proximity to the project site.

These objectives were met for this first round of the program by establishing 16 exposure sites and five control sites that will be used for monitoring every three years. At each site between one and five vegetation samples were collected along with samples of each distinguishable soil horizon.

Results from the 2016 monitoring event present evidence that some metals are elevated in the certain plant species near the mine when compared to control sites. As no baseline vegetation metals samples were collected during the 2009-2010 ecosystem mapping program it cannot be determined that elevated metals were not present in the pre-mining condition.

Results between the rinsed and unrinsed samples were highly variable. Results for some metals were greater for rinsed samples then unrinsed, suggesting that rinsing was not always removing dust particulates. There appeared to be other processes involved since some metals increased after rinsing.

Lichen and willow samples showed significantly higher metals at exposure sites compared to control sites. Lichen species are known to be good indicators of airborne metals and range from being tolerant to sensitive to airborne metals, depending on the physiological form and species (Garty, 2000; Branquinho et al., 2000; Kabata-Pendias et al., 2011). Findings around the Minto site were that lichen samples accumulated more metals than the other plant species and had significantly elevated concentrations of arsenic, cadmium, iron, and lead compared to control sites.

Willows species are known to be accumulators of heavy metals (Kosvakinka and Quigley, 2004). In particular, willows are known to uptake cadmium and zinc from surrounding soils (Tlustos et al., 2007). Willows showed significantly higher arsenic, iron and lead concentrations in exposure than control sites. Conversely and contrary to expectations, willow samples at control sites appeared to have higher (but not significantly higher) concentrations of cadmium and zinc than exposure sites.

Horsetail and Labrador tea appeared to have similar responses, and were both significantly higher in copper and iron at exposure than control sites, but not for arsenic, iron, or lead.

Blueberry did not show any significant difference between control and exposure sites. This may have been due to the short exposure period when the plant is producing berries.

There were some interesting trends in other metals. Soil metals in general were higher at exposure than control sites. Iron concentrations increased significantly for all plant species other than blueberry. Iron is not a COPC, but it does indicate that there were generally higher levels of dust at the exposure than control sites. Zinc concentrations were not higher at exposure than control sites which indicates that zinc was not significantly picked up into plant tissue in the area surrounding the mine. CCME exceedances in soil were limited occuring in two of the 13 metals of interest with 5% of samples for arsenic and 25% of samples for copper exceeding the industrial guideline. When present, copper exceedances were often detected for the depth of the pit which reflects the mineralization of the area.

Large amounts of variation (noted by high standard deviations) are present within the data that were collected in 2016. The sources of variation are potentially attributed to natural variability in soil and plant

tissue, plant species, source types and distance to exposure sample sites, field sampling conditions, and small sample size.

A main factor attributing to field variability for this sampling event was weather. The rain during the beginning of the sampling period could have affected the quantity of metals that were present on species that were more exposed compared to species in closed canopy conditions. There were scattered thunder showers for the remainder of the sampling period that could have affected parts of the study area. This variability is likely to persist through future sampling events as weather is unpredicatble and cannot always be avoided.

Variability attributed to sample size is reflected in the limited number of control sites and the number of target species present within each site. Blueberry sample size was limited for both control and exposure sites as they are less abundant across the landscape compared to the other species.

Laboratory variability was encounted by the nature of the selected lab's data quality objective (DQO). The DQO implemented by the lab for tissue analysis was 40% repeatability. This threshold allows for 40% variation in concentrations between any duplicate samples. This threshold was set by that lab and is a factor of the natural variability that is present in vegetation tissue sampling. This variation is compounded when the lab homogonized, subsampled, and rinsed half of the samples for the purpose of quantifying external and internal metal concentrations. Large variation made comparisons between rinsed and unrinsed samples challanging when there were low metal concentations and minimal differences between subsamples. Additionaly, many of the results received were below the method detection limits. When this was the case, the value used to calculate statistics was half the detection limits. Including these halved detection limits is likely to have increased the variation and standard deviation for each variable.

Vegetation metal uptake surveys will continue on a three-year basis as a condition of the current licence to monitor trends and changes in metal concentrations in vegetation and soil.

# 10 GEOCHEMISTRY AND GEOTECHNICAL INFORMATION

## 10.1 GEOCHEMISTRY

Minto conducted pre-production testing and continues to conduct operational monitoring. Detailed information on geochemistry can be found in Appendix 1-8 to this report.

The primary conclusions from the pre-production testing were that Main Pit and Minto North Pit waste rock was expected to be net acid neutralizing, and that the main acid neutralizing mineral was calcite (calcium carbonate, $CaCO_3$). The primary conclusions of preproduction testing for Area 2/ Area 118, Ridgetop, and proposed underground developments were that bulk granodiorite waste rock was expected to be net acid neutralizing, and that some mineralized waste rock was expected to have NP:AP values less than the threshold value of 3 specified by the water use license (YWB, 2015 and its predecessors).

Since mining commenced at Minto, operational ABA monitoring has been carried out on composite samples of blast hole cuttings from each waste blast. Waste rock monitoring reports have been prepared and submitted to regulators as part of the mine's compliance reporting (initially semi-annually, now annually). The results show that Main Pit and Minto North Pit waste rock generally had low AP and NP:AP ratios greater than the threshold value of 3. Results for Area 2/ Area 118, Ridgetop, and proposed underground developments waste rock were mixed with most samples having NP:AP values greater than 3. There were sufficient samples with NP:AP less than 3 that Minto modified its waste rock management strategy to include segregation of NP:AP<3 materials. See Appendix 1-8 and Figure 10-1 for summary results of operational waste rock geochemistry monitoring.

No pre-production characterization tests were carried out on tailings from Main Pit ore. For the Phase IV and Phase V/VI deposits (Area 2, Area 118, Minto North, Ridgetop and Minto South underground), a range of preproduction tests were carried out on residues from locked cycle testing. Residues from metallurgical testing carried out on Area 2 and Area 118 ore samples were subjected to additional testing for purposes of ML/ARD characterization. Results of the pre-production testing on Phase IV and Phase V/VI tailings indicated that the material would be net acid neutralizing, and that risks of neutral pH metal leaching would be similar to those for Main Pit tailings produced from full-scale operations.

Operational monitoring of as-produced tailings has been carried out to track the ABA characteristics of the tailings produced over the operating period. Results of operational ABA monitoring of tailings produced to date confirm excess of neutralization potential (NP) over acid potential (AP), indicating that the tailings produced to date are net acid neutralizing. See Appendix 1-8 and Figure 10-2 for summary results of operational tailings geochemistry monitoring.

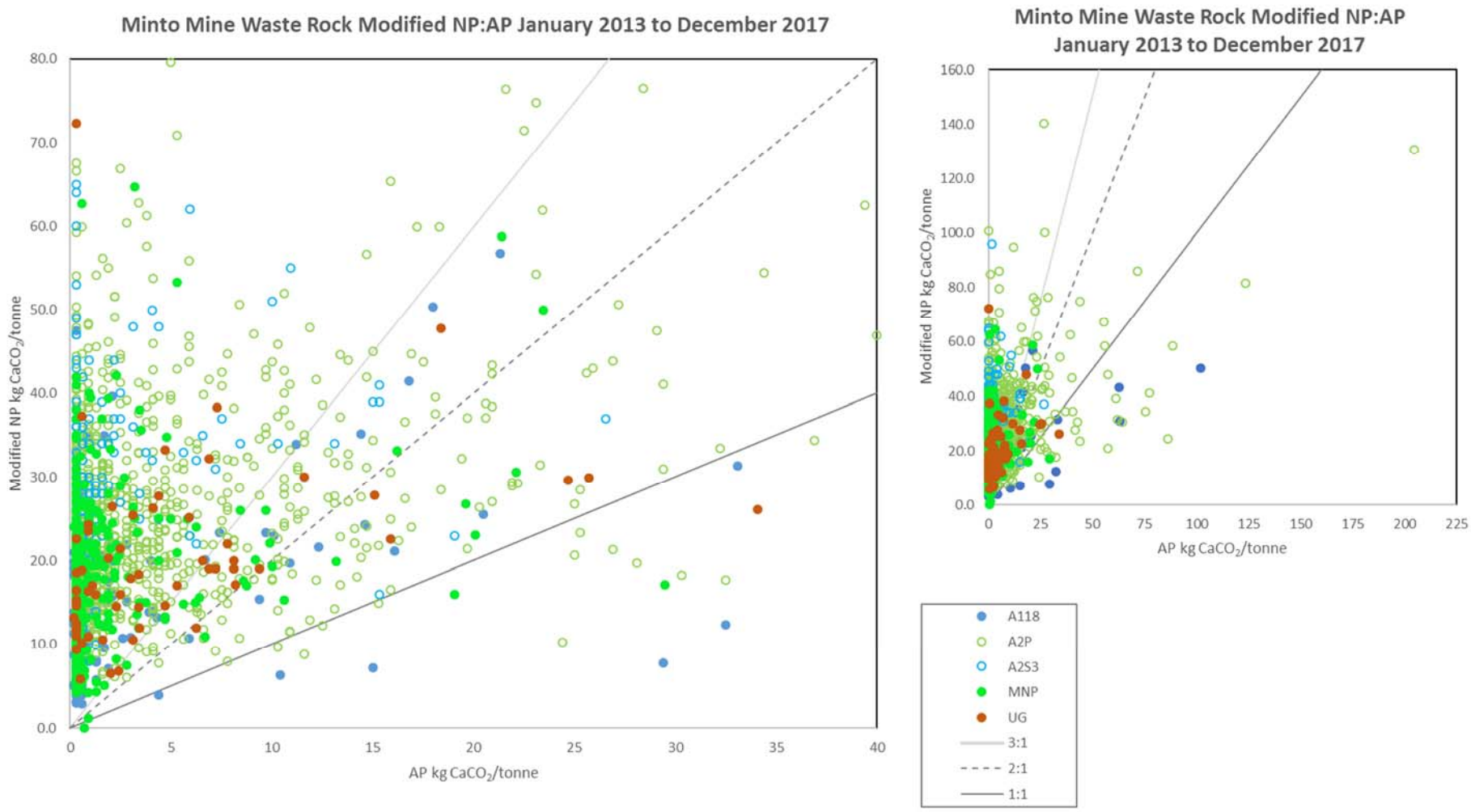



**Figure 10-1: Minto Mine Waste Rock Modified NP:AP January 2013 to December 2017.**

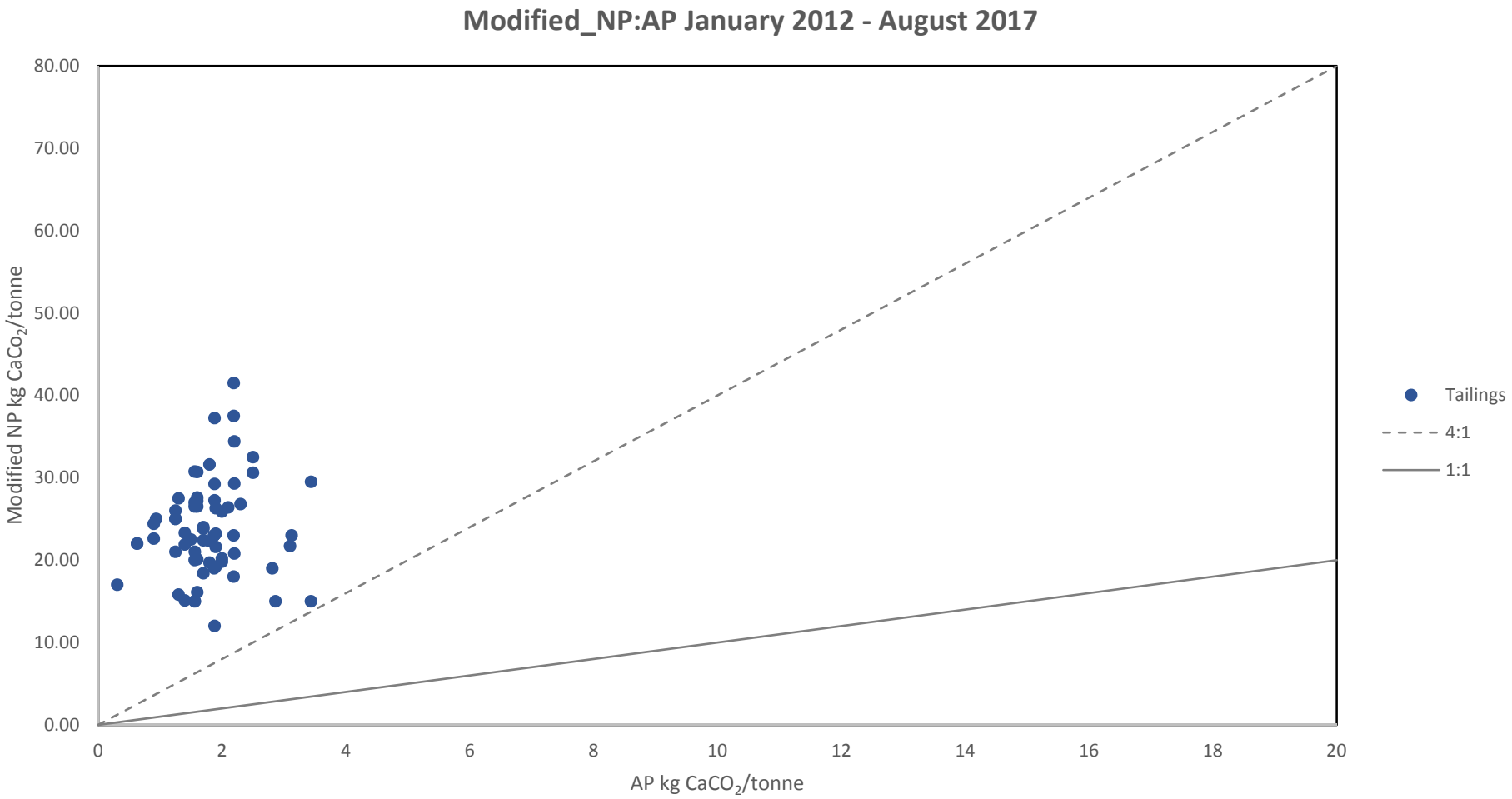



**Figure 10-2: Modified NP:AP January 2012 – August 2017.**

## 10.2 GEOTECHNICAL INFORMATION

The geotechnical stability of individual structures is addressed in geotechnical annual review reports. The site has in the past experienced slope instabilities and slow movements along a suspected shear zone underlying parts of some existing facilities; the physical monitoring program is carried out to monitor geotechnical performance of major site facilities, and review of monitoring results is an important component of the geotechnical annual inspections. The report documenting the most recent geotechnical annual review (SRK 2017) is attached as Appendix 1-9.

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# Water and Load Balance Model Report 2018

**Prepared for**

## Minto Explorations Ltd.



**Prepared by**

SRK Consulting (Canada) Inc.
1CM002.044
February 2018

# Water and Load Balance Model Report 2018

February 2018


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# 1 Introduction

## 1.1 Purpose and Overview

This report describes the development and results of the water and load balance model developed for the Minto Mine 2018 Reclamation and Closure Plan (RCP). This report was written in accordance with the Water Use License (WUL) requirements (YWB 2015; Clause 110c). The main features of the 2018 RCP are summarized in Section 1.2.

The water and load balance model builds on previous water balance modelling work prepared for Minto Explorations Ltd. as part of past water license applications, environmental assessments, annual reporting and operational water management efforts. The model covers the end of the operations phase, as well as the active closure and post-closure phases (Post-Closure I and Post Closure II).

The water balance model accounts for all inflows to and outflows from the Minto Mine site, as well as accumulation of water in reservoirs within the mine site. The model can be run in stochastic mode where annual precipitation rates are varied to simulate randomly occurring wet and dry climatic conditions. Water quality results are based on estimates of geochemical loadings applied to modelled water flow. Water quality predictions are presented for 'expected case' and 'reasonable worst case' scenarios, which represent the best estimate geochemical loading rates and loading rates that are unlikely to be exceeded.

Section 2 describes inputs to and components of the water balance model. Section 3 summarizes the load balance model inputs. Model scenario implementation is described in Section 4 and modelling results are presented in Section 5 followed by a discussion in Section 6.

## 1.2 Closure Summary

Closure at the Minto Mine has been subdivided into three periods: Active Closure (AC), Post-Closure I (PCI) and Post Closure II (PCII) (Minto 2018). Estimated timelines for the different phases are listed in Table 1-1.

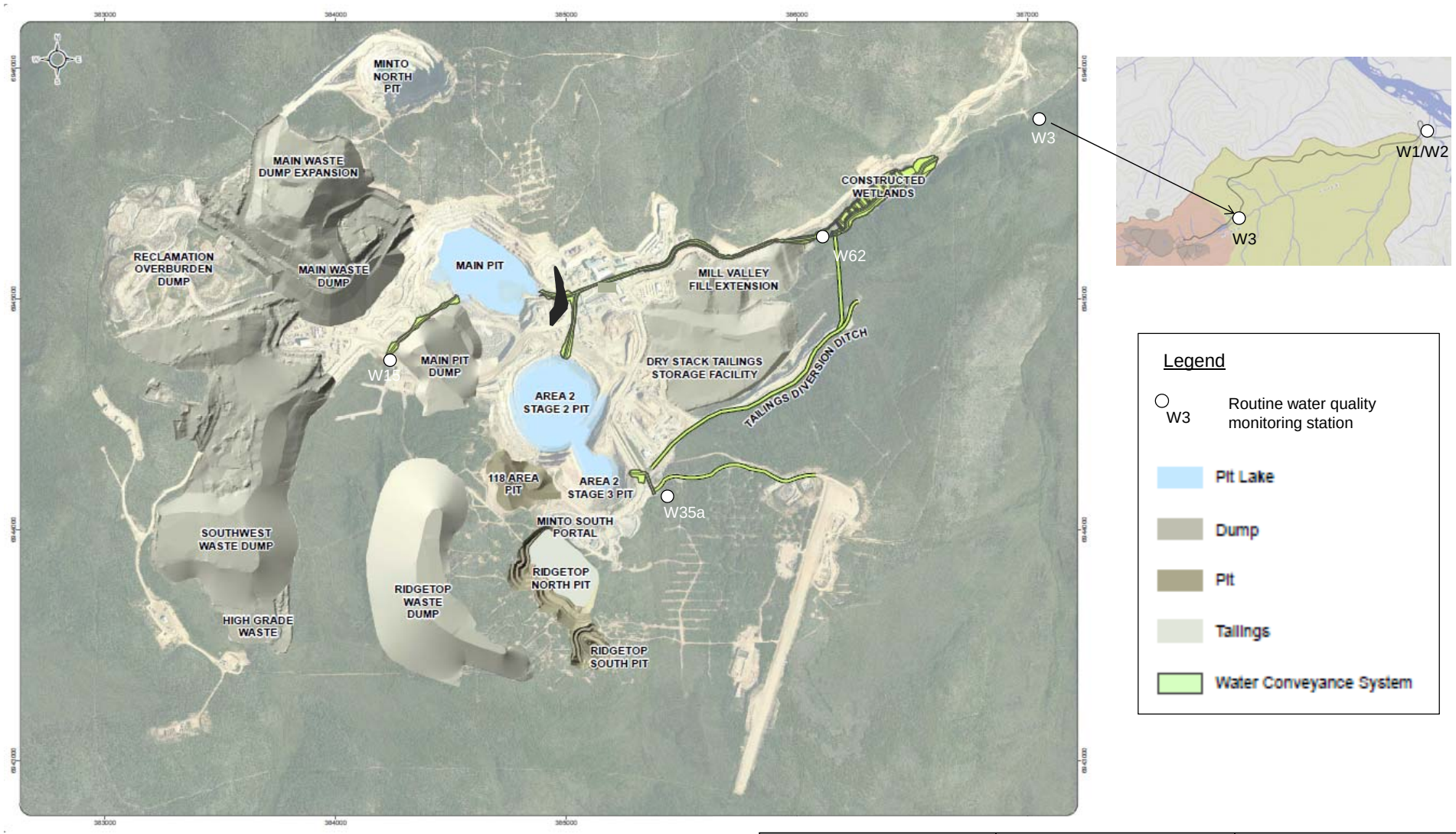
**Table 1-1 Project Schedule**

| Year | Summary of Main Project Activity |
|---|---|
| 2018 | Underground production continues from the Minto South underground portal. Open pit mining continues in Area 2 Stage 3 until the pit is completed by the end of the first quarter of the year. Open pit mining begins at Ridgetop. Underground mining begins at the Copper Keel deposit |
| 2019 | Open pit mining continues at Ridgetop until the pit is complete in the second quarter. Underground mining continues at the Minto East deposit until it is completed in the first quarter. Underground mining begins at the Minto East 2 deposit. |
| 2020 | Underground mining begins at the Minto North Underground deposit. |
| 2021 | Underground mining from the Minto East and the Minto North Underground deposits and milling continues until the last quarter of the year. Active closure to begin. |
| 2022 – 2024 | Active closure period continues (total duration expected three years) with post closure one beginning near the end of 2025. |
| 2025 – 2029 | Post closure one period continues (total duration expected five years but will be performance based) with post closure two beginning near the end of 2030 |
| 2030 – 2039 | Post closure two period continues (total duration of post closure two is ten years) until near the end of 2040. |

The AC period includes the implementation and construction of most closure measures, including recontouring, soil placement, closure water conveyance construction, revegetation, construction of passive water treatment facilities, decommissioning of the Water Storage Dam, demobilization and demolition. During the AC period, operational water quality objectives/effluent standards will still apply. Active treatment will be used as required to meet discharge water quality limits. The AC period is expected to span approximately three years.

In the PCI period, the closure measures and infrastructure will become operational and the performance will be assessed. During this period, maintenance on soil covers will be undertaken as required as vegetation begins to establish. Water conveyance features will be commissioned along with the passive treatment system. During PCI, operational water quality objectives/effluent standards will still apply. A pump-back system will be established downstream of the passive treatment system to direct any water that does not meet effluent standards to the treatment plant or the open pits. Passive treatment will be commissioned and will over time become the primary water treatment system. The PCI phase nominally spans five years but the duration of this phase will depend on the performance of the closure measures.

During the PCII period, the closure measures and infrastructure will be monitored to confirm that performance meets the design intents. PCII is primarily a monitoring phase with maintenance activities as required. During PCII the closure water quality objectives will apply and passive treatment will be the primary water treatment onsite.




Source: Adapted from Figure 7-2 (prepared by Access Consulting Group) in Minto Explorations Ltd. 2018. Minto Mine Reclamation and Closure Plan Revision 2018-01.

| | | |
|---|---|---|
| srk consulting | capstone MINTO MINE | Water and Load Balance Model Report 2018 |
| | | **General Arrangement- End of Mine** |
| Job No: 1CM002.044<br>Filename: Fig_1-1_EOM_GeneralArrangement.pptx | Minto Mine | Date: Feb 2018 / Approved: DBM / Figure: **1-1** |

# 2 Water Balance Model Description

## 2.1 Water Balance Overview

Figure 2-1 shows a schematic of the conceptual water balance for the Minto Site. The water balance can be described as:

$$Water\ Input = Water\ Storage + Water\ Output \quad (1)$$

Precipitation is the only source of water to site and therefore the only input. The open pits and the Water Storage Pond (WSP) are the primary water storage reservoirs on site during the Operational Period. Water outputs include water released to Minto Creek and water lost to evapotranspiration. The net input of water to reservoirs on site, or net yield, can be expressed as:

$$Net\ Yield = Precipitation + Groundwater\ Discharge\ - Evapotranspiration - Groundwater\ Recharge \quad (2)$$

Note that the yield term includes both surface and groundwater terms. Net yield is a measure of the total volume of water that report to the reservoirs on site, regardless of flow path. Net yield can be described in terms of a yield coefficient, defined as follows:

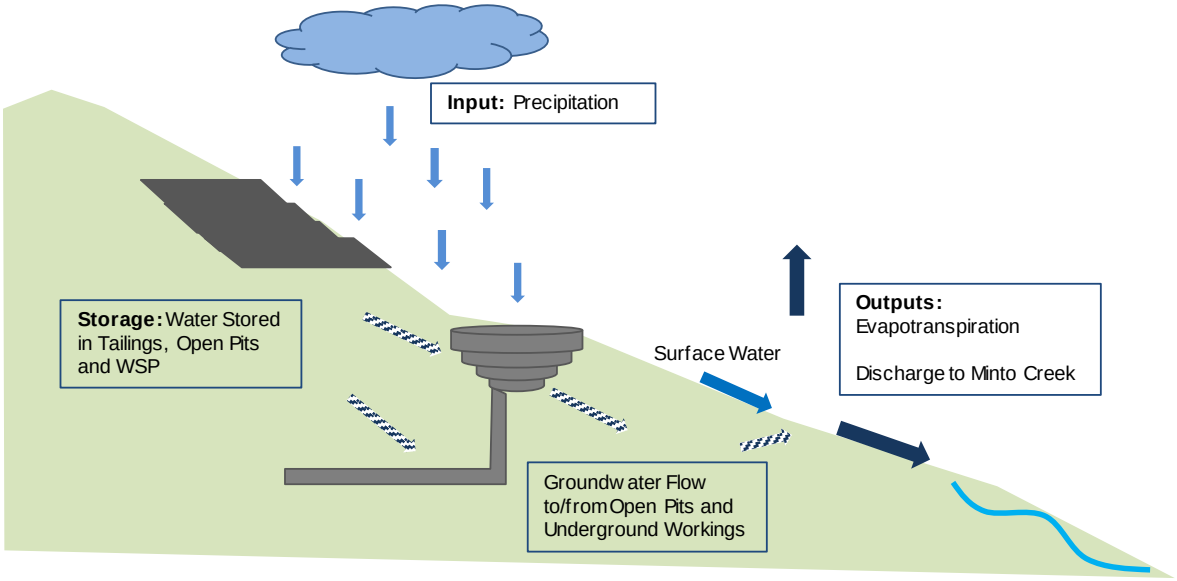
$$Net\ Yield = Precipitation * Yield\ Coefficient \quad (3)$$

The yield coefficient approach allows the water balance to be simplified to:

$$Net\ Yield - Water\ stored\ on\ Site = Water\ Released\ to\ Minto\ Creek \quad (4)$$

Figure 2-1 shows a schematic of the simplified water balance. In a year with average annual precipitation (329 mm/year) the net yield from catchments within the Minto Mine site is approximately 950,000 $m^3$. Of that, approximately 530,000 $m^3$ will report to tailings pores during the period when the mill is running. The annual volume of water reporting to waste rock pores range from zero to about 200,000 $m^3$, depending on the volume of waste inundated in any given year. On average, waste rock pore water amounts to roughly 60,000 $m^3$/year. This leaves approximately 360,000 $m^3$ of surplus water that must be stored on site or released to Minto Creek in an average-precipitation year.

In previous versions of the water and load balance model for the Minto Mine, groundwater was not included as a discrete path. At Minto, the cross section of the Minto Creek Valley at the Water Storage Dam is narrow and bedrock is relatively shallow. As such, the majority of groundwater that flows toward Minto Creek is expected to report to the stream as surface water and only a small fraction is expected to flow from site via subsurface pathways (SRK, 2015a). In this 2018 revision of the water and load balance model, the assumption that the majority of the groundwater reports to the surface upstream of the Water Storage Pond (WSP) is carried forward. However, discrete groundwater discharge and recharge terms for the open pit zones have been included. The groundwater flow estimates are based on a revised version of the 2015 Groundwater Model as described in SRK (2015a).




Source: X:\01_SITES\Minto\1CM002.0XX_PhaseVII_Support\!080_Deliverables\Water and Load Balance Report\040_Figures\Figure 2.1 and 2.2 Water_Balance_Schematic_Minto_REV01.pptx

**Figure 2-1 Water Balance Schematic**

## 2.2 Water Balance Inputs

Inputs for the water balance model are summarized in Table 2-1 and discussed in the following sections.

**Table 2-1 Input Required for Water Balance Model**

| Water Balance Component | Input Required |
|---|---|
| Net Yield | Annual precipitation rates<br>Open water evaporation rates<br>Sub-catchment areas<br>Site-wide yield coefficient<br>Typical hydrograph |
| Water storage | Open pit water volumes<br>Tailings and waste rock deposition schedules |
| Groundwater | Estimated seepage rates to/from open pits<br>Underground dewatering rates |
| Water Discharged to Minto Creek | Historical WSP pumping schedule |

### 2.2.1 Precipitation

Precipitation is the only input of water to the Minto Mine site water balance model. The water balance model calculates annual yield based on annual precipitation and a site-wide yield coefficient. Therefore, a reliable estimate of the frequency and intensity of total annual precipitation is important for the accuracy of model predictions.

Rainfall data collected on site was used in conjunction with long-term regional precipitation records to estimate the distribution of annual precipitation rates. The precipitation record for the Minto site is shown in Table 2-2. Rainfall data has been recorded at site beginning in September 2005. In October 2011, Minto installed an adapter for measuring snowfall as water equivalent. For this update, on-site rainfall and total precipitation data from the period September 2005 through December 2016 were used.

**Table 2-2 Monthly Rainfall and Total Precipitation Measured at Minto**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2005** | ** | ** | ** | ** | ** | ** | ** | ** | 21.60 | 23.00 | 11.60 | 4.60 | 60.8 |
| **2006** | 0.00 | 0.40 | 2.80 | ** | 22.84 | 35.80 | 28.63 | 29.20 | 12.20 | 12.20 | 0.00 | 0.00 | 144.1 |
| **2007** | 0.20 | 0.00 | 0.40 | 5.80 | 4.60 | 36.00 | 47.80 | 21.00 | 33.80 | 11.80 | 0.00 | 0.00 | 161.4 |
| **2008** | 1.20 | 2.00 | 0.80 | 1.80 | 9.60 | 26.20 | ** | 100.60 | 21.80 | 6.40 | 0.00 | 0.00 | 170.4 |
| **2009** | 5.20 | 0.00 | 0.80 | 3.23 | ** | ** | 6.08 | 50.76 | 7.20 | 16.60 | 0.00 | 0.00 | 89.9 |
| **2010** | 0.00 | 0.00 | 0.00 | 0.00 | 7.60 | 48.8 | 75.6 | 46.4 | 18.0 | 16.3 | 3.05 | 0.00 | 215.8 |
| **2011** | 0.00 | 6.40 | 0.20 | 0.40 | 15.3 | 56.0 | 101.8 | 64.8 | 15.6 | 4.40(A) | 0.15** | 3.94** | 269.0 |
| **2012** | 9.0** | 9.9** | 34.9 | 0.0 | 0.1** | 32.1 | 44.8 | 20.6 | 26.1 | 16.5 | 17.1 | 18.4 | 229.5 |
| **2013** | 4.4 | 73.8 | 7.4 | 0.0 | 7.9 | 21.0 | 113.5 | 46.8 | 59.7 | 13.6 | 36.6 | 27.0 | 441.7 |
| **2014** | 16.9 | 8.0 | 0.0 | 3.8 | 15.0 | 12.0 | 50.5 | 13.4 | 30.5 | 22.0 | 2.9 | 21.0 | 196.0 |
| **2015** | 12.4 | 0.0 | 10.9 | 8.0 | 4.9 | 20.5 | 37.7 | 80.3 | 16.7 | 27.7 | 7.1 | 11.5 | 237.7 |
| **2016** | 11.7 | 7.8 | 3.3 | 14.7 | 31.5 | 22.2 | 68.2 | 35.9 | 17.8 | 9.8 | 13.6 | 14.1 | 250.6 |

Source: Minto Site Data: X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2015_Water_Balance_Update\Minto Water Balance\2016 Met Station DataSummary.xlsx

**Notes:**

** partial data only.

(A) Measurement transitioned from rainfall to total precipitation on Oct. 15/2011.

Green highlight: total precipitation measurements.

Regional precipitation data were available from a number of meteorological stations in the Yukon (Table 2-3). Rainfall data up until 2012 from each station were correlated with precipitation data collected from the Minto site to determine whether long-term regional precipitation data would be suitable for use as a basis for estimating annual precipitation at the site.

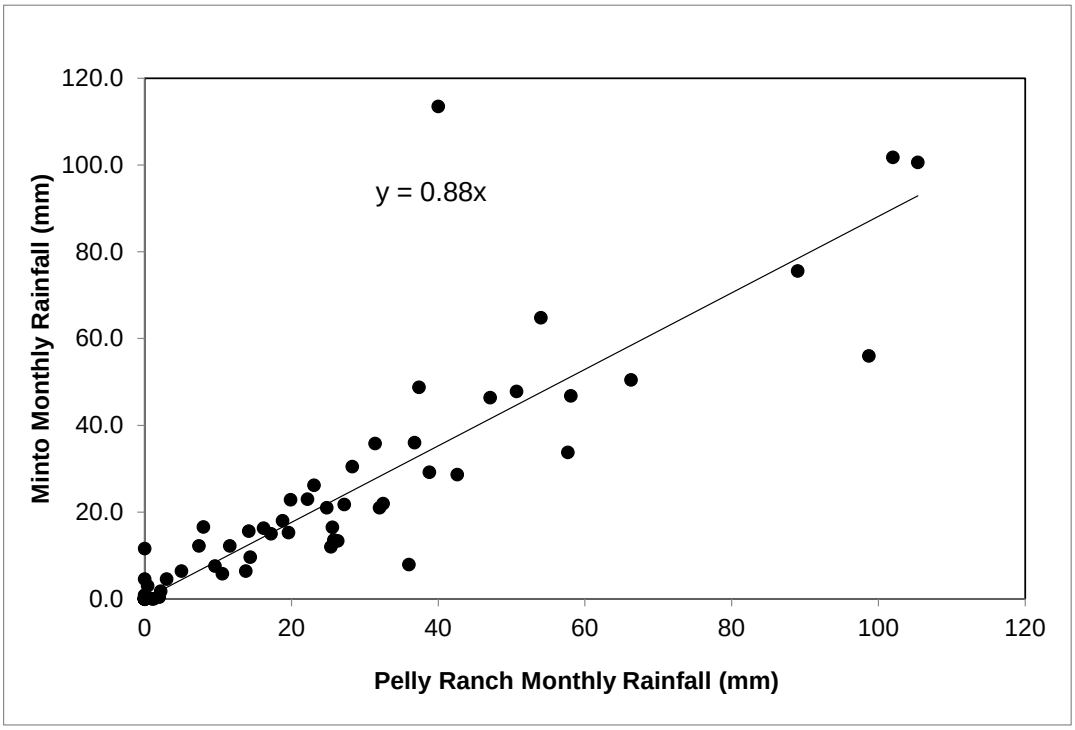
Rainfall data at the closest regional meteorological station at Pelly Ranch (Climate ID: 2100880), located 23 km from the Minto Mine, resulted in the best correlation with rainfall data from site. The precipitation record at Pelly Ranch dates back to December 1951 and has continued to the present day. Figure 2-2 shows a plot of monthly rainfall values at Minto and at the Pelly Ranch station. The correlation can be expressed as:

$$Minto\ Rainfall = 0.88 * Pelly\ Ranch\ Rainfall \quad (6)$$

**Table 2-3 Regional Meteorological Stations**

| Station | Latitude | Longitude | Distance From Site (km) | Elevation (m) | Record Begins | Record Ends |
|---|---|---|---|---|---|---|
| Minto Site | 62°36'59" | 137°15'00" | 0 | 887 | Sep-05 | Present |
| Burwash Airport | 61°22'00" | 139°03'00" | 168 | 807 | Oct-66 | Present |
| Carmacks | 62°06'00" | 136°18'00" | 109 | 525 | Aug-63 | Present |
| Dawson Airport | 64°02'35" | 139°07'40" | 184 | 370 | Jan-76 | Present |
| Faro Airport | 62°12'27" | 133°22'33" | 205 | 717 | Dec-77 | Present |
| Haines Junction | 60°46'21" | 137°34'49" | 206 | 595 | Oct-44 | Present |
| Mayo Airport | 63°37'00" | 135°52'00" | 131 | 504 | Oct-11 | Present |
| McQuesten | 63°36'00" | 137°31'00" | 110 | 457 | Oct-86 | Present |
| Pelly Ranch | 62°49'00" | 137°22'00" | 23 | 454 | Dec-51 | Present |
| Whitehorse Airport | 60°42'34" | 135°04'07" | 241 | 706 | Apr-42 | Present |

Source: SRK, :\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\02_Hydrology_and_Meteorology\Regional_Analysis\Regional Precipitation Data\Regional_Met_Station_Summary_1CM002.003_Rev01_TC.xlsx




Source: X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\!080_Deliverables\2016_RCP_Water_and_Quality_Report\040_Figures\Figure 2-3.xlsx

**Figure 2-2 Comparing Minto Mine and Pelly Ranch Rainfall (Sept. 2005 to March 2015)**

A comparison of snow-water equivalent data from Minto and Pelly Ranch (not shown) resulted in the following correlation:

$$Minto\ Snowfall = 1.24 * Pelly\ Ranch\ Snowfall \quad (7)$$

Based on these correlations the annual precipitation at Minto correlates to the annual precipitation at Pelly Ranch as follows:

$$Minto\ Annual\ Total\ Precip. = 1.09 * Pelly\ Ranch\ Annual\ Total\ Precip. \quad (8)$$

Table 2-4 shows the estimated average total annual precipitation values for Minto based on the correlation with Pelly Ranch precipitation data. A frequency (or probability) distribution of total annual precipitation was developed for the Minto site based on the long-term total precipitation record available for the Pelly Ranch station. Pelly Ranch precipitation values were only used if a calendar year contained valid information for more than 95% of the total number of days in that year. The use of this data quality criteria resulted in a total of 51 years of valid data to be included in the frequency distribution analysis.

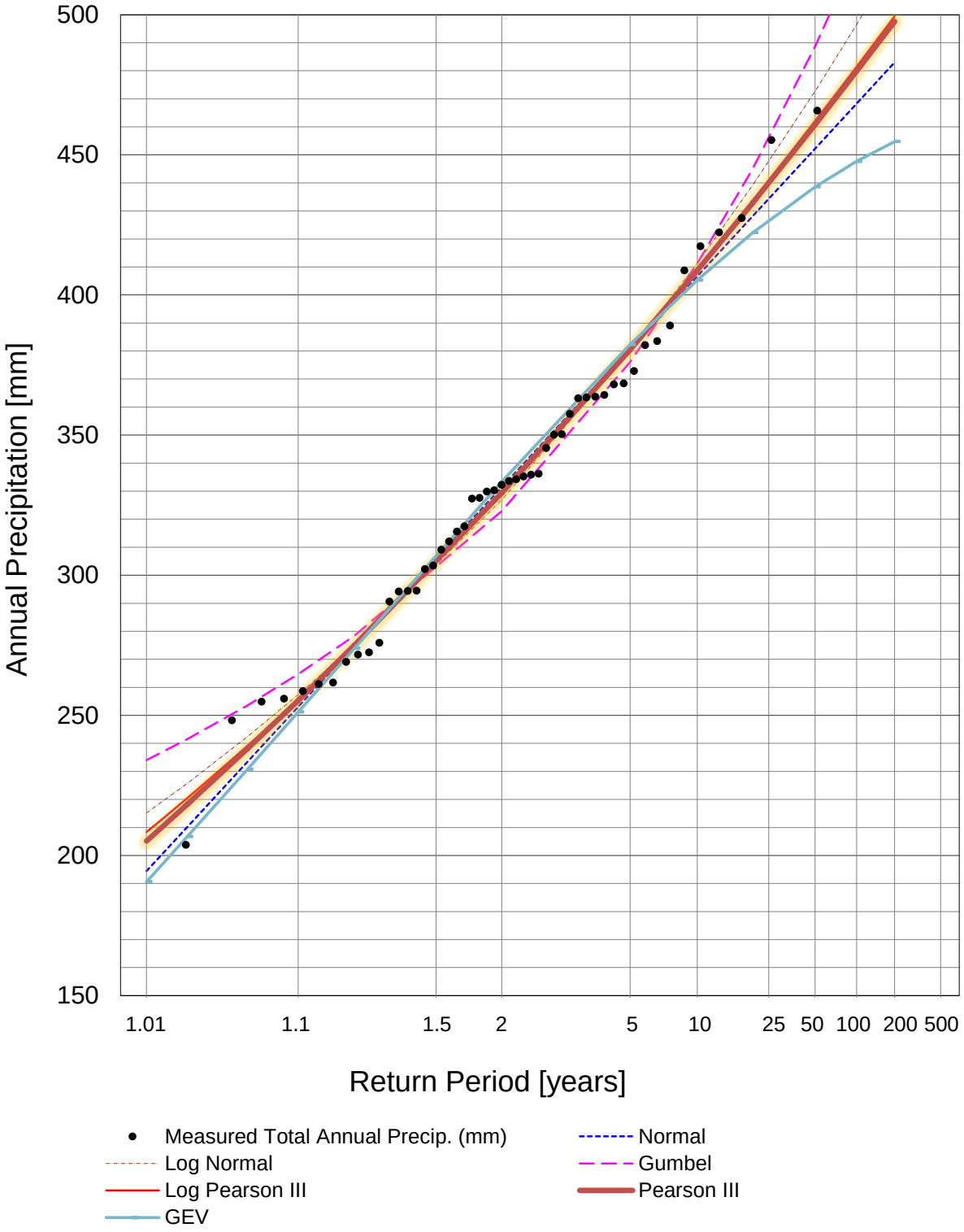
The 51 years of annual precipitation data were fitted against six different statistical distributions: Normal, Log-Normal, Gumbel, Log-Pearson, Pearson III, and GEV. The best fit was obtained with a Pearson III Distribution ($r^2 = 0.99$). This Intensity/frequency distribution was used as input for the water balance model. The final results are presented in Figure 2-3 and Table 2-5.

**Table 2-4 Estimated Average Precipitation at Minto Based On Pelly Ranch Precipitation Data**

| Month | Average Rainfall (mm/month) | Average Snowfall (mm/month) | Average Total Precipitation (mm/month) |
|---|---|---|---|
| Jan | 0.08 | 28.6 | 28.7 |
| Feb | 0.08 | 20.3 | 20.4 |
| Mar | 0.14 | 15.9 | 16.0 |
| Apr | 3.10 | 9.29 | 12.4 |
| May | 19.16 | 0.63 | 19.8 |
| Jun | 32.38 | 0.00 | 32.4 |
| Jul | 47.85 | 0.00 | 47.9 |
| Aug | 34.98 | 0.02 | 35.0 |
| Sep | 22.91 | 3.07 | 26.0 |
| Oct | 6.72 | 22.0 | 28.7 |
| Nov | 0.30 | 37.3 | 37.6 |
| Dec | 0.08 | 30.4 | 30.4 |
| Total (mm/year) | 167.8 | 167.5 | 335.3 |

Source:Z:\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\2_Hydrology_and_Meteorology\Met_Data\Minto_MasterStationFile_20130607.xlsx

The estimated average total precipitation for Minto was slightly lower for the frequency analysis (329 mm/year) than for the direct computation using the average total precipitation value from Pelly Ranch (335 mm/year). This difference is a result of the imperfect fit between the data and the distribution model that is used. In the interest of consistency with frequency distribution approach, the total precipitation value generated by the Pearson III distribution (329 mm) was used as input to the water balance model.




Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\PMP & PMF\PMP Hershfield Estimation & Freq Distribution_VM_Rev4_SRJ.xlsx

**Figure 2-3 Precipitation Frequency Analysis for the Minto Mine Site**

**Table 2-5 Precipitation Frequency Analysis Statistics**

| Cumulative Probability | Return Period | Season | Normal | Log Normal | Gumbel | Log Pearson III | Pearson III | GEV |
|---|---|---|---|---|---|---|---|---|
| 0.005 | 200 | | 483 | 519 | 554 | 499 | 498 | 455 |
| 0.01 | 100 | | 468 | 496 | 521 | 481 | 480 | 448 |
| 0.02 | 50 | | 452 | 473 | 489 | 462 | 461 | 439 |
| 0.05 | 20 | Wet | 428 | 439 | 445 | 434 | 433 | 422 |
| 0.1 | 10 | | 407 | 411 | 411 | 409 | 409 | 405 |
| 0.2 | 5 | | 381 | 380 | 376 | 380 | 380 | 382 |
| 0.5 | 2 | | 331 | 327 | 323 | 329 | 329 | 333 |
| 0.8 | 5 | | 275 | 275 | 278 | 275 | 275 | 274 |
| 0.9 | 10 | | 253 | 257 | 265 | 256 | 255 | 251 |
| 0.95 | 20 | Dry | 233 | 242 | 254 | 239 | 238 | 231 |
| 0.98 | 50 | | 210 | 226 | 242 | 220 | 218 | 207 |
| 0.99 | 100 | | 194 | 215 | 234 | 208 | 205 | 191 |
| | $R^2$ | | 0.98 | 0.98 | 0.97 | 0.98 | 0.99 | 0.97 |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\PMP Hershfield Estimation & Freq Distribution_VM_Rev4_SRJ.xlsx

### 2.2.2 Evaporation

For modelling purposes evaporation estimates were based on regional data. Monthly lake evaporation (aka potential evaporation) has been recorded at the Pelly Ranch station from 1965 to 2005; the mean annual lake evaporation value is 452 mm. In historical revisions of Minto's water balance, open water evaporation and evapotranspiration were estimated based on the regional data and model estimates.

Estimated evaporation values for the site were adopted from work completed by Clearwater Consultants Ltd. as part of the previous year's water balance update completed for the mine site (CCL 2010). Table 2-6 shows the adopted monthly evaporation values, which for modelling purposes were assumed to be constant for each year included in the scenario runs.

Evaporation estimates are associated with considerable uncertainty. However, in the present model revision, evaporation losses were only discretely applied to open water bodies, including the pit lakes and the Water Storage Pond. A sensitivity analysis was completed to quantify the effect of uncertainties associated with the annual evaporation rate. The analysis showed that a difference of +/- 100 mm of annual evaporation would make a +/- 2.6% difference to the annual water balance (net inflow) estimate, which was considered to be relatively insignificant in the context of other uncertainties and year-to-year variability.

**Table 2-6 Estimated Monthly Open Water Evaporation Values for Minto**

| Month | April | May | June | July | August | September | Total |
|---|---|---|---|---|---|---|---|
| Evaporation (mm) | 12 | 83 | 119 | 112 | 83 | 30 | 439 |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\01_Project_Phases\04_Amendment_8_Support\02_Source_Term_Archive\[Minto Mine Water Balance_2011 Update Modified Goldsim_SRJ_Rev01

### 2.2.3 Catchments

The Minto Mine site, excluding the proposed Minto North Pit, is located within the Upper Minto Creek watershed. For the purposes of this report, Upper Minto Creek will refer to the portion of the Minto Creek catchment upstream of the Water Storage Dam. The catchment downstream of the Water Storage Dam will be referred to as Lower Minto Creek. The Upper Minto Creek catchment covers an area of 1,038 ha, which has been divided into sub-catchments for modeling purposes. Table 2-7 and Figure 2-4 show Upper Minto Creek sub-catchments that were delineated for the Phase V/VI water balance model.

The Minto North Pit is located within the McGinty Creek catchment to the north of the Minto Mine. Table 2-8 and Figure 2-5 shows McGinty Creek sub-catchments delineated for the Phase V/VI water and load balance model.

**Table 2-7 Upper Minto Creek Catchment Areas**

| | |
|---|---|
| **n1_Main_Pit_Undisturbed** | **11.5** |
| **n2_SW_Waste_Rock** | **40.7** |
| **n3_Overburden_Dump** | **31.5** |
| **n4_Overburden_Dump_Undisturbed** | **16.6** |
| **n5_Main_Waste_Dump_Undisturbed** | **12.8** |
| **n6_Main_Waste_Dump** | **48.1** |
| **n7_SW_Waste_Rock_Undisturbed** | **47.6** |
| **n8_W15_Undisturbed** | **110.9** |
| **n9_Main_Pit_Highwall** | **26.3** |
| **n10_Mill_Area_Undisturbed** | **27.6** |
| **n11_Area_2_Pit** | **18.3** |
| **n12_Portal_Area** | **2.2** |
| **n13_Ridgetop_N_Highwall** | **2.9** |
| **n14_Mill_Area** | **16.0** |
| **n15_Ore_Stockpiles** | **13.3** |
| **n16_WSP_Undisturbed_N** | **139.8** |
| **n17_Dry_Stack** | **19.3** |
| **n18_Dry_Stack_Shell** | **5.6** |
| **n19_Main_Pit_Submerged** | **15.2** |
| **n20_Ridgetop_N_Pit** | **8.2** |
| **n21_Mill_Valley_Fill_Stage_1** | **12.4** |
| **n22_Ridgetop_Waste_Dump** | **28.1** |
| **n23_Area_118_Pit** | **6.9** |
| **n24_Ridgetop_South_Pit** | **2.3** |
| **n25_Main_Pit_Dump** | **14.9** |
| **n26_Portal_Undisturbed** | **7.6** |
| **n27_Area_118_Undisturbed** | **2.7** |
| **n28_Ridgetop_N_Undisturbed** | **13.1** |
| **n29_W35_Undisturbed_South** | **144.1** |
| **n30_WSP_Undisturbed_S** | **66.5** |
| **n31_Area_2_Highwall** | **17.7** |
| **n32_Mill_Valley_Fill_Stage_2** | **4.7** |
| **n33_Underground_Laydown** | **2.9** |
| **n34_Drystack_Undisturbed** | **4.8** |
| **n35_Tails_Diversio_Upstr_Undis** | **27.9** |
| **n36_W35_Undisturbed_East** | **28.8** |
| **n42_Contractor_Area** | **5.0** |
| **n43_Overburden_undisturbed** | **1.1** |
| **n44_medium_grade_waste** | **22.2** |
| **n45_high_grade_waste** | **5.8** |
| **n46_ice_rich_overburden** | **4.2** |
| **SUM** | **1038** |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\04_Catchments\RCP_Catchments\Minto_Phase_VII_RCP_Catchment_Table




N

0 100 200 400 600 Meters

**Legend**

Subcatchments

srk consulting

Job No: 1CM002.58

Filename: Minto_20171101_SubCatchments_rev00

capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.

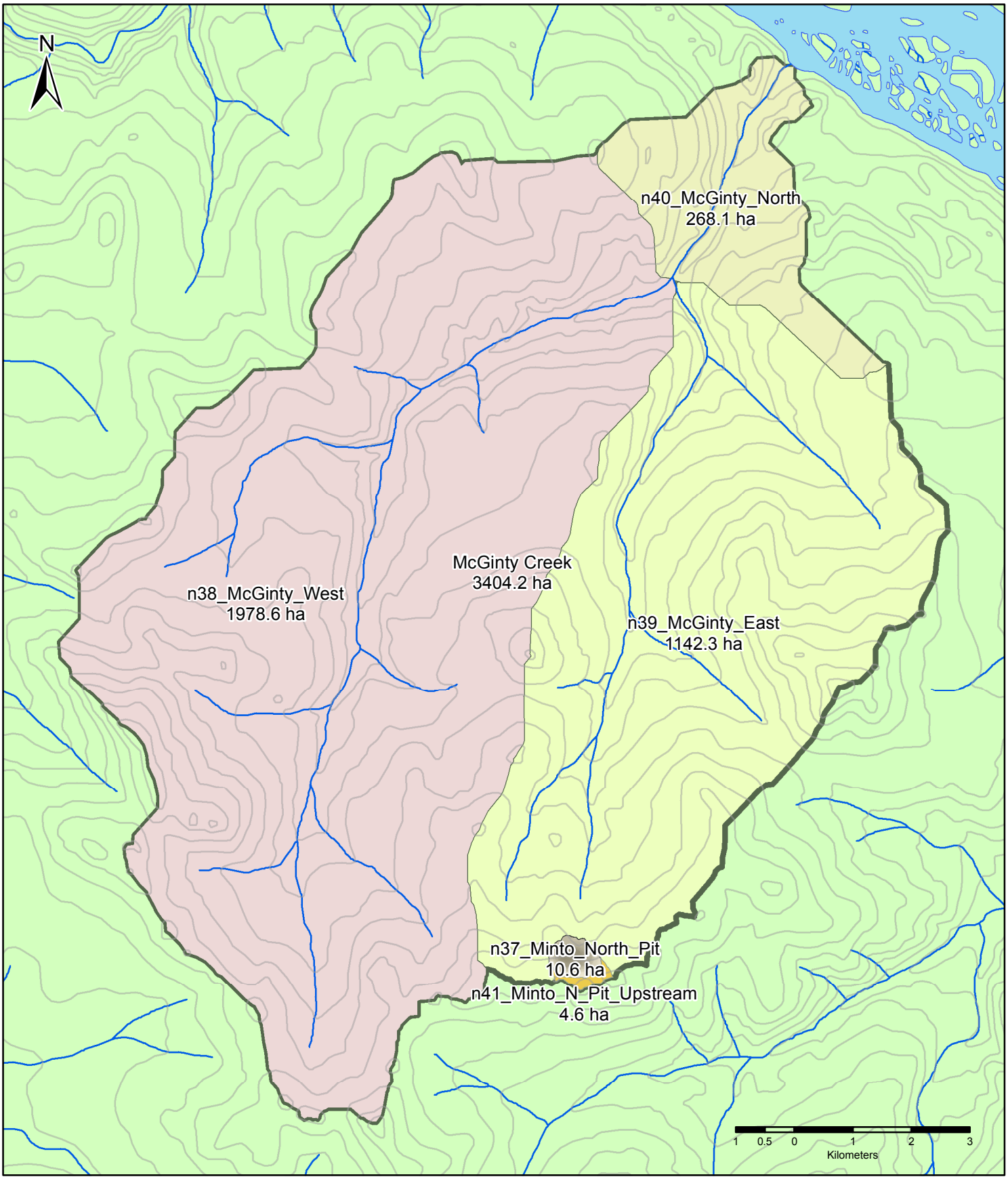
Minto Mine

Water and Load Balance Report
Report 2018

Subcatchments within
Minto Mine Site

| Date: | Approved: | Figure: |
|---|---|---|
| Feb 2018 | SRJ | 2.4 |

Document Path: X:\01_SITES\Minto\!020_Site_Wide_Data\!GIS\0.figures\Minto_20171101_SubCatchments_rev00.mxd




| | | |
|---|---|---|
| srk consulting | CAPSTONE MINING CORP. MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD. | Water and Load Balance Report 2018 |
| | | McGinty Creek Sub-Catchments |
| Job No: 1CM002.024<br>Filename: PhV_VI_Minto_North_REV06_AMD | Minto Mine | Date: February 2018 \| Approved: KNK \| Figure: 2.5 |

**Table 2-8 McGinty Creek Sub-Catchments**

| Sub-Catchment | Area (ha) |
|---|---|
| n37_Minto_North_pit | 10.6 |
| n38_McGinty_West | 1978.6 |
| n39_McGinty_East | 1142.3 |
| n40_McGinty_North | 268.1 |
| n41_Minto_N_Pit_Upstream | 4.6 |
| **Total Catchment Area** | **3404.2** |

Source:X:\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\04_Catchments\Phase_V_VI_Catchments\Minto_Phase_V_VI_Catchment_Table.xlsx

### 2.2.4 Yield Coefficient

As described in Section 2.1, annual catchment yield (water that reports to reservoirs on site) can be estimated by multiplying the total annual precipitation by a site-wide yield coefficient (Equation 3). This yield includes surface runoff and steady-state flow of shallow and deep groundwater. Groundwater flows to or from the open pits or underground workings are not included in the yield estimate. Such groundwater flows are caused by advancement and dewatering of underground workings or by inundation of open pits and are therefore not influenced directly by the same-year precipitation and run-off. For the 2018 water and load balance, the use of a site-wide yield coefficient for land areas was found to be more appropriate than assigning specific yield coefficients to areas with different land use and surface cover characteristics. Firstly, flow measurements on site (hydrological monitoring stations and flow meters) measure water collected from different land use areas, *i.e.* a combination of undisturbed and developed mine areas. This makes it difficult to evaluate yield coefficients for any one type of land use area based on actual site performance data. Therefore, uncertainties associated with area-specific yield coefficients would magnify the uncertainty of the site-wide water balance and it would be necessary to arbitrarily adjust each of the yield coefficients to match the site-wide water balance. Secondly, during the operations and closure (pit filling) phases the available water storage capacity on site is generally greater than the annual volume of surface yield, and therefore reliable forecasts of total site-wide annual yield volumes are more important for water management planning than forecasts of yield from individual sub-catchments.

Monitoring data collected on site since 2007 was used to estimate the value of the site-wide yield coefficient for Upper Minto Creek. The yield coefficient estimate is updated once a year in conjunction with the annual water balance update for the site. The 2015 and 2016 water balance updates (Appendix B) generally agreed with the established yield coefficient value of 0.30, which was derived based on previous years' water balance data.

The estimated total annual precipitation at the Minto Mine has generally been greater than 300 mm/year for the period 2007 to 2015. Consequently, the site-wide yield coefficient of 0.30 was effectively derived for annual precipitation greater than 300 mm/year. However, this yield coefficient may overestimate yield in relatively dry years. In order to account for this the site-wide yield coefficient for dry years was assigned lower values in the water balance model. The dry year coefficients were based on work completed by Clearwater Consultants Ltd. (CCL 2010) for the Minto Mine site as follows:

- A yield coefficient of 0.15 was used for dry years with less than 190 mm total precipitation.
- A yield coefficient of 0.30 was used for years with greater than 309 mm total precipitation.
- Yield coefficients for years with total precipitation between 190 mm and 309 mm were interpolated values between 0.15 and 0.30.

Figure 2-6 shows yield coefficient values used in the model as a function of total annual precipitation.

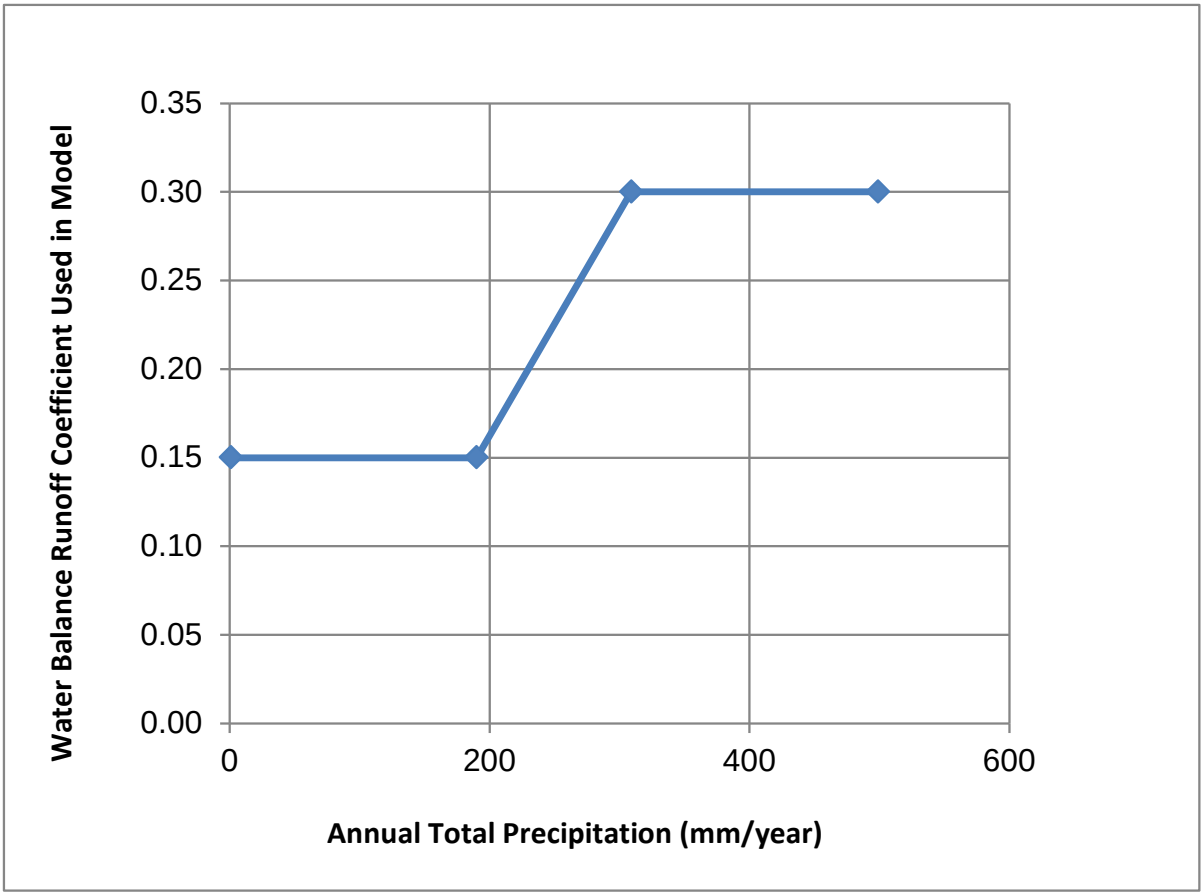



**Figure 2-6 Water Balance Yield Coefficient vs. Total Annual Precipitation**

The one exception is that open water areas (flooded pits and the WSP) were treated differently than land areas. Open water was assigned a yield coefficient of 1.0 along with an annual evaporation rate. This approach relies on the assumptions that any precipitation that falls on a water body becomes part of the water inventory and that the open water evaporation rate is relatively constant from year to year. As discussed in Section 2.2.2, the effect of uncertainty associated with the estimate of annual evaporation on the site-wide water balance is relatively insignificant.

Catchment yield estimates calculated from the annual precipitation frequency distribution, catchment area and site-wide yield coefficient are listed in Table 2-9.

**Table 2-9 Annual Site-Wide Runoff Estimates**

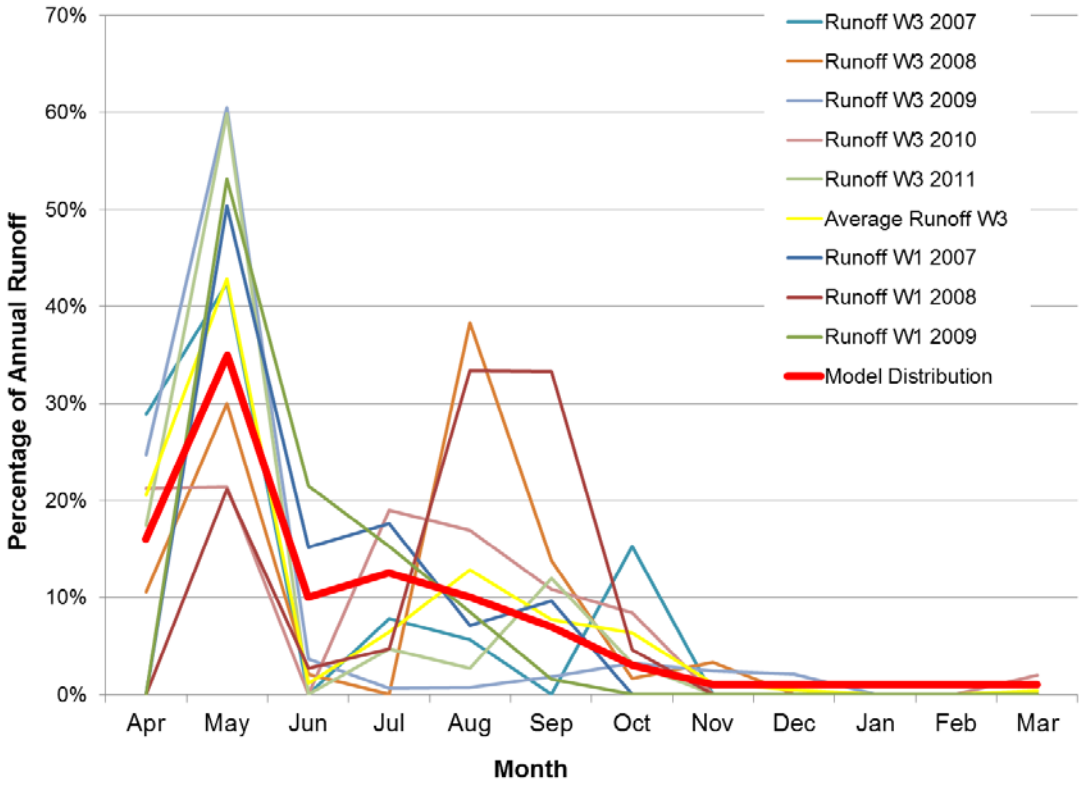
| Annual Total Precipitation | Description | Total Catchment Runoff |
|---|---|---|
| mm/year | | $m^3$/year |
| 498 | 1:200 Wet | 1,480,000 |
| 480 | 1:100 Wet | 1,420,000 |
| 461 | 1:50 Wet | 1,360,000 |
| 433 | 1:20 Wet | 1,280,000 |
| 409 | 1:10 Wet | 1,200,000 |
| 380 | 1:5 Wet | 1,110,000 |
| **329** | **Average** | **950,000** |
| 275 | 1:5 Dry | 660,000 |
| 255 | 1:10 Dry | 540,000 |
| 238 | 1:20 Dry | 450,000 |
| 218 | 1:50 Dry | 350,000 |
| 205 | 1:100 Dry | 290,000 |

Notes: Source:\ X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2016_Water_Balance_Update\ 2016 Water Balance Update REV00 KNK.xlsx

### 2.2.5 Runoff Distribution

The natural hydrograph for the Minto Creek catchment can vary considerably from year to year. This variability is an important consideration when designing conveyance structures and storage reservoirs for shorter-term storm events. However, the specific daily or monthly runoff distribution does not significantly affect Minto's site-wide water balance during operations and closure.

Because Minto's site-wide water balance is relatively unaffected by short-term runoff events, a fixed monthly runoff distribution was adopted for the water balance model. The fixed monthly runoff distribution used in the water balance model was based on observed monthly flows rates at the hydrometric stations at W3 and W1 in Minto Creek. Figure 2-7 shows the measured runoff distributions at W3 and W1 as well as the distribution that was used in the model.




Source:Z:\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\02_Hydrology_and_Meteorology\Hydrology_Data\Aggregated_Runoff_Data_1CM002.003_Rev01_TC

**Figure 2-7 Runoff Distribution Model**

### 2.2.6 Groundwater

Assumptions for groundwater flows from the open pits were based on a revised version of the 2015 Groundwater Model (SRK 2018). Construction details for the model are presented in SRK (2015a). Pit lake water levels were updated for the revised model to reflect current pit level elevations and final pit elevations based on current mine plans:

- Current Pit Levels: Main Pit = 786.28 masl; Area 2 Pit = 765 masl
- Final Pit Levels: Main Pit = 786.28 masl; Area 2 Pit = 799 masl

No other changes were made to the model. The model water balance was queried to determine flows into and out of the pits, and groundwater discharge to surface water features. Table 2-10 summarizes groundwater flows from the open pits to several stations from the revised model.

**Table 2-10 Groundwater Flows from Source to Station**

| Station | Total Groundwater Flow to Station | | Total Inflow from Pit Lakes to Station | |
|---|---|---|---|---|
| | Current Pit Levels | Final Pit Levels | Current Pit Levels | Final Pit Levels |
| | (m3/d) | (m3/d) | ($m^3$/d) | ($m^3$/d) |
| WSPu | 176.36 | 208.18 | 29.55 | 63.66 |
| WSPdg | 269.45 | 304.26 | 29.98 | 65.07 |
| W3 | 338.37 | 373.09 | 29.99 | 65.12 |
| W46 | 758.19 | 786.52 | 29.99 | 65.12 |
| MC1 | 1384.70 | 1404.09 | 29.99 | 65.12 |
| YR | 1836.00 | 1844.42 | 29.99 | 65.12 |
| **Component of Total Inflow to Station from Source** | | | | |
| WSPu | | | 16.8% | 30.6% |
| WSPdg | | | 0.2% | 0.5% |
| W3 | | | 0.0% | 0.0% |
| W46 | | | 0.0% | 0.0% |
| MC1 | | | 0.0% | 0.0% |
| YR | | | 0.0% | 0.0% |
| **Percentage of Total Flow from Source Reaching Station** | | | | |
| WSPu | | | 22.7% | 49.0% |
| WSPdg | | | 0.3% | 1.1% |
| W3 | | | 0.0% | 0.0% |
| W46 | | | 0.0% | 0.0% |
| MC1 | | | 0.0% | 0.0% |
| YR | | | 0.0% | 0.0% |

### 2.2.7 Reservoirs

Reservoirs on the Minto Mine site include the Main Pit, the Area 2 Pit, and the future Ridgetop North Pit Tailings Management Facilities (TMFs) and the Water Storage Pond. Historically, the dry-stack tailings were also considered a reservoir because of the pore water stored in the tailings mass. In the model, the available storage capacities of the open pit TMFs are defined as the volume that can be filled with water, waste rock and tailings solids. Requirements for freeboard and contingency storage are not considered to be available storage and are therefore not included in values for available storage capacity.

**Main Pit**

The Main Pit was mined between 2007 and 2011. Since completion of mining, the pit has been used for storage of mine water and for deposition of waste rock and tailings. The estimated storage capacity of the Main Pit above the August 2016 tailings bathymetry surface and below the spill elevation of 786 m is 917,000 $m^3$ (Minto, 2017). In October 2017 approximately 576,000 $m^3$ of free mine water was stored in the Main Pit along with approximately 2,500,000 $m^3$ of bulk saturated tailings and 1,136,000 $m^3$ of bulk saturated waste rock (Minto, 2017). During the operations phase, reclaim water for processing of ore is sourced from the Main Pit TMF. After the end of the milling operation, excess water will be diverted to the Area 2 Pit until the pit is full. At that time, the Main Pit TMF outflow will be directed towards the lower Minto Creek via constructed channels that will be built as part of the closure water conveyance system.

**Area 2 Pit**

Development of the Area 2 Pit commenced in 2011 and mining is expected to be completed in 2018. The available storage capacity of the Area 2 Pit was approximately 3,700,000 $m^3$ as of early 2015 when mining of Stage 2 was complete and will be approximately 7,800,000 $m^3$ following the completion of Stage 3 in 2018. At the end of the mine life in 2018 it is anticipated that approximately 5,200,000 $m^3$ of bulk tailings and 50,000 $m^3$ of waste rock will be stored sub-aqueously in the Area 2 Pit.

Following the operations phase, the Area 2 Pit will be allowed to fill with water. Water from the Main Pit TMF will be directed to the Area 2 Pit through the filling phase. When full, water discharging from Area 2 Pit will flow through the primary water conveyance system via constructed channels toward lower Minto Creek.

**Area 118 Pit**

The Area 118 Pit is relatively small with estimated storage capacities of approximately 210,000 $m^3$. The pit is expected to be filled in with overburden during mining of Area 2 Stage 3 Pit. Therefore, Area 118 Pit is not considered to be a reservoir for storage of mine water or runoff.

**Ridgetop North Pit**

Development of the Ridgetop North Pit is planned for early 2018 and is expected to be completed in 2019. The storage capacity of the Ridgetop North Pit will ultimately be approximately 1,900,000 $m^3$. Tailings deposition in the Ridgetop North Pit will commence as soon as development is completed and will stop when the pit is full of tailings. The Ridgetop North Pit TSF will be covered in the dry at closure as a local high elevation to prevent a pit lake from forming.

**Ridgetop South Pit**

The Ridgetop South Pit is relatively small and expected to be filled in with overburden during mining. Therefore, Ridgetop South Pit is not considered to be a reservoir for storage of mine water or runoff.

#### Minto North

Development at the Minto North Pit began in 2015 and open pit mining is now complete. During that time, mine water was collected in the pit and pumped to Main Pit TMF. Underground development in the Minto North Pit is planned for mid-2020 to late-2021. When underground mining is complete the pit will be allowed to fill; a pit lake is expected to form (based on baseline groundwater levels in the area) but the influence of groundwater losses via pit wall fractures will only be known through performance monitoring once the pit is completed. There are no plans to store tailings or waste rock in the Minto North Pit, or to actively use the pit as a reservoir for water management purposes.

#### Water Storage Pond

The WSP was constructed in 2007 and has a maximum water storage volume of 320,000 $m^3$. Initially, the WSP was used as a source of process water for the mill. However, when the Main Pit was converted to a tailings management facility following completion of mining, reclaim from the pit supplied water for the mill, the WSP transitioned to function as a storage reservoir for clean runoff and treated water destined for release to Minto Creek. During Active Closure, the Water Storage Dam will be lowered and the footprint of the existing WSP will be converted to a Constructed Wetland Treatment System and a parallel High Flow Bypass Channel (Contango 2016).

### 2.2.8 Underground

#### Minto South Underground

Development of the Minto South Underground began in 2012 and mining is expected to be completed in 2018. Any water collected in the underground is pumped or trucked to the surface to either the Main Pit or the Area 2 Pit. Dewatering of the Minto South Underground will continue until development of the other underground areas, excluding the Minto North Underground, is complete.

#### Minto East Underground

Development of the Minto East Underground is planned for early 2018 and mining is expected to be completed in early 2019. Any water collected in the underground is pumped or trucked to the surface to either the Main Pit or the Area 2 Pit. Dewatering of the Minto East Underground will continue until development of the other underground areas, excluding the Minto North Underground, is complete.

#### Copper Keel Underground

Development of the Copper Keel Underground is planned for early 2018 and mining is expected to be completed in late 2021. Any water collected in the underground is pumped or trucked to the surface to either the Main Pit or the Area 2 Pit. Dewatering of the Copper Keel Underground will continue until development of the other underground areas, excluding the Minto North Underground, is complete.

#### Minto East 2 Underground

Development of the Minto East 2 Underground is planned for early 2019 and mining is expected to be completed in late 2021. Any water collected in the underground is pumped or trucked to the surface to either the Main Pit or the Area 2 Pit. Dewatering of the Minto East 2 Underground will

continue until development of the other underground areas, excluding the Minto North Underground, is complete.

**Minto North Underground**

Development of the Minto North Underground is planned for mid-2020 and mining is expected to be completed in late 2021. Any water collected in the underground is pumped or trucked to the surface to either the Main Pit or the Area 2 Pit.

### 2.2.9 Tailings Management Facilities

Minto halted deposition of tailings to the Dry Stack Tailings Storage Facility in November 2012 and transitioned to sub-aqueous deposition of tailings in the Main Pit TMF. From now until the end of mine life, tailings will primarily be deposited such that they will be saturated over the long term, with a partial volume forming unsaturated beaches in the Main Pit TMF and Ridgetop North TMF. The water and load balance model incorporates projected water volumes associated with tailings slurry, with mill reclaim water, and with pore-water in the settled tailings mass based on the life-of-mine production schedule provided by Minto.

### 2.2.10 Waste Rock and Tailings Cover

During the active closure period a cover system will be constructed on all waste rock piles and the Dry Stack Tailings Storage Facility. The water and load balance model assumes that the cover will reduce the infiltration of mean annual precipitation from 30% to 20%. This is consistent with previous modelling efforts for the Minto project and is supported by recent soil cover modelling results (SRK, 2015b).

# 3 Load Balance Inputs

All geochemical sources in the load balance model, including sources representing mine components and background catchment runoff were incorporated as dissolved loadings. Historically, the model accounted for increases in parameter concentrations arising from suspended solids in mine discharge by adding a separate source term for suspended solids at the point of discharge. Although the model retains this capability, this revision only reports on dissolved constituent loadings and concentrations; this is consistent with the dissolved nature of both effluent standards and receiving environment water quality objectives in the current site water use licence (WUL QZ14-031).

**Table 3-1 Summary of Load Balance Source Terms**

| Source Term | Units | Applies to |
|---|---|---|
| Background Upper and Lower Minto Creek | mg/L | Undisturbed catchments within and downstream of the Minto Mine site |
| Dry Stack Tailings Seepage | mg/L | Seepage from the Dry Stack Tailings Storage Facility |
| Main Pit TMF Unsaturated Tailings Load | mg/year | Main Pit TMF |
| Mill Area Loadings | mg/year | Mill Area |
| Minto North Background | mg/L | Undisturbed sub-catchments in McGinty Creek |
| Minto North Pit Loadings | mg/year | Minto North Pit |

| Source Term | Units | Applies to |
|---|---|---|
| Nitrogen Contribution | mg/L | Added to all water released from the mine to account for loadings of nitrogen species |
| Ore Stockpile Concentrations | mg/L | Ore Stockpile Area, Operations |
| Ore Stockpile Loadings | mg/year | Ore Stockpile Area, Closure |
| Pit Wall Loadings | mg/year | All pit walls |
| Tailings Slurry | mg/L | Tailings slurry supernatant |
| Waste Rock Loadings | mg/m$^3$/year | Large Waste Rock Dumps and Mill Valley Fill Expansion (Stage 1 and Stage 2) |

Source: Z:\01_SITES\Minto\1CM002.024_Water_Balance_Support\!080_Deliverables\2016_RCP_Water_and_Quality_Report\020_Tables\Source_terms_Summary_REV00_SRJ_KNK

For this update of the water and load balance, the sulphate source term for the tailings slurry was reviewed. In 2017, sulphate concentrations is the Area 2 and Main Pit water increased at a greater rate than in previous years. After investigating possible causes, SRK concluded that variability in sulphate loadings from tailings slurry was the most likely cause of the concentration increases. Details of the source term review are described in Appendix D.

In order to properly represent the variability in the mill effluent water quality, the tailings slurry source term was divided into two parts: sulphide ore tailings source term and oxide ore (referred to as POX) tailings source term. Typically, just sulphide ore or a blend of sulphide ore and POX ore are processed in the mill. Elevated concentrations of sulphate in the mill effluent coincided with processing of POX. Accordingly, the tailings slurry source terms for sulphide ore and POX ore were developed based on measured sulphate concentrations in the tailings thickener when sulphide ore and POX ore were milled. The loading rates associated with POX processing are highly variable. To maintain conservatism in the model predictions, the Expected Case and Worst Case POX ore slurry source term that represents the highest sulphate loading rates was used for all model scenarios. Details of this review and source term updates are provided in Appendix D.

## 3.1 Minto Creek

The load balance model was developed to evaluate the potential effects of water quality parameter loadings from mine components on water quality in lower Minto Creek and McGinty Creek. Table 3-1 shows a summary of updated geochemical source terms used in the load balance. Figure 3-1 shows the allocation of source term by sub-catchments within Upper Minto Creek. Each source term represents an estimate of runoff water quality (mg/L) or parameter loadings (mg/year) contributed by a sub-catchment or mine component.

Source term estimates were generated for two scenarios described as “Expected Case” and “Reasonable Worst Case”. The Expected Case scenario is intended to represent typical geochemical loadings (including the scale of variability observed to date) while the Reasonable Worst Case represents an upper limit to water quality parameter concentrations that may be observed in the mine water on site and consequently in Lower Minto Creek.

Source terms defined as concentrations (mg/L) were incorporated in the load balance model by assigning the water quality to all flow from the corresponding sub-catchment. Alternately, source

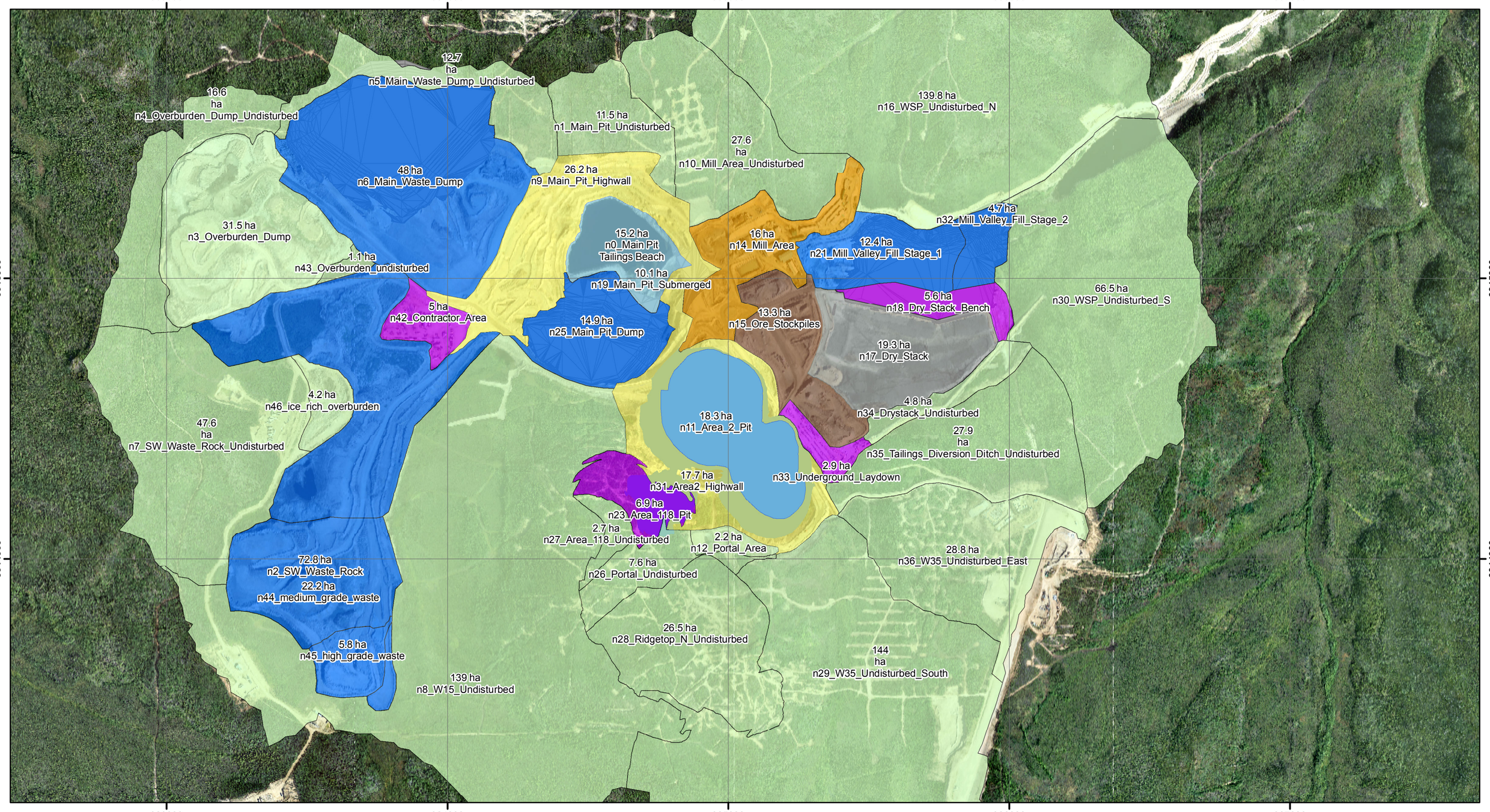
terms which were defined as loadings were added as a “dry” load to the appropriate flow or water reservoir.

Details concerning the development of source terms are described in the Minto Mine Expansion-Phase V/VI ML/ARD Assessment and Post-closure Water Quality Predictions report (SRK 2013) and in the 2016 Water Balance and Water Quality Model Summary for the Minto Mine Site provided in Appendix C. Source terms used in the model are provided in Appendix B.

All applicable source terms were updated to include water quality data up to and including December 2016 sampling events. Alexco Environmental Group conducted a review of the dataset used to update the source terms and removed erroneous data and select data points below detection (AEG 2018).

Estimates of background water quality for Minto Creek were initially developed by Minnow Environmental in 2009. Minto Creek water quality monitoring data was compiled into a pooled data set that reflected background conditions (i.e. conditions not affected by mine development activities). The data set was updated and refined in 2016 as part of a process for development of post-closure water quality objectives (WQOs). Details can be found in the Background Water Quality report (Minnow 2016). Post-closure WQOs, based on the summary statistics calculated by Minnow, have been defined by Minto. Details regarding the Post-closure WQOs can be found in the Minto Mine 2018 Reclamation and Closure Plan (RCP 2018-01(Minto 2018)).

It is important to note that both the Post-closure WQOs and background water quality source terms used in the model were derived from the same data set. However the post-closure WQOs were calculated on an annual basis and the background water quality source terms were calculated on a monthly basis. Some months, particularly in the winter, have little water quality sample data. Individual data points in these months therefore have a higher statistical weighting than the more numerous individual data points from summer months in the background water quality summary statistics. Therefore, the monthly summary statistics for background concentrations are in some cases higher than the WQOs, which are based on annual summary statistics. This is the case for dissolved copper and iron concentrations. Figure 3-2 and Figure 3-3 compare measured background concentrations to the WQOs for dissolved copper and iron. Months where background water quality source terms are derived from few data points with elevated measured background concentrations will show consistent exceedance of WQOs in the model results.




N

0 75 150 300 450 600 Meters

**Legend**

**Minto Phase V/VI Source Term Allocation**

- Background Upper Minto Creek
- Drystack Seepage
- Main Pit TMF Unsaturated Tailings Load
- Mill Area Loadings
- None
- Ore Stockpile Loadings or Concentrations
- Pit Wall Loadings
- Ridgetop TMF Unsaturated Tailings Load
- Waste Rock Concentrations
- Waste Rock Loadings

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Filename: PhV_VI_Source_Terms_REV02_AMD

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# Water and Load Balance Report 2016

## Source Term Allocation

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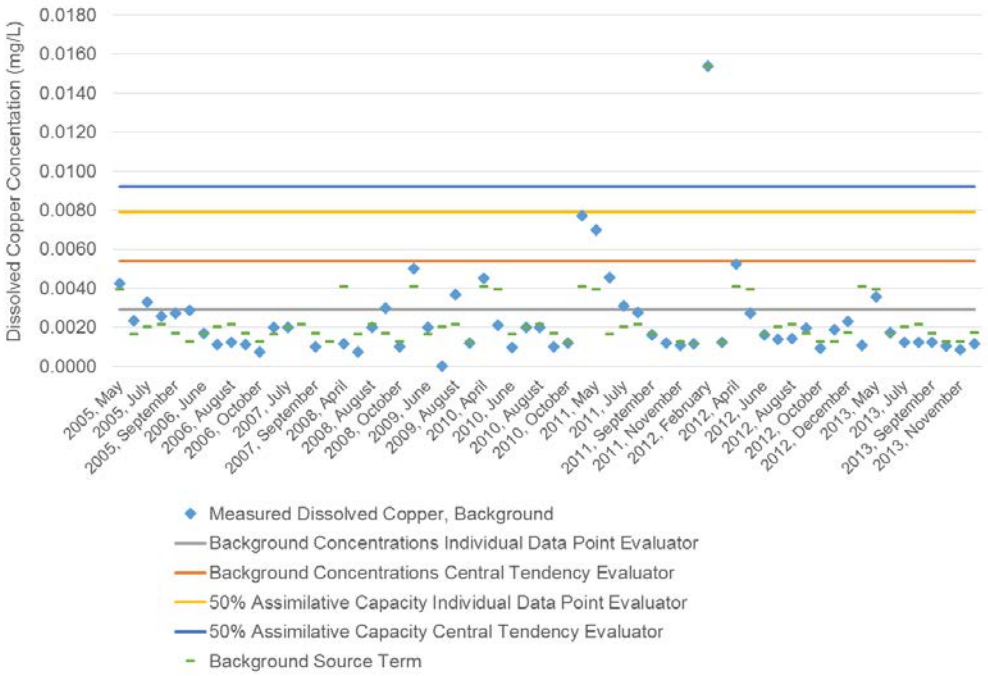


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**Figure 3-2 Measured Background Water Quality and WQOs for Dissolved Copper**

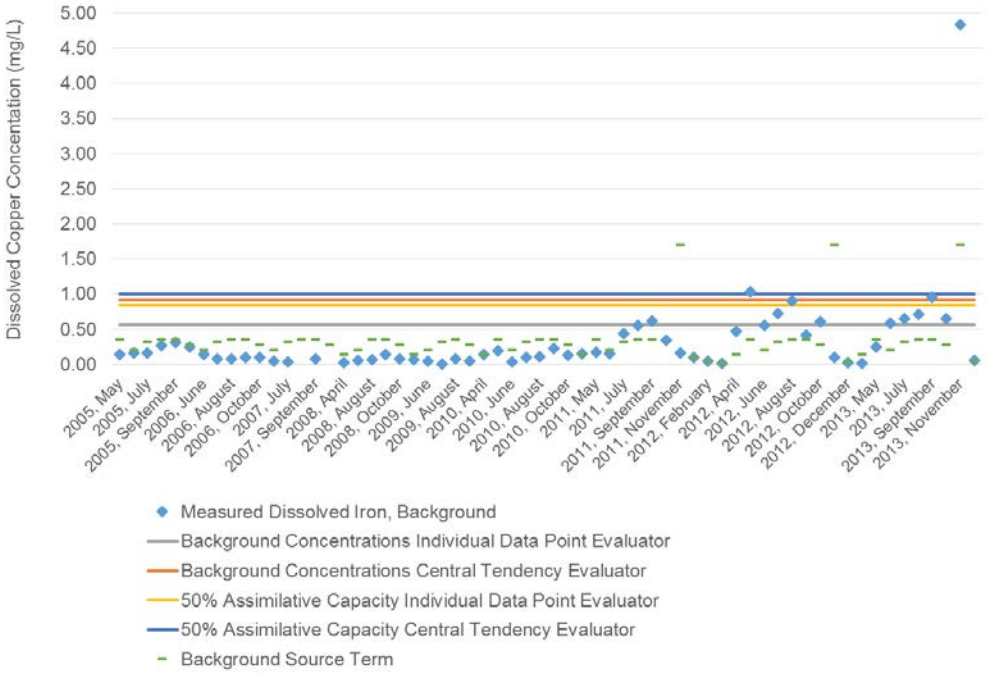


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**Figure 3-3 Measured Background Water Quality and WQOs for Dissolved Iron**

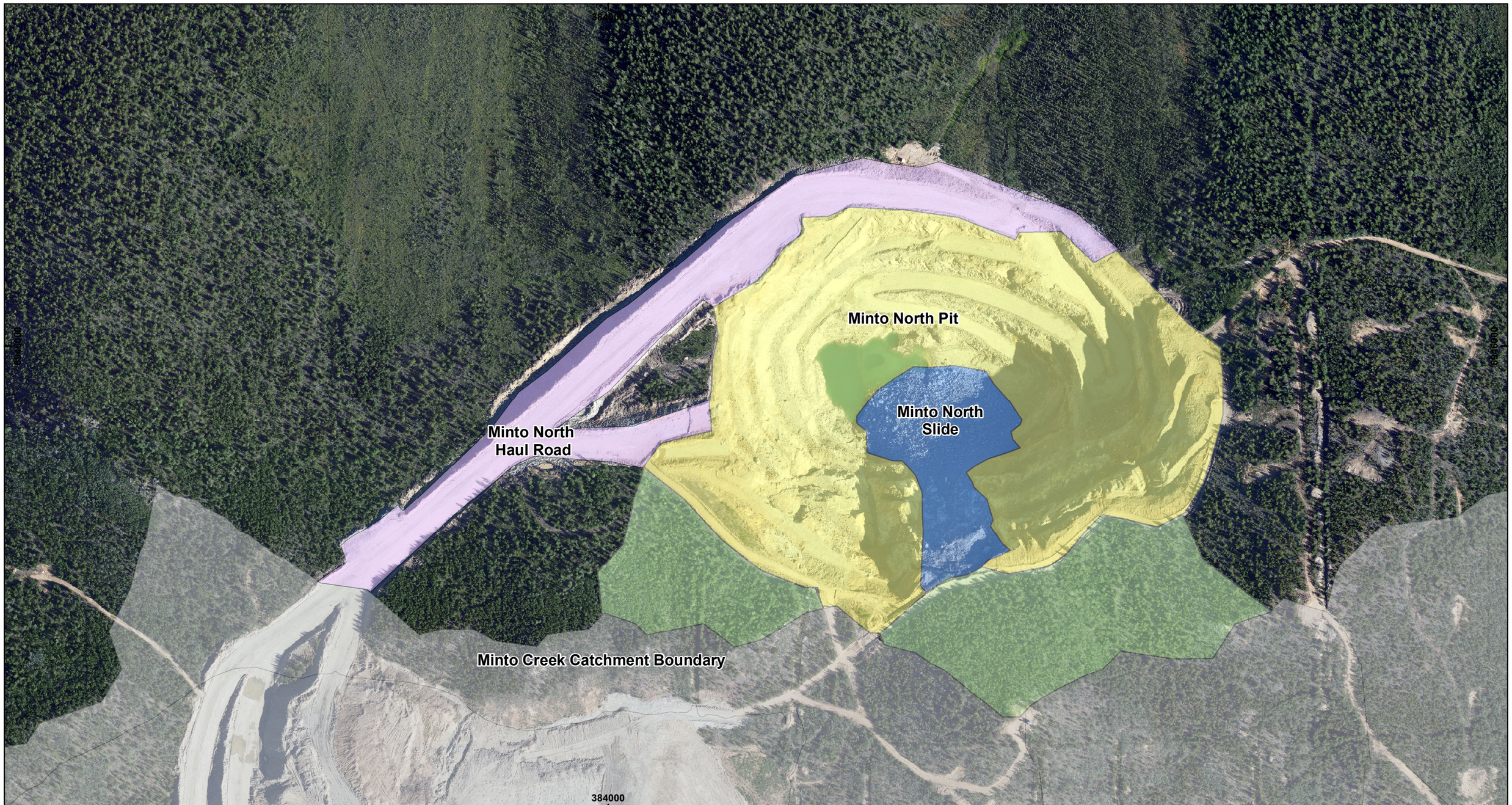
## 3.2 McGinty Creek

Background water quality data for McGinty Creek is available for the months of April to November. The McGinty background water quality used in the model for all undisturbed sub-catchments was the average of the water quality data at the monitoring station located in McGinty Creek upstream of the confluence with the Yukon River (Station MN-4.5).

The source terms for the Minto North Pit walls were determined based on humidity cell test results (SRK 2013). The source terms for the access road and pit wall failure were assigned the waste rock source term which were determined based on measured water quality at W15.

Figure 3-4 shows the allocation of source terms for the Minto North Pit area. In the water and load balance model, the Minto North Haul Road material was routed towards the upper-eastern catchments of McGinty Creek and from there to lower McGinty Creek. Loadings from the pit walls and slide material was assumed to report to the bottom of the open pit. The rate of seepage of mine water from the open pit to the surrounding groundwater aquifer is difficult to estimate. Therefore, a very conservative approach was adopted to estimate of the theoretical effect of groundwater seepage on water quality in McGinty Creek. It was assumed that all loadings associated with the open pit mine water would report to McGinty Creek after following a lag time of 15 years. This approach is expected to overestimate the transfer of loadings from Minto North Pit to McGinty Creek by at least one order of magnitude.

In addition, the load balance model for Minto North incorporated worst case conditions in terms of source loadings. The entire Minto North Pit wall and waste rock slide material was assumed to remain exposed in the post-closure phase (i.e. maximum exposed area acting as a loading source). The combination of maximum loading rates and maximum pit area exposed is considered to be a very conservative estimate of future loading rates. Partial flooding of the Minto North Pit or application of steady state loading rates, as observed in the humidity cell tests, would result in lower loading rates. Source terms derived for the Minto North Pit are listed in Appendix B.




N

0 20 40 80 120 Meters

**Legend**

- Minto Creek Catchment

**Source Term**

- Background McGinty Creek
- Pit Wall Loadings
- Waste Rock Concentrations
- Waste Rock Loadings

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Water and Load Balance Report
Report 2018

Source Term Allocation
Minto North Pit

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# 4 Model Implementation

## 4.1 Model Version

The water and load balance model for Minto was developed using the GoldSim software package (version 11.1). The model scenarios described here were implemented in model Version #68.

## 4.2 General Modelling Approach

### 4.2.1 Stochastic Water Balance Model

Water balance results for the 2018 water balance model were generated by running the model as a Monte Carlo simulation. Monte Carlo simulations are well suited for situations where the value of a key input cannot be predicted but where the distribution of the input is known or can be adequately estimated. Total annual precipitation for the Minto site is an example of such a variable. Although it is not possible to predict the rate of annual precipitation in any given year, it is possible to develop a probability distribution (see Section 2.2.1).

In the water balance Monte Carlo run, the model randomly selected a value for total annual precipitation from the probability distribution developed for the site (see the Pearson III distribution shown in Table 2-5, Section 2.2.1). Annual runoff volumes were then calculated by multiplying total annual precipitation by a runoff coefficient and catchment area (see Sections 2.2.3 and 2.2.4). The calculated runoff would then be distributed over all months of the year according to the typical hydrograph used in the model (described in Section 2.2.5). The model was run in this manner from year 2015 through 2050, each year with a randomly selected precipitation value, and all results were recorded and stored by the model. A total of 1,000 model runs were completed in this way.

At the end of 1,000 model runs, all results were compiled and probability distributions of the results were generated. Figure 4-1 shows an example of model results for a single year from the Monte Carlo simulation. For illustration purposes, a year well into the post-closure two period is shown to avoid having the example be affected by active water management at site or by transient conditions that correspond to filling of pits in the closure periods. The results show the possible range of flow rates from Upper Minto Creek to W3 as represented by the model. The most likely flow distribution is the mean flow (black line).

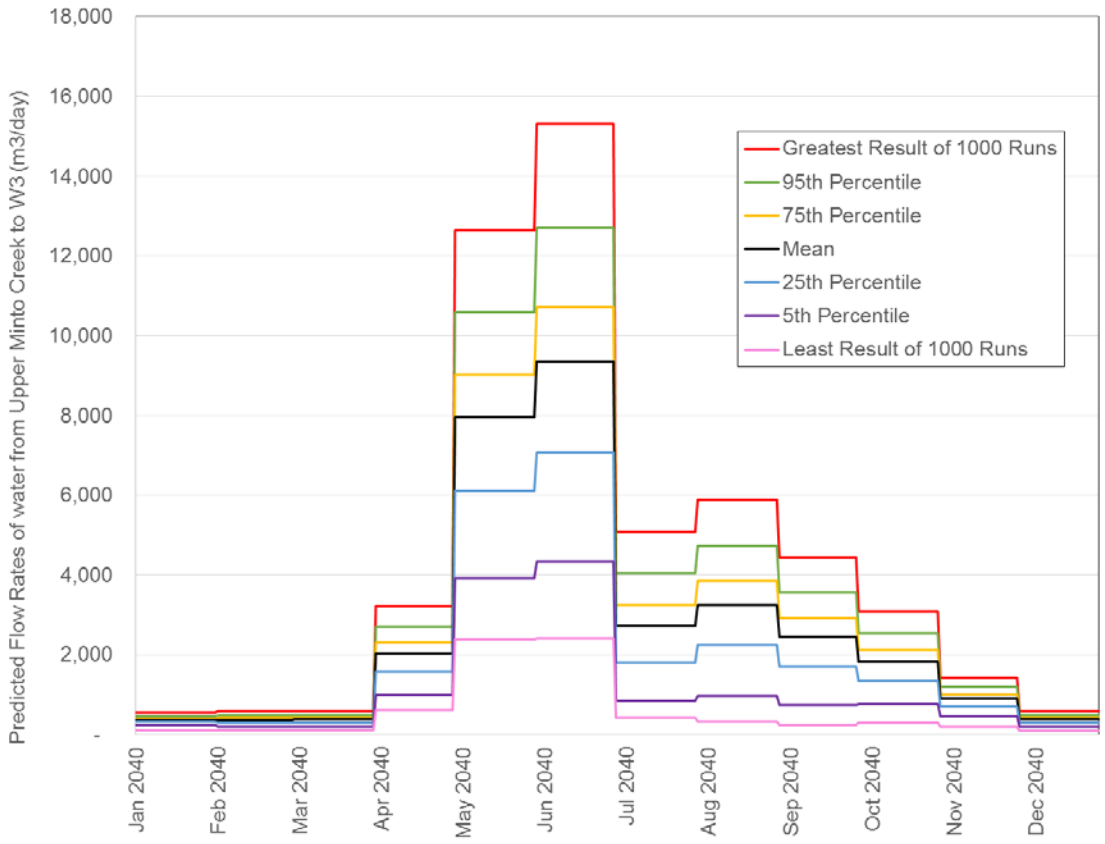


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**Figure 4-1 Example of Result Generated by the Monte Carlo Simulation – Predicted Range of Average Flow from Upper Minto Creek to W3 in 2040**

Routing of runoff in the model followed the plan detailed in the water management plan and closure plan as described in Section 4.3. The modelling period began on January 1, 2015 and ended on January 1, 2050. The operations period was modelled as ending at the end of April 2022, followed by the closure periods. The water and load balance model assumed that all closure activities were implemented instantaneously at the end of operations.

### 4.2.2 Loading Balance Model

Loadings were incorporated in the model by associating loadings source terms with the corresponding water flows or mine components as follows:

- Concentration based source terms were applied as constant values to monthly runoff volumes from corresponding sub-catchments as described in Section 3.
- Loading based source terms were incorporated into the model as a “dry” load either to runoff or to water reservoirs. For example, loadings from tailings solids were applied to the water in the reservoir where tailings were deposited.

The development of loadings source terms is discussed in Section 3. The source terms have been updated periodically as new data becomes available. The most recent source term update is described in Appendix B.

## 4.3 Water Management

The focus of the water management strategy during the operations phase is to maintain a minimal but adequate inventory of mine water on site. The water inventory will, to the extent possible, be managed by diverting clean (i.e. discharge compliant) surface runoff away from developed mine areas and towards the WSP to potentially be released to Minto Creek. The modelling representation of water conveyance and water diversion options are described in the following section.

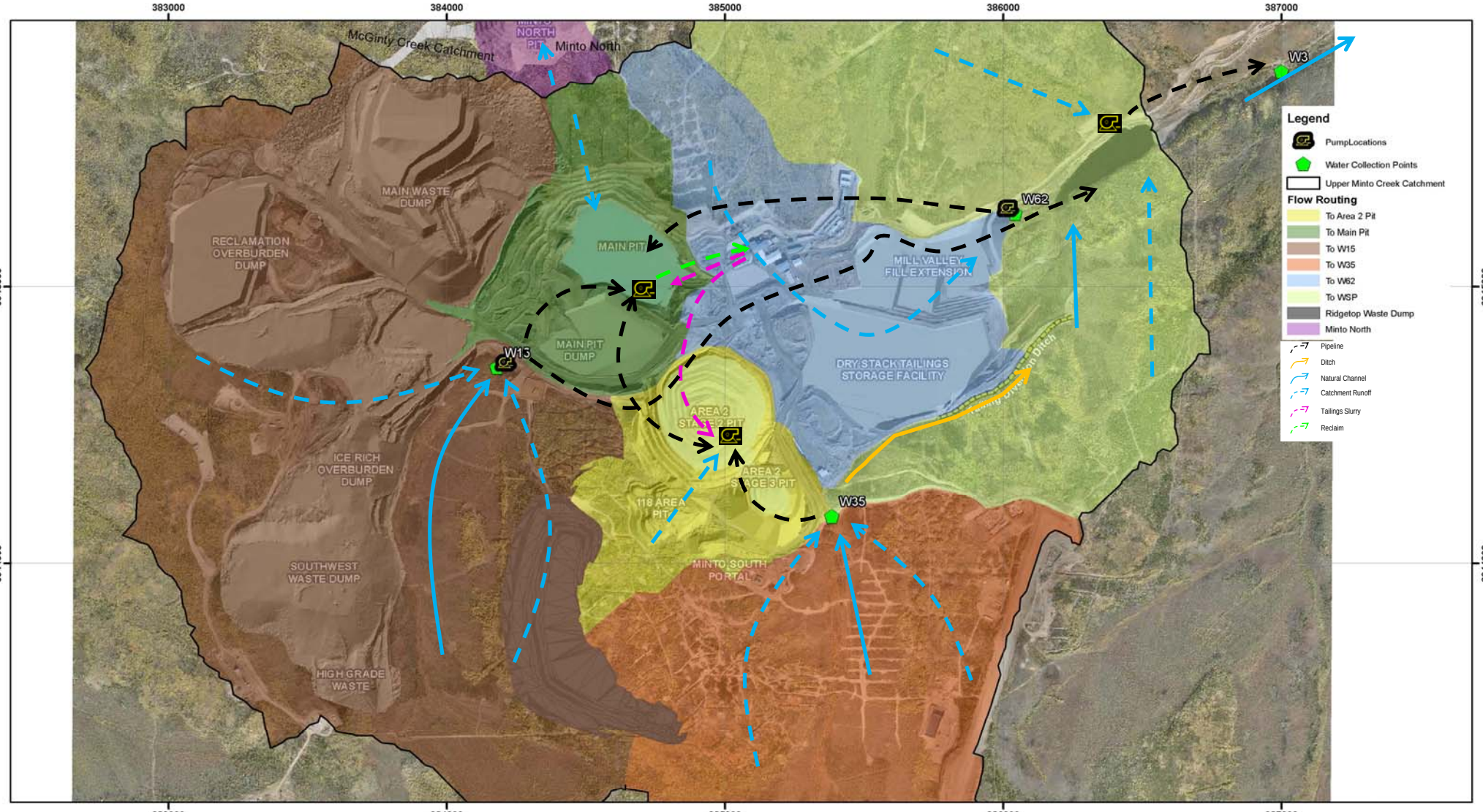
Figure 4-2 and Figure 4-3 show schematics of how water was routed in the water balance model during operations and in the post-closure phases.

During the operations period water collected at W15 is directed to the Main Pit or to the WSP through the piping network on site. Runoff collected by the W35 channel is directed to the Main Pit or to the WSP via a pipeline. Mine water collected at W62 is pumped to the Main Pit. Slurry tailings were deposited in the Main Pit until April 2015 and in the Stage 2 area of the Area 2 Pit thereafter. Tailings are planned to be deposited in the Area 2 Pit Stage 2 and Stage 3 until development of the Ridgetop North Pit is complete. At that time tailings will be deposited in the Ridgetop North Pit until it is full at which point tailings will be deposited in the Area 2 Pit. All mill reclaim water is sourced from the Main Pit throughout the operations period.

The model assumes that the mine enters the post-closure phases immediately following the end of mine life in April 2022. During post-closure (Figure 4-3), water conveyance structures were assumed to be constructed to direct runoff as follows:

- Water collected at W15 reports to the Main Pit along with runoff from upstream catchment areas.
- The Main Pit outflow reports to the Area 2 Pit, until the pit has filled with water and a post-closure pit lake has formed (not shown on Figure 4-3).
- When the Area 2 Pit Lake has formed, the outflow from the Main Pit area reports to the former mill site area, through a channel along the mine access road to the WSP Wetland.
- Catchments upstream of the Area 2 Pit reported directly to the Area 2 pit lake.
- Water in the Area 2 Pit flows via a spill-way through the former mill site and through a channel along the mine access road to the WSP Wetland.
- Runoff from the former mill area and from slopes along the Mill Valley reported directly to the WSP Wetland.
- Water treated by the WSP Wetland report directly to Minto Creek.

Table 4-1 provides further details concerning the implementation of water routing in the water balance model.




Notes: catchment delineation by Access Consulting Group (2013)

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Filename: Minto_Water_Flow_V_VI_20180130_SRJ

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Water and Load Balance Report 2018

Modelled Routing of Water: Operations

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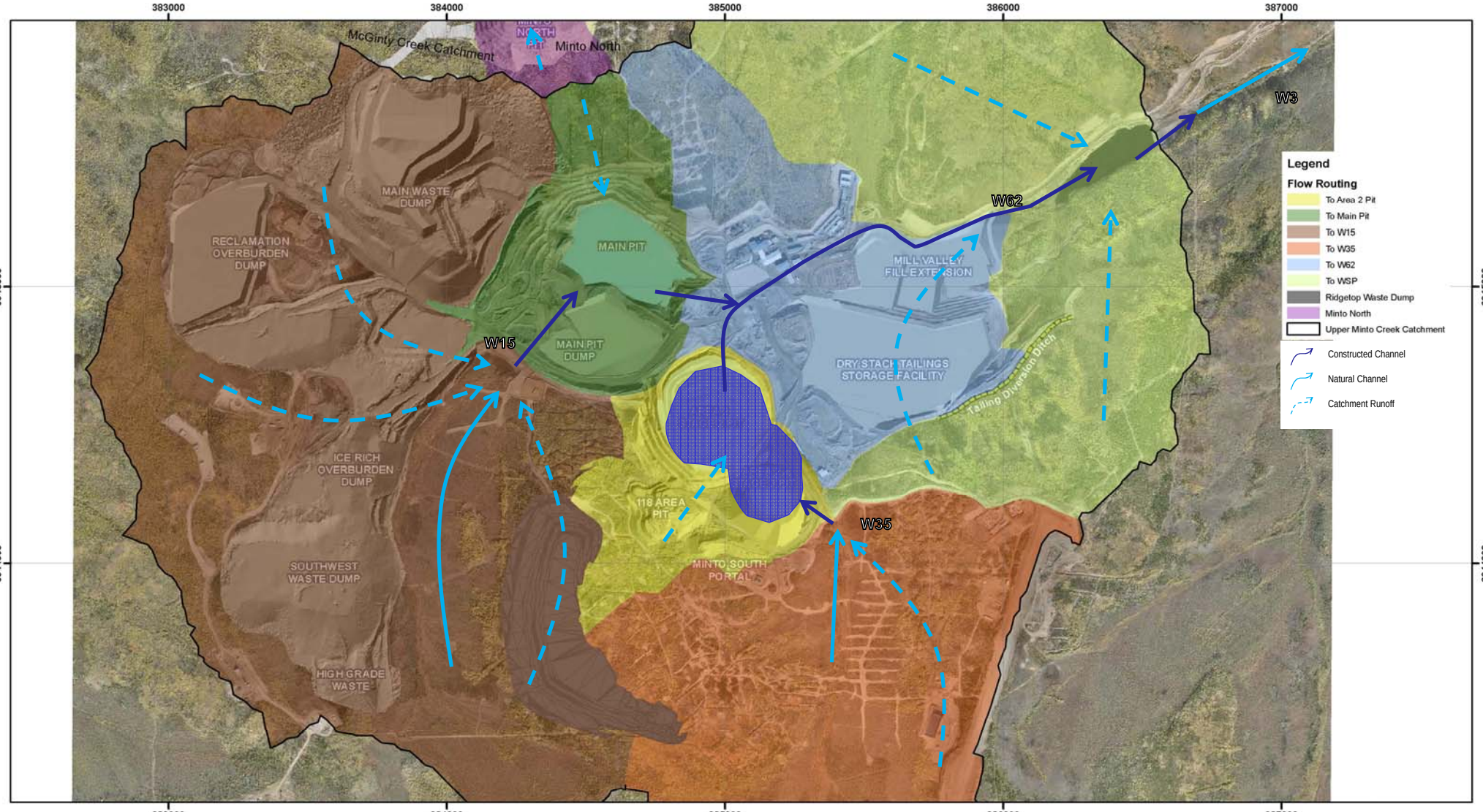


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0 100 200 400 600 800 Meters

Notes: catchment delineation by Access Consulting Group (2013)

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Water and Load Balance Report 2018

Modelled Routing of Water: Post Closure

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**Table 4-1 Modelled Routing of Runoff and Mine Water Conveyance**

| Input | Period | Reservoir | Output | Period |
|---|---|---|---|---|
| Catchment Yield | Always | **WSP (WSP Wetland as of 2023)** | Minto Creek | Always |
| W15 | Until 2022 | | | |
| W35 | Until 2022 | | | |
| Area 2 Pit | 2025 onwards | | | |
| W62 | Until 2026 | **Main Pit** | to Area 2 | 2018 to 2024 |
| Catchment Yield | Always | | | |
| Minto North Pit | 2015 to 2016 | | Evaporation | Open water seasons |
| W15 | Always | | | |
| | | | WSP Wetland | 2026 onwards |
| Tailings Slurry Water | Intermittently 2015 to 2016 & in 2018 | | Reclaim Water | 2015 to 2022 |
| Catchment Yield | Always | **Area 2 Pit** | Main Pit | Intermittently 2015-2022 |
| W35 | 2022 onwards | | Evaporation | Open water seasons |
| Main Pit | 2018 onwards | | | |
| Tailings Slurry Water | Intermittently 2015 to 2022 | | WSP Wetland | 2025 onwards |
| | | | Reclaim Water | Intermittently 2020-2022 |
| Catchment Yield | Until 2022 | **Ridgetop North Pit** | Area 2 Pit | 2018 to 2022 |
| Tailings Slurry Water | 2019 to 2022 | | W35 | 2022 onwards |
| Catchment Yield | Always | **Minto North Pit** | to Main Pit | 2015 to 2016 |
| | | | to McGinty Creek | 2017 onwards |

## 4.4 Tailings Slurry Deposition

Tailings slurry deposition was implemented in the water balance as follows:

- Q1 2015 to Main Pit TMF
- Q2 2015 to Main Pit TMF and Area 2 Pit TMF
- Q3 2015 to Q2 2019 to Area 2 Pit TMF
- Q2 2019 to Q1 2021 to Ridgetop North Pit TMF
- Q1 2021 to Q1 2022 to Area 2 Pit TMF

The dry bulk tailings density was assumed to be 1.35 tonnes/$m^3$. Details concerning tailings slurry deposition for the operations period were provided by Minto.

## 4.5 Model Calibration

### 4.5.1 Water Balance Model Calibration

The approach used to calibrate the water model was a site wide yield coefficient that correlated the total annual precipitation to the total annual yield. This approach avoids the uncertainties inherent in quantifying appropriate input values for individual parameters (evaporation, evapotranspiration, sublimation, etc.) by determining a single site wide yield coefficient based on measured values of both precipitation and catchment yield (stream flows) from historical records. The yield coefficient approach integrates all catchment processes into a single empirical factor that describes the relationship between precipitation and catchment yield.

In years for which the total annual precipitation was known, the actual (measured) total annual yield was compared to the modelled total annual yield. The modelled data was calibrated to the measured data by adjusting the yield coefficient to achieve a best fit. After a suitable yield coefficient was identified, it was used to model future site yield estimates.

### 4.5.2 Loading Balance Model Calibration

The load balance was calibrated by comparing constituent concentrations in the Main Pit and Area 2 Pit water to model predictions and then adjusting source terms accordingly to improve the fit between measured and modelled concentrations. The main sources of loadings to pit water is waste rock seepage and tailings slurry. Source terms for waste rock seepage are based on measured seepage water quality and are therefore, in a sense, already calibrated. Also, waste rock seepage water quality is not expected to change abruptly because of the size of the waste rock areas. Loadings from tailings slurry, on the other hand, are directly related to the characteristics of the ore processed, which can change in short order as the ore type changes. Therefore, the load balance calibration was focused on the ore source term.

The tailings slurry source term update sought to address some of the variability inherent with tailings slurry water quality by generating multiple source terms that characterize sulphide ore tailings slurry and POX ore tailings slurry. These source terms were generated using water quality data from the tailings thickener from 2015 to 2017 as well as the sulphide ore and POX ore milling schedules. Details regarding the updated tailings slurry source terms can be found in Appendix D. In general, the model predictions matched the measured concentrations in the Main Pit and Area 2 Pit reasonably well so calibrations were not needed.

## 4.6 Water Treatment

### 4.6.1 Active Treatment

The water treatment plant at Minto can be operated in different configurations depending on the quality of feed water to be treated. Treatment options range from simple TSS removal to sulphide precipitation to reverse osmosis (RO) treatment, which removes 95% to 99.5% of all constituents in the mine water.

In the load balance model scenarios, it was assumed that the water treatment plant would not be operated. This assumption is conservative and allows the effectiveness of the passive water treatment options to be assessed independently.

### 4.6.2 Passive Treatment

The Minto Mine plans to construct a wetland where the WSP is currently located for long-term passive treatment of water flowing from the mine site during the post-closure phases. The WSP wetland is expected to remove a variety of water quality constituents as described in (Contango 2017). In the load balance model, it was assumed that the wetland will be operational at the start of 2027, approximately 5 years from the end of mine life. The actual commissioning date of the WSP wetland will be contingent on the wetland testing phase that will begin once the wetland has been constructed after the end of mine life. Once the wetland is operational and treats water to an acceptable standard all active water treatment facilities will be decommissioned.

Implementation of the wetland in the water and load balance model was based on the preliminary design basis and operational philosophy. Accordingly, the model assumes that the WSP Wetland will have a total active volume of approximately 2,000 $m^3$ and a maximum inflow of 3,000 $m^3$/day. This results in a minimum Hydraulic Retention Time (HRT) of about 16 hours. Should the flow rate into the WSP Wetland exceed 3,000 $m^3$/day, excess water will be diverted around the wetland untreated. Estimates of removal rates for dissolved cadmium, copper and selenium were incorporated in the model. The estimates rates were based on results of the wetland testing program carried out by Minto (Contango 2016). The estimated removal rate equations are shown in Table 4-2.

**Table 4-2 WSP Wetland Load Balance Dissolved Metal Removal**

| WQ Constituent | Rate Equation | Order | Removal Limit |
|---|---|---|---|
| Ammonia-N | $[NH_3]e^{-0.143/day*HRT}$ | First | MDL |
| Cadmium – Cd | $[Cd]e^{-1.14/day*HRT}$ | First | 0.000009 mg/L |
| Copper – Cu | $[Cu]e^{-1.17/day*HRT}$ | First | 0.015 mg/L |
| Molybdenum - Mo | $[Mo] - \frac{0.0006\frac{mg}{L}}{hr} * HRT$ | Zero | 0.005 mg/L |
| Nitrate-N | $[NO_3]e^{-0.591/day*HRT}$ | First | MDL |
| Selenium - Se | $[Se]e^{-0.319/day*HRT}$ | First | 0.001 mg/L |
| Zinc - Zn | $[Zn]e^{-1.14/day*HRT}$ | First | 0.030 mg/L |

**Notes:**

(1) HRT = Hydraulic Retention Time in hours

(2) MDL = Method Detection Limit

(3) [Cd] = Concentration of dissolved cadmium in WSP Wetland Influent in mg/L

(4) [Cu] = Concentration of dissolved copper in WSP Wetland Influent in mg/L

(5) [Se] = Concentration of dissolved selenium in WSP Wetland Influent in mg/L

The modelled performance of the WSP Wetland was not explicitly adjusted for hydraulic efficiency. Rather, hydraulic efficiencies were assumed to be on the same order of magnitude (or higher) than

hydraulic efficiencies associated with the pilot-scale or field scale wetlands that were used as a basis for estimating removal rates.

# 5 Model Results

## 5.1 Water Balance Results

### 5.1.1 Minto Creek Water Balance Results

The primary water management challenge for the Minto Mine is to maintain sufficient storage capacity to meet the anticipated life-of-mine storage requirements and that sufficient stored water is available to meet the needs of the milling operation.

The volume of water that must be released from site each year to maintain an appropriate water inventory is an important factor for managing water on site. By quantifying the volume of water that can be added to the inventory in each year, and consequently the volume of water that should be released, water management staff can implement diversions or plan water treatment campaigns, if required.

Figure 5-1 shows projected volumes of tailings and free mine water in the Area 2 Pit through the operations and post-closure periods for the modelled scenarios. Note that, in the modelled scenarios, filling of Area 2 Stage 2 Pit reaches the saddle elevation prior to the completion of mining in Area 2 Stage 3-4. At that time tailings deposition will be redirected to the Main Pit TMF until Area 2 Stage 3-4 is complete and available for tailings storage. The results indicate that, under the mean runoff model scenario, the Area 2 Pit will be full of water by mid-2024.

### 5.1.2 McGinty Creek Water Balance Results

The water balance for the Minto North Pit consists of inflows from a small upgradient catchment and from direct precipitation on the open pit. During development and mining of the pit the mine water is being transferred to the Main Pit in the Upper Minto Creek catchment. After mining is complete, the open pit will be allowed to fill. Although it appears that there is a slight net positive water balance for the pit (including the contributions from the upgradient catchment), it is expected that it will take years for the pit to fill and discharge as surface flow to lower McGinty Creek, if it fills at all. Depending on the rate of groundwater flow into and out of the pit area, it is possible that the pit may never discharge via surface overflow (as noted in Section 2.2.7). At this stage of the project, it is not possible to definitively predict whether a lake will form, and what steady state water surface elevation will be established if a lake does form.

The catchment area influenced by the pit is a small component of the overall McGinty Creek catchment (roughly 15 ha vs. 3,400 ha) and therefore the Minto North development is expected to have minimal (i.e. likely not measurable) effect on flow volumes in McGinty Creek.

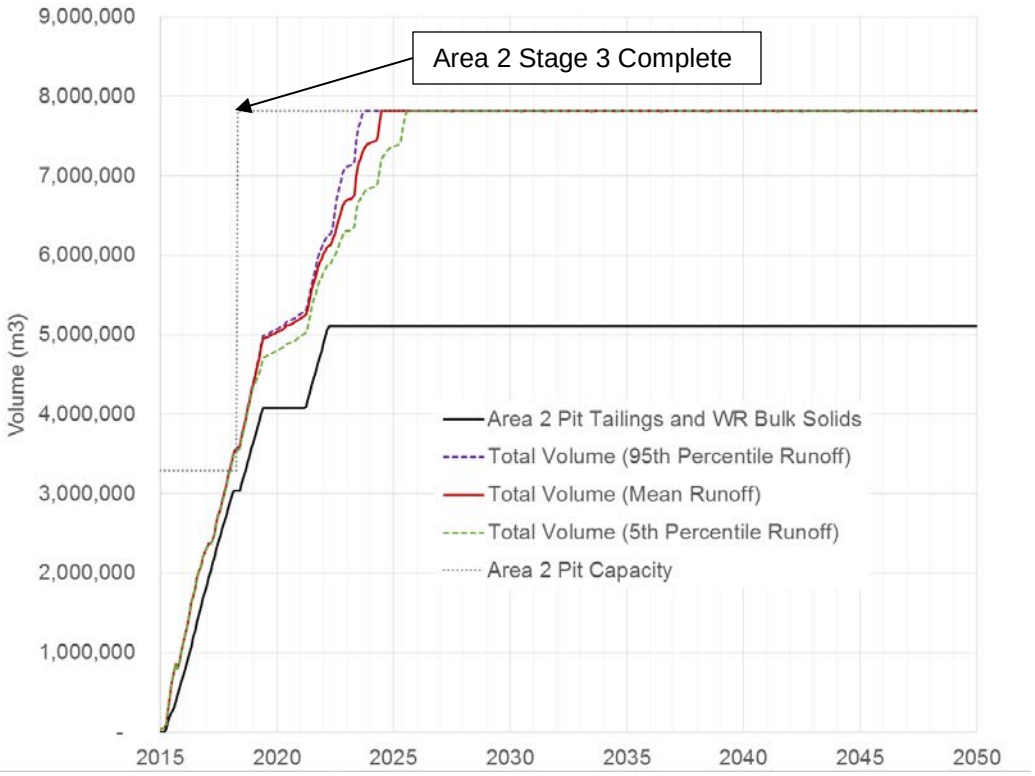


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**Figure 5-1 Modelled Area 2 Pit Water and Tailings Volumes**

### 5.1.3 Constructed Wetland Water Balance Results

The design treatment capacity of the wetland is 3,000 $m^3$/day. The flow rate through the proposed wetland system and high-flow bypass structure during a typical year are shown in Figure 5-2.

As discussed in Section 4.2.1, the stochastic water balance model results produced by the Monte Carlo simulation are probability distributions of water balance outcomes. The average values presented Figure 5-1 are the most likely outcomes, but a range of outcomes are possible. In the results for the post-closure periods when the Area 2 Pit is full, the modelled discharge volumes change with annual rates of precipitation but there is no longer any net change in water storage on site.

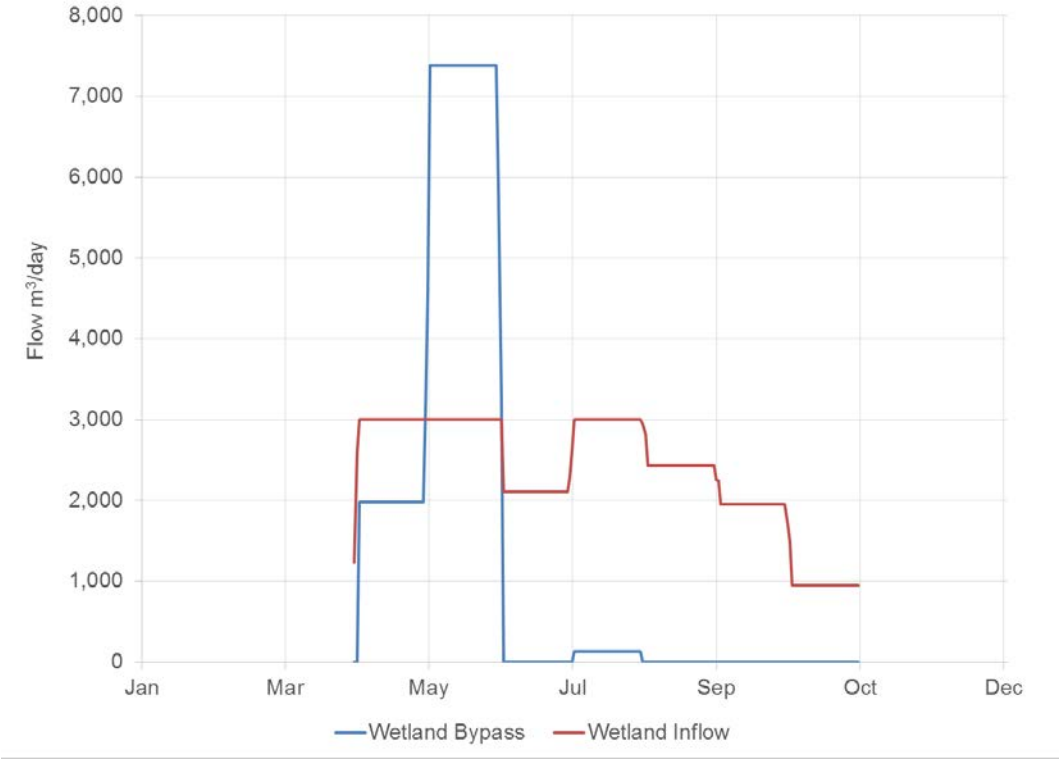


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**Figure 5-2 CWTS and High-Flow Bypass Typical Monthly Flow Rates**

## 5.2 Water Quality and Parameter Loadings Results

### 5.2.1 Post-Closure Water Quality Objectives

Water Quality Objectives (WQOs) have been developed by Minnow Environmental and agreed upon by Minto Explorations and the Selkirk First Nations. Details of the development and application of the WQOs is outlined in the RCP (Minto 2018). In general, the WQOs are summarized as follows:

1. *Closure WQOs that meet the criteria for non-degradation of background concentrations in Minto and McGinty creeks.*

2. *If non-degradation of water quality is not achievable, the closure WQOs shall be set at no more than 50% of the assimilative capacity of Minto Creek using the following formula:*

*Closure WQO = BKGD + (0.5*[WQO Operations – BKGD])*

*where: BKGD = background concentration*

The post-closure 50% assimilative capacity WQOs, as calculated using the above equation utilizing the background water quality summary statistics provided by Minnow (2016), are included in the water quality results for station W1 for comparison purposes. A complete list of the Post-closure WQOs is provided in Minto (2018).

### 5.2.2 Minto Creek Water Quality Results

Water quality predictions for RCP 2018-01 were produced for the five scenarios listed in Table 5-1.

**Table 5-1 Model Scenarios**

| Scenario | Source Term | Phase VII Developments | Passive Treatment |
|---|---|---|---|
| 1 | Expected Case | Included | None |
| 2 | *Reasonable Worst Case* | Included | None |
| 3 | *Reasonable Worst Case* | Not Included | None |
| 4 | Expected Case | Included | Included |
| 5 | *Reasonable Worst Case* | Included | Included |

All scenarios include the effect of soil covers as described in Section 2.2.10.

The *Reasonable Worst Case* is a conservative case while the *Expected Case* can be considered to be the most likely outcome, based on the available information. The water quality results shown below include concentrations of copper, selenium, cadmium, and sulphate which currently are parameters of potential concern and are demonstrative of the effectiveness of passive treatment with the exception of sulphate. Copper and selenium are generally indicative of the behaviour of other parameters.

The five scenarios were selected to show the potential effects of source terms, the WSP wetland and the addition of the Phase VII mine developments on the quality of water immediately downstream of site (reported as concentrations at W3) as well as concentrations at W1 in Lower Minto Creek as follows:

- Scenarios 1 and 2 allow for a comparison between effects of *Expected Case* and *Reasonable Worst Case* source terms.
- Scenarios 2 and 3 compare effects on water quality with and without Phase VII mine development.
- Scenario 4 and 5 allow for comparison of wetland performance in cases where the inflow water quality has been influenced by the *Reasonable Worst Case* source terms and by *Expected Case* source terms using the load removal rate equations shown in Table 4-2.

The two model scenarios that do not incorporate passive treatment give a sense of the range of concentrations that may occur based solely on variation in geochemical loading rates from mine-related and background sources and on runoff volumes that vary seasonally with precipitation and melt. The two model scenarios that incorporate passive treatment illustrate the potential improvement in water quality that could be achieved by a constructed wetland treatment system.

Model results for water quality in pits, water released to station W3 in upper Minto Creek and at station W1 in Lower Minto Creek for the entire modelled period (2015 to 2050) are included in Appendix A1. Tabular monthly results are provided for a single year well into post-closure (2045) in Appendix A2 to illustrate typical modelled seasonal variability during the post-closure period. Results are included for open water season only (April to October) as the background water quality source terms for the winter months are highly variable and poorly characterized, and therefore produced misleading results when used as inputs for modelling.

The following acronyms are used in the legends for the figures below:

- EC: *Expected Case* source terms
- WC: *Reasonable Worst Case* source terms
- PhVII UG: Includes Phase VII underground developments
- no PhVII UG: does NOT Includes Phase VII underground developments
- WT: includes wetland treatment
- no WT: does not include wetland treatment

Figure 5-3 to Figure 5-6 show predicted dissolved copper, selenium, cadmium, and sulphate concentrations for mine water in the Main Pit and Area 2 Pit. Concentrations in the pits are expected to increase during the operational stage when waste rock and tailings are deposited. Selenium concentrations increase markedly during periods when tailings are deposited to the pit. After closure, copper, selenium, cadmium, and sulphate concentrations are expected to decline to steady-state levels that are representative of long-term post-mining geochemical loading rates. Concentrations in the Main Pit remain relatively constant, again reflecting geochemical loading rates.

Figure 5-7 to Figure 5-10 show model predictions for dissolved copper, selenium, cadmium, and sulphate concentrations for mine water in the WSP as released to station W3 in Minto Creek. Both profiles show relatively low concentrations during the operational period followed by a modest increase in concentrations at closure. This is because residual mine water stored in the Area 2 TMF begins reporting to Minto Creek at that time.

Figure 5-11 to Figure 5-14 shows modelled values total copper, selenium, cadmium, and sulphate concentrations in Lower Minto Creek (the W1 water quality station). Copper and selenium concentrations follow the trends noted for the W3 water quality predictions but the difference between concentrations during the operations stage and post-closure periods is less pronounced because of dilution from the Lower Minto Creek catchment. Concentrations of nitrate, nitrite and ammonia (not shown) are expected to decrease gradually following the end of active mining in 2018. Residual ammonium nitrate/fuel oil (ANFO) explosives in tailings and water rock contribute the vast majority of nitrogen species to the mine water. Once mining is complete and ANFO use ends, there will be no new sources of nitrate and ammonia loadings.

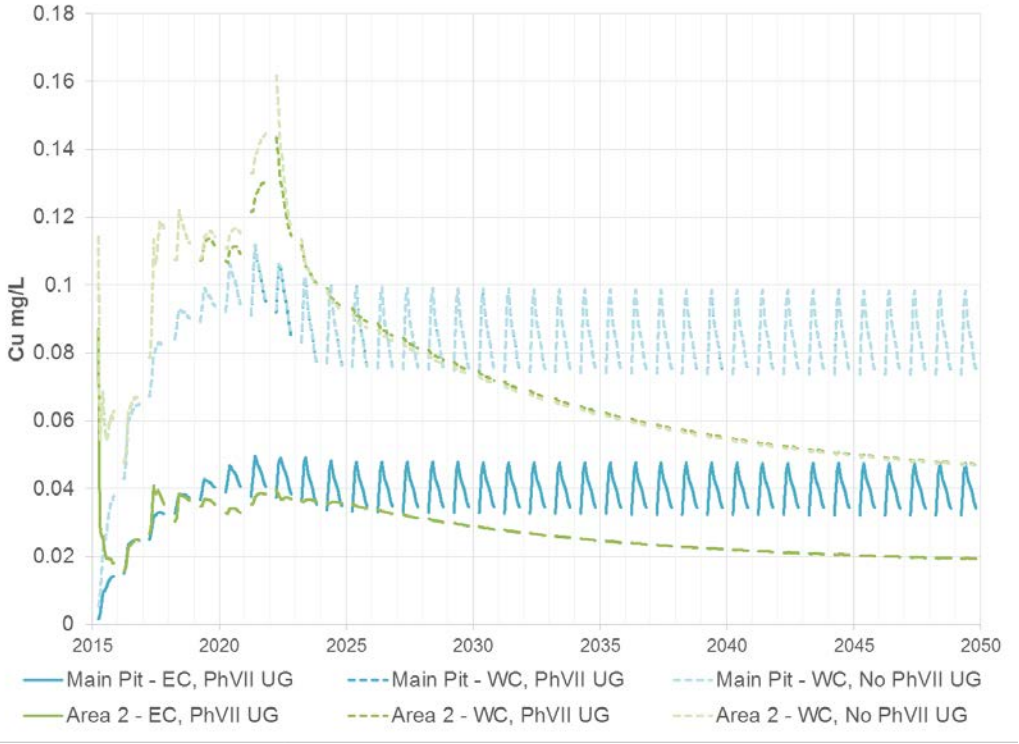


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**Figure 5-3 Model Predictions of Dissolved Copper Concentrations in Pit Lake Water**

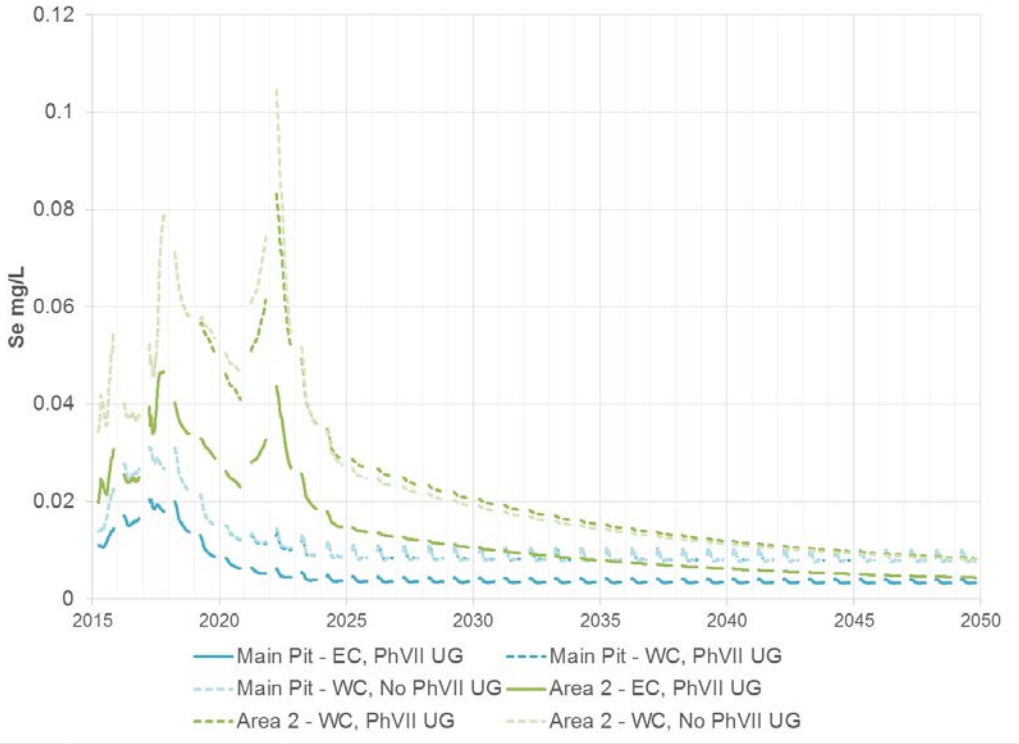


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**Figure 5-4 Model Predictions of Dissolved Selenium Concentrations in Pit Lake Water**

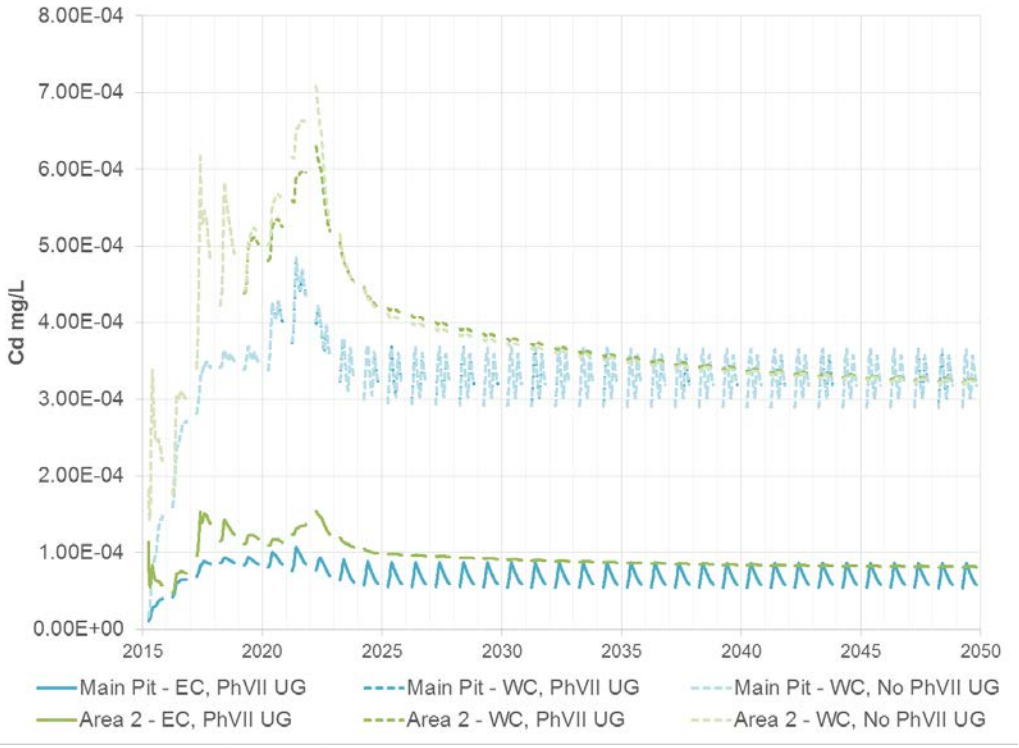


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**Figure 5-5 Model Predictions of Dissolved Cadmium Concentrations in Pit Lake Water**

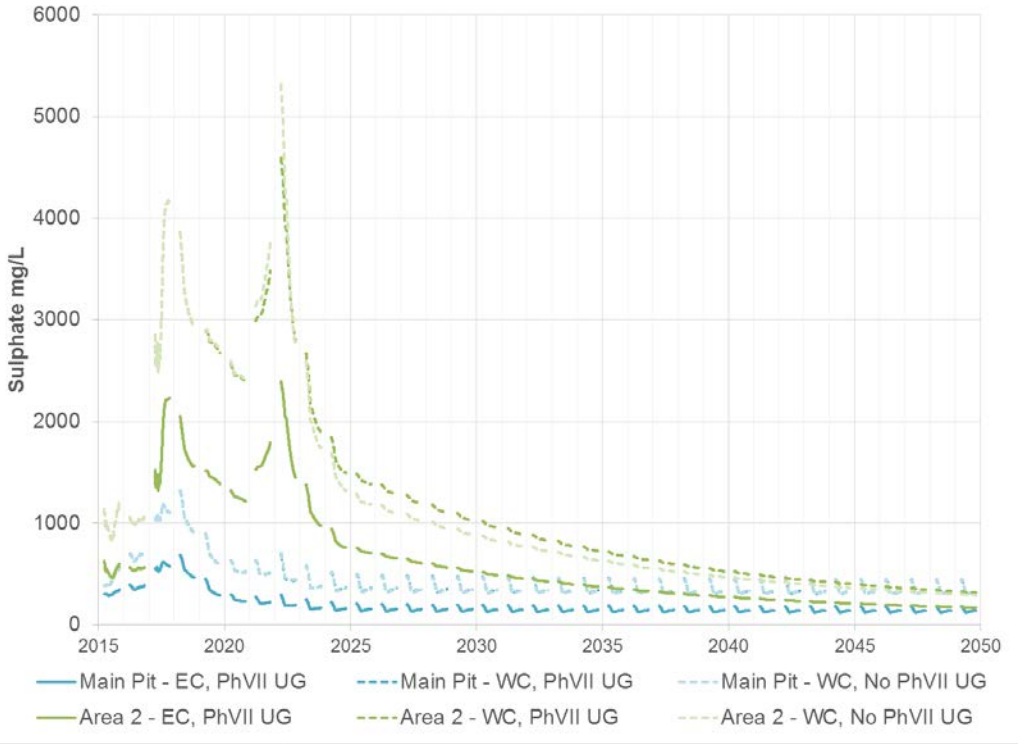


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**Figure 5-6 Model Predictions of Sulphate Concentrations in Pit Lake Water**

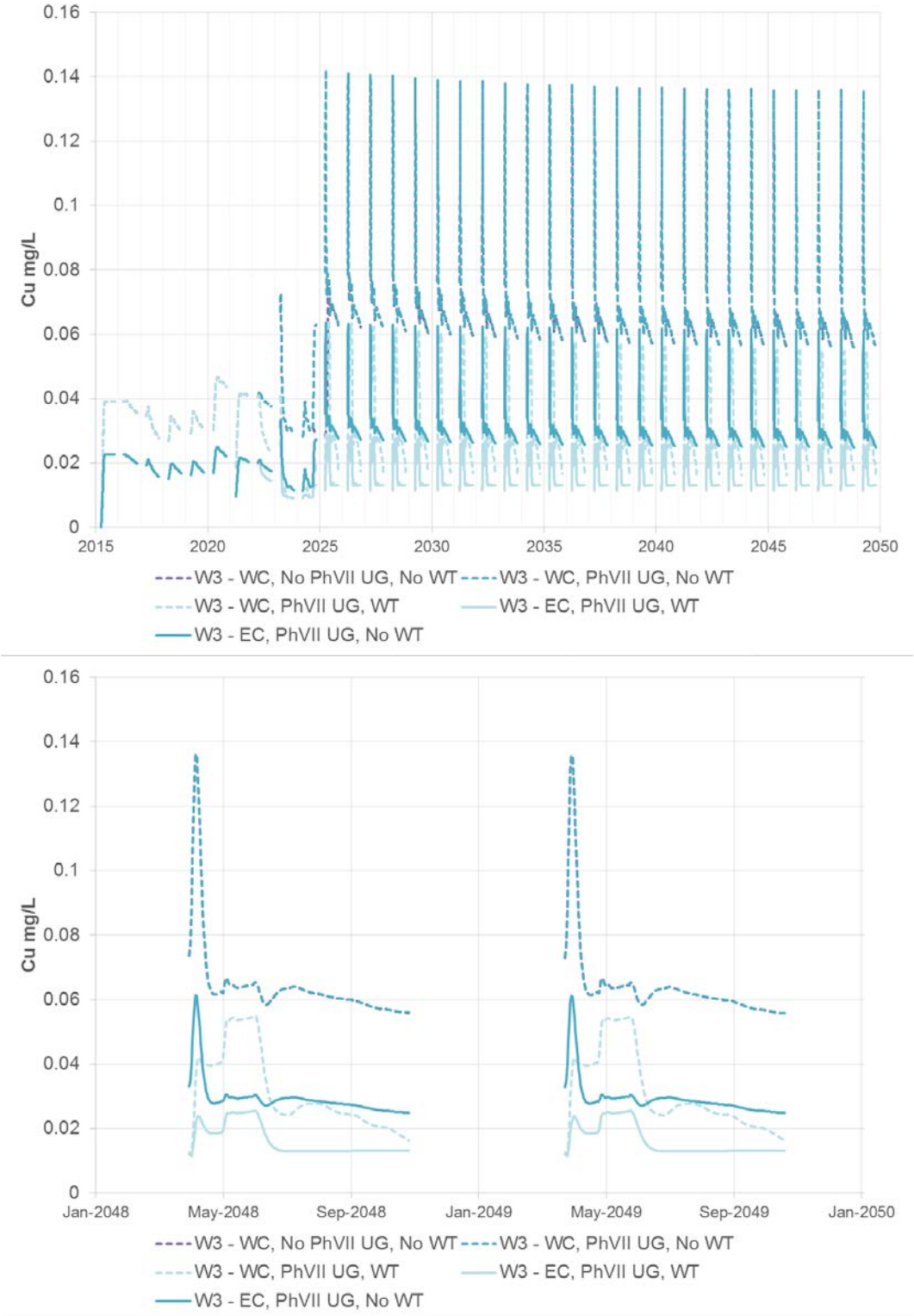


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**Figure 5-7 Model Predictions of Dissolved Copper Concentrations at W3**

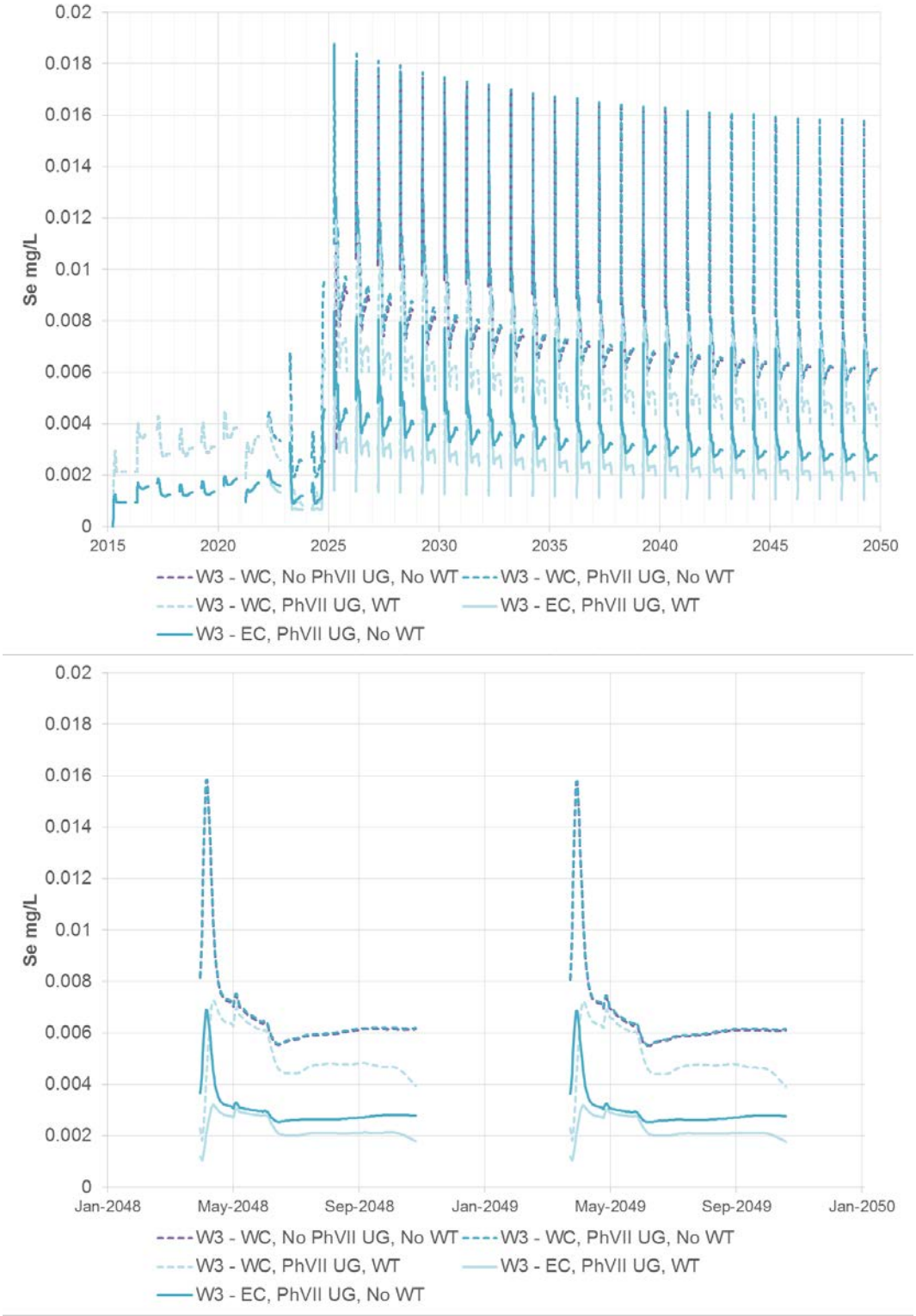


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**Figure 5-8 Model Predictions of Dissolved Selenium Concentrations at W3**

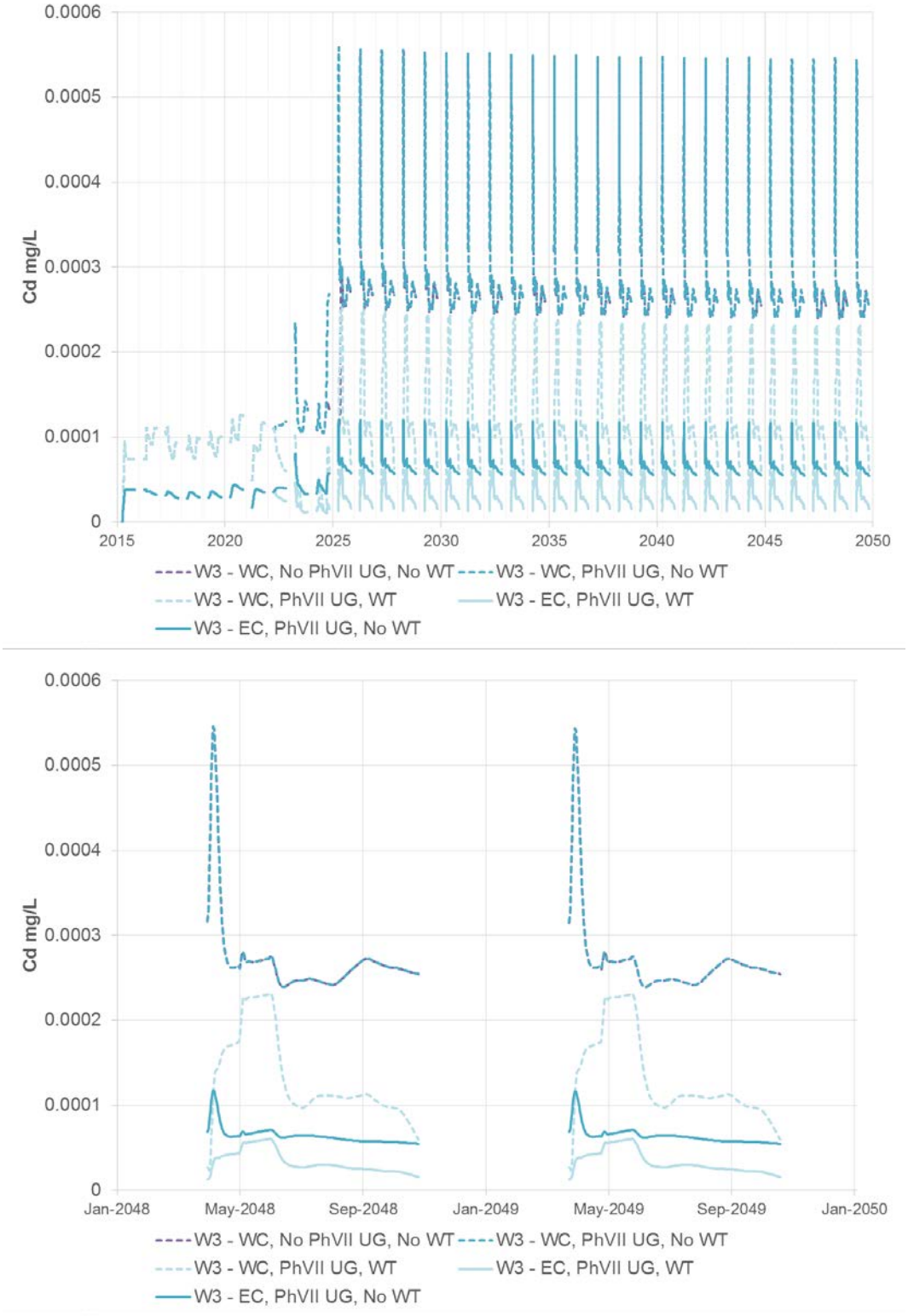


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**Figure 5-9 Model Predictions of Dissolved Cadmium Concentrations at W3**

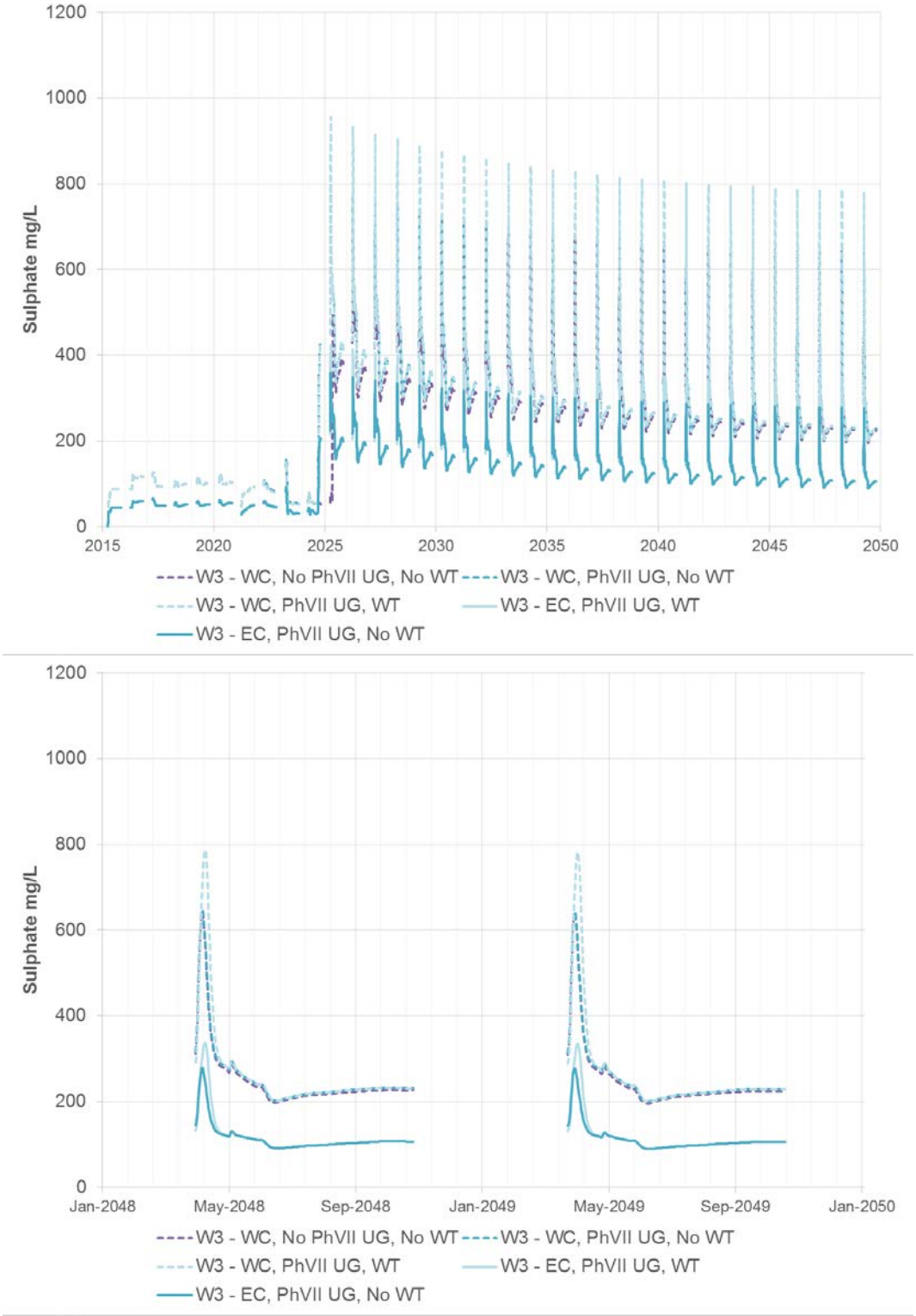


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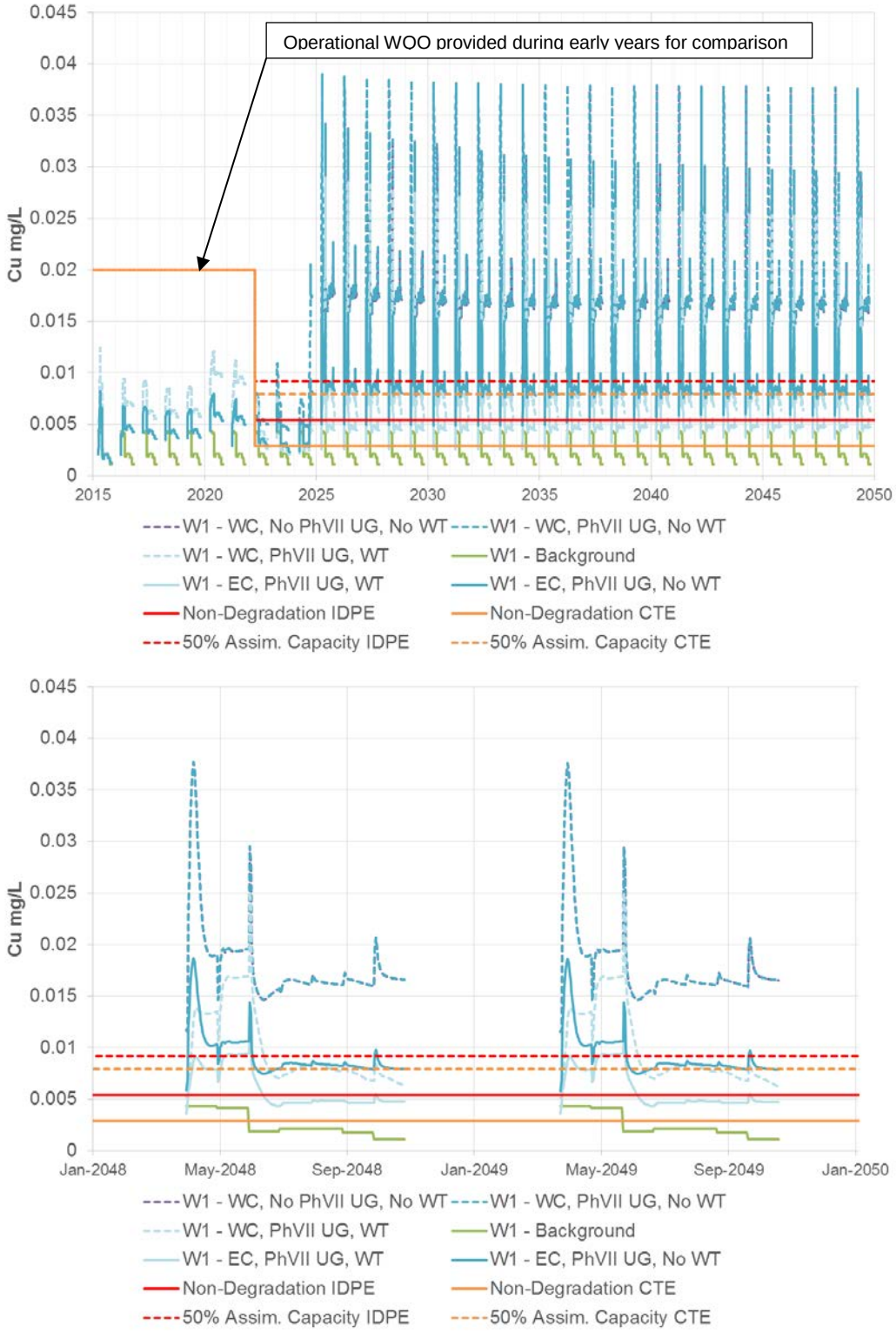
**Figure 5-10 Model Predictions of Sulphate Concentrations at W3**

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Note: The WQO for copper shown assumes dissolved organic carbon (DOC) < 10 mg/L

**Figure 5-11 Model Predictions of Dissolved Copper Concentrations in Lower Minto Creek**

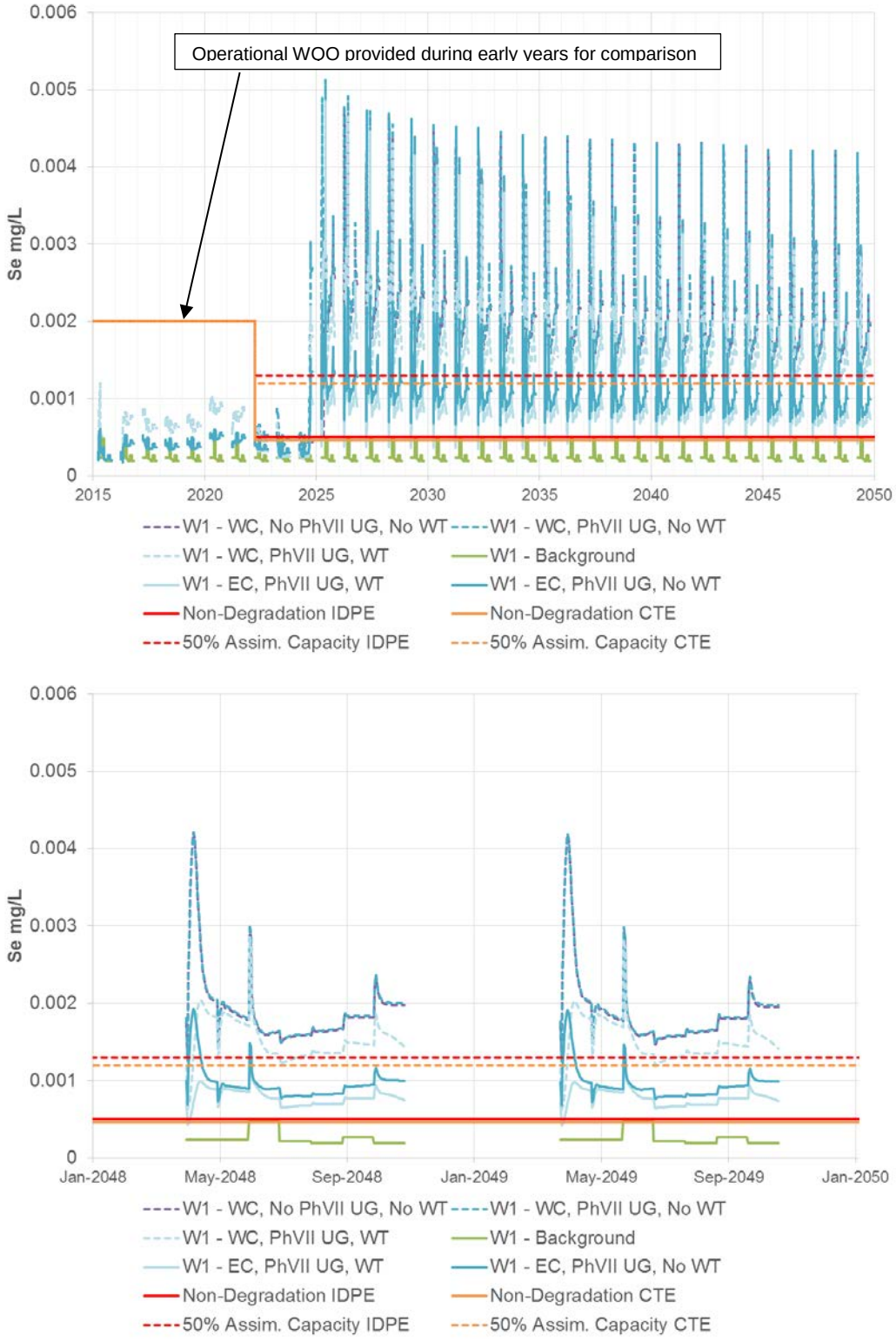


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**Figure 5-12 Model Predictions of Dissolved Selenium Concentrations in Lower Minto Creek**

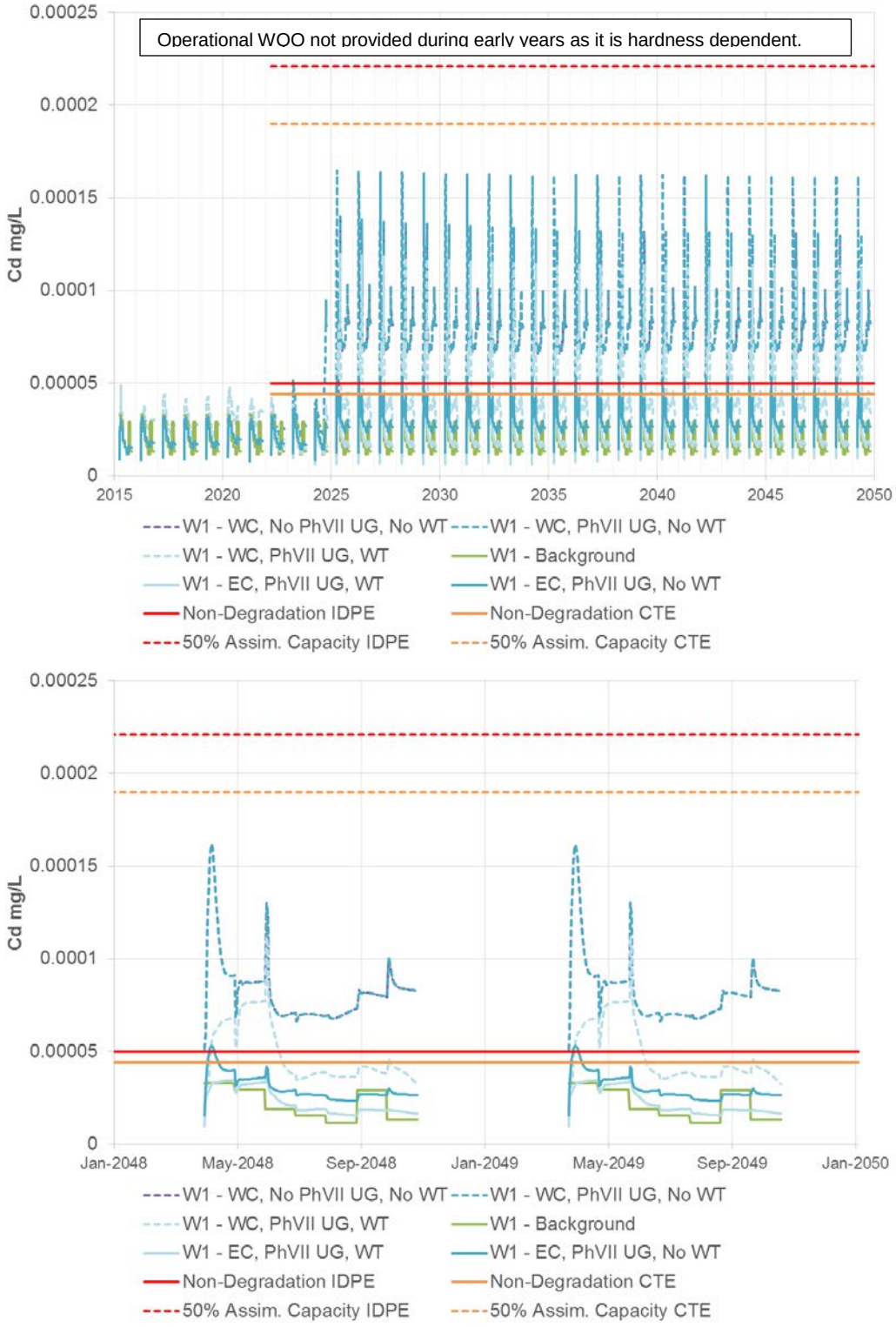


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**Figure 5-13 Model Predictions of Dissolved Cadmium Concentrations in Lower Minto Creek**

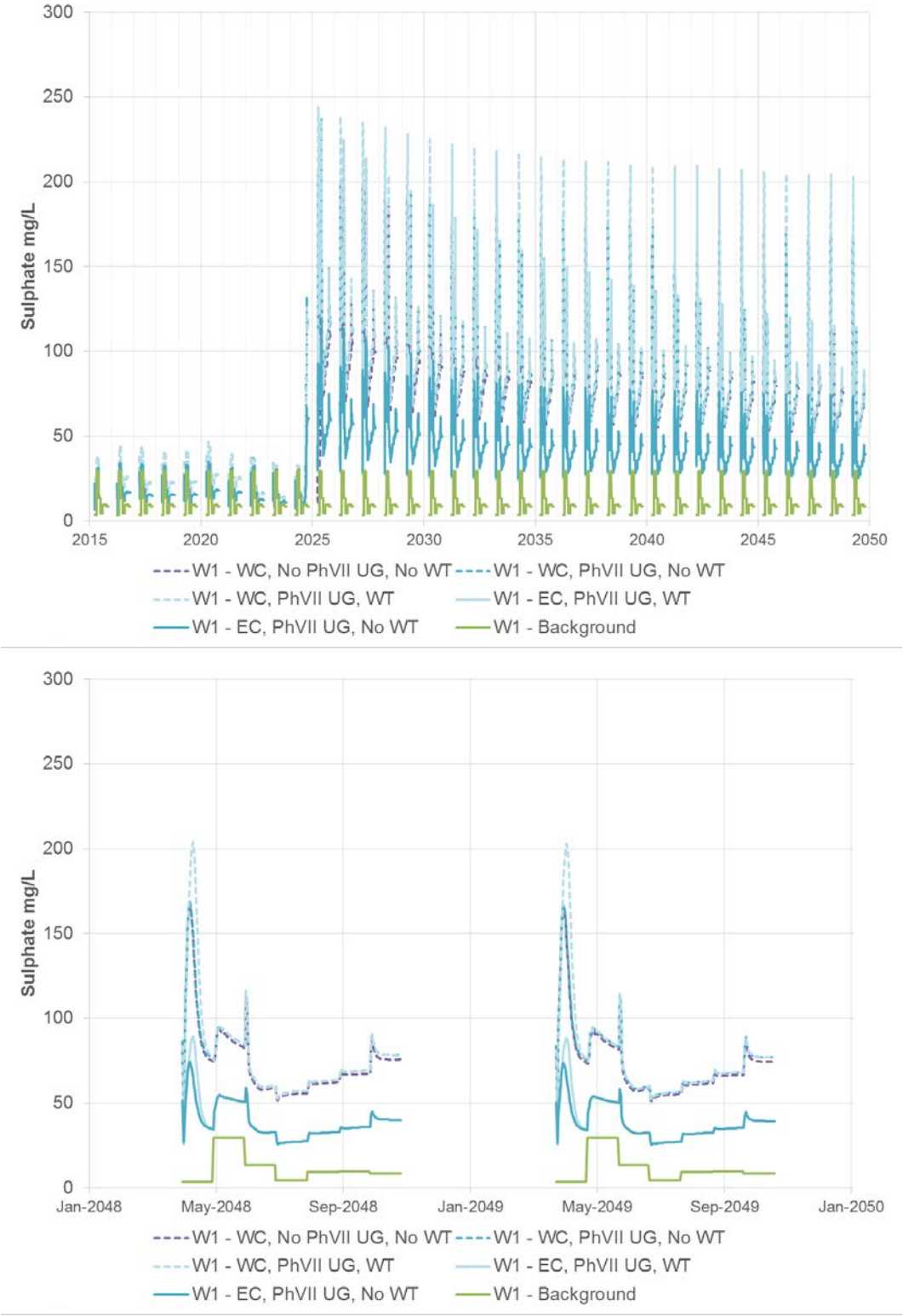


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**Figure 5-14 Model Predictions of Dissolved Sulphate Concentrations in Lower Minto Creek**

Evaluation of the effects of the predicted water quality on aquatic resources in Minto Creek and McGinty Creek has been addressed elsewhere (Minto 2013) and is not considered here in detail. The predicted concentrations of water quality parameters include 'Expected Case' values and 'Reasonable Worst Case' values. In the context of actual project performance, the predicted 'expected case' concentrations should be considered to be typical performance values (including the range of variability observed over operations at the Minto Mine). The predictions which represent the 'Reasonable Worst Case' scenario are considered to be unlikely to occur, and should be considered to represent the upper end of the range of potential water quality performance of the mine. In the unlikely event that water quality concentrations in the range of the 'Reasonable Worst Case' values occur, it is expected that this condition would be transient and of short duration (as observed with the upper range of water quality concentrations in the site monitoring results to date).

Comparison of model results between 'no treatment' and 'passive treatment' cases shows that the CWTS has the potential to materially reduce dissolved concentrations of copper, selenium, and other parameters in surface water leaving the mine site during low flow summer and fall months when most or all of the surface water can be routed through the CWTS. However, under typical spring conditions and under high flow conditions at other times of the year, a portion of the surface water will bypass the CWTS and will therefore report to lower Minto Creek without the benefit of wetland treatment. A number of other factors will affect the performance of the CWTS, and the reclamation research into constructed wetlands treatment system that has been underway for several years will continue going forward with the intent of refining the understanding of factors that will be most critical to optimizing performance at the full scale. At present, given the range of uncertainty, it is prudent to consider the range of performance that is book-ended by the 'no treatment' and 'passive treatment' scenarios as representative of the range of future surface water quality leaving the mine site.

Comparison of model results between 'PhVII UG' and 'No PhVII UG' cases show that the inclusion of the Phase VII Underground components in the model have little to no numerical effect on the modelled water quality in the open pits and Minto Creek in post-closure. There are some very minor differences in water quality in the Main Pit and Area 2 Pit during operations but these changes are not reflected in the long-term.

### 5.2.3 McGinty Creek Water Quality Results

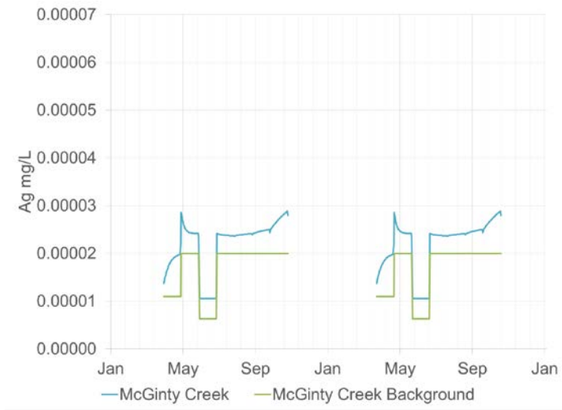
The McGinty Creek water quality modelling was a scoping evaluation for a worst-case scenario that included the following assumptions:

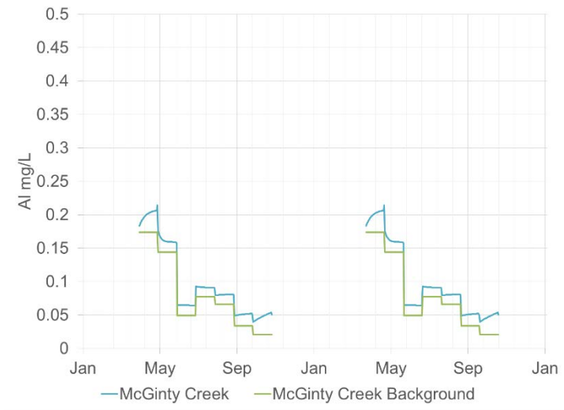
- The magnitude of loadings was set to be equal to the loads determined for the full extent of the pit walls exposed at the end of mining (i.e. there was no gradual decrease in loadings estimates even if the pit was to fill).
- All geochemical loading generated by weathering of the pit walls, pit wall failure debris, and access road is both flushed from the weathering sites and reports to water in the Minto North Pit.

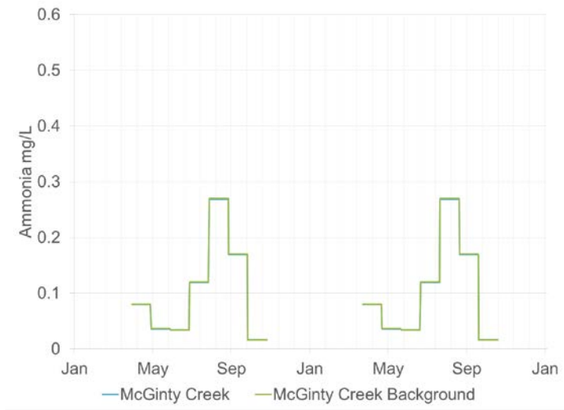
- Accumulated loadings would report unattenuated to McGinty Creek by surface discharge and/ or via groundwater pathways.

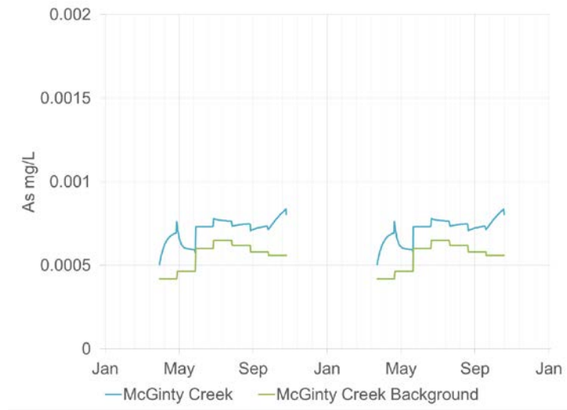
Under this scenario, Minto North loadings are maximized. This highly conservative approach evaluates the upper limit of the magnitude of potential changes to McGinty Creek water quality from geochemical loadings from the Minto North Pit.

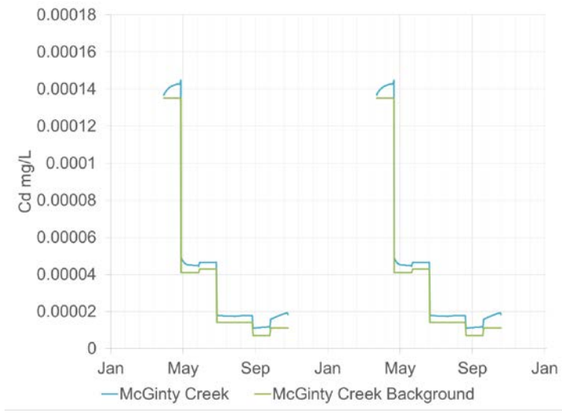
Average and maximum results of the scoping exercise for lower McGinty Creek are presented in Table 5-2, along with average and maximum values in the baseline water quality results. Long-term steady state results for selected parameters are shown in Figure 5-14a and Figure 5-15b, along with the monthly background source term representing the 95$^{th}$ percentile concentrations in the baseline data. Although the assessment of aquatic effects is addressed elsewhere (Minto 2013 and references therein), inspection of the baseline and worst case post-mining model results in Figure 5-14a and 5-14b reveals that the changes in water quality of McGinty Creek from mining Minto North will be minimal.

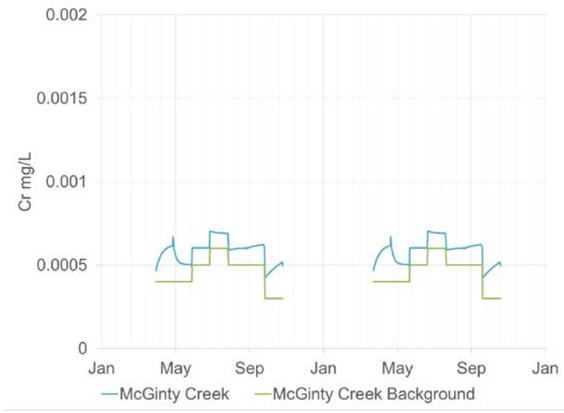


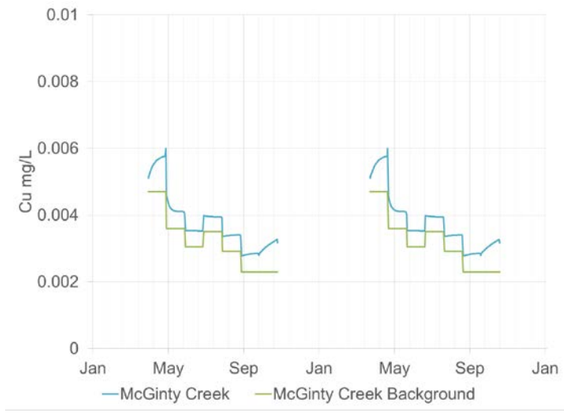



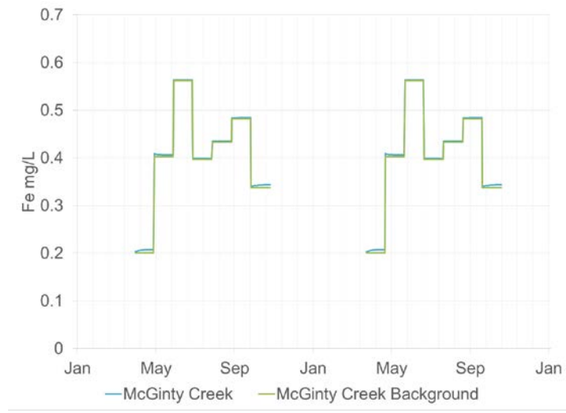
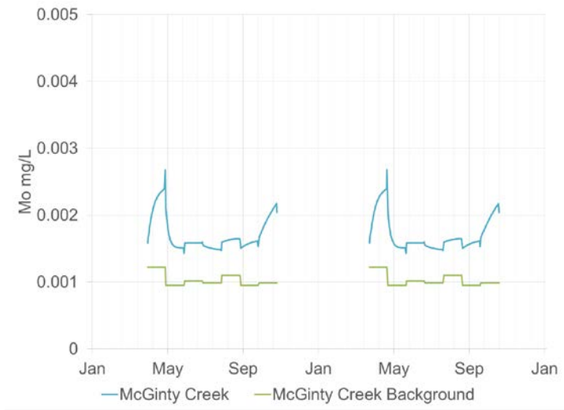
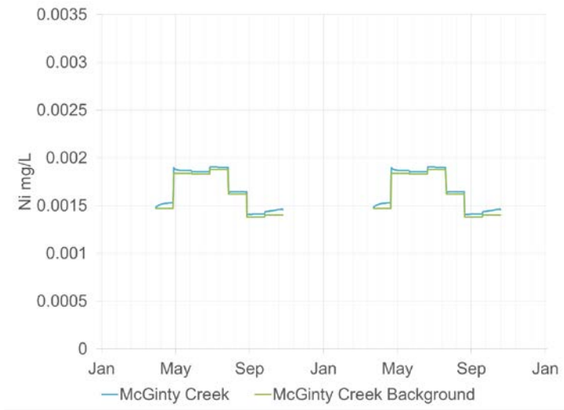
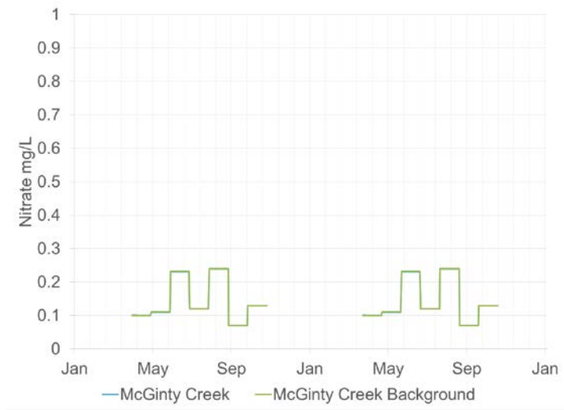
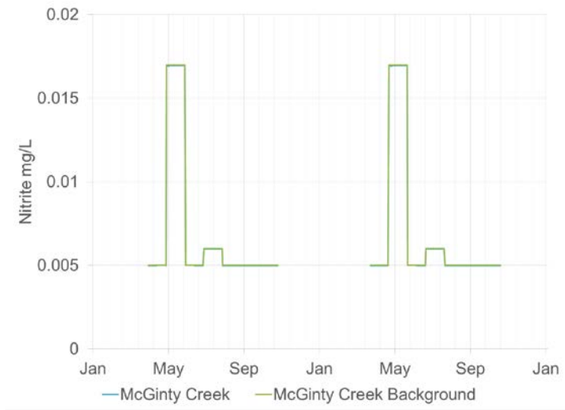



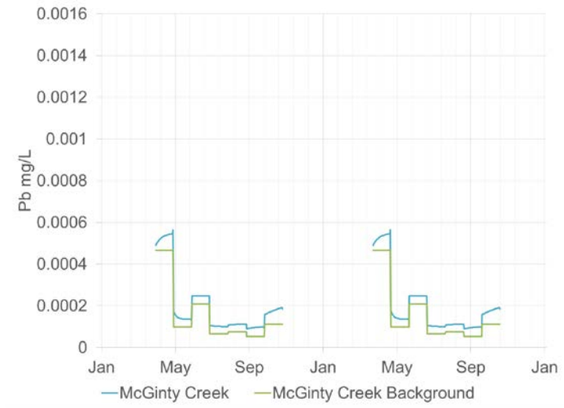

**Figure 5-15a McGinty Creek Water Quality Prediction: Worst Case Results (1 of 2)**

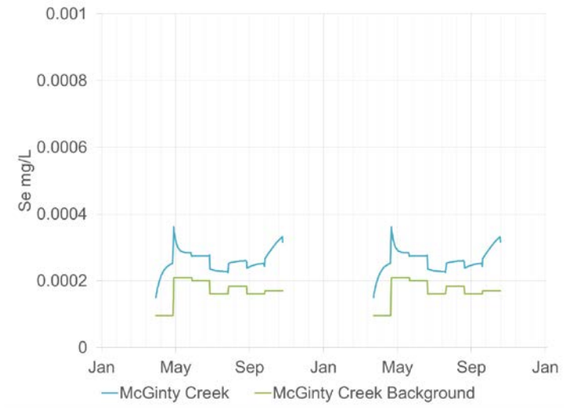


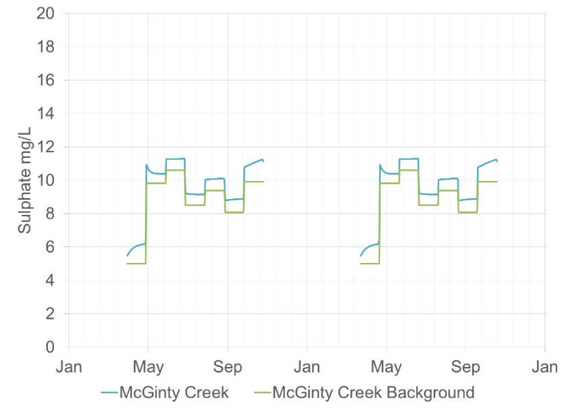



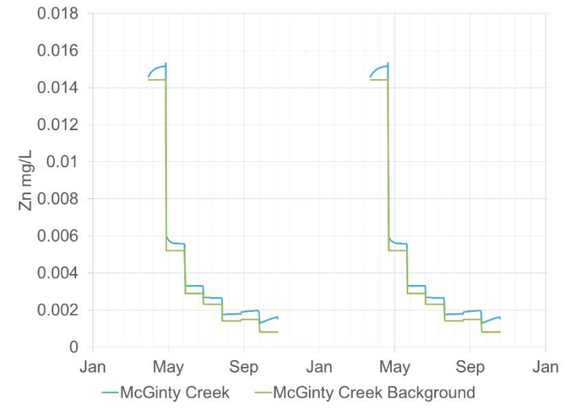




**Figure 5-14b McGinty Creek Water Quality Prediction: Worst Case Results (2 of 2)**

**Table 5-2 Water Quality Modelling Results for McGinty Creek at Mouth**

| Parameter*/ Unit | | Baseline Conditions | | After Mining at Minto North | |
|---|---|---|---|---|---|
| | | | | Worst Case | |
| | | Average | Max | Average | Max |
| Ammonia | mg/L | 0.104 | 0.27 | 0.103 | 0.269 |
| $N\text{-}NO_2$ | mg/L | 0.00686 | 0.017 | 0.00683 | 0.0169 |
| $N\text{-}NO_3$ | mg/L | 0.143 | 0.24 | 0.143 | 0.239 |
| Sulphate | mg/L | 8.75 | 10.6 | 9.55 | 11.3 |
| Al | mg/L | 0.0807 | 0.174 | 0.0995 | 0.214 |
| As | mg/L | 0.000557 | 0.00065 | 0.000715 | 0.000836 |
| Cd | mg/L | 0.0000378 | 0.000135 | 0.0000425 | 0.000145 |
| Cr | mg/L | 0.000457 | 0.0006 | 0.000583 | 0.000703 |
| Cu | mg/L | 0.0032 | 0.00471 | 0.00379 | 0.006 |
| Fe | mg/L | 0.402 | 0.562 | 0.405 | 0.564 |
| Mn | mg/L | 0.0275 | 0.0458 | 0.0347 | 0.0581 |
| Mo | mg/L | 0.00103 | 0.00122 | 0.00171 | 0.00268 |
| Ni | mg/L | 0.00163 | 0.00188 | 0.00167 | 0.00191 |
| Se | mg/L | 0.000168 | 0.00021 | 0.000262 | 0.000361 |
| Ag | mg/L | 0.0000168 | 0.00002 | 0.0000219 | 0.0000289 |
| Zn | mg/L | 0.00407 | 0.0144 | 0.00454 | 0.0153 |

Source: Source: \\VAN-SVR0\Projects\01_SITES\Minto\!020_Site_Wide_Data\Water_and_Load_Balance_Files\01_Project_Phases\07_Phase_5_6\Results\Minto_North\[1CM002-003_MintoNorth_WQ_Prediction_2013-06-26.xlsx]

**Notes:**

*: all concentrations are dissolved concentrations

## 5.3 Limitations of the Water and Load Balance Model

The water and load balance for Minto was developed according to standard practices and was based on best available input data. However, as with any model representation of a complex system there are inherent uncertainties associated with inputs and modelled processes. In most cases, uncertainties are accounted for by using conservative assumptions that are intended to capture the most adverse conditions. One obvious exception to this approach is the water quality results from the “Expected Case” scenarios.

Uncertainties that may affect the accuracy of the model outcome include:

- Geochemical processes not incorporated in the model. The load balance is a mass conservative model. Chemical reactions such as dissolution, precipitation, oxidation or reduction are not incorporated in the model. In addition, processes such as attenuation of constituents along surface and subsurface flow paths, adsorption, and exposure of more reactive mine waste than previously-mined materials at Minto all

may contribute to actual water quality performance being different than the predictions presented here indicate.

- Significant changes to the operations and closure plans used as a basis for the modelling scenarios.
- Change in local climatic conditions that cause the historical climatic record to inaccurately represent the duration, frequency and intensity of precipitation and runoff events.

### 5.3.1 Variability in Precipitation

The long term results produced by the water and load balance model reflect a case where the site experiences the average annual precipitation each year, and that the annual precipitation is distributed according to a fixed monthly runoff distribution. The future reality of the site will undoubtedly deviate from that model scenario- the example shown in Figure 4-1 suggests that it is reasonable to expect at least 3-to-5-fold variability in annual precipitation over a 10-year period (i.e. the range represented by the 5$^{th}$ and 95th percentile results for different months). Other meteorological and hydrological parameters that affect catchment processes and stream flows in Minto Creek will undoubtedly have analogous variability (monthly distribution of runoff as just one example, as shown in Figure 2-7). For this reason, the water quality values represented by the reported model results should be considered as a range spanning the different model scenarios.

### 5.3.2 POX Ore and Sulphide Ore Tailings Slurry

During the Minto operations phase, the open pit water quality is sensitive to changes in the tailings slurry water quality due to the large volumes of water circulating through the mill. The tailings slurry water quality is variable over time and is linked to the amount of POX ore being milled. There is a large amount of variability in the grade of POX being milled during operations which introduces variability into the tailings source terms. The water and load balance results presented here are based on the current sulphide ore and POX ore milling schedule which is very subject to change throughout operations.

# 6 Key Conclusions

The Minto Mine Water and Load Balance Model was updated as part of the 2018 Reclamation and Closure Plan (Minto 2018). The key conclusions of this update are:

- that recent trends in sulphate concentrations in the in-pit tailings management facilities are likely caused by increased sulphate loading due to milling of POX ore, and
- the model results indicate that the inclusion of Phase VII mine components have very little effect on the water quality in the open pits and Minto Creek.

This report, "*Water and Load Balance Model Report 2018*", has been prepared by SRK Consulting (Canada) Inc.

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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.

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# Appendix A: Water and Load Balance Results

# Appendix A1: Monthly Water and Load Balance Results – 2045

**Scenario 1 - Area 2 Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000573 | 0.448 | 1.21 | 0.00277 | 0.0000819 | 0.00168 | 0.0202 | 0.368 | 0.247 | 0.0238 | 0.00222 | 7.27 | 0.356 | 0.00043 | 0.00505 | 207 | 0.00875 |
| May | 0.0000575 | 0.451 | 1.18 | 0.00278 | 0.0000823 | 0.00168 | 0.0202 | 0.366 | 0.244 | 0.0236 | 0.00221 | 7.12 | 0.349 | 0.000431 | 0.00501 | 204 | 0.00876 |
| June | 0.0000579 | 0.456 | 1.17 | 0.00281 | 0.0000829 | 0.00169 | 0.0203 | 0.366 | 0.242 | 0.0235 | 0.00221 | 7.04 | 0.346 | 0.000433 | 0.00499 | 202 | 0.0088 |
| July | 0.0000579 | 0.456 | 1.16 | 0.00281 | 0.0000829 | 0.00169 | 0.0203 | 0.367 | 0.242 | 0.0235 | 0.00222 | 7.03 | 0.345 | 0.000433 | 0.00499 | 202 | 0.0088 |
| August | 0.0000579 | 0.456 | 1.16 | 0.00281 | 0.0000828 | 0.00169 | 0.0203 | 0.367 | 0.242 | 0.0235 | 0.00222 | 7 | 0.344 | 0.000433 | 0.00498 | 201 | 0.0088 |
| September | 0.0000577 | 0.454 | 1.15 | 0.0028 | 0.0000826 | 0.00169 | 0.0202 | 0.367 | 0.241 | 0.0234 | 0.00222 | 6.97 | 0.343 | 0.000432 | 0.00496 | 201 | 0.00877 |
| October | 0.0000576 | 0.453 | 1.15 | 0.00279 | 0.0000823 | 0.00168 | 0.0201 | 0.367 | 0.24 | 0.0233 | 0.00221 | 6.95 | 0.341 | 0.000431 | 0.00495 | 200 | 0.00875 |

**Scenario 1 - Main Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000573 | 0.448 | 1.21 | 0.00277 | 0.0000819 | 0.00168 | 0.0202 | 0.368 | 0.247 | 0.0238 | 0.00222 | 7.27 | 0.356 | 0.00043 | 0.00505 | 207 | 0.00875 |
| May | 0.0000575 | 0.451 | 1.18 | 0.00278 | 0.0000823 | 0.00168 | 0.0202 | 0.366 | 0.244 | 0.0236 | 0.00221 | 7.12 | 0.349 | 0.000431 | 0.00501 | 204 | 0.00876 |
| June | 0.0000579 | 0.456 | 1.17 | 0.00281 | 0.0000829 | 0.00169 | 0.0203 | 0.366 | 0.242 | 0.0235 | 0.00221 | 7.04 | 0.346 | 0.000433 | 0.00499 | 202 | 0.0088 |
| July | 0.0000579 | 0.456 | 1.16 | 0.00281 | 0.0000829 | 0.00169 | 0.0203 | 0.367 | 0.242 | 0.0235 | 0.00222 | 7.03 | 0.345 | 0.000433 | 0.00499 | 202 | 0.0088 |
| August | 0.0000579 | 0.456 | 1.16 | 0.00281 | 0.0000828 | 0.00169 | 0.0203 | 0.367 | 0.242 | 0.0235 | 0.00222 | 7 | 0.344 | 0.000433 | 0.00498 | 201 | 0.0088 |
| September | 0.0000577 | 0.454 | 1.15 | 0.0028 | 0.0000826 | 0.00169 | 0.0202 | 0.367 | 0.241 | 0.0234 | 0.00222 | 6.97 | 0.343 | 0.000432 | 0.00496 | 201 | 0.00877 |
| October | 0.0000576 | 0.453 | 1.15 | 0.00279 | 0.0000823 | 0.00168 | 0.0201 | 0.367 | 0.24 | 0.0233 | 0.00221 | 6.95 | 0.341 | 0.000431 | 0.00495 | 200 | 0.00875 |

**Scenario 1 - W3 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000625 | 0.318 | 0.272 | 0.00251 | 0.0000798 | 0.00247 | 0.0385 | 0.691 | 0.453 | 0.0141 | 0.00307 | 1.6 | 0.0766 | 0.000549 | 0.00448 | 180 | 0.0129 |
| May | 0.0000477 | 0.3 | 0.332 | 0.00198 | 0.0000676 | 0.00174 | 0.0297 | 0.535 | 0.35 | 0.0117 | 0.00222 | 1.9 | 0.0931 | 0.000407 | 0.00318 | 125 | 0.00935 |
| June | 0.0000479 | 0.304 | 0.253 | 0.00201 | 0.0000653 | 0.00174 | 0.0287 | 0.56 | 0.362 | 0.0104 | 0.00217 | 1.41 | 0.0702 | 0.0004 | 0.00278 | 102 | 0.00926 |
| July | 0.0000494 | 0.293 | 0.193 | 0.00208 | 0.0000639 | 0.00186 | 0.0293 | 0.589 | 0.359 | 0.00999 | 0.00232 | 1.06 | 0.053 | 0.000418 | 0.00269 | 98.9 | 0.00967 |
| August | 0.0000504 | 0.279 | 0.21 | 0.00208 | 0.00006 | 0.00186 | 0.0281 | 0.586 | 0.332 | 0.0102 | 0.00236 | 1.19 | 0.0586 | 0.000423 | 0.00272 | 104 | 0.00952 |
| September | 0.0000493 | 0.265 | 0.223 | 0.00203 | 0.0000574 | 0.00188 | 0.0268 | 0.577 | 0.32 | 0.0102 | 0.0024 | 1.28 | 0.0626 | 0.000428 | 0.00283 | 109 | 0.00933 |
| October | 0.0000472 | 0.255 | 0.237 | 0.00196 | 0.000056 | 0.00185 | 0.0254 | 0.553 | 0.305 | 0.0102 | 0.00236 | 1.38 | 0.0675 | 0.000422 | 0.00289 | 112 | 0.00906 |

**Scenario 1 - W1 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000221 | 0.106 | 0.0915 | 0.00084 | 0.0000426 | 0.00105 | 0.0126 | 0.276 | 0.142 | 0.00426 | 0.00138 | 0.515 | 0.0335 | 0.000216 | 0.0013 | 49.7 | 0.00616 |
| May | 0.0000195 | 0.113 | 0.132 | 0.000808 | 0.0000351 | 0.000816 | 0.0104 | 0.396 | 0.158 | 0.00343 | 0.00151 | 0.525 | 0.0275 | 0.000207 | 0.000942 | 53.2 | 0.00554 |
| June | 0.0000174 | 0.0956 | 0.126 | 0.000853 | 0.0000302 | 0.000845 | 0.0084 | 0.295 | 0.133 | 0.00358 | 0.00151 | 0.514 | 0.0327 | 0.000161 | 0.000989 | 37.8 | 0.00517 |
| July | 0.0000182 | 0.0843 | 0.0954 | 0.000956 | 0.0000268 | 0.000884 | 0.0084 | 0.377 | 0.136 | 0.00324 | 0.00157 | 0.413 | 0.0229 | 0.000185 | 0.00082 | 28.3 | 0.00472 |
| August | 0.0000252 | 0.0825 | 0.091 | 0.000985 | 0.0000239 | 0.000926 | 0.0084 | 0.41 | 0.145 | 0.00333 | 0.00165 | 0.452 | 0.024 | 0.000211 | 0.000846 | 33.5 | 0.00466 |
| September | 0.0000198 | 0.0833 | 0.0931 | 0.000957 | 0.0000267 | 0.0011 | 0.00817 | 0.415 | 0.142 | 0.00341 | 0.00181 | 0.464 | 0.0236 | 0.000259 | 0.000955 | 37 | 0.00444 |
| October | 0.0000198 | 0.084 | 0.136 | 0.000934 | 0.0000272 | 0.000877 | 0.00825 | 0.363 | 0.154 | 0.00405 | 0.00149 | 0.701 | 0.0447 | 0.000187 | 0.00106 | 43 | 0.00413 |

Notes:
All concentration reported in mg/L

**Scenario 2 - Area 2 Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000128 | 0.859 | 4.53 | 0.00689 | 0.000326 | 0.00485 | 0.0497 | 0.629 | 0.492 | 0.0646 | 0.00531 | 19.7 | 0.711 | 0.00311 | 0.00961 | 394 | 0.0277 |
| May | 0.000129 | 0.866 | 4.43 | 0.00693 | 0.000328 | 0.00488 | 0.0497 | 0.624 | 0.486 | 0.0642 | 0.00531 | 19.3 | 0.697 | 0.00313 | 0.00951 | 388 | 0.0277 |
| June | 0.00013 | 0.874 | 4.36 | 0.00699 | 0.000331 | 0.00492 | 0.0499 | 0.622 | 0.482 | 0.0643 | 0.00533 | 19 | 0.688 | 0.00316 | 0.00949 | 385 | 0.0279 |
| July | 0.00013 | 0.874 | 4.34 | 0.00699 | 0.000331 | 0.00492 | 0.0499 | 0.622 | 0.481 | 0.0643 | 0.00533 | 19 | 0.686 | 0.00316 | 0.00947 | 384 | 0.0279 |
| August | 0.00013 | 0.873 | 4.32 | 0.00698 | 0.00033 | 0.00491 | 0.0498 | 0.622 | 0.48 | 0.0642 | 0.00532 | 18.9 | 0.683 | 0.00316 | 0.00945 | 383 | 0.0278 |
| September | 0.00013 | 0.87 | 4.3 | 0.00696 | 0.000329 | 0.0049 | 0.0496 | 0.62 | 0.478 | 0.0639 | 0.00531 | 18.8 | 0.68 | 0.00315 | 0.00942 | 381 | 0.0277 |
| October | 0.000129 | 0.867 | 4.28 | 0.00694 | 0.000328 | 0.00489 | 0.0494 | 0.619 | 0.476 | 0.0637 | 0.0053 | 18.8 | 0.677 | 0.00314 | 0.00939 | 380 | 0.0277 |

**Scenario 2 - Main Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000801 | 0.491 | 0.364 | 0.00449 | 0.000309 | 0.00341 | 0.0817 | 1.6 | 1.3 | 0.0319 | 0.00664 | 1.53 | 0.0494 | 0.00152 | 0.00989 | 429 | 0.0295 |
| May | 0.000102 | 0.713 | 0.264 | 0.00546 | 0.000356 | 0.00418 | 0.0957 | 1.76 | 1.43 | 0.0347 | 0.00734 | 1.11 | 0.0379 | 0.00211 | 0.00915 | 354 | 0.0331 |
| June | 0.000113 | 0.776 | 0.208 | 0.006 | 0.000342 | 0.00455 | 0.0936 | 1.87 | 1.49 | 0.0348 | 0.00712 | 0.844 | 0.0302 | 0.00238 | 0.00792 | 302 | 0.0347 |
| July | 0.000107 | 0.699 | 0.21 | 0.00575 | 0.000311 | 0.00435 | 0.0876 | 1.99 | 1.57 | 0.0325 | 0.00709 | 0.855 | 0.0304 | 0.0022 | 0.00768 | 308 | 0.0324 |
| August | 0.000102 | 0.643 | 0.21 | 0.00562 | 0.000324 | 0.00425 | 0.0842 | 2.26 | 1.73 | 0.0318 | 0.00723 | 0.874 | 0.0303 | 0.00204 | 0.0079 | 317 | 0.031 |
| September | 0.0000961 | 0.59 | 0.214 | 0.00532 | 0.000349 | 0.00413 | 0.0803 | 2.22 | 1.63 | 0.0315 | 0.00699 | 0.898 | 0.0305 | 0.00188 | 0.00798 | 320 | 0.03 |
| October | 0.0000907 | 0.543 | 0.226 | 0.005 | 0.000326 | 0.00392 | 0.0762 | 2.09 | 1.49 | 0.03 | 0.00665 | 0.941 | 0.0318 | 0.00175 | 0.00786 | 324 | 0.0289 |

**Scenario 2 - W3 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000106 | 0.64 | 0.999 | 0.00572 | 0.000354 | 0.00439 | 0.0857 | 1.72 | 1.35 | 0.0405 | 0.00712 | 4.34 | 0.154 | 0.00214 | 0.0102 | 413 | 0.0324 |
| May | 0.0000878 | 0.591 | 1.2 | 0.00461 | 0.000271 | 0.00348 | 0.0647 | 1.09 | 0.876 | 0.034 | 0.00532 | 5.17 | 0.186 | 0.00191 | 0.00713 | 277 | 0.0245 |
| June | 0.0000892 | 0.598 | 0.882 | 0.00469 | 0.000253 | 0.00352 | 0.062 | 1.12 | 0.891 | 0.0312 | 0.00503 | 3.79 | 0.139 | 0.00195 | 0.00606 | 224 | 0.0243 |
| July | 0.0000895 | 0.579 | 0.656 | 0.00476 | 0.000247 | 0.00357 | 0.0634 | 1.28 | 1.01 | 0.0296 | 0.0053 | 2.82 | 0.103 | 0.00192 | 0.00601 | 222 | 0.0243 |
| August | 0.0000892 | 0.553 | 0.732 | 0.00476 | 0.000252 | 0.00355 | 0.0612 | 1.44 | 1.09 | 0.0299 | 0.0054 | 3.18 | 0.115 | 0.00187 | 0.00618 | 231 | 0.0234 |
| September | 0.0000864 | 0.529 | 0.789 | 0.00463 | 0.000269 | 0.00355 | 0.0592 | 1.44 | 1.06 | 0.0303 | 0.00534 | 3.44 | 0.124 | 0.0018 | 0.00633 | 237 | 0.0229 |
| October | 0.0000831 | 0.509 | 0.849 | 0.00447 | 0.00026 | 0.00347 | 0.0569 | 1.37 | 0.979 | 0.0299 | 0.00516 | 3.7 | 0.134 | 0.00176 | 0.00635 | 240 | 0.0223 |

**Scenario 2 - W1 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000033 | 0.187 | 0.318 | 0.00164 | 0.000111 | 0.00153 | 0.0243 | 0.53 | 0.366 | 0.011 | 0.00239 | 1.36 | 0.0577 | 0.000613 | 0.00275 | 109 | 0.011 |
| May | 0.0000296 | 0.186 | 0.363 | 0.00147 | 0.0000864 | 0.00125 | 0.0192 | 0.536 | 0.29 | 0.00909 | 0.00229 | 1.39 | 0.0523 | 0.000585 | 0.00194 | 91.9 | 0.00935 |
| June | 0.0000276 | 0.168 | 0.33 | 0.00152 | 0.0000767 | 0.00129 | 0.0166 | 0.433 | 0.264 | 0.00889 | 0.00222 | 1.27 | 0.0547 | 0.000545 | 0.00183 | 69.6 | 0.00891 |
| July | 0.0000277 | 0.151 | 0.243 | 0.00158 | 0.0000699 | 0.00129 | 0.0164 | 0.537 | 0.288 | 0.00798 | 0.00226 | 0.963 | 0.0389 | 0.000537 | 0.00162 | 58.4 | 0.00816 |
| August | 0.0000346 | 0.149 | 0.261 | 0.00163 | 0.0000701 | 0.00134 | 0.0164 | 0.614 | 0.328 | 0.00824 | 0.00238 | 1.09 | 0.0424 | 0.00056 | 0.0017 | 65.5 | 0.00804 |
| September | 0.0000293 | 0.151 | 0.292 | 0.00163 | 0.000081 | 0.00154 | 0.0165 | 0.636 | 0.331 | 0.00875 | 0.00257 | 1.2 | 0.0449 | 0.000614 | 0.00188 | 71.6 | 0.00797 |
| October | 0.0000303 | 0.158 | 0.446 | 0.00166 | 0.0000861 | 0.00135 | 0.0174 | 0.596 | 0.348 | 0.0102 | 0.00231 | 1.84 | 0.0777 | 0.000574 | 0.00213 | 84.3 | 0.00802 |

Notes:
All concentration reported in mg/L

**Scenario 3 - Area 2 Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000128 | 0.858 | 3.59 | 0.00684 | 0.000325 | 0.00484 | 0.0494 | 0.622 | 0.473 | 0.0621 | 0.00524 | 17.4 | 0.609 | 0.0031 | 0.00923 | 357 | 0.027 |
| May | 0.000129 | 0.865 | 3.51 | 0.00688 | 0.000327 | 0.00486 | 0.0494 | 0.617 | 0.467 | 0.0619 | 0.00524 | 17.1 | 0.597 | 0.00313 | 0.00915 | 352 | 0.027 |
| June | 0.00013 | 0.873 | 3.46 | 0.00694 | 0.000329 | 0.0049 | 0.0496 | 0.615 | 0.464 | 0.062 | 0.00526 | 16.9 | 0.59 | 0.00316 | 0.00913 | 350 | 0.0272 |
| July | 0.00013 | 0.873 | 3.45 | 0.00694 | 0.000329 | 0.0049 | 0.0496 | 0.615 | 0.463 | 0.062 | 0.00526 | 16.8 | 0.589 | 0.00316 | 0.00912 | 349 | 0.0272 |
| August | 0.00013 | 0.872 | 3.44 | 0.00694 | 0.000329 | 0.0049 | 0.0495 | 0.614 | 0.462 | 0.0619 | 0.00526 | 16.8 | 0.587 | 0.00315 | 0.0091 | 348 | 0.0272 |
| September | 0.000129 | 0.87 | 3.42 | 0.00692 | 0.000328 | 0.00488 | 0.0493 | 0.613 | 0.46 | 0.0617 | 0.00524 | 16.7 | 0.584 | 0.00315 | 0.00907 | 347 | 0.0271 |
| October | 0.000129 | 0.867 | 3.41 | 0.0069 | 0.000327 | 0.00487 | 0.0491 | 0.612 | 0.459 | 0.0615 | 0.00523 | 16.6 | 0.582 | 0.00313 | 0.00904 | 346 | 0.027 |

**Scenario 3 - Main Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.00008 | 0.491 | 0.326 | 0.00448 | 0.000309 | 0.00341 | 0.0817 | 1.6 | 1.3 | 0.0318 | 0.00663 | 1.43 | 0.0453 | 0.00152 | 0.00988 | 427 | 0.0294 |
| May | 0.000102 | 0.713 | 0.237 | 0.00546 | 0.000356 | 0.00418 | 0.0957 | 1.76 | 1.43 | 0.0346 | 0.00734 | 1.04 | 0.035 | 0.00211 | 0.00914 | 353 | 0.0331 |
| June | 0.000113 | 0.776 | 0.188 | 0.006 | 0.000342 | 0.00455 | 0.0936 | 1.87 | 1.49 | 0.0347 | 0.00712 | 0.794 | 0.028 | 0.00238 | 0.00791 | 301 | 0.0347 |
| July | 0.000107 | 0.699 | 0.19 | 0.00575 | 0.000311 | 0.00435 | 0.0876 | 1.99 | 1.57 | 0.0325 | 0.00709 | 0.805 | 0.0282 | 0.0022 | 0.00768 | 307 | 0.0324 |
| August | 0.000102 | 0.643 | 0.19 | 0.00562 | 0.000324 | 0.00425 | 0.0842 | 2.26 | 1.73 | 0.0318 | 0.00723 | 0.825 | 0.0281 | 0.00204 | 0.0079 | 316 | 0.031 |
| September | 0.0000961 | 0.59 | 0.193 | 0.00532 | 0.000349 | 0.00413 | 0.0803 | 2.22 | 1.63 | 0.0315 | 0.00699 | 0.847 | 0.0282 | 0.00188 | 0.00797 | 319 | 0.03 |
| October | 0.0000907 | 0.543 | 0.203 | 0.005 | 0.000326 | 0.00392 | 0.0761 | 2.09 | 1.49 | 0.0299 | 0.00665 | 0.886 | 0.0293 | 0.00175 | 0.00785 | 323 | 0.0289 |

**Scenario 3 - W3 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000106 | 0.64 | 0.822 | 0.00571 | 0.000354 | 0.00439 | 0.0857 | 1.72 | 1.35 | 0.04 | 0.00711 | 3.91 | 0.135 | 0.00214 | 0.0101 | 406 | 0.0323 |
| May | 0.0000877 | 0.591 | 0.968 | 0.0046 | 0.000271 | 0.00347 | 0.0646 | 1.09 | 0.871 | 0.0334 | 0.0053 | 4.6 | 0.161 | 0.00191 | 0.00704 | 268 | 0.0243 |
| June | 0.0000891 | 0.598 | 0.714 | 0.00468 | 0.000252 | 0.00352 | 0.062 | 1.12 | 0.888 | 0.0307 | 0.00502 | 3.38 | 0.12 | 0.00195 | 0.00599 | 218 | 0.0241 |
| July | 0.0000895 | 0.579 | 0.536 | 0.00475 | 0.000247 | 0.00357 | 0.0634 | 1.28 | 1 | 0.0293 | 0.00529 | 2.52 | 0.0903 | 0.00192 | 0.00596 | 217 | 0.0242 |
| August | 0.0000891 | 0.553 | 0.596 | 0.00475 | 0.000252 | 0.00355 | 0.0612 | 1.44 | 1.09 | 0.0295 | 0.00539 | 2.85 | 0.1 | 0.00187 | 0.00612 | 225 | 0.0233 |
| September | 0.0000863 | 0.528 | 0.641 | 0.00462 | 0.000269 | 0.00355 | 0.0592 | 1.44 | 1.05 | 0.0299 | 0.00533 | 3.08 | 0.108 | 0.0018 | 0.00628 | 232 | 0.0228 |
| October | 0.000083 | 0.508 | 0.688 | 0.00447 | 0.000259 | 0.00347 | 0.0568 | 1.37 | 0.976 | 0.0295 | 0.00514 | 3.31 | 0.116 | 0.00175 | 0.00628 | 234 | 0.0221 |

**Scenario 3 - W1 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000329 | 0.186 | 0.26 | 0.00164 | 0.000111 | 0.00153 | 0.0243 | 0.53 | 0.364 | 0.0108 | 0.00239 | 1.21 | 0.0513 | 0.000612 | 0.00273 | 107 | 0.011 |
| May | 0.0000295 | 0.186 | 0.3 | 0.00147 | 0.0000862 | 0.00125 | 0.0192 | 0.536 | 0.289 | 0.00893 | 0.00228 | 1.24 | 0.0455 | 0.000584 | 0.00192 | 89.5 | 0.00931 |
| June | 0.0000276 | 0.168 | 0.273 | 0.00151 | 0.0000766 | 0.00129 | 0.0166 | 0.433 | 0.262 | 0.00874 | 0.00222 | 1.14 | 0.0485 | 0.000544 | 0.0018 | 67.4 | 0.00887 |
| July | 0.0000276 | 0.151 | 0.203 | 0.00158 | 0.0000698 | 0.00129 | 0.0164 | 0.537 | 0.287 | 0.00787 | 0.00226 | 0.864 | 0.0344 | 0.000536 | 0.0016 | 56.8 | 0.00813 |
| August | 0.0000346 | 0.149 | 0.214 | 0.00163 | 0.0000701 | 0.00134 | 0.0164 | 0.614 | 0.327 | 0.00812 | 0.00238 | 0.973 | 0.0372 | 0.00056 | 0.00168 | 63.6 | 0.00801 |
| September | 0.0000293 | 0.151 | 0.237 | 0.00163 | 0.0000809 | 0.00153 | 0.0165 | 0.635 | 0.329 | 0.00861 | 0.00256 | 1.07 | 0.0389 | 0.000613 | 0.00186 | 69.4 | 0.00793 |
| October | 0.0000303 | 0.157 | 0.357 | 0.00166 | 0.0000859 | 0.00135 | 0.0174 | 0.595 | 0.346 | 0.00995 | 0.0023 | 1.62 | 0.068 | 0.000574 | 0.00209 | 80.8 | 0.00796 |

Notes:
All concentration reported in mg/L

**Scenario 4 - Area 2 Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000573 | 0.448 | 1.21 | 0.00277 | 0.0000819 | 0.00168 | 0.0202 | 0.368 | 0.247 | 0.0238 | 0.00222 | 7.27 | 0.356 | 0.00043 | 0.00505 | 207 | 0.00875 |
| May | 0.0000575 | 0.451 | 1.18 | 0.00278 | 0.0000823 | 0.00168 | 0.0202 | 0.366 | 0.244 | 0.0236 | 0.00221 | 7.12 | 0.349 | 0.000431 | 0.00501 | 204 | 0.00876 |
| June | 0.0000579 | 0.456 | 1.17 | 0.00281 | 0.0000829 | 0.00169 | 0.0203 | 0.366 | 0.242 | 0.0235 | 0.00221 | 7.04 | 0.346 | 0.000433 | 0.00499 | 202 | 0.0088 |
| July | 0.0000579 | 0.456 | 1.16 | 0.00281 | 0.0000829 | 0.00169 | 0.0203 | 0.367 | 0.242 | 0.0235 | 0.00222 | 7.03 | 0.345 | 0.000433 | 0.00499 | 202 | 0.0088 |
| August | 0.0000579 | 0.456 | 1.16 | 0.00281 | 0.0000828 | 0.00169 | 0.0203 | 0.367 | 0.242 | 0.0235 | 0.00222 | 7 | 0.344 | 0.000433 | 0.00498 | 201 | 0.0088 |
| September | 0.0000577 | 0.454 | 1.15 | 0.0028 | 0.0000826 | 0.00169 | 0.0202 | 0.367 | 0.241 | 0.0234 | 0.00222 | 6.97 | 0.343 | 0.000432 | 0.00496 | 201 | 0.00877 |
| October | 0.0000576 | 0.453 | 1.15 | 0.00279 | 0.0000823 | 0.00168 | 0.0201 | 0.367 | 0.24 | 0.0233 | 0.00221 | 6.95 | 0.341 | 0.000431 | 0.00495 | 200 | 0.00875 |

**Scenario 4 - Main Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000517 | 0.234 | 0.0966 | 0.00197 | 0.0000608 | 0.00215 | 0.0373 | 0.596 | 0.422 | 0.0112 | 0.00266 | 0.533 | 0.0217 | 0.000466 | 0.00401 | 170 | 0.0111 |
| May | 0.0000615 | 0.344 | 0.0756 | 0.00235 | 0.0000793 | 0.0024 | 0.0458 | 0.759 | 0.543 | 0.0113 | 0.00277 | 0.388 | 0.0172 | 0.000534 | 0.00372 | 138 | 0.0124 |
| June | 0.0000661 | 0.383 | 0.0665 | 0.00257 | 0.0000824 | 0.00251 | 0.0452 | 0.859 | 0.586 | 0.0112 | 0.00283 | 0.3 | 0.0139 | 0.000564 | 0.00336 | 121 | 0.0129 |
| July | 0.0000641 | 0.346 | 0.0679 | 0.00248 | 0.0000756 | 0.00249 | 0.0421 | 0.815 | 0.525 | 0.011 | 0.00288 | 0.304 | 0.0144 | 0.000553 | 0.00322 | 126 | 0.0129 |
| August | 0.0000627 | 0.314 | 0.0673 | 0.00241 | 0.0000694 | 0.00249 | 0.0402 | 0.788 | 0.478 | 0.0108 | 0.00292 | 0.312 | 0.0143 | 0.000546 | 0.00322 | 132 | 0.0127 |
| September | 0.0000606 | 0.285 | 0.0667 | 0.0023 | 0.0000638 | 0.00243 | 0.0377 | 0.762 | 0.451 | 0.0104 | 0.0029 | 0.324 | 0.0143 | 0.000533 | 0.0033 | 135 | 0.0124 |
| October | 0.0000579 | 0.263 | 0.0686 | 0.00218 | 0.0000597 | 0.00237 | 0.0351 | 0.726 | 0.423 | 0.0101 | 0.00284 | 0.337 | 0.0147 | 0.000517 | 0.00332 | 137 | 0.012 |

**Scenario 4 - W3 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000072 | 0.356 | 0.273 | 0.00287 | 0.0000357 | 0.00287 | 0.0189 | 0.809 | 0.528 | 0.0142 | 0.00356 | 1.6 | 0.0754 | 0.000636 | 0.0026 | 207 | 0.00506 |
| May | 0.0000477 | 0.299 | 0.332 | 0.00198 | 0.0000556 | 0.00174 | 0.0241 | 0.533 | 0.349 | 0.0115 | 0.00222 | 1.9 | 0.093 | 0.000406 | 0.00297 | 125 | 0.00771 |
| June | 0.000048 | 0.305 | 0.258 | 0.00202 | 0.0000411 | 0.00174 | 0.0184 | 0.56 | 0.362 | 0.0102 | 0.00217 | 1.44 | 0.0717 | 0.0004 | 0.0024 | 103 | 0.00582 |
| July | 0.0000494 | 0.293 | 0.192 | 0.00208 | 0.0000284 | 0.00186 | 0.013 | 0.589 | 0.36 | 0.00958 | 0.00232 | 1.05 | 0.0527 | 0.000417 | 0.00212 | 98.7 | 0.00438 |
| August | 0.0000504 | 0.279 | 0.21 | 0.00208 | 0.0000273 | 0.00186 | 0.013 | 0.586 | 0.333 | 0.0098 | 0.00236 | 1.19 | 0.0585 | 0.000423 | 0.00216 | 104 | 0.00442 |
| September | 0.0000494 | 0.265 | 0.222 | 0.00203 | 0.0000239 | 0.00188 | 0.013 | 0.578 | 0.32 | 0.00976 | 0.0024 | 1.28 | 0.0623 | 0.000428 | 0.00218 | 109 | 0.00392 |
| October | 0.0000472 | 0.256 | 0.238 | 0.00197 | 0.0000199 | 0.00185 | 0.0131 | 0.554 | 0.305 | 0.00965 | 0.00236 | 1.38 | 0.0677 | 0.000423 | 0.00209 | 112 | 0.00315 |

**Scenario 4 - W1 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000246 | 0.116 | 0.0917 | 0.000934 | 0.0000319 | 0.00116 | 0.00778 | 0.306 | 0.161 | 0.0043 | 0.00151 | 0.515 | 0.0332 | 0.000238 | 0.000845 | 56.6 | 0.00427 |
| May | 0.0000195 | 0.113 | 0.132 | 0.000808 | 0.0000322 | 0.000815 | 0.00904 | 0.395 | 0.158 | 0.0034 | 0.00151 | 0.525 | 0.0275 | 0.000206 | 0.000889 | 53.3 | 0.00513 |
| June | 0.0000174 | 0.0958 | 0.127 | 0.000854 | 0.0000248 | 0.000845 | 0.00607 | 0.295 | 0.133 | 0.00354 | 0.00151 | 0.52 | 0.033 | 0.000161 | 0.000904 | 37.9 | 0.0044 |
| July | 0.0000182 | 0.0844 | 0.0952 | 0.000956 | 0.0000186 | 0.000884 | 0.00463 | 0.377 | 0.137 | 0.00315 | 0.00157 | 0.411 | 0.0228 | 0.000185 | 0.000688 | 28.3 | 0.0035 |
| August | 0.0000252 | 0.0827 | 0.0909 | 0.000985 | 0.0000162 | 0.000926 | 0.00482 | 0.41 | 0.145 | 0.00325 | 0.00165 | 0.451 | 0.024 | 0.000211 | 0.000714 | 33.5 | 0.00346 |
| September | 0.0000198 | 0.0835 | 0.0929 | 0.000958 | 0.0000183 | 0.0011 | 0.0047 | 0.415 | 0.142 | 0.00331 | 0.00181 | 0.462 | 0.0235 | 0.000259 | 0.000794 | 36.9 | 0.00309 |
| October | 0.0000199 | 0.0842 | 0.136 | 0.000935 | 0.0000175 | 0.000878 | 0.00488 | 0.363 | 0.154 | 0.00391 | 0.00149 | 0.702 | 0.0447 | 0.000187 | 0.000852 | 43 | 0.00254 |

Notes:
All concentration reported in mg/L

**Scenario 5 - Area 2 Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000128 | 0.859 | 4.53 | 0.00689 | 0.000326 | 0.00485 | 0.0497 | 0.629 | 0.492 | 0.0646 | 0.00531 | 19.7 | 0.711 | 0.00311 | 0.00961 | 394 | 0.0277 |
| May | 0.000129 | 0.866 | 4.43 | 0.00693 | 0.000328 | 0.00488 | 0.0497 | 0.624 | 0.486 | 0.0642 | 0.00531 | 19.3 | 0.697 | 0.00313 | 0.00951 | 388 | 0.0277 |
| June | 0.00013 | 0.874 | 4.36 | 0.00699 | 0.000331 | 0.00492 | 0.0499 | 0.622 | 0.482 | 0.0643 | 0.00533 | 19 | 0.688 | 0.00316 | 0.00949 | 385 | 0.0279 |
| July | 0.00013 | 0.874 | 4.34 | 0.00699 | 0.000331 | 0.00492 | 0.0499 | 0.622 | 0.481 | 0.0643 | 0.00533 | 19 | 0.686 | 0.00316 | 0.00947 | 384 | 0.0279 |
| August | 0.00013 | 0.873 | 4.32 | 0.00698 | 0.00033 | 0.00491 | 0.0498 | 0.622 | 0.48 | 0.0642 | 0.00532 | 18.9 | 0.683 | 0.00316 | 0.00945 | 383 | 0.0278 |
| September | 0.00013 | 0.87 | 4.3 | 0.00696 | 0.000329 | 0.0049 | 0.0496 | 0.62 | 0.478 | 0.0639 | 0.00531 | 18.8 | 0.68 | 0.00315 | 0.00942 | 381 | 0.0277 |
| October | 0.000129 | 0.867 | 4.28 | 0.00694 | 0.000328 | 0.00489 | 0.0494 | 0.619 | 0.476 | 0.0637 | 0.0053 | 18.8 | 0.677 | 0.00314 | 0.00939 | 380 | 0.0277 |

**Scenario 5 - Main Pit 2045 Monthly Water Quality Results**

| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000801 | 0.491 | 0.364 | 0.00449 | 0.000309 | 0.00341 | 0.0817 | 1.6 | 1.3 | 0.0319 | 0.00664 | 1.53 | 0.0494 | 0.00152 | 0.00989 | 429 | 0.0295 |
| May | 0.000102 | 0.713 | 0.264 | 0.00546 | 0.000356 | 0.00418 | 0.0957 | 1.76 | 1.43 | 0.0347 | 0.00734 | 1.11 | 0.0379 | 0.00211 | 0.00915 | 354 | 0.0331 |
| June | 0.000113 | 0.776 | 0.208 | 0.006 | 0.000342 | 0.00455 | 0.0936 | 1.87 | 1.49 | 0.0348 | 0.00712 | 0.844 | 0.0302 | 0.00238 | 0.00792 | 302 | 0.0347 |
| July | 0.000107 | 0.699 | 0.21 | 0.00575 | 0.000311 | 0.00435 | 0.0876 | 1.99 | 1.57 | 0.0325 | 0.00709 | 0.855 | 0.0304 | 0.0022 | 0.00768 | 308 | 0.0324 |
| August | 0.000102 | 0.643 | 0.21 | 0.00562 | 0.000324 | 0.00425 | 0.0842 | 2.26 | 1.73 | 0.0318 | 0.00723 | 0.874 | 0.0303 | 0.00204 | 0.0079 | 317 | 0.031 |
| September | 0.0000961 | 0.59 | 0.214 | 0.00532 | 0.000349 | 0.00413 | 0.0803 | 2.22 | 1.63 | 0.0315 | 0.00699 | 0.898 | 0.0305 | 0.00188 | 0.00798 | 320 | 0.03 |
| October | 0.0000907 | 0.543 | 0.226 | 0.005 | 0.000326 | 0.00392 | 0.0762 | 2.09 | 1.49 | 0.03 | 0.00665 | 0.941 | 0.0318 | 0.00175 | 0.00786 | 324 | 0.0289 |

**Scenario 5 - W3 2045 Monthly Water Quality Results**

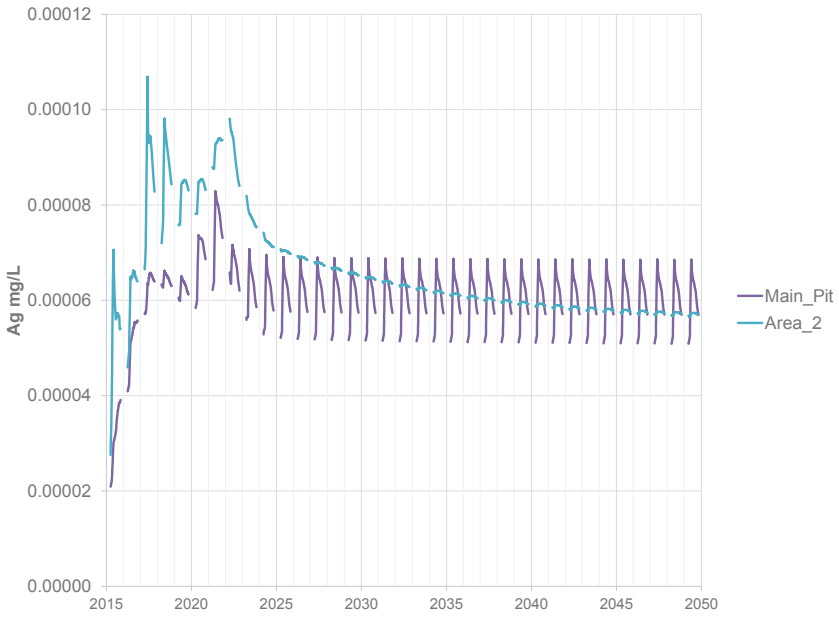
| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.000121 | 0.72 | 0.997 | 0.00653 | 0.000136 | 0.00502 | 0.0355 | 2.05 | 1.61 | 0.0438 | 0.0082 | 4.34 | 0.153 | 0.00242 | 0.00574 | 475 | 0.0123 |
| May | 0.0000876 | 0.59 | 1.2 | 0.0046 | 0.000221 | 0.00347 | 0.0524 | 1.09 | 0.875 | 0.0338 | 0.00532 | 5.17 | 0.186 | 0.0019 | 0.00665 | 278 | 0.02 |
| June | 0.0000894 | 0.6 | 0.902 | 0.0047 | 0.000156 | 0.00353 | 0.0372 | 1.12 | 0.89 | 0.0311 | 0.00503 | 3.87 | 0.142 | 0.00195 | 0.00522 | 225 | 0.015 |
| July | 0.0000895 | 0.58 | 0.652 | 0.00475 | 0.000105 | 0.00357 | 0.0262 | 1.27 | 1 | 0.0292 | 0.00529 | 2.8 | 0.103 | 0.00192 | 0.00472 | 222 | 0.0105 |
| August | 0.0000893 | 0.554 | 0.731 | 0.00476 | 0.00011 | 0.00356 | 0.0263 | 1.44 | 1.09 | 0.0295 | 0.0054 | 3.18 | 0.115 | 0.00187 | 0.0049 | 231 | 0.0104 |
| September | 0.0000865 | 0.529 | 0.785 | 0.00464 | 0.000107 | 0.00356 | 0.0229 | 1.44 | 1.06 | 0.0299 | 0.00535 | 3.43 | 0.123 | 0.00181 | 0.00488 | 237 | 0.00926 |
| October | 0.0000833 | 0.51 | 0.851 | 0.00448 | 0.0000851 | 0.00348 | 0.0191 | 1.37 | 0.982 | 0.0295 | 0.00517 | 3.72 | 0.134 | 0.00176 | 0.00457 | 240 | 0.00739 |

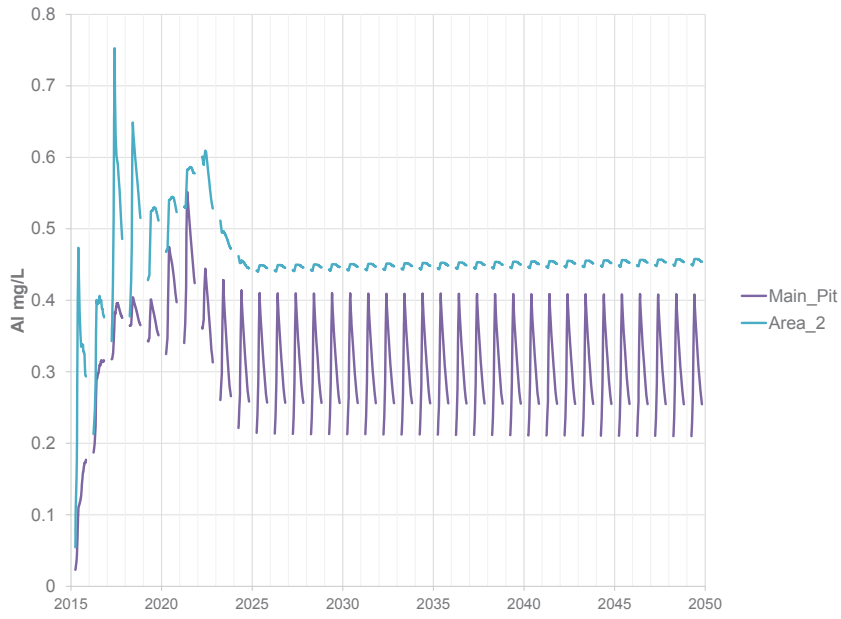
**Scenario 5 - W1 2045 Monthly Water Quality Results**

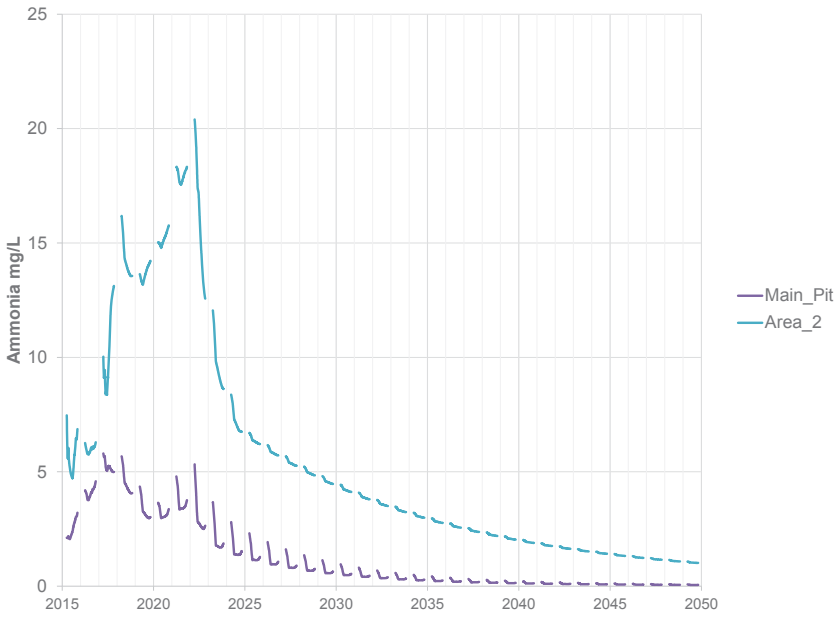
| | Ag-Dissolved | Al-Dissolved | Ammonia | As-Dissolved | Cd-Dissolved | Cr-Dissolved | Cu-Dissolved | Fe-Dissolved | Mn-Dissolved | Mo-Dissolved | Ni-Dissolved | Nitrate | Nitrite | Pb-Dissolved | Se-Dissolved | Sulphate | Zn-Dissolved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April | 0.0000368 | 0.207 | 0.318 | 0.00185 | 0.0000577 | 0.0017 | 0.0121 | 0.616 | 0.431 | 0.0118 | 0.00267 | 1.36 | 0.0573 | 0.000683 | 0.00166 | 125 | 0.00616 |
| May | 0.0000295 | 0.186 | 0.363 | 0.00147 | 0.0000738 | 0.00125 | 0.0162 | 0.536 | 0.29 | 0.00906 | 0.00229 | 1.39 | 0.0523 | 0.000584 | 0.00182 | 92.1 | 0.00824 |
| June | 0.0000276 | 0.169 | 0.334 | 0.00152 | 0.000055 | 0.00129 | 0.0111 | 0.433 | 0.263 | 0.00887 | 0.00222 | 1.29 | 0.0553 | 0.000546 | 0.00164 | 69.9 | 0.00683 |
| July | 0.0000277 | 0.151 | 0.242 | 0.00158 | 0.0000372 | 0.00129 | 0.00783 | 0.536 | 0.287 | 0.00788 | 0.00226 | 0.959 | 0.0387 | 0.000536 | 0.00132 | 58.3 | 0.00499 |
| August | 0.0000346 | 0.149 | 0.261 | 0.00163 | 0.0000368 | 0.00134 | 0.00816 | 0.614 | 0.328 | 0.00815 | 0.00238 | 1.09 | 0.0423 | 0.000561 | 0.0014 | 65.4 | 0.00498 |
| September | 0.0000293 | 0.152 | 0.291 | 0.00163 | 0.0000404 | 0.00154 | 0.00742 | 0.636 | 0.331 | 0.00865 | 0.00257 | 1.2 | 0.0448 | 0.000614 | 0.00152 | 71.6 | 0.00455 |
| October | 0.0000304 | 0.158 | 0.446 | 0.00167 | 0.0000391 | 0.00135 | 0.00715 | 0.596 | 0.349 | 0.0101 | 0.00231 | 1.84 | 0.0777 | 0.000575 | 0.00166 | 84.3 | 0.00403 |

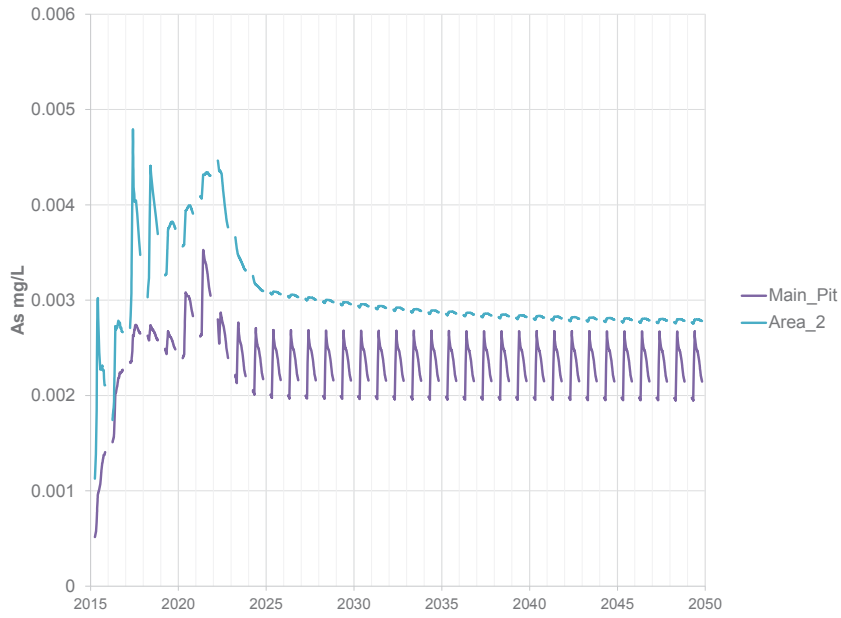
Notes:
All concentration reported in mg/L

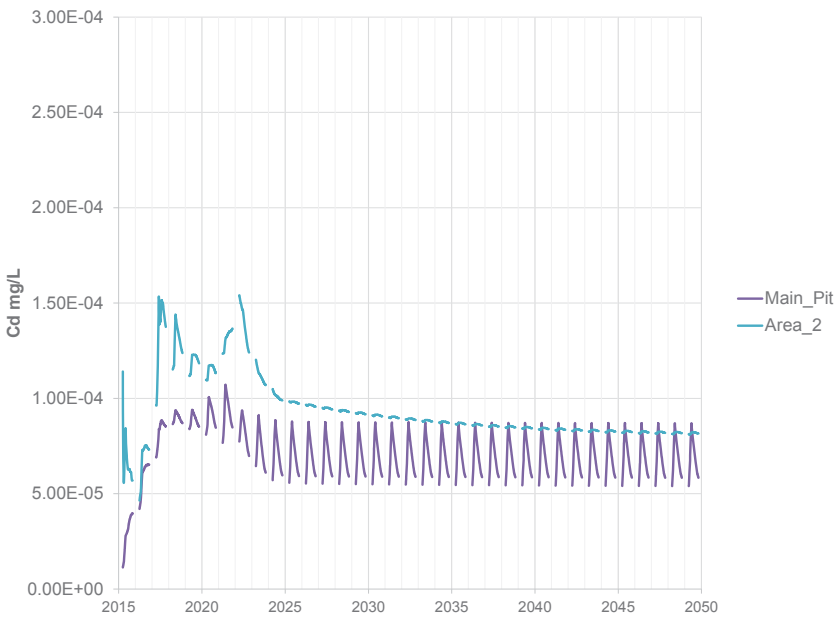
# Appendix A2: Water and Load Balance Results Plots

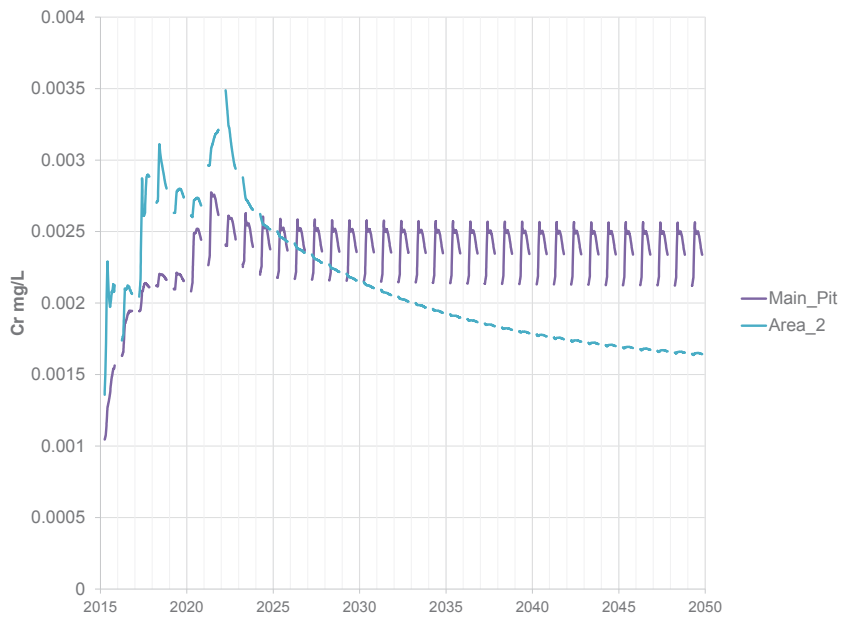


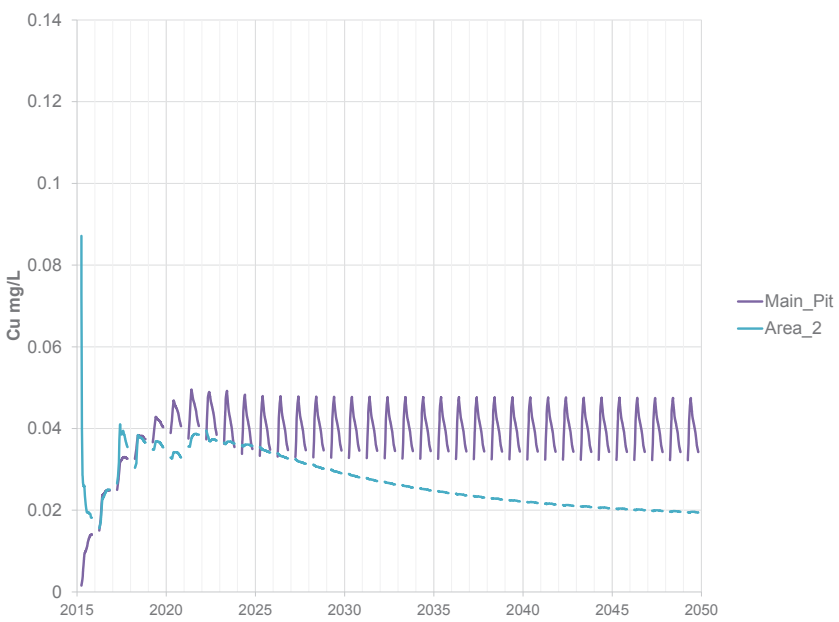



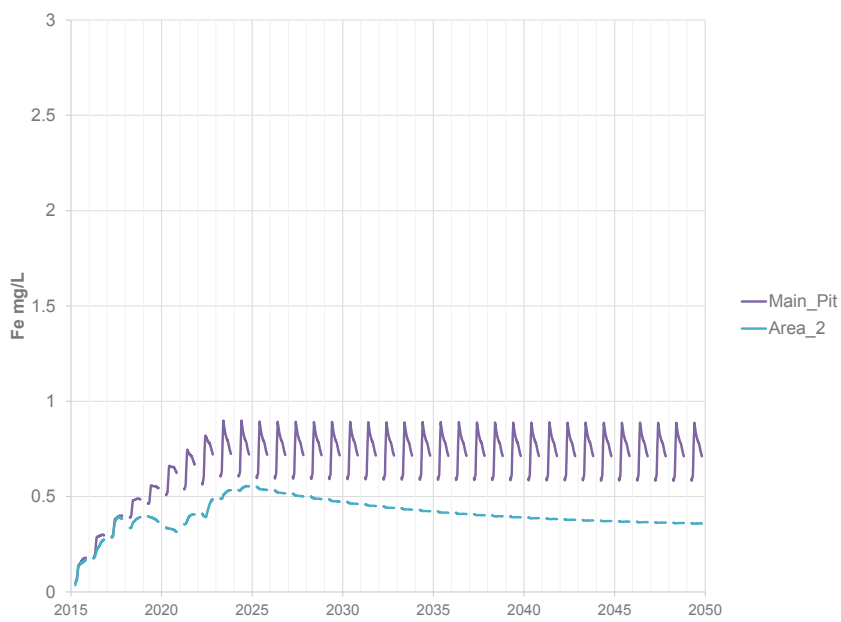

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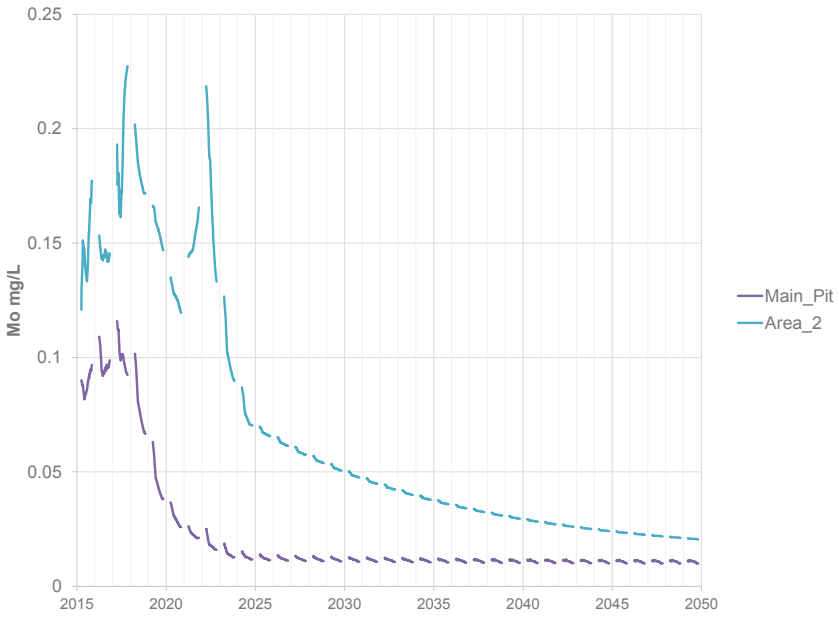


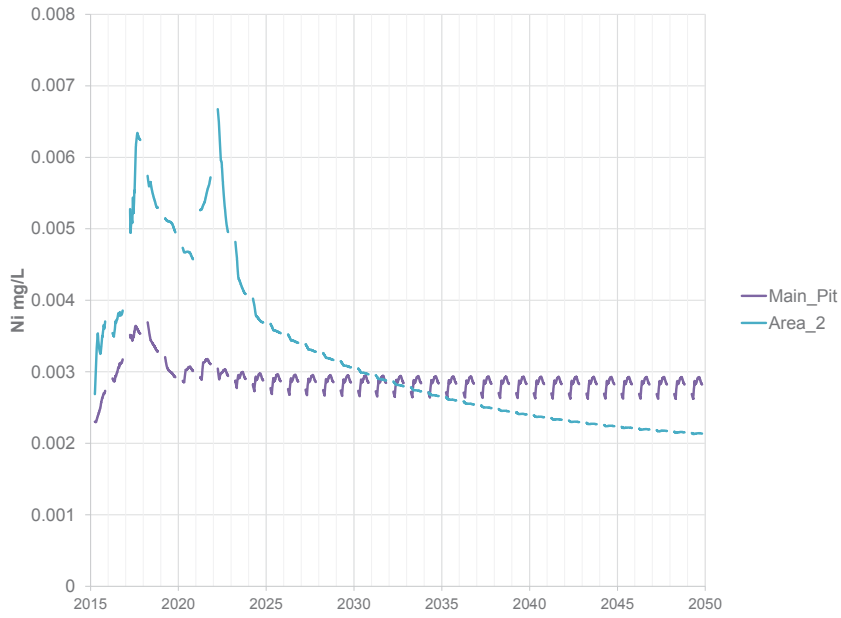


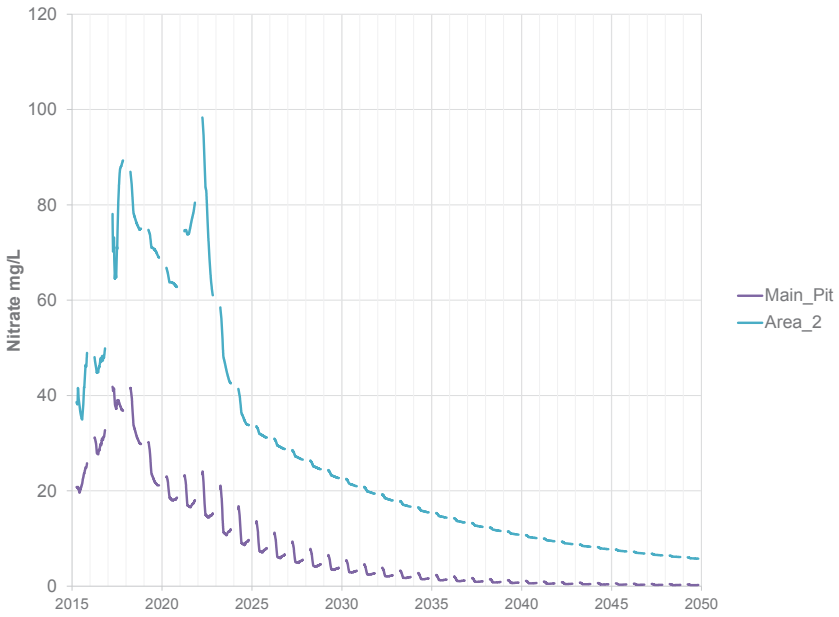


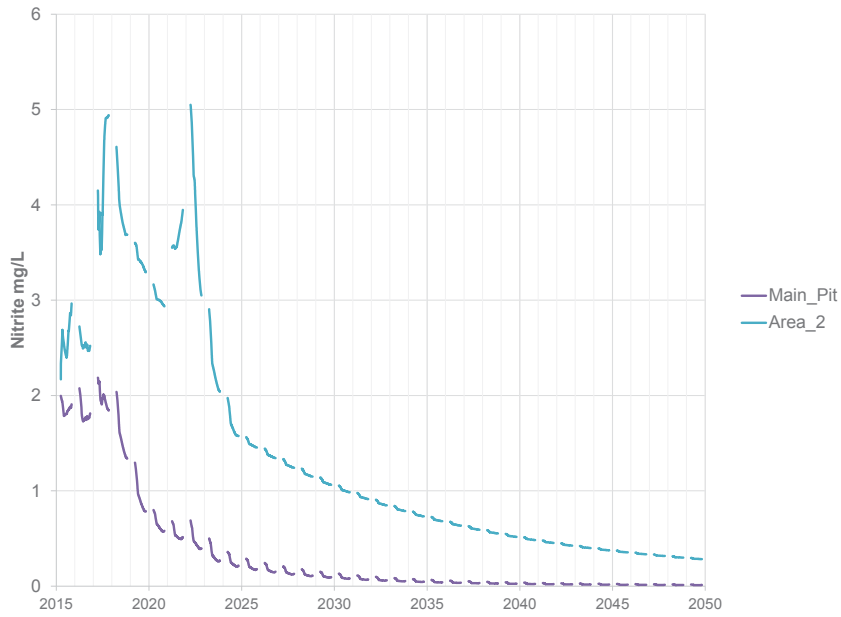


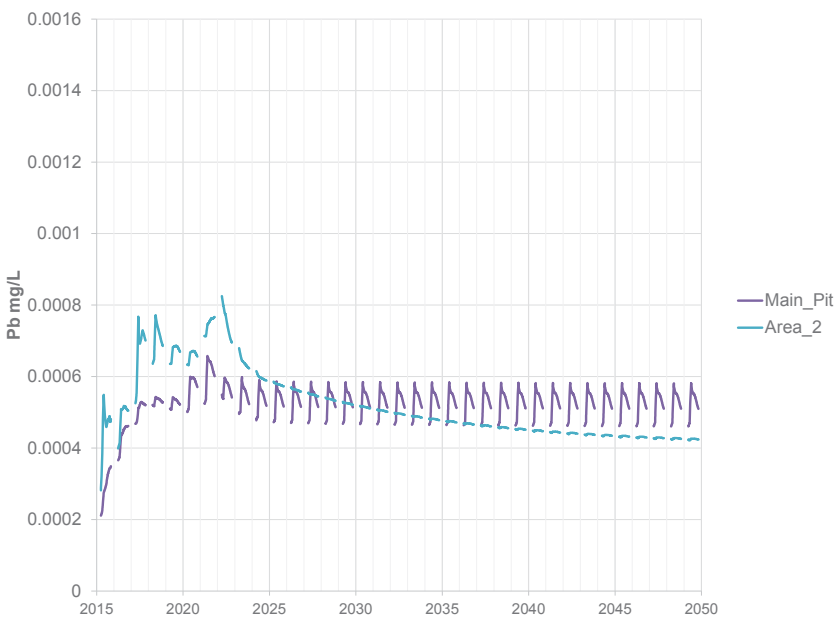


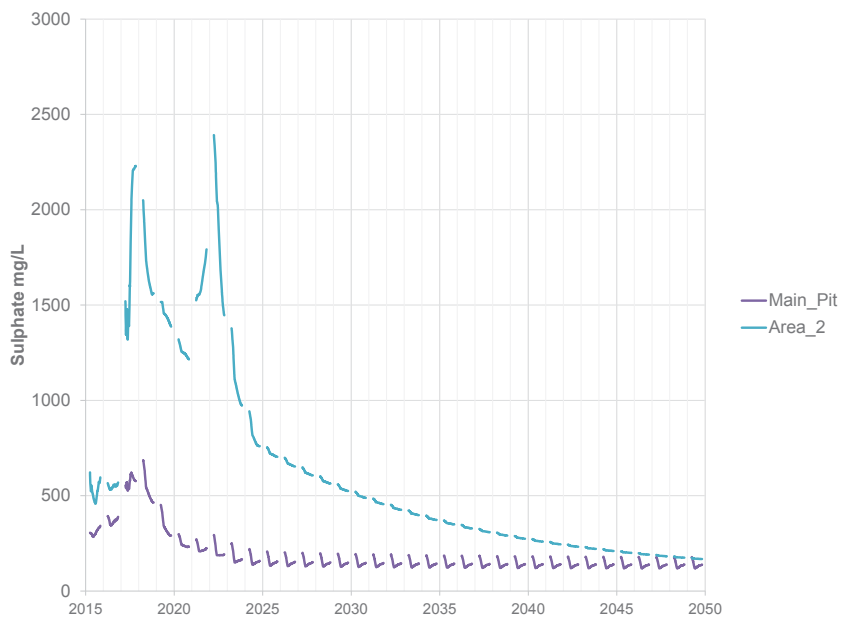


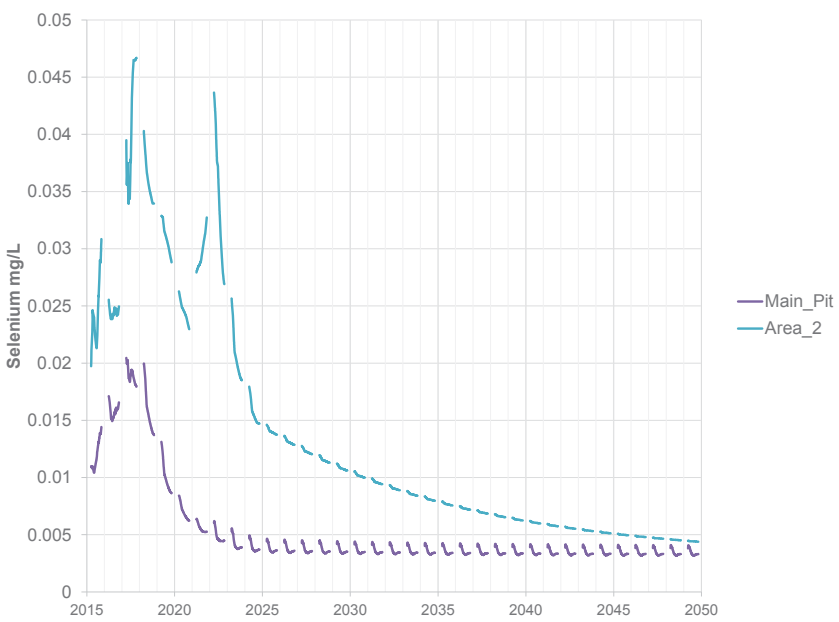


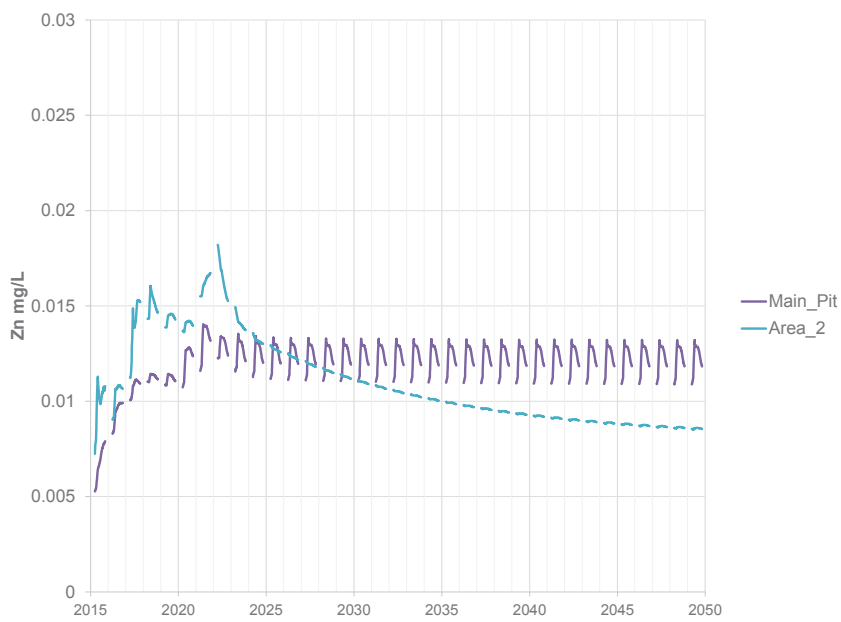


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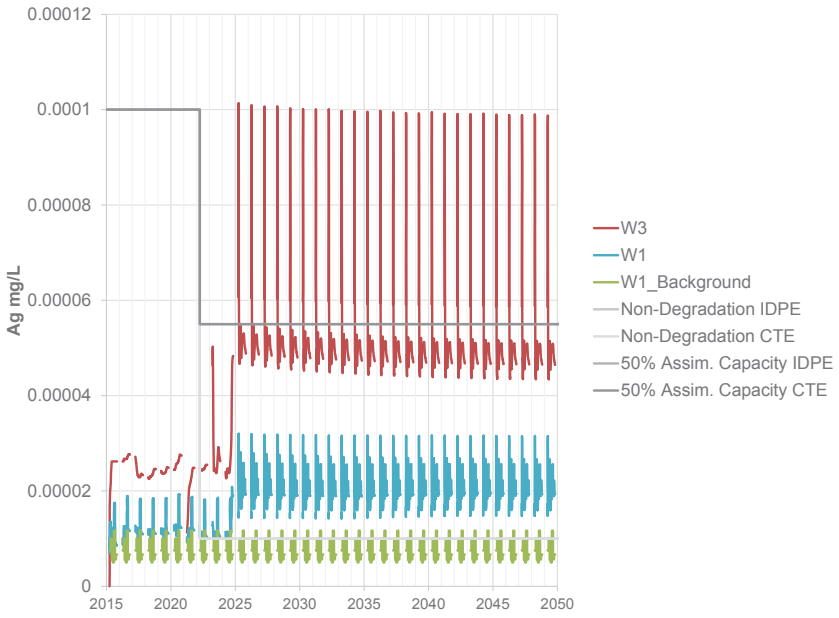


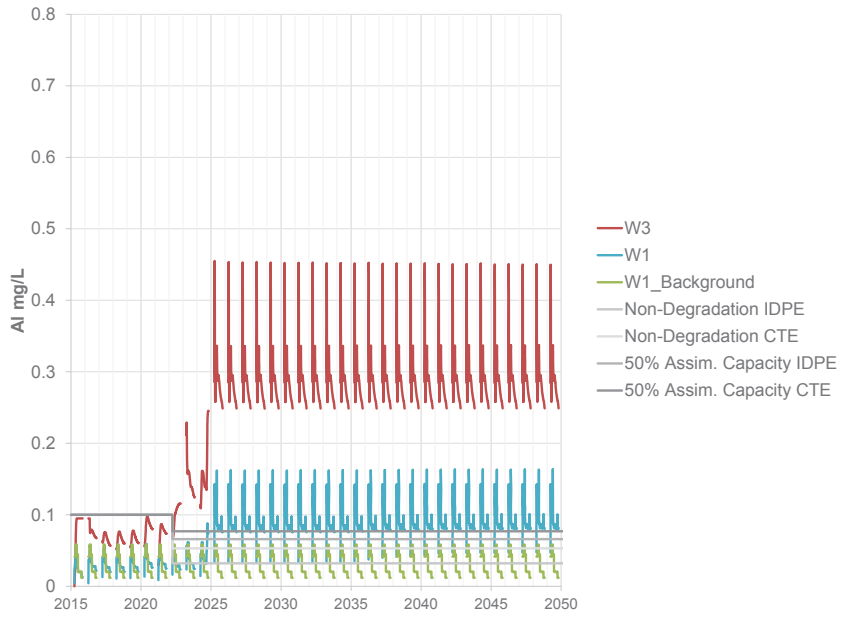


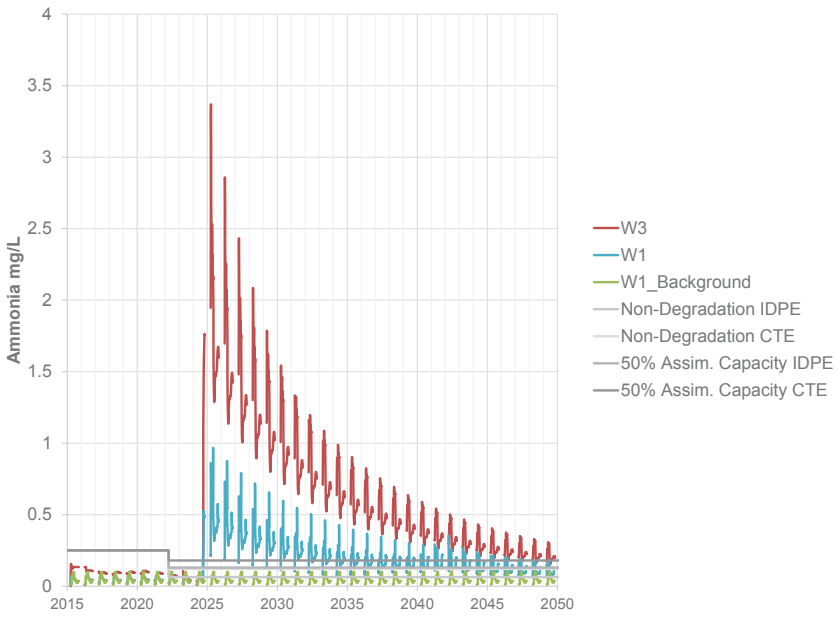


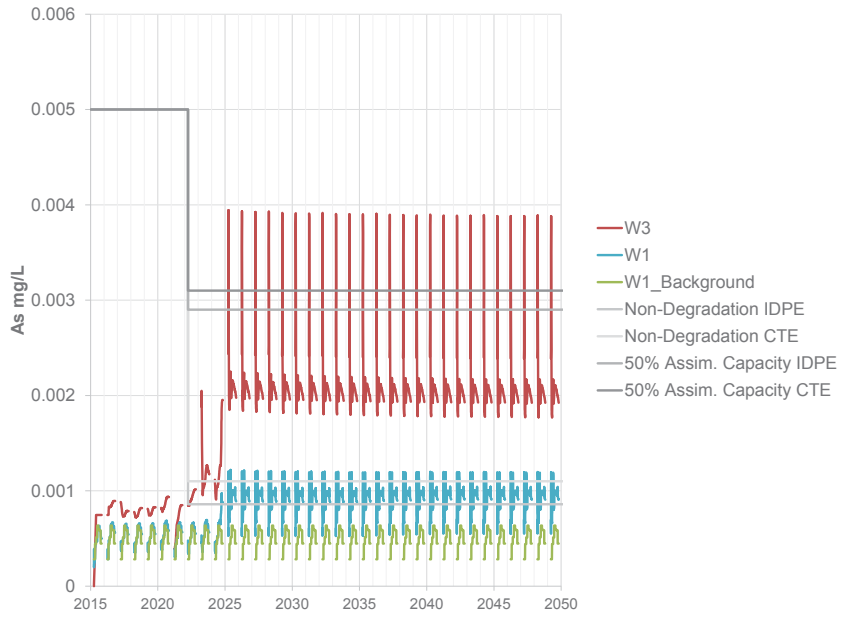


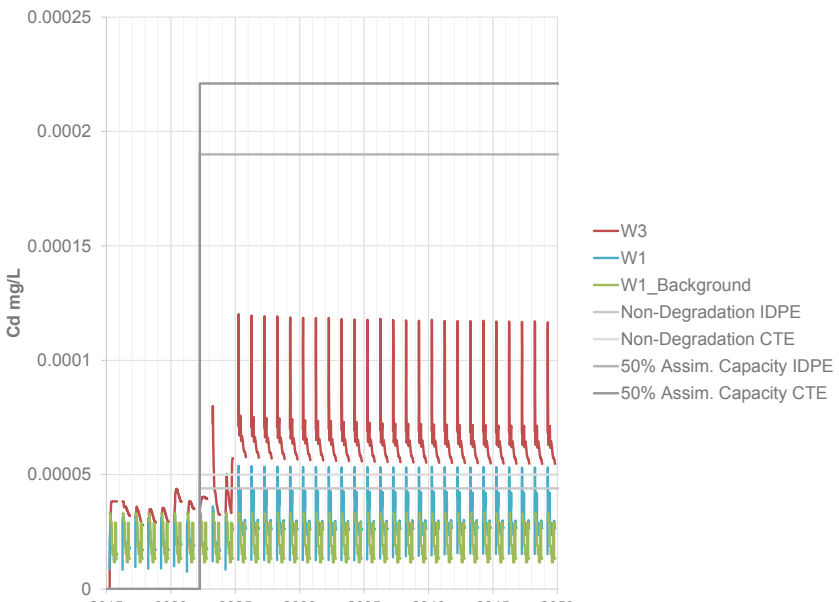


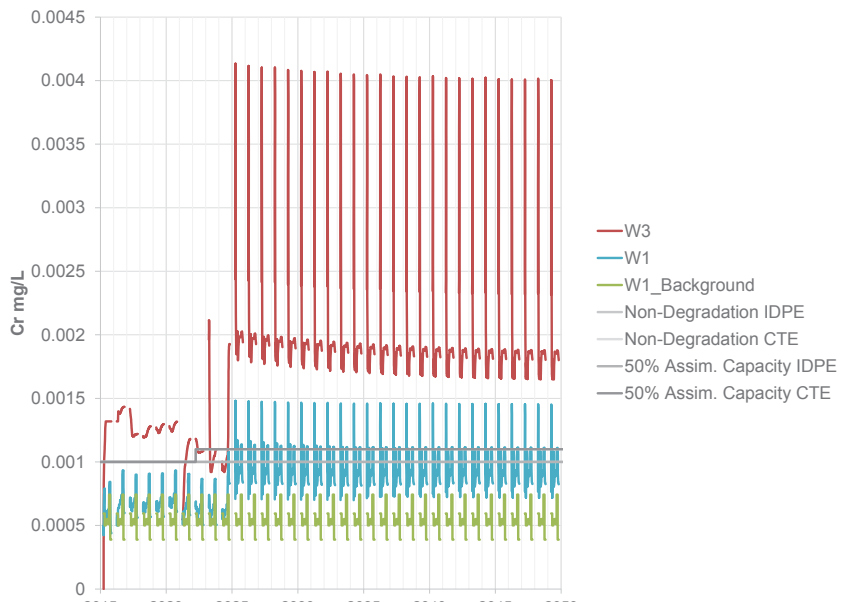


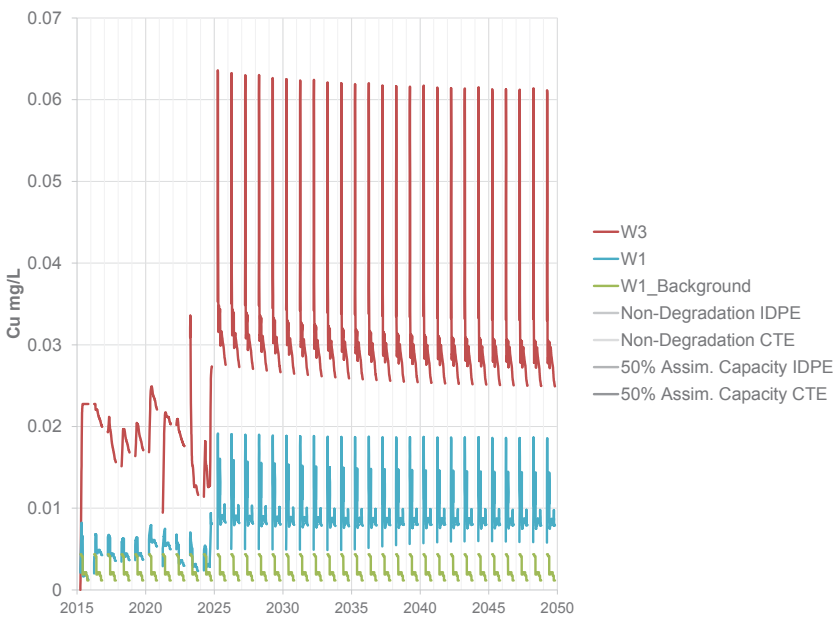


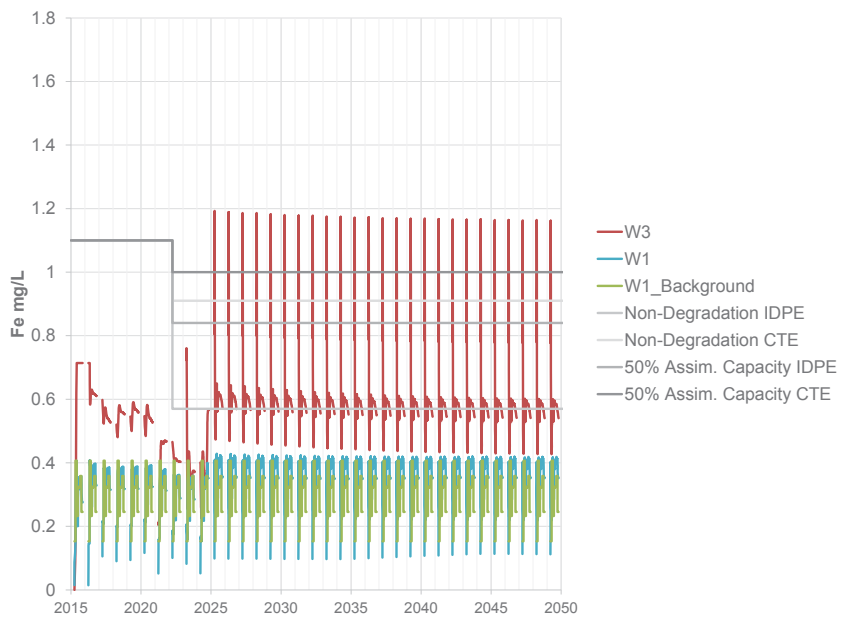


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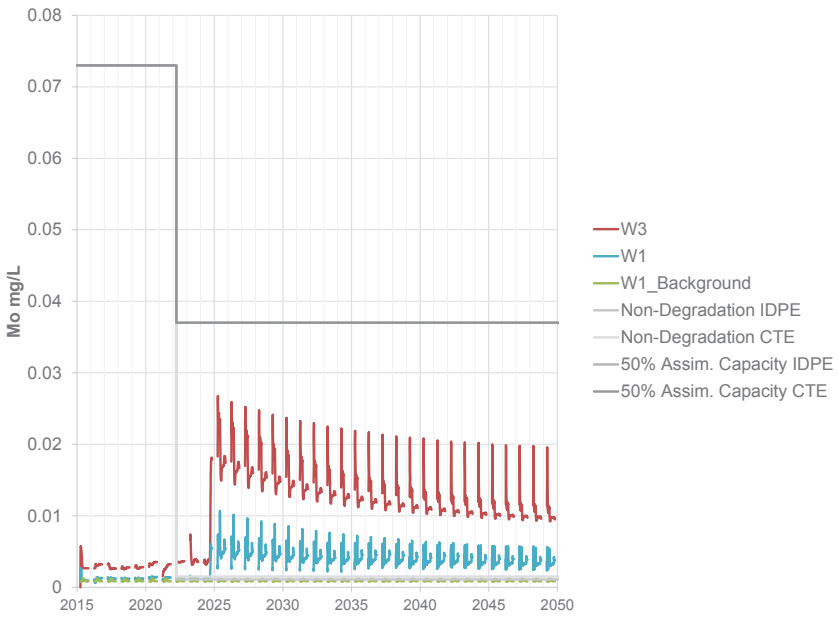


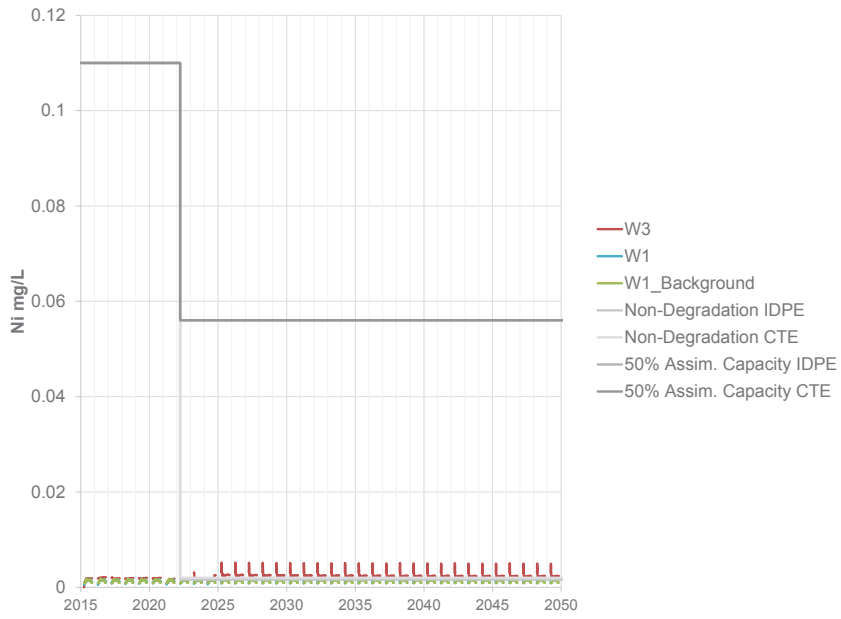


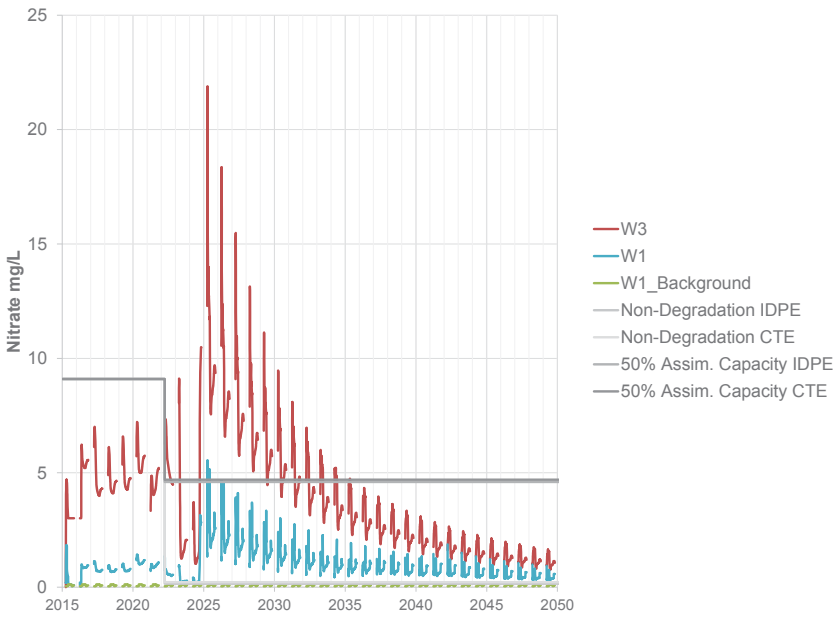


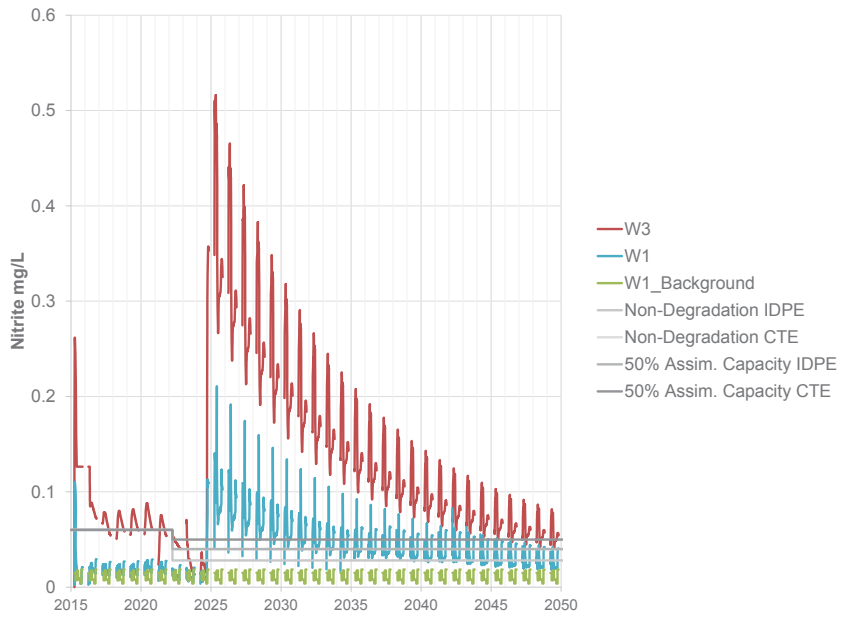


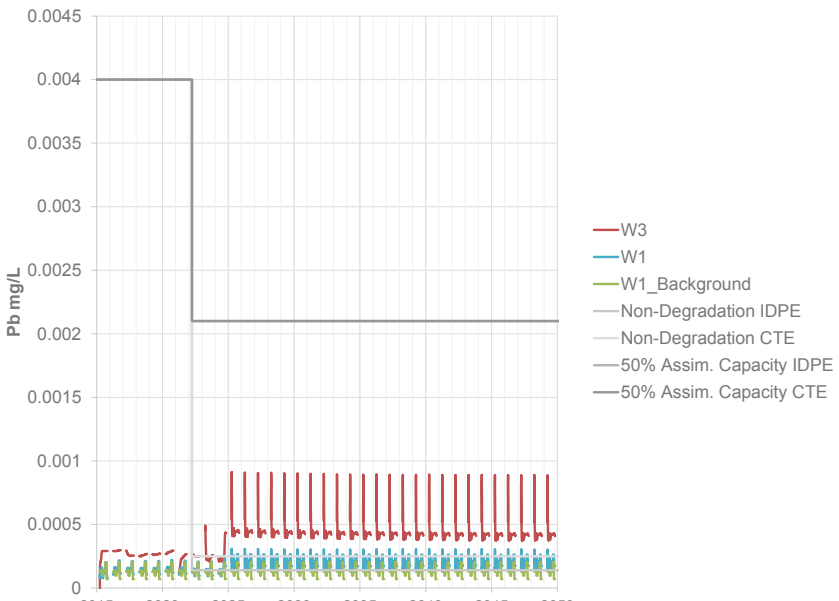


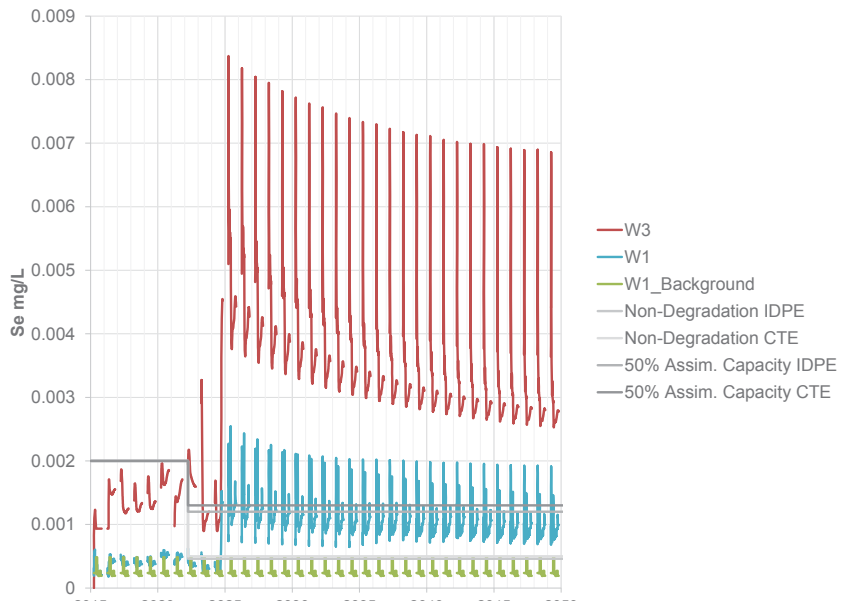


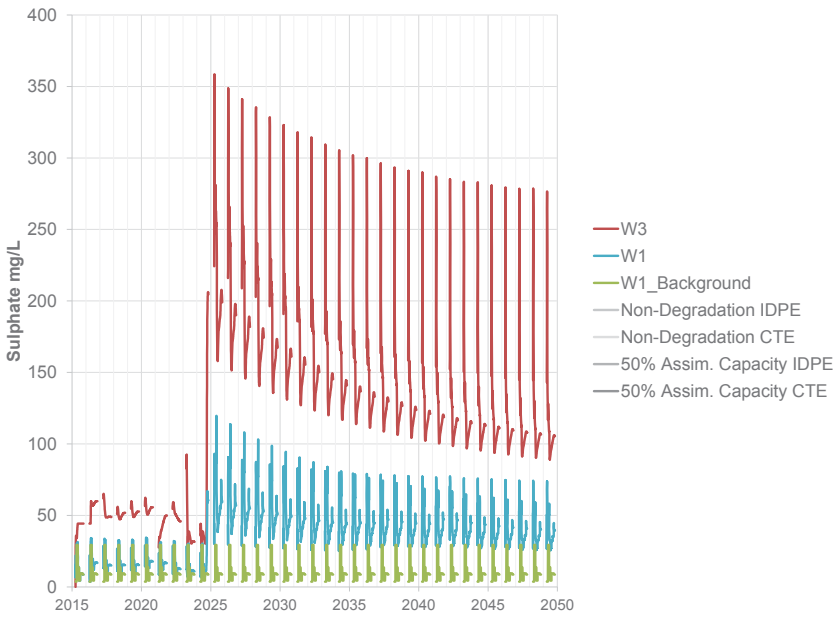


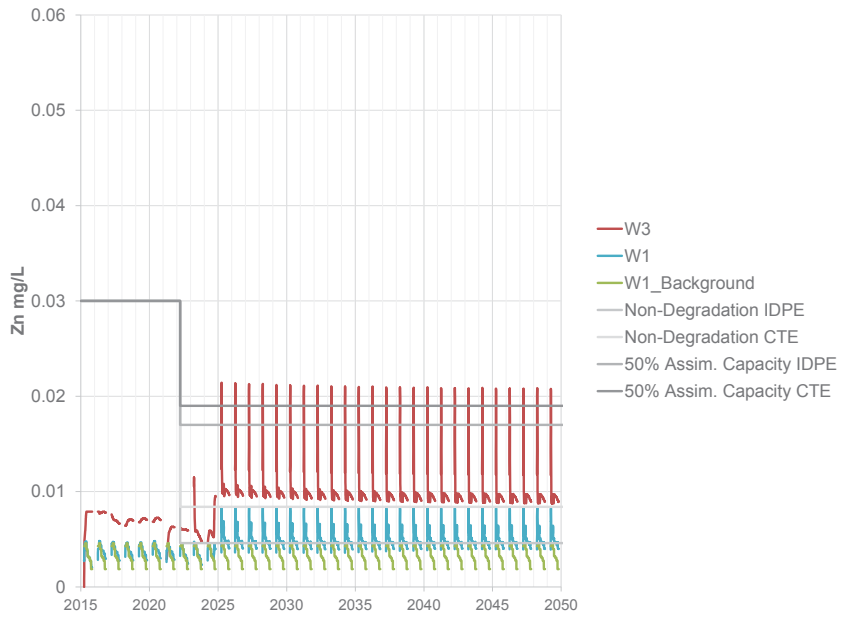


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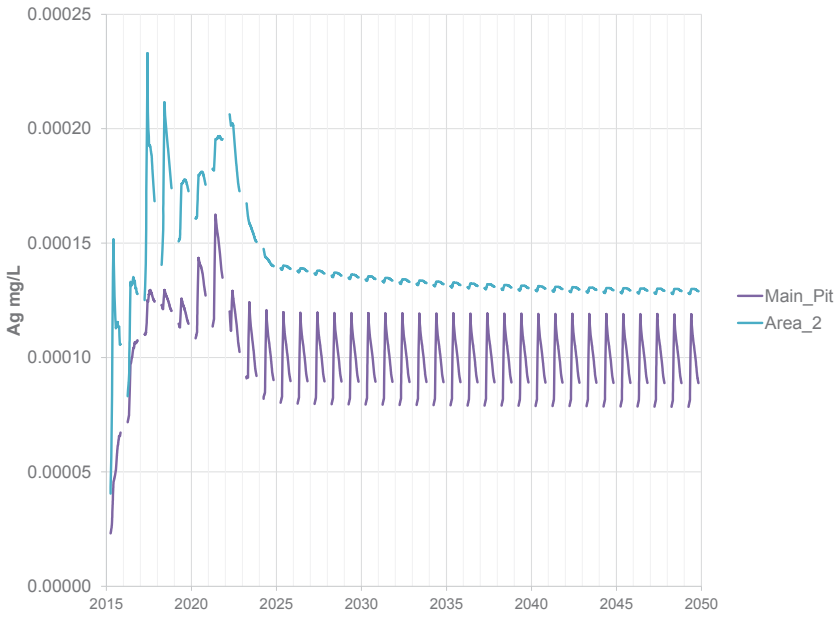
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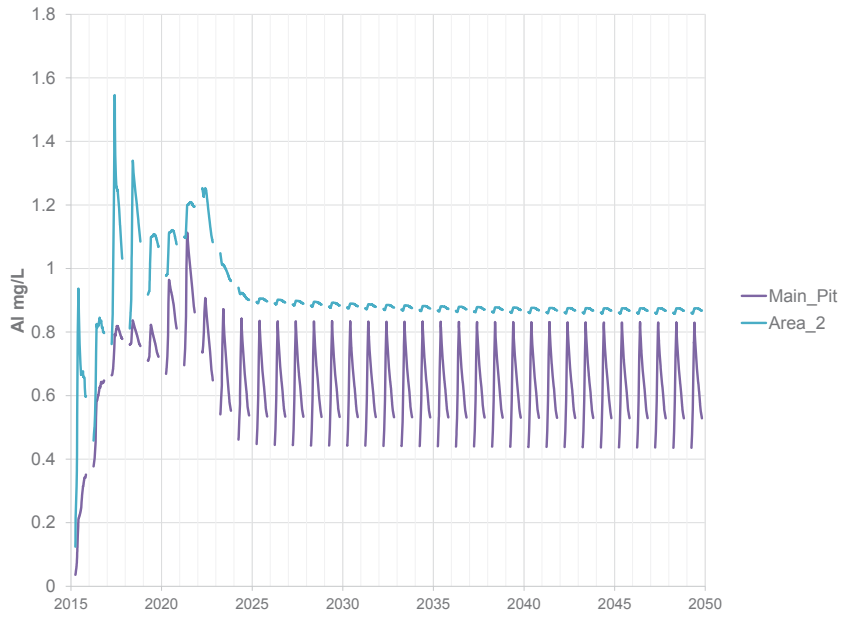
0.00020
0.00015
0.00010
0.00005
0.00000
2015
2020
2025
2030
2035
2040
2045
2050
Main_Pit
Area_2


Al mg/L
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
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2015
2020
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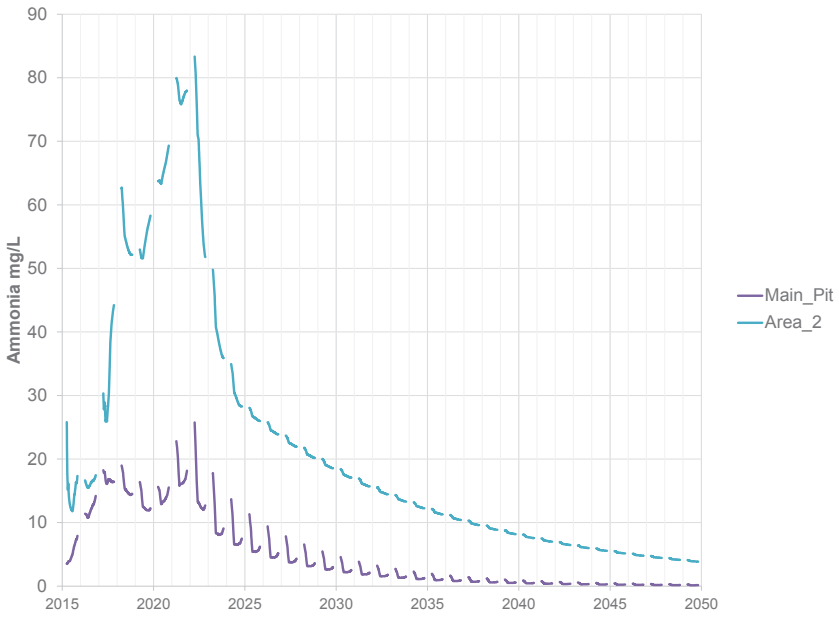
Ammonia mg/L
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80
70
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0
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2020
2025
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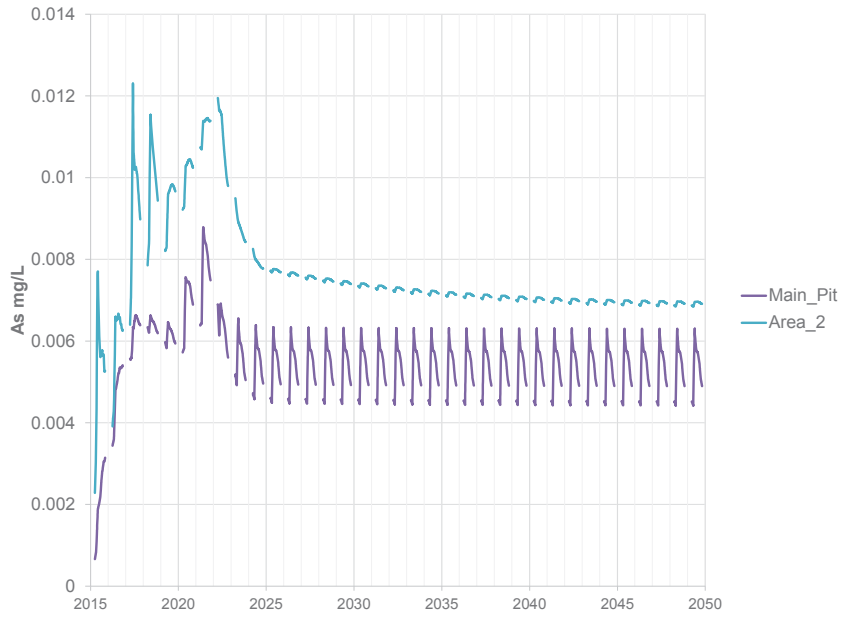
2050
Main_Pit
Area_2


As mg/L
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0.012
0.01
0.008
0.006
0.004
0.002
0
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2025
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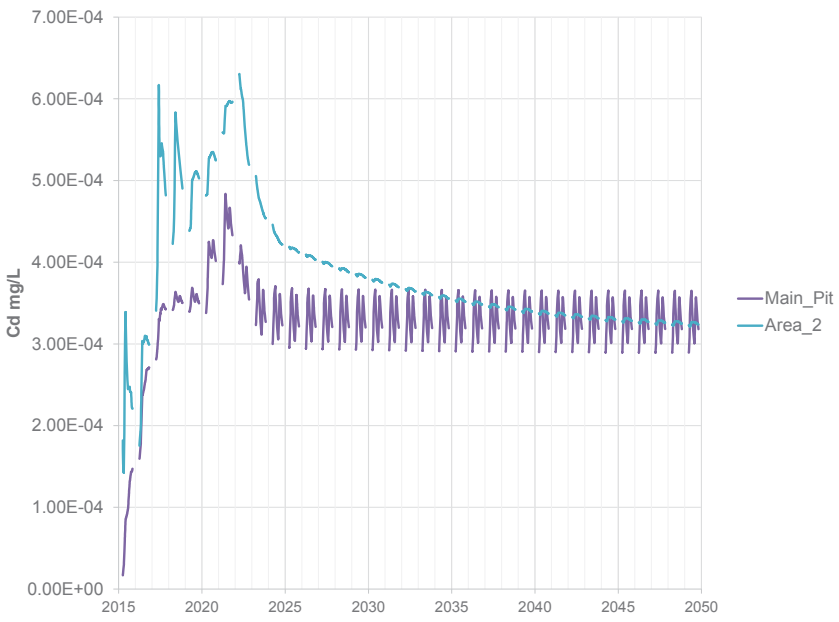
Main_Pit
Area_2


Cd mg/L
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6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
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0.00E+00
2015
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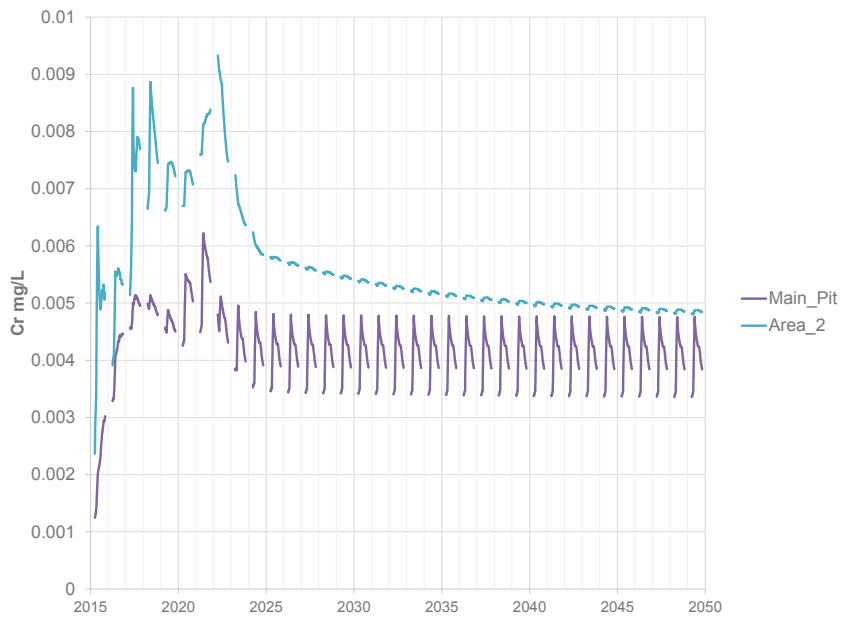
Cr mg/L
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0.008
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0.006
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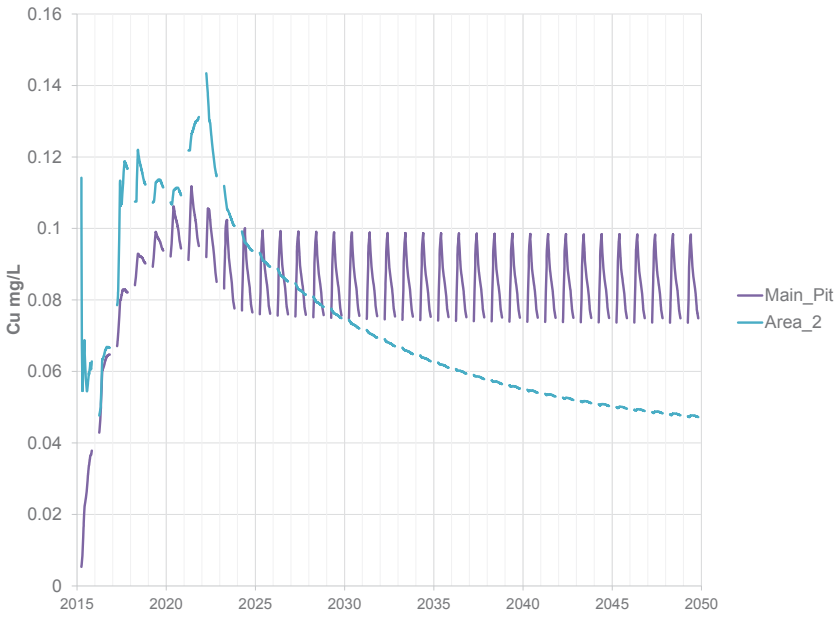
Cu mg/L
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0.14
0.12
0.1
0.08
0.06
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0.02
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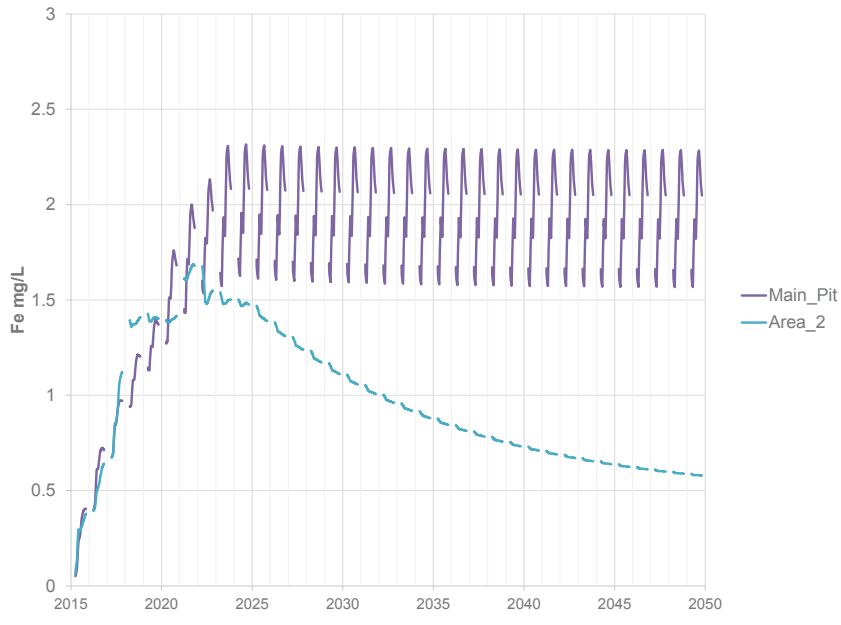
Fe mg/L
3
2.5
2
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2020
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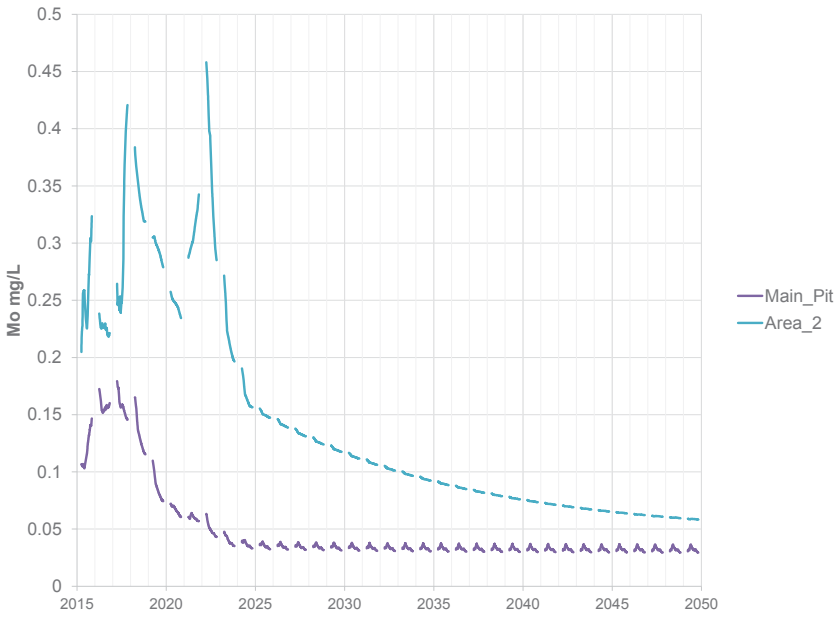
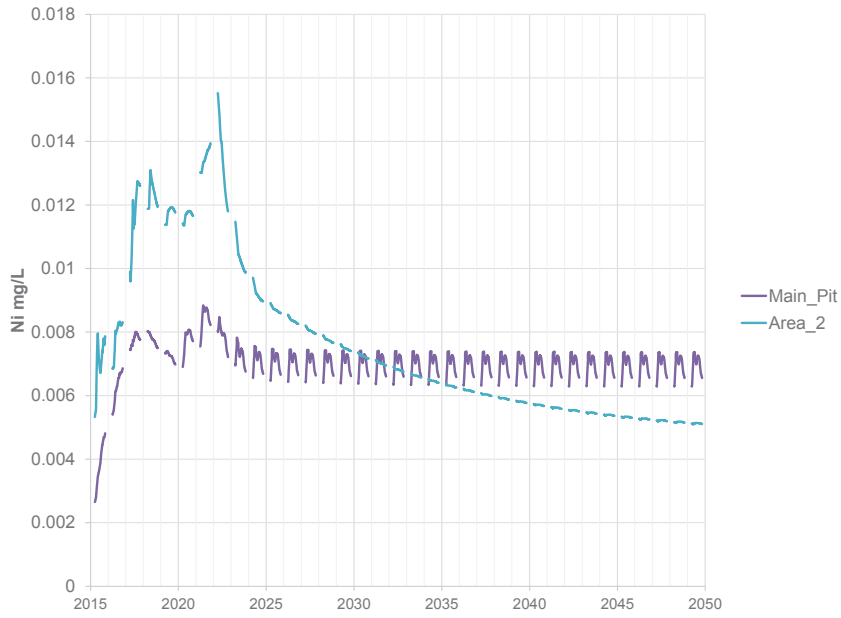
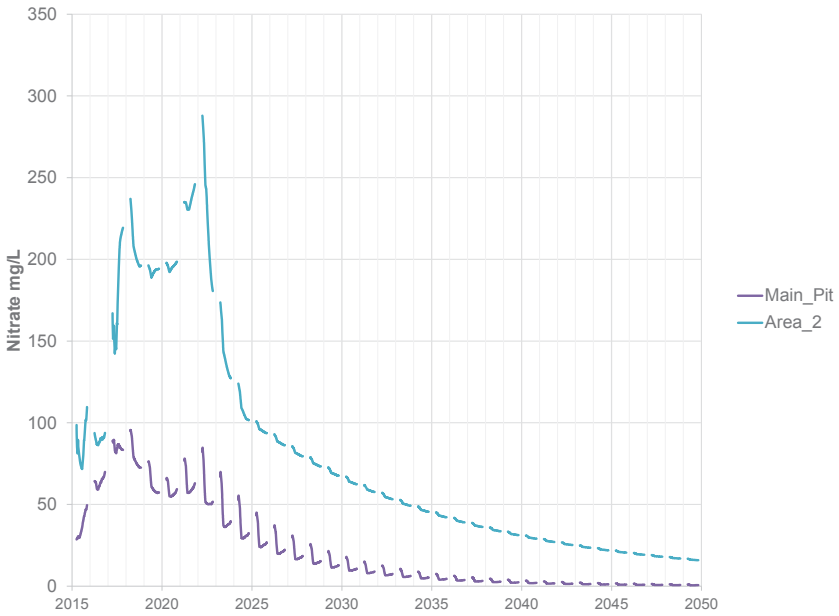
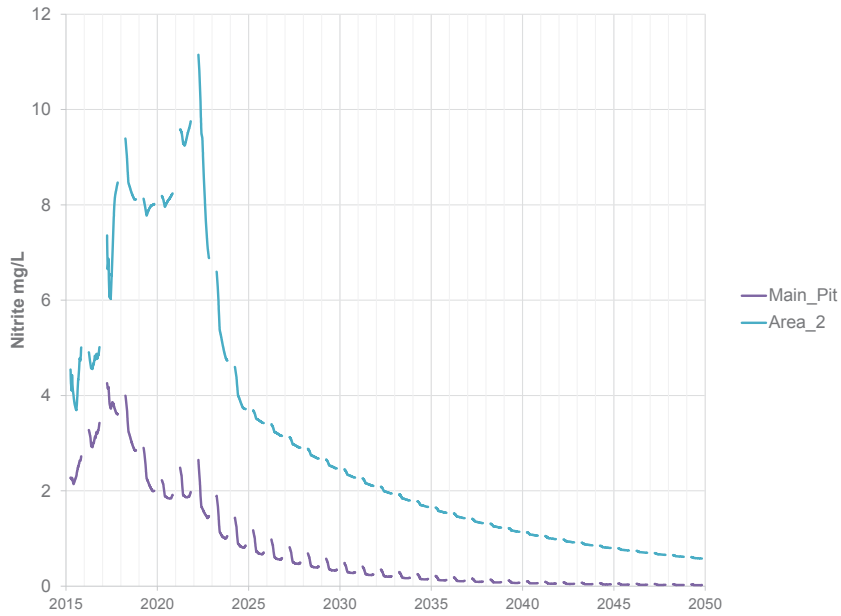
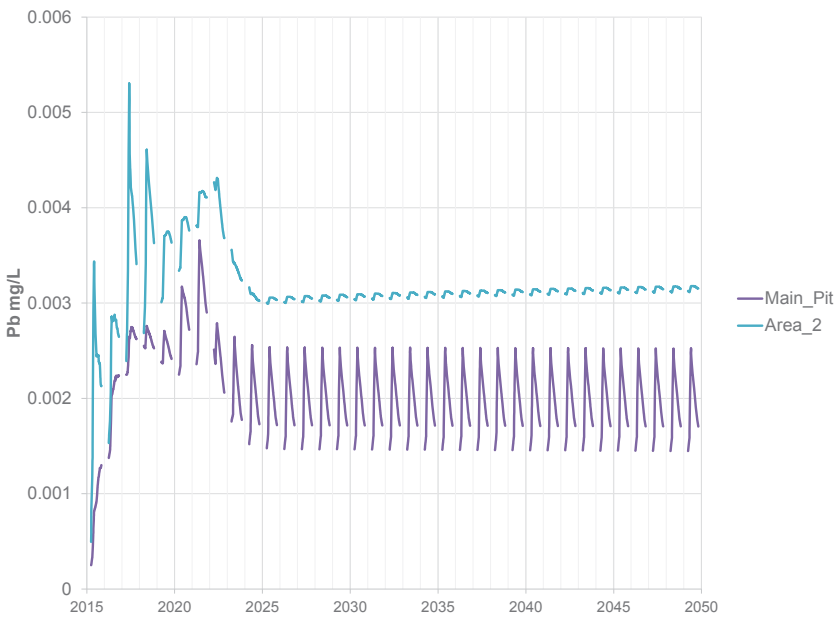
Main_Pit
Area_2

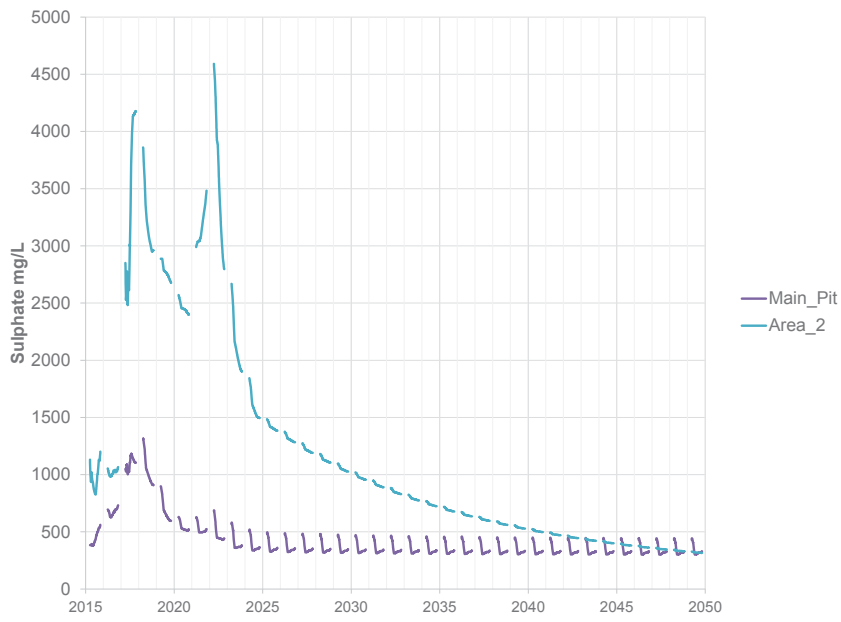


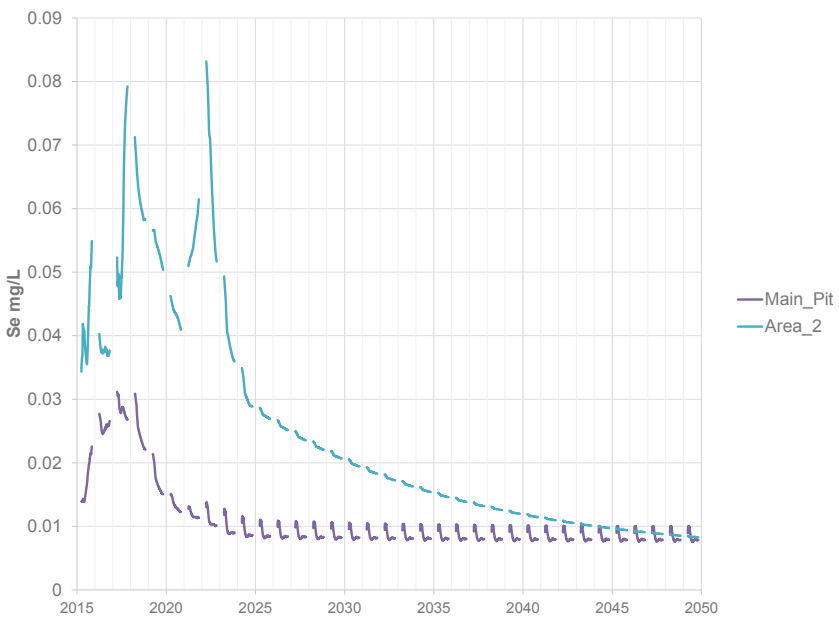



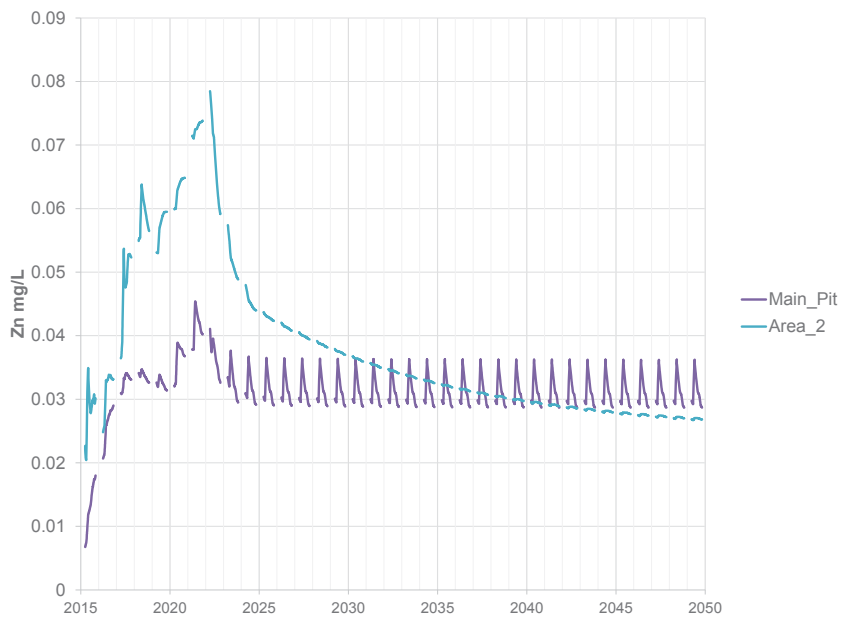

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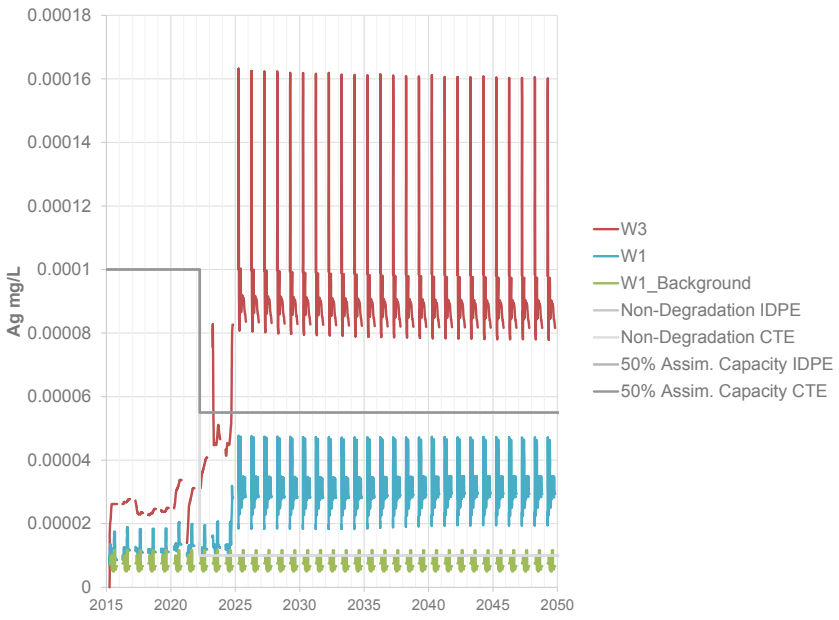


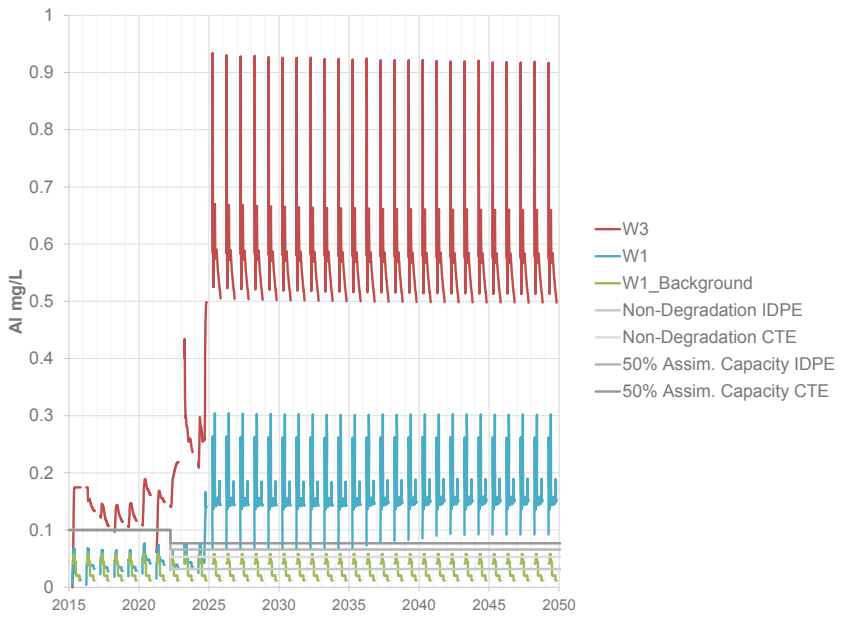


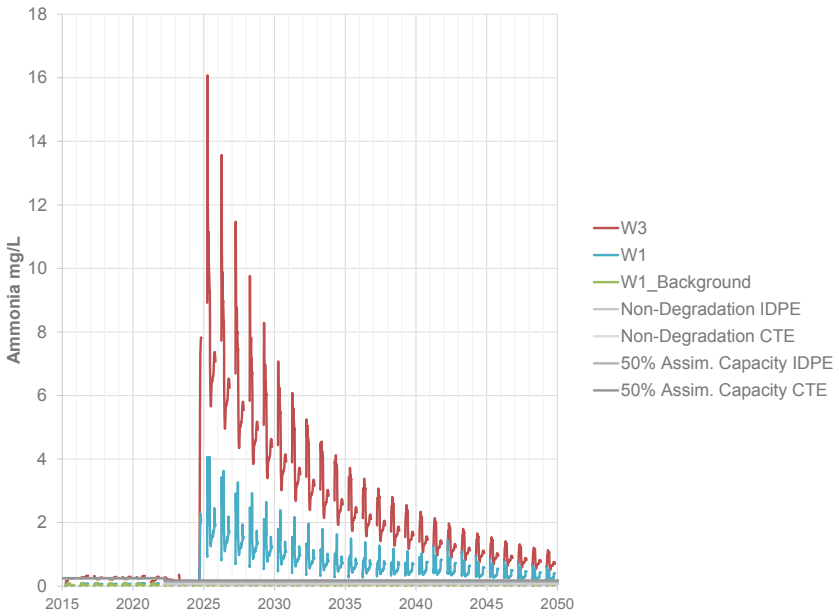


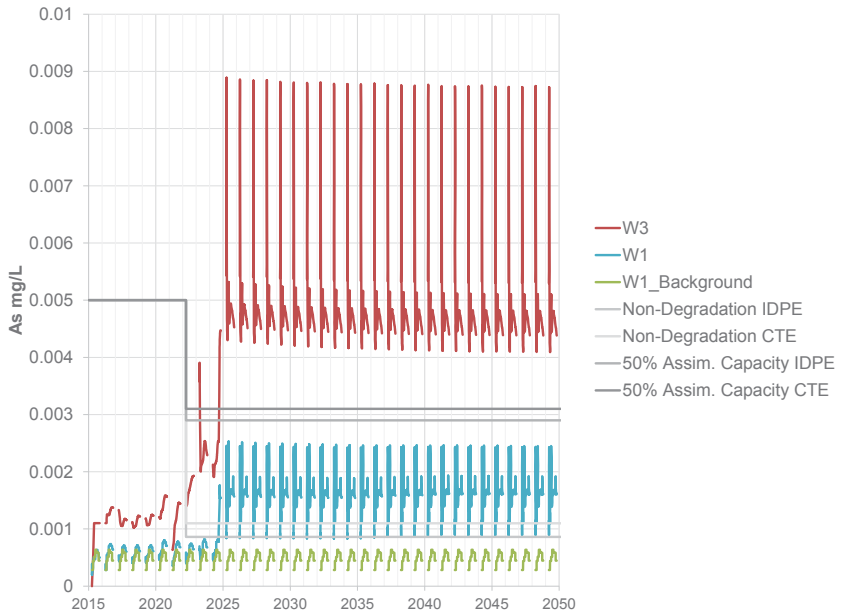


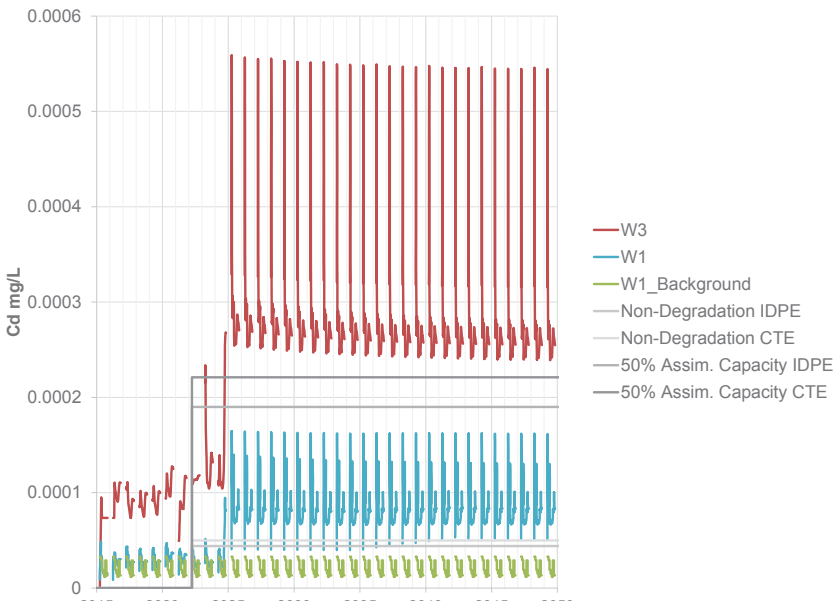


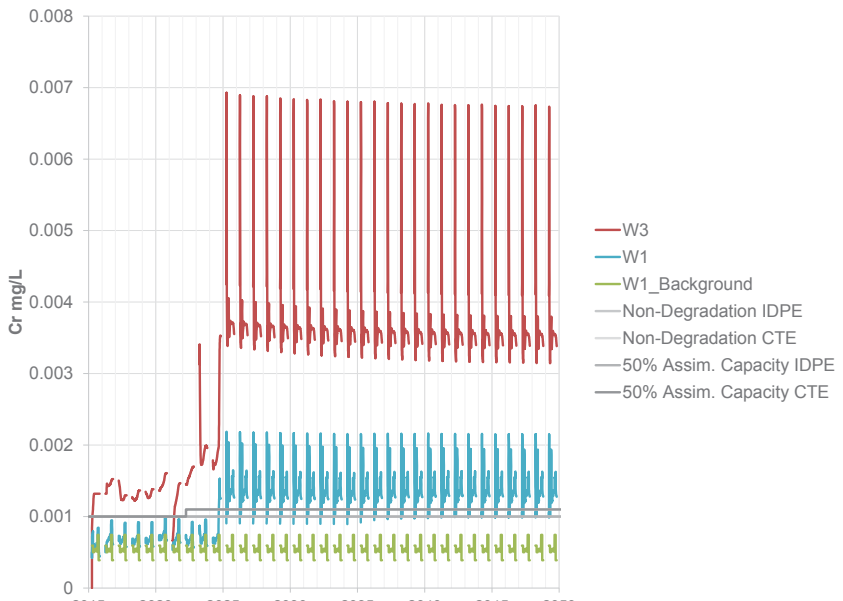


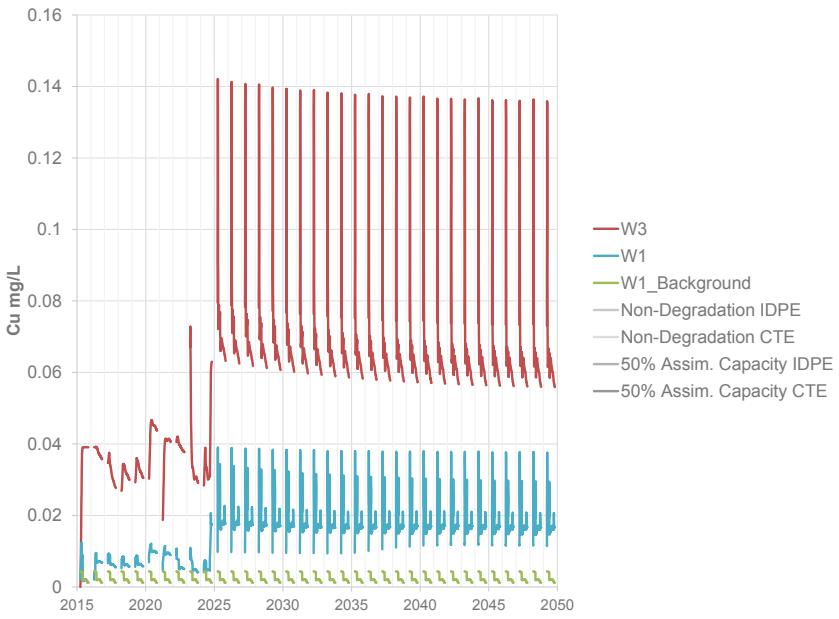


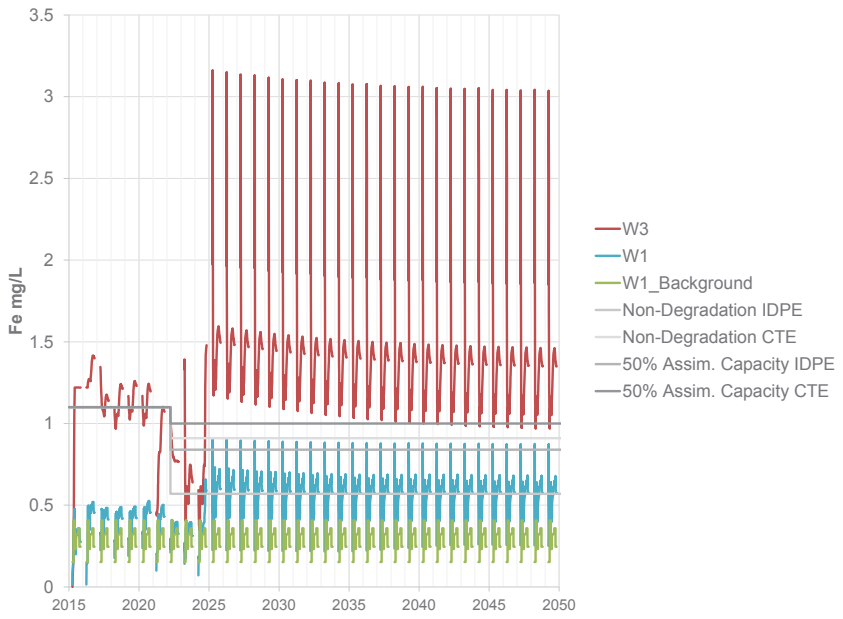


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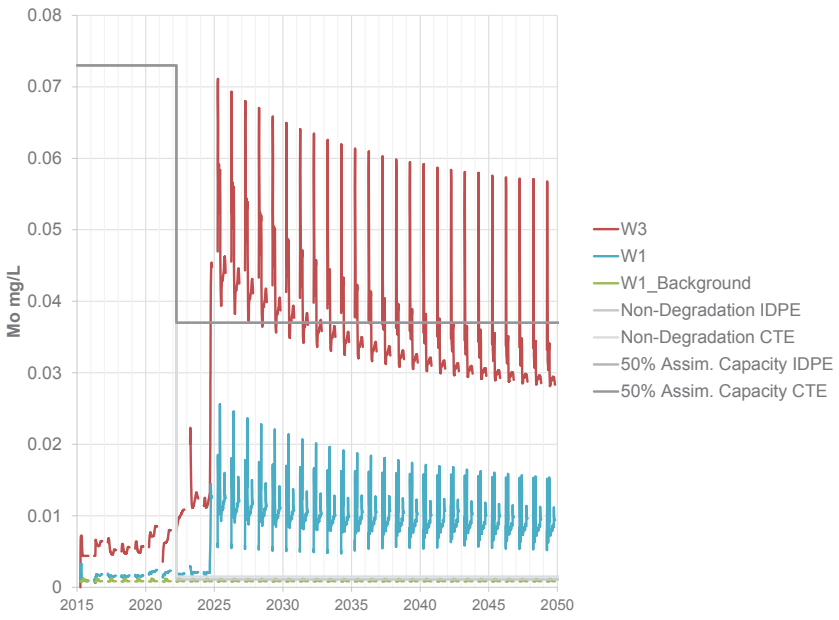
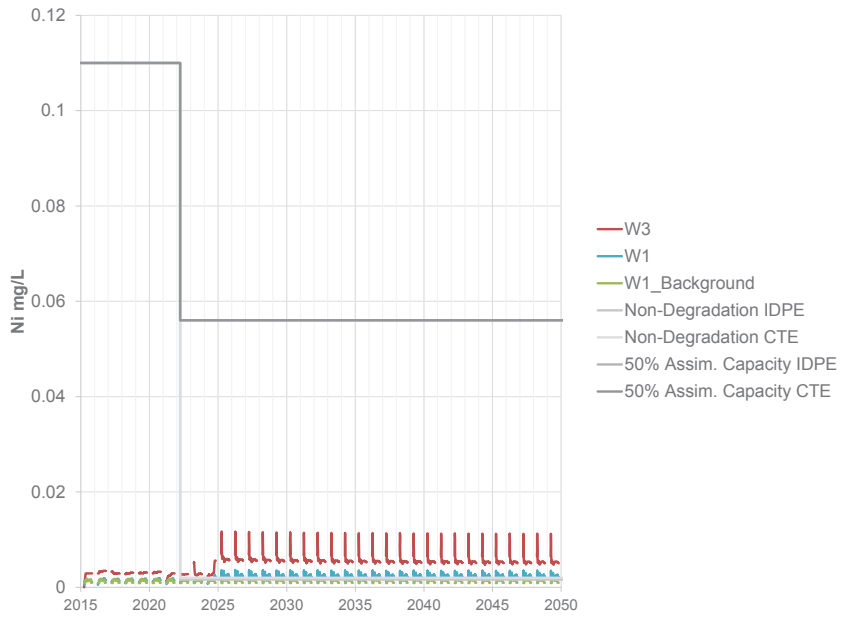
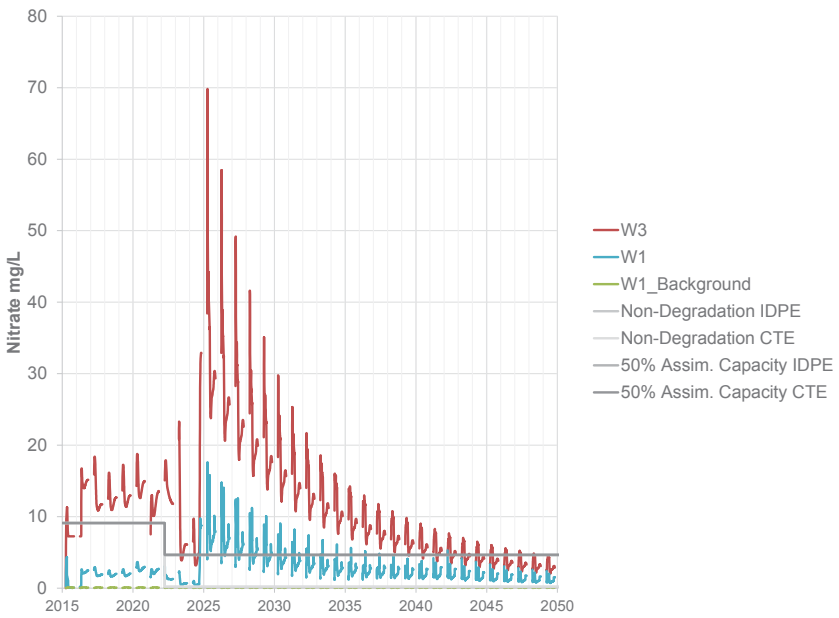
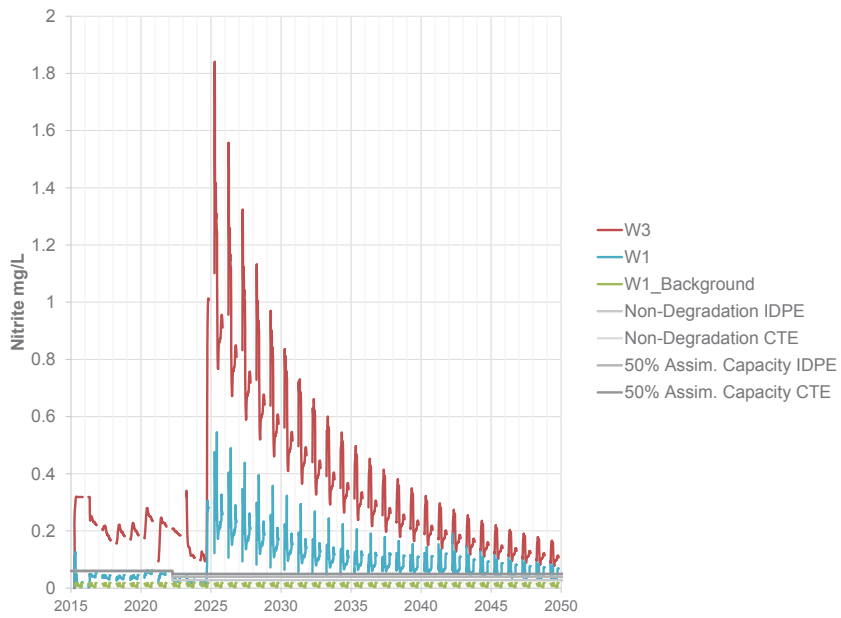
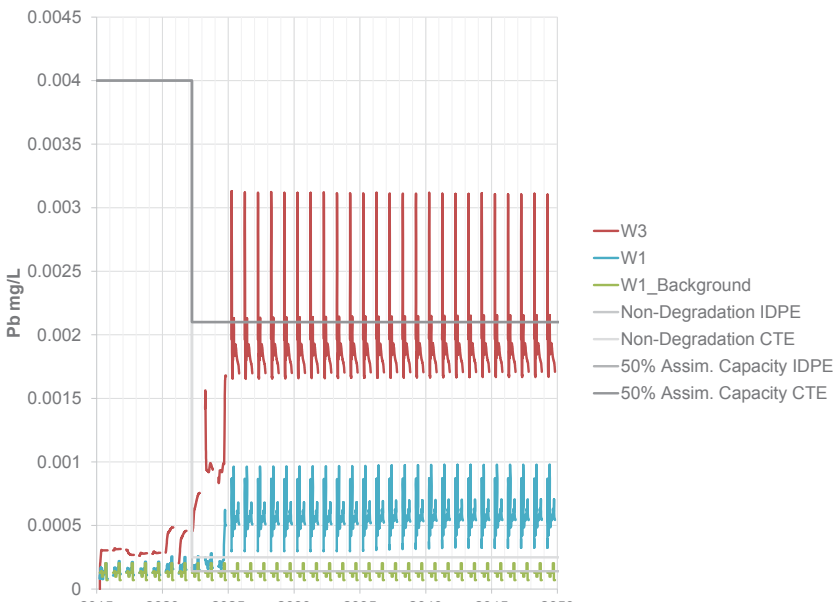

Mo mg/L
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2015
2020
2025
2030
2035
2040
2045
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Ni mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
2015
2020
2025
2030
2035
2040
2045
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Nitrate mg/L
80
70
60
50
40
30
20
10
0
2015
2020
2025
2030
2035
2040
2045
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Nitrite mg/L
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2015
2020
2025
2030
2035
2040
2045
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Pb mg/L
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
2015
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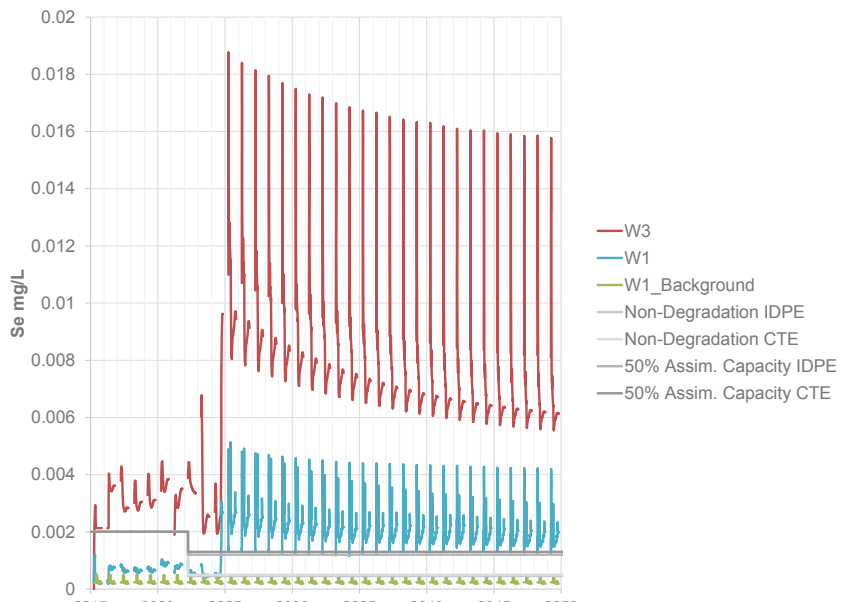
2025
2030
2035
2040
2045
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Se mg/L
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
2015
2020
2025
2030
2035
2040
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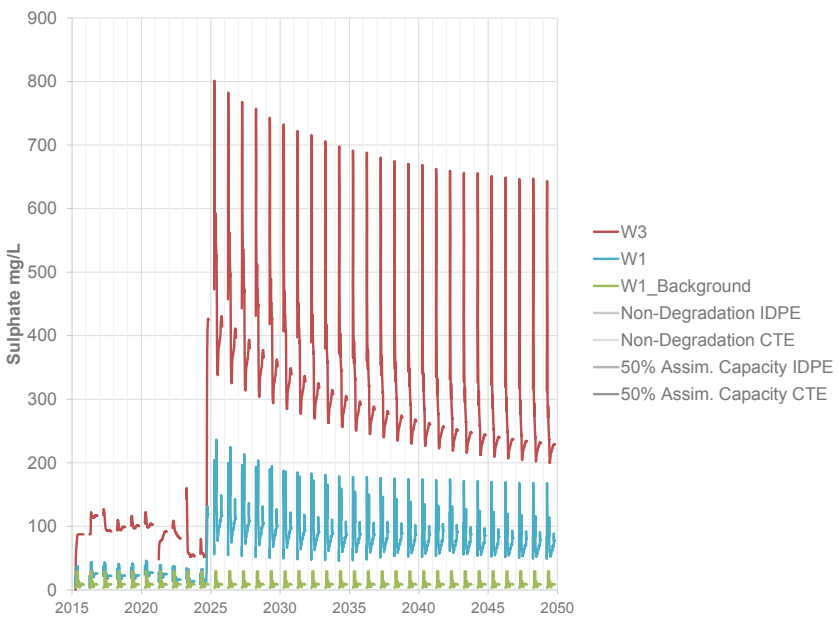
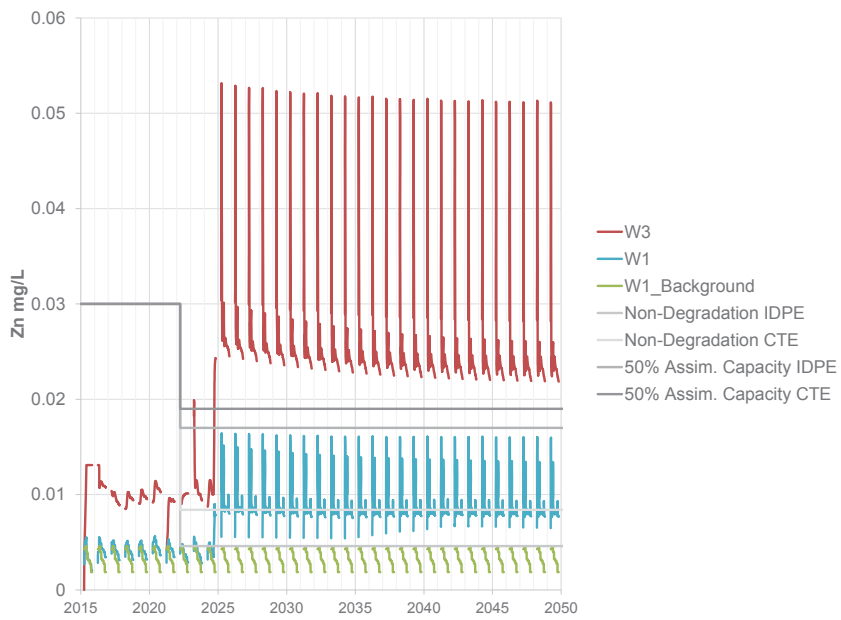
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Sulphate mg/L
900
800
700
600
500
400
300
200
100
0
2015
2020
2025
2030
2035
2040
2045
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE


Zn mg/L
0.06
0.05
0.04
0.03
0.02
0.01
0
2015
2020
2025
2030
2035
2040
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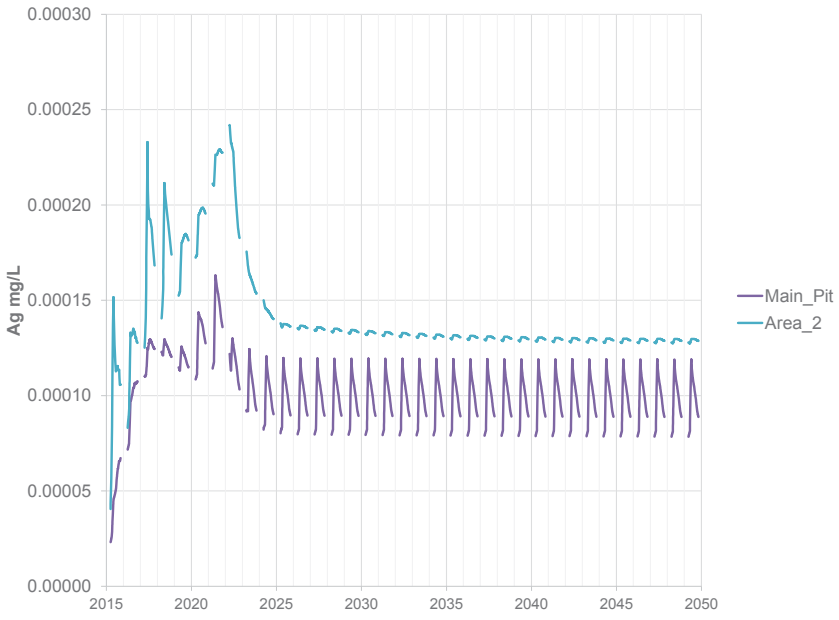
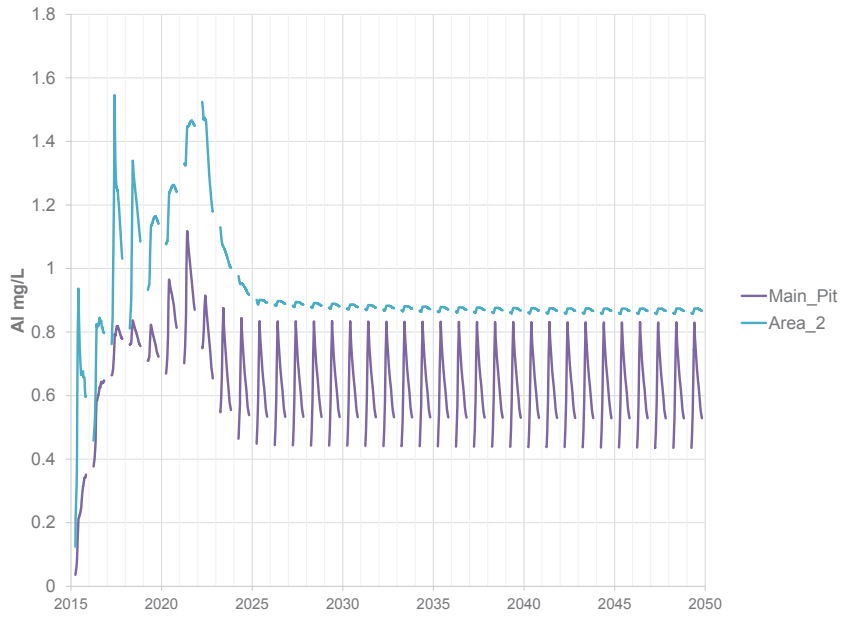
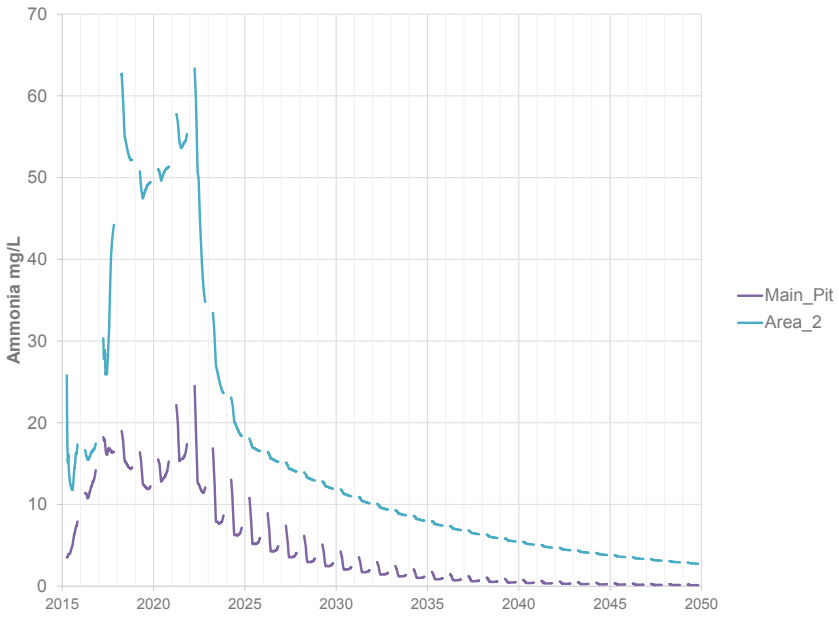
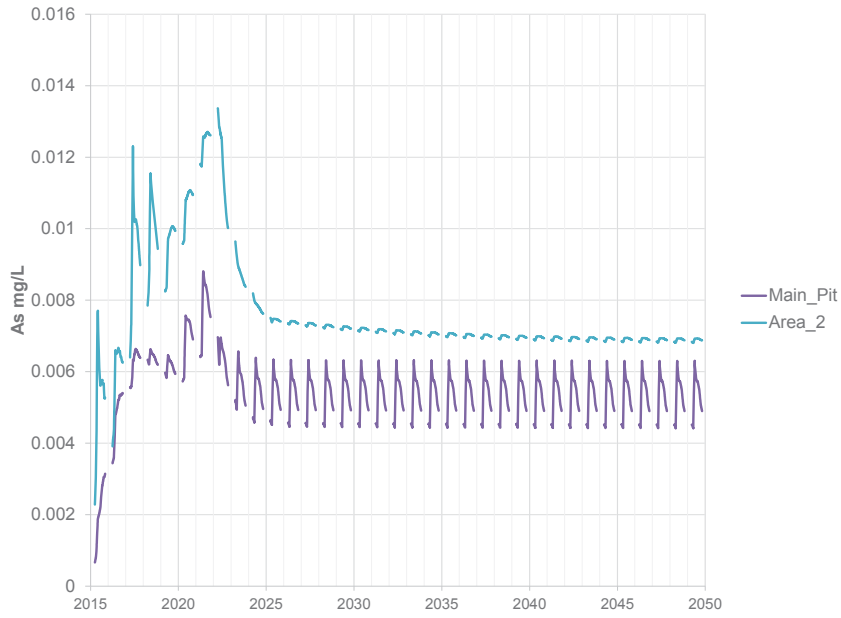
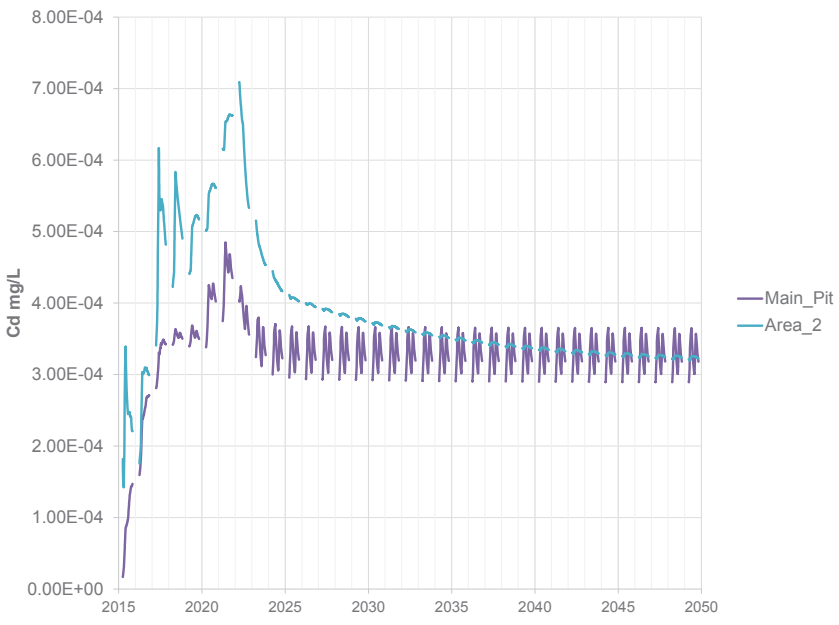
2050
W3
W1
W1_Background
Non-Degradation IDPE
Non-Degradation CTE
50% Assim. Capacity IDPE
50% Assim. Capacity CTE

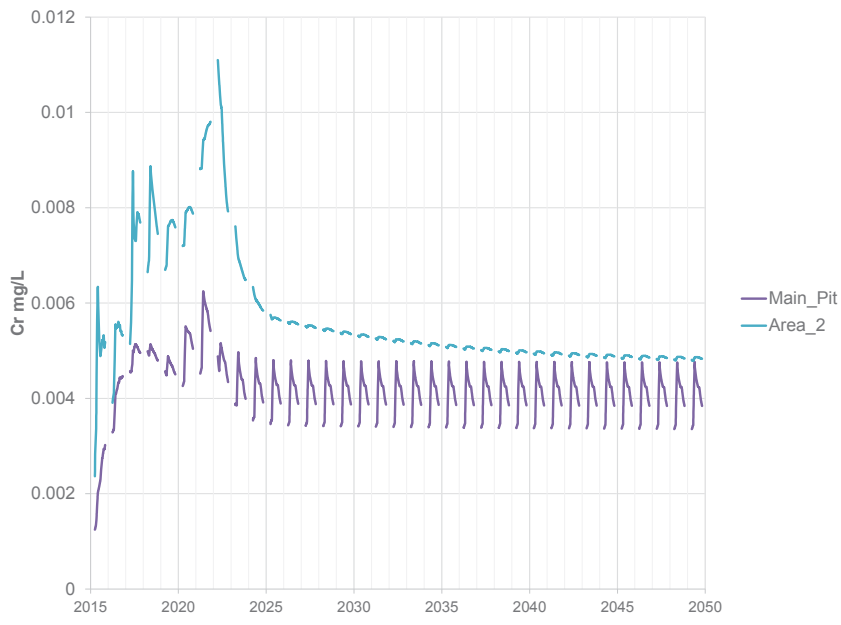


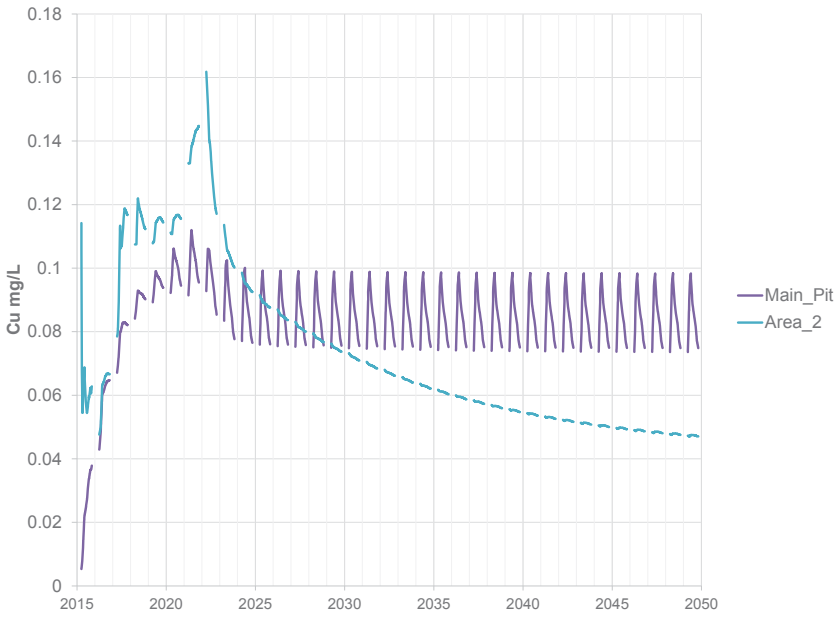



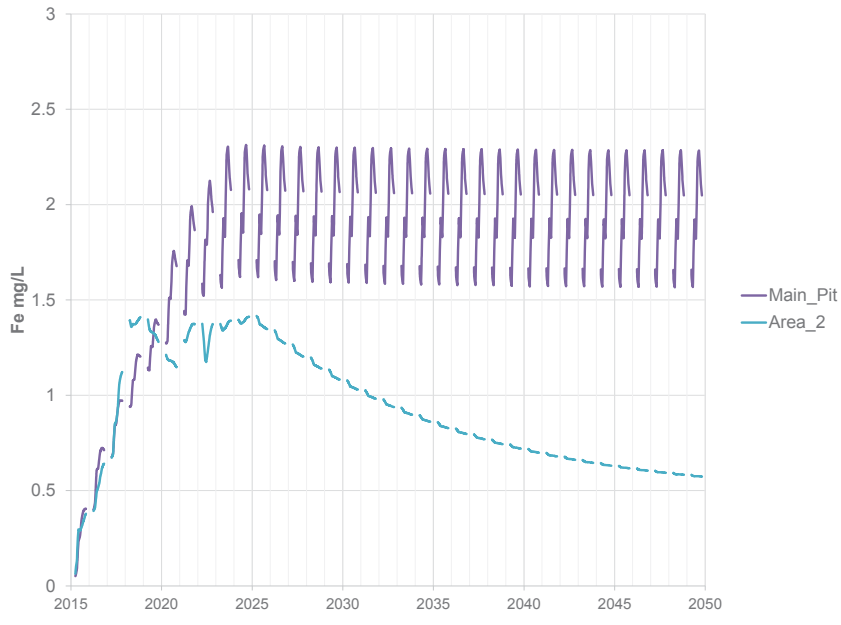

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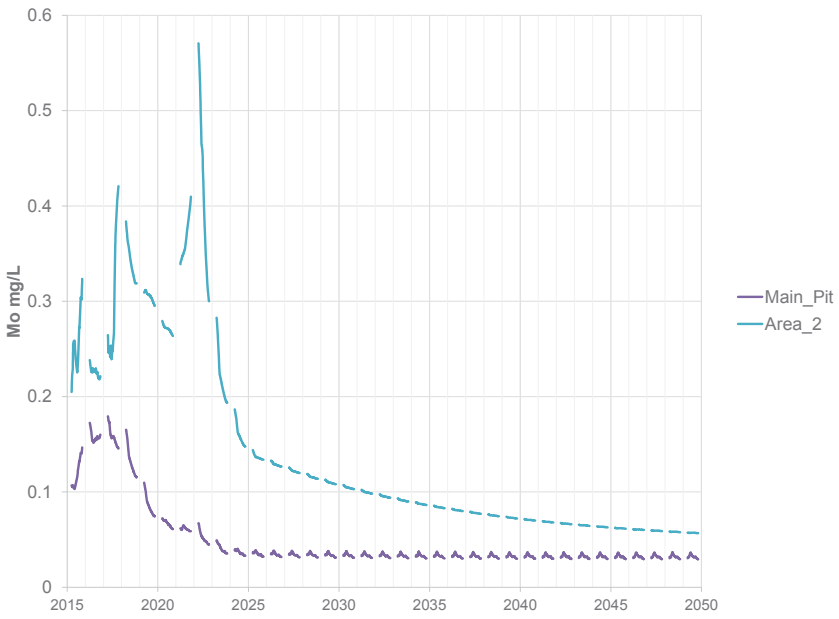


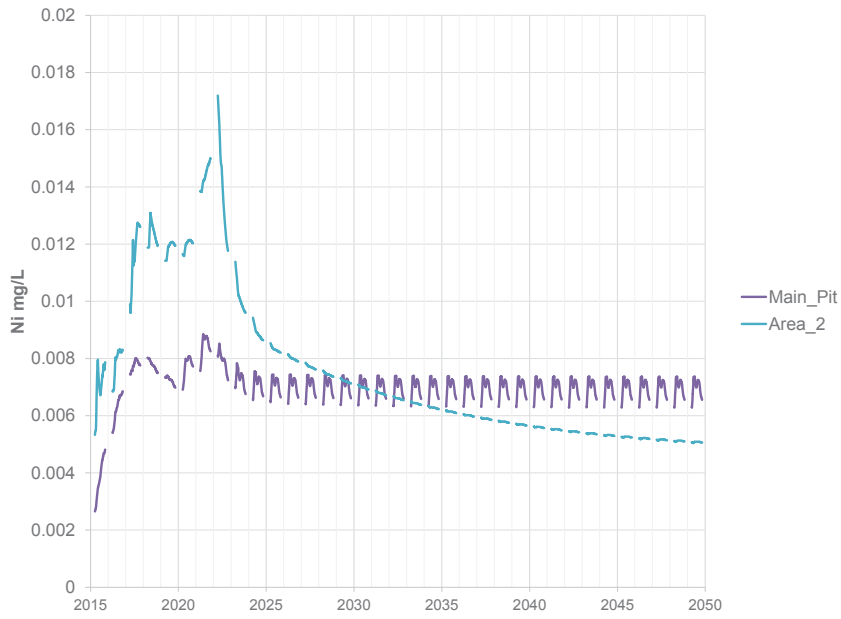


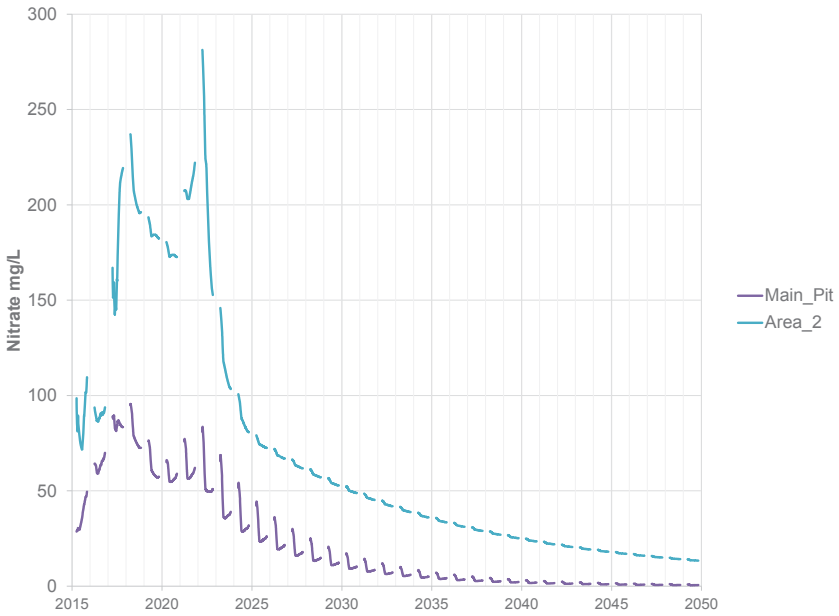


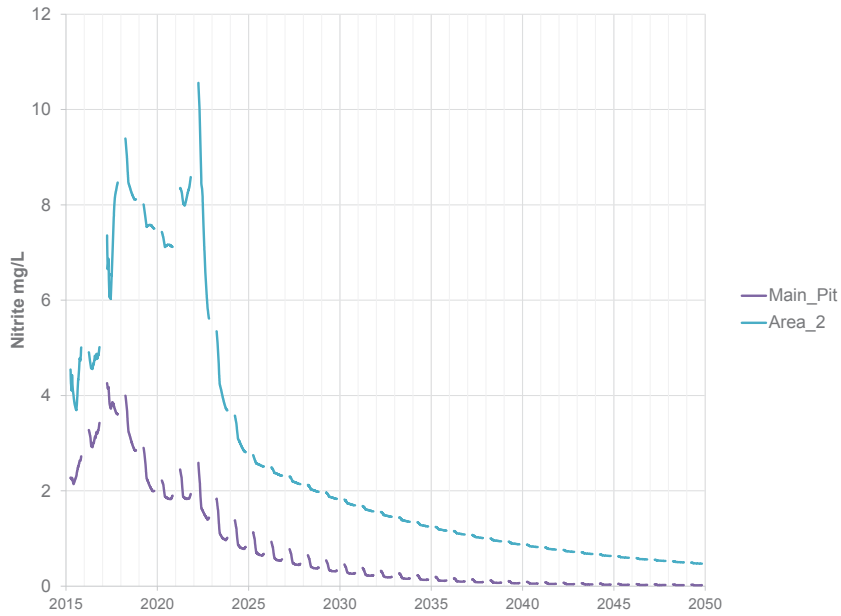


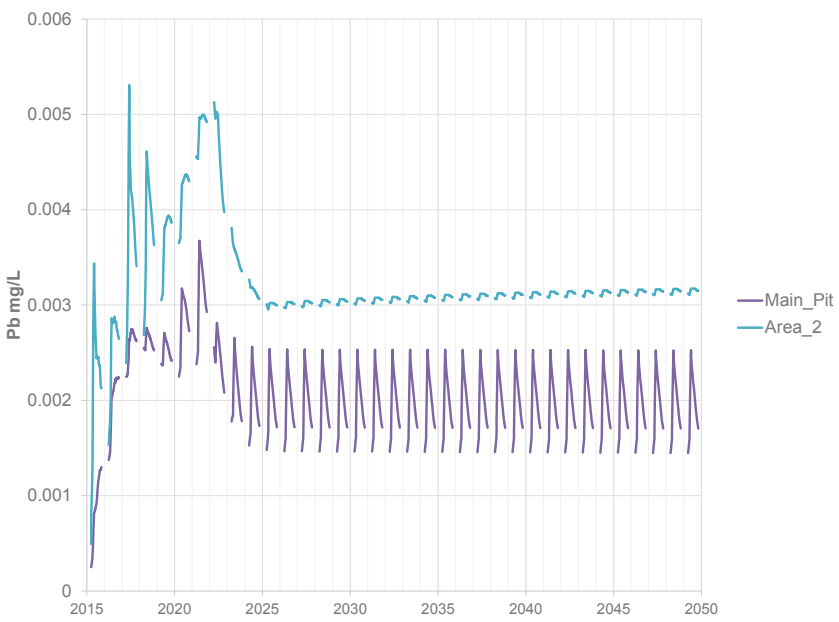


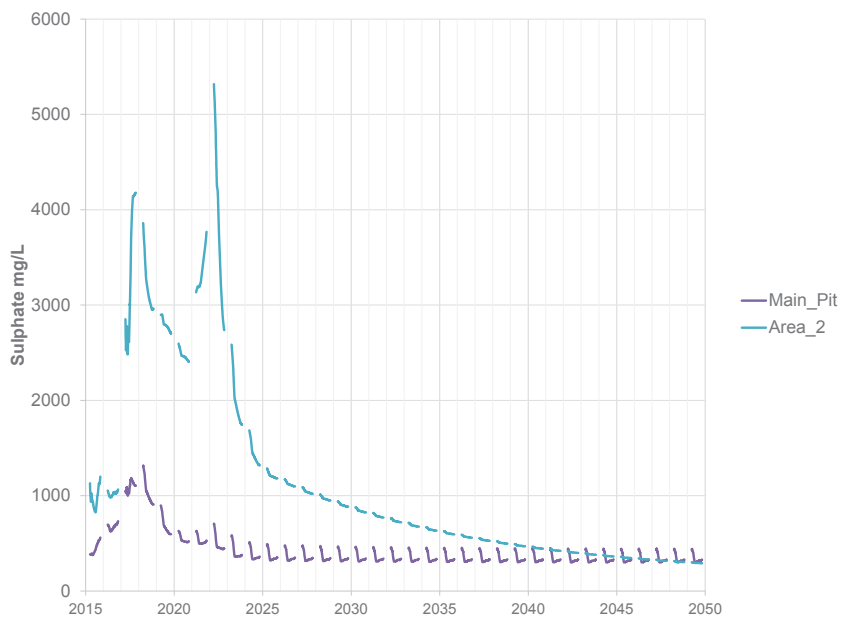


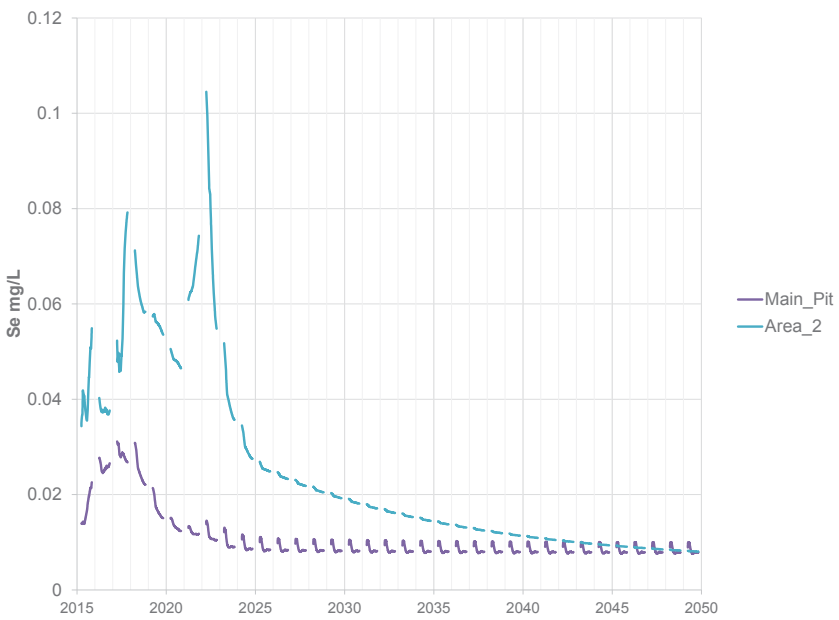


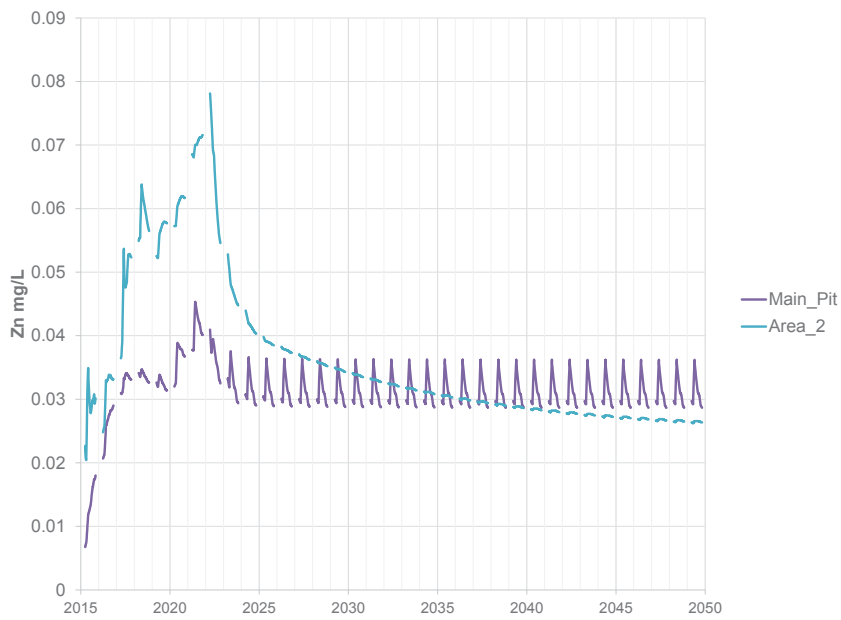


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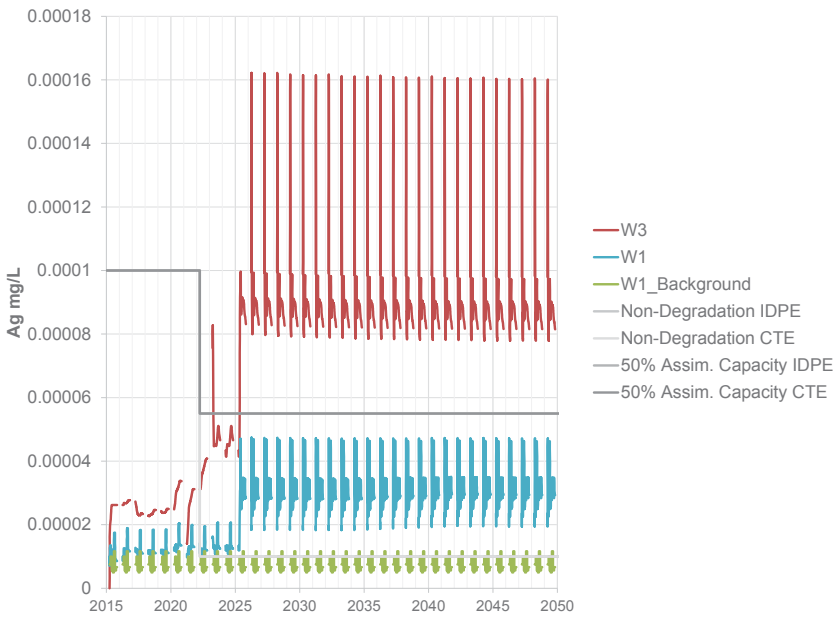


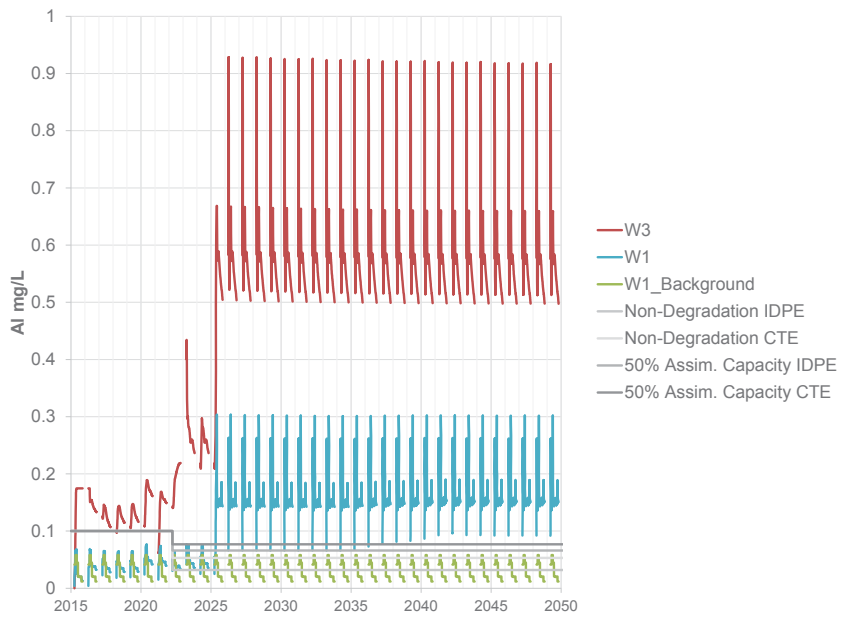


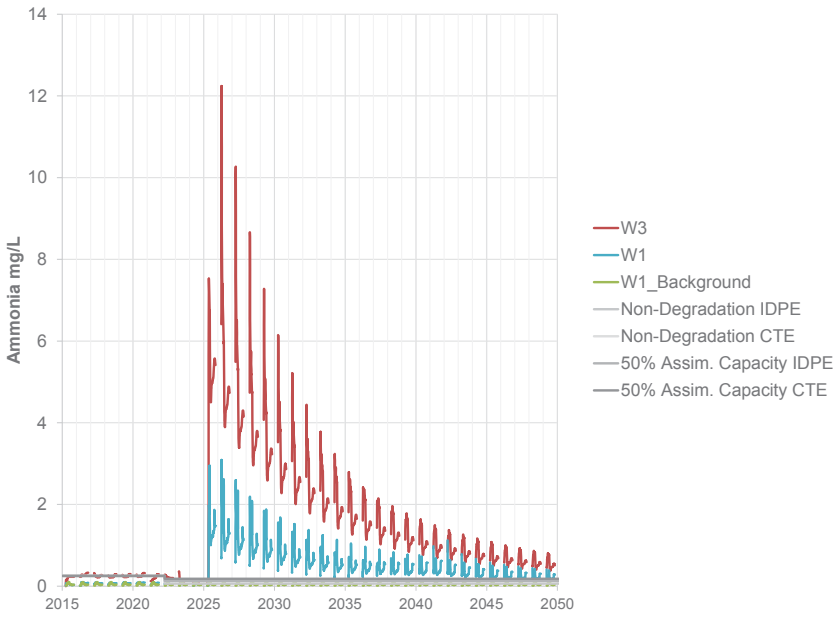


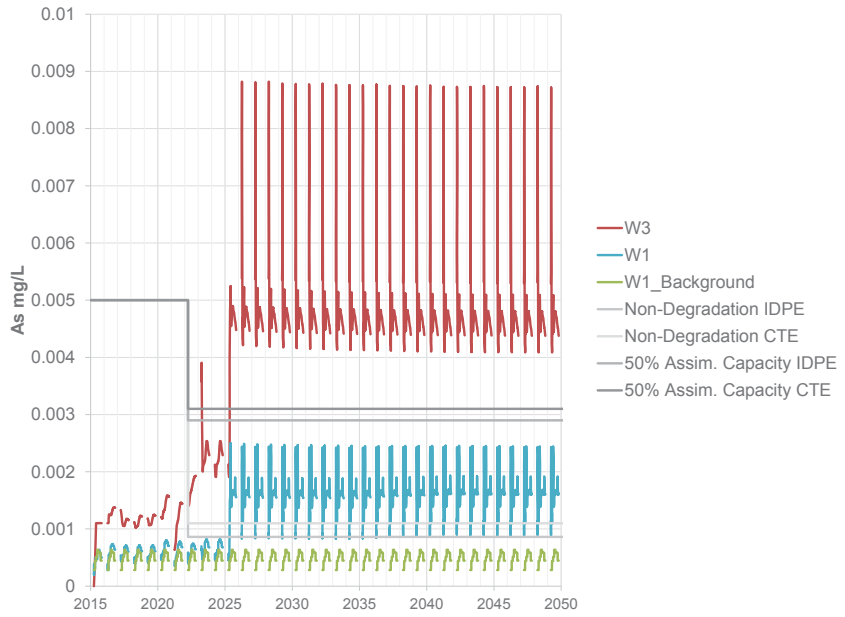


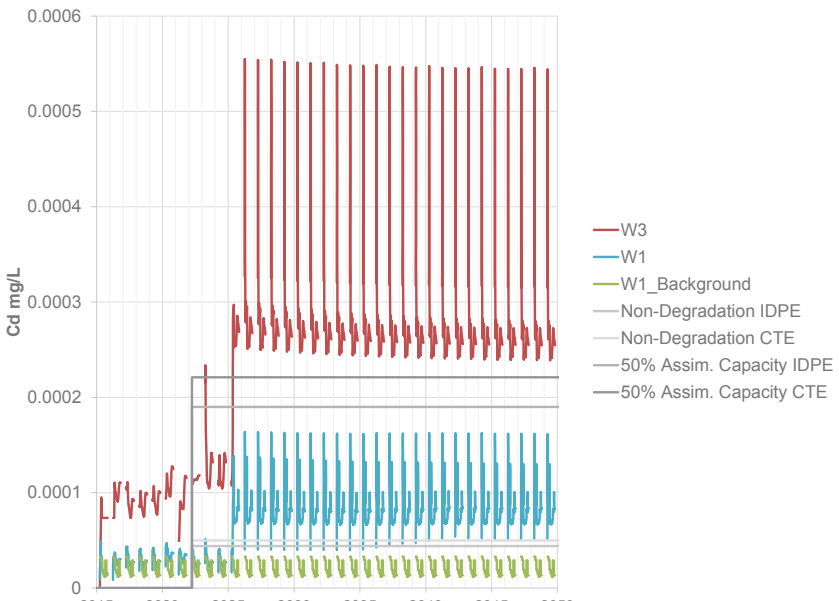


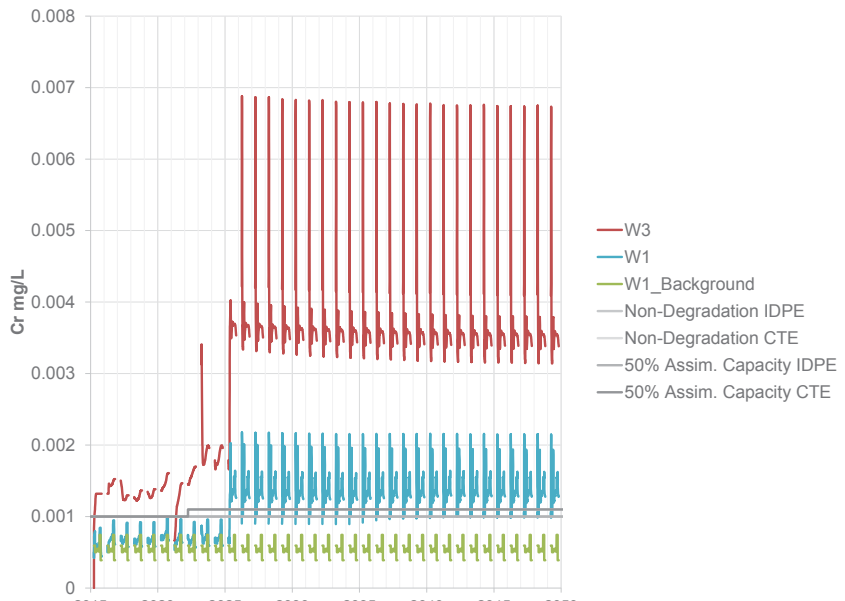


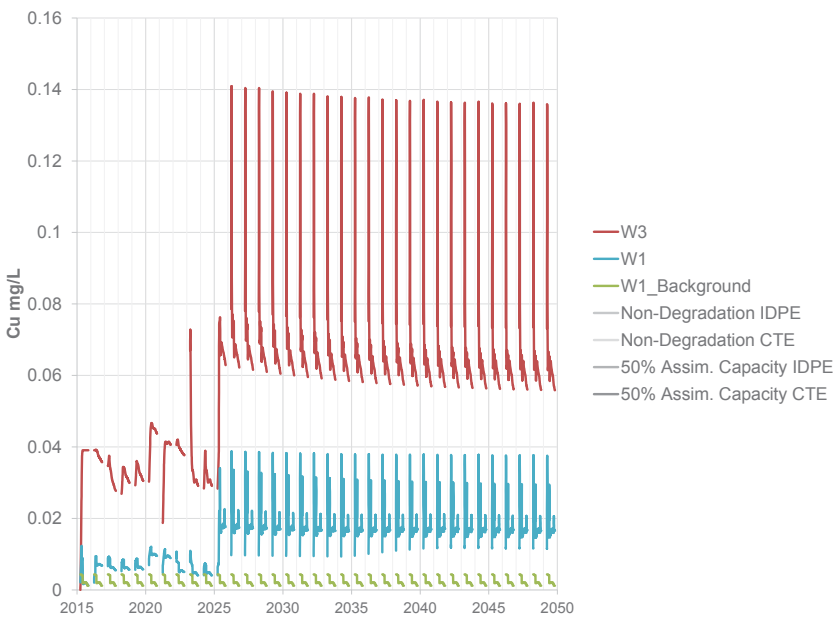


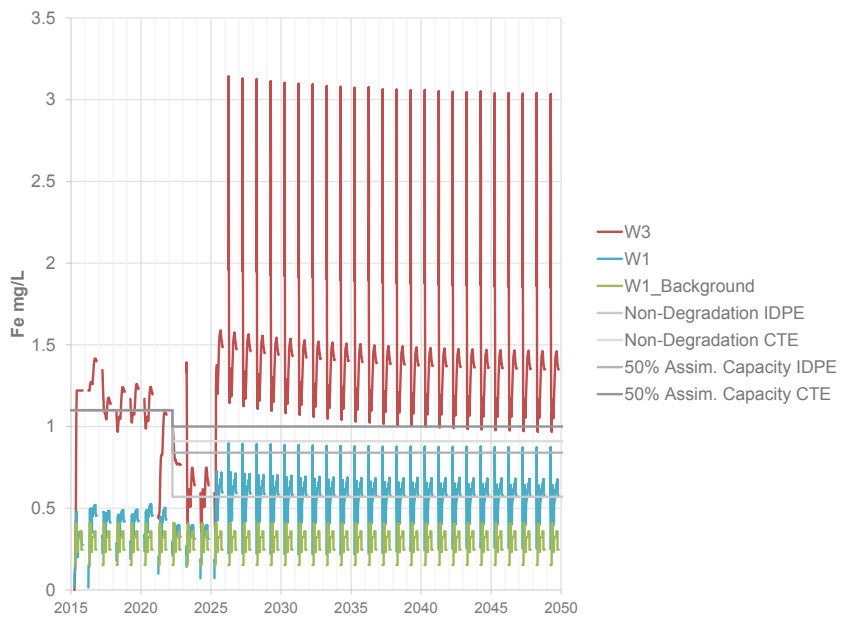


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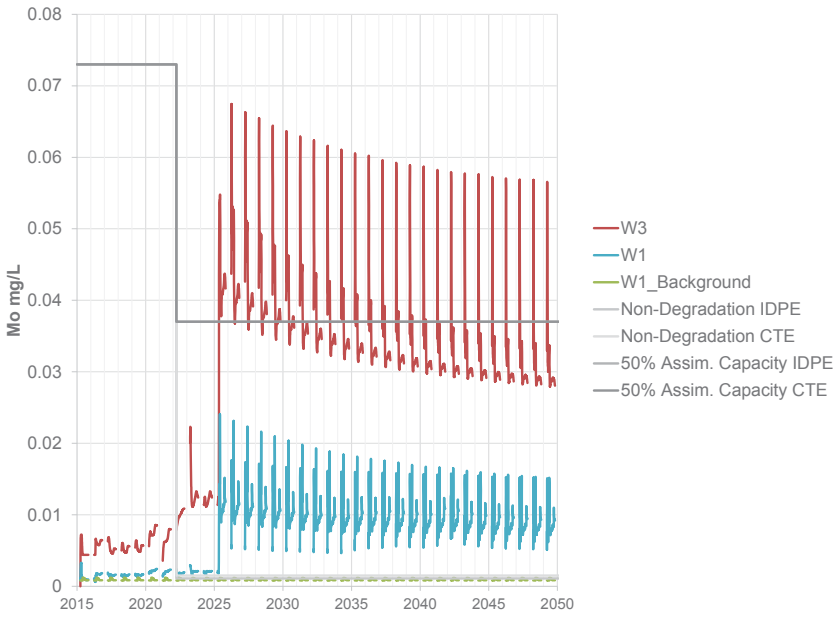


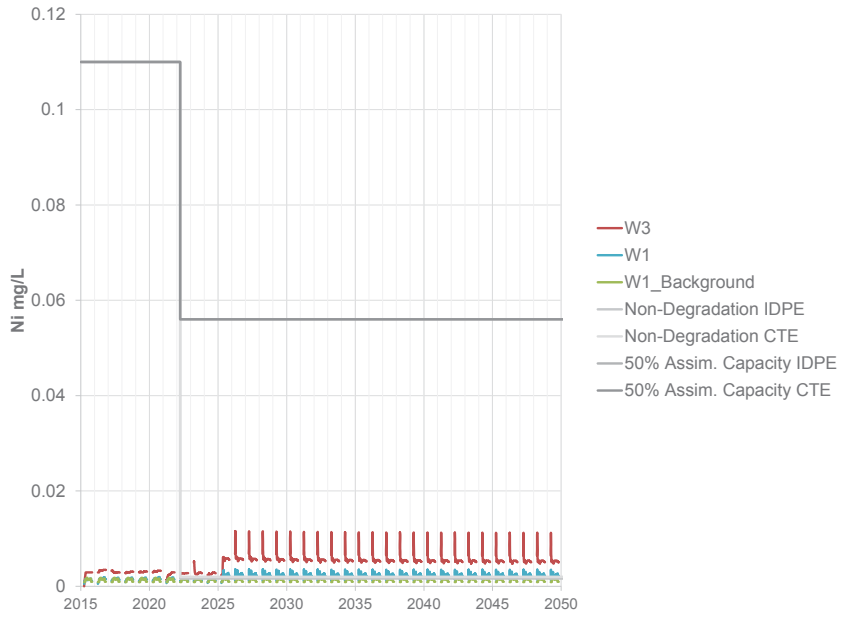


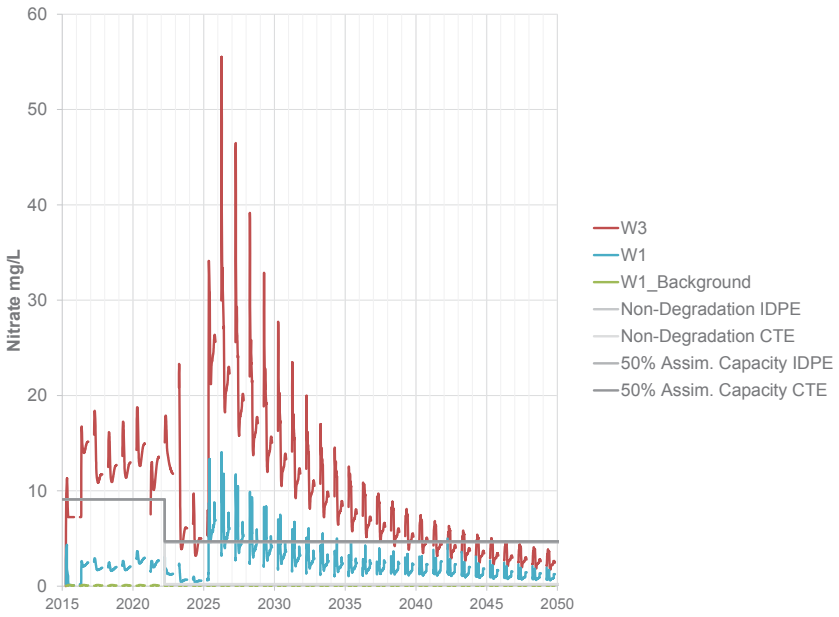


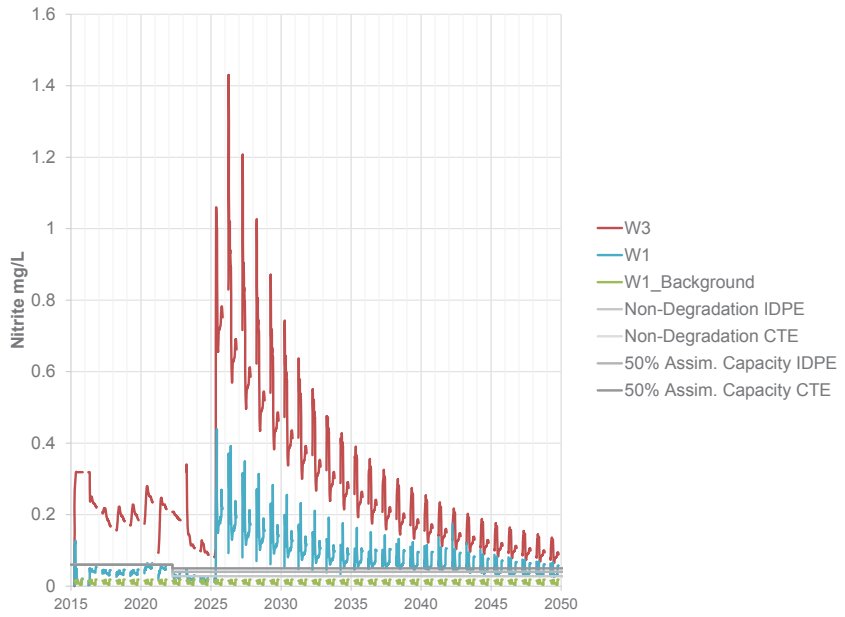


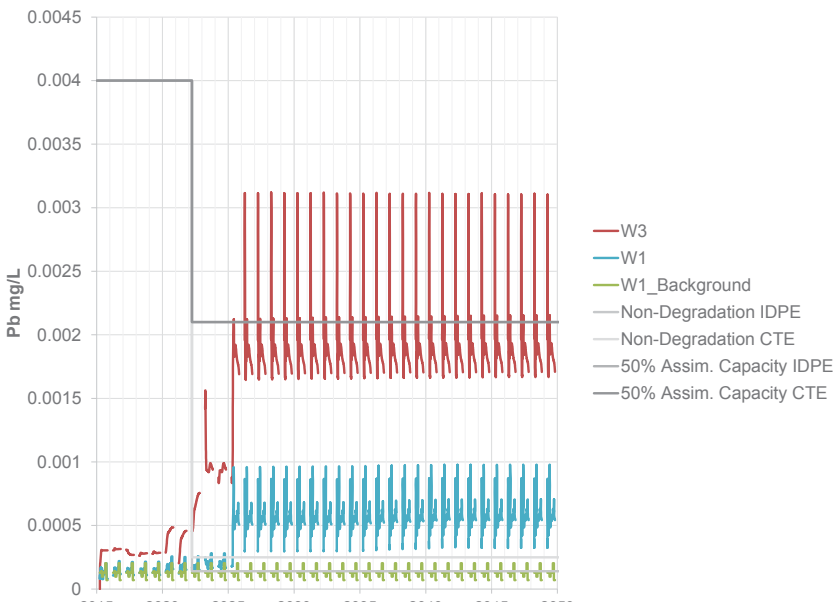





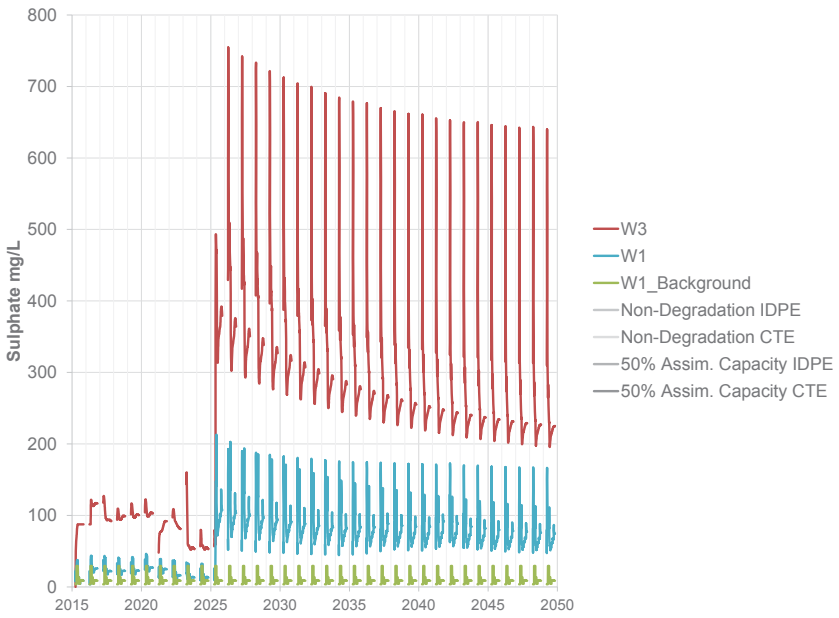


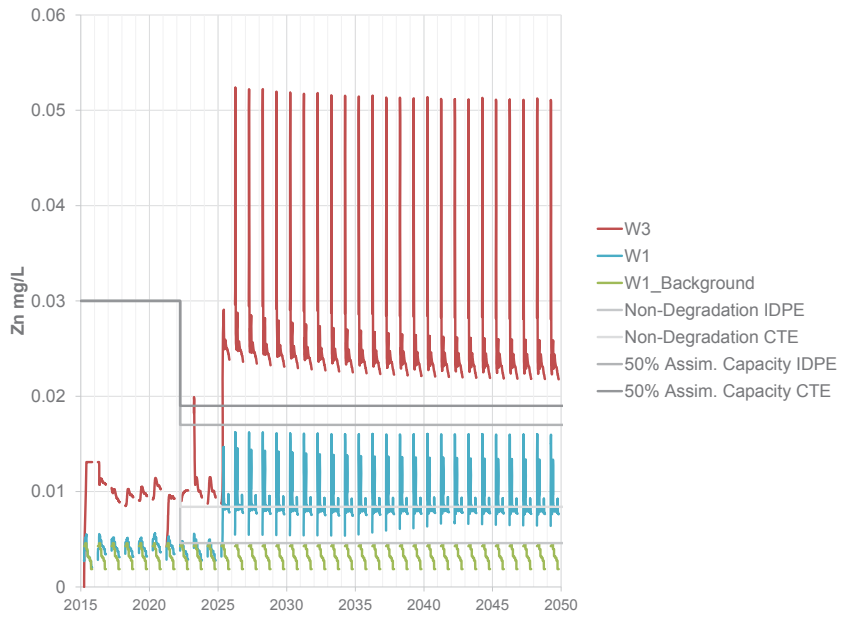


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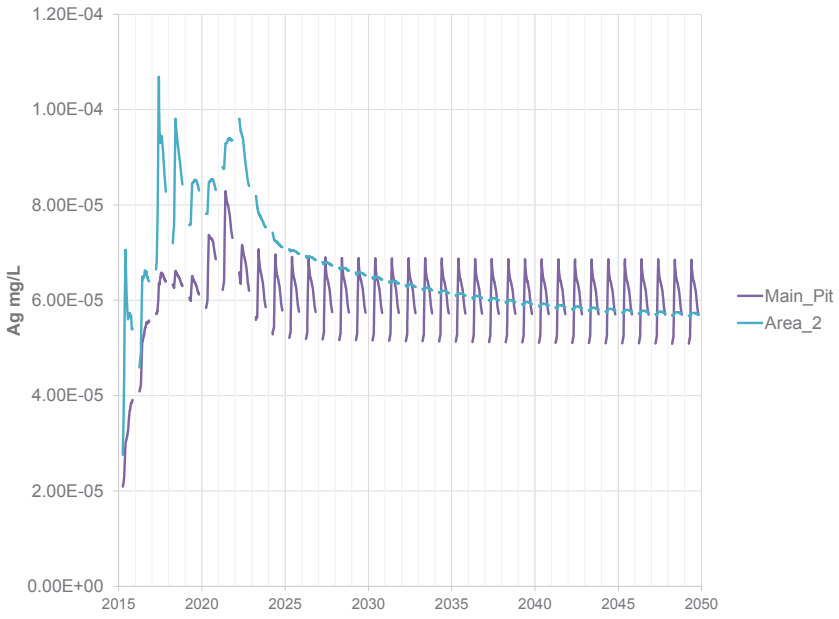


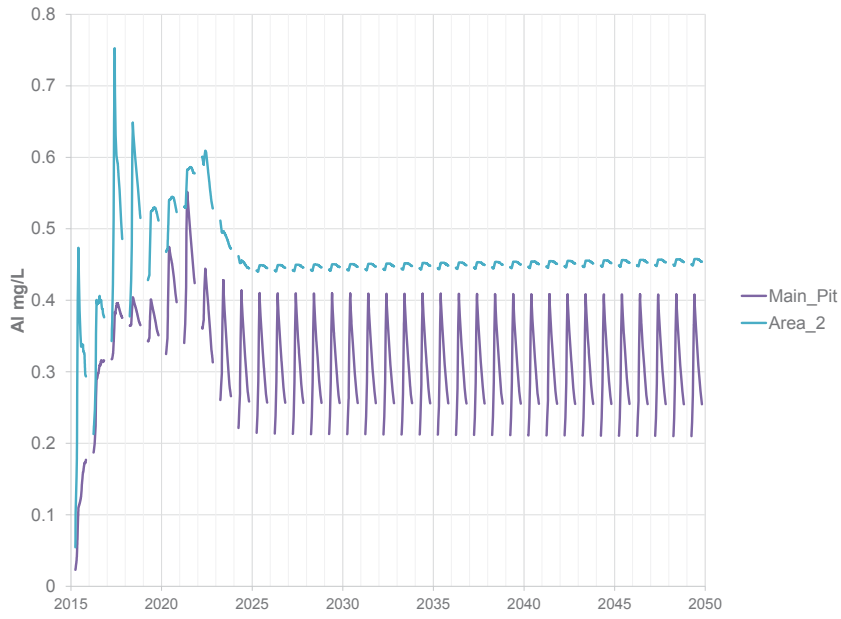


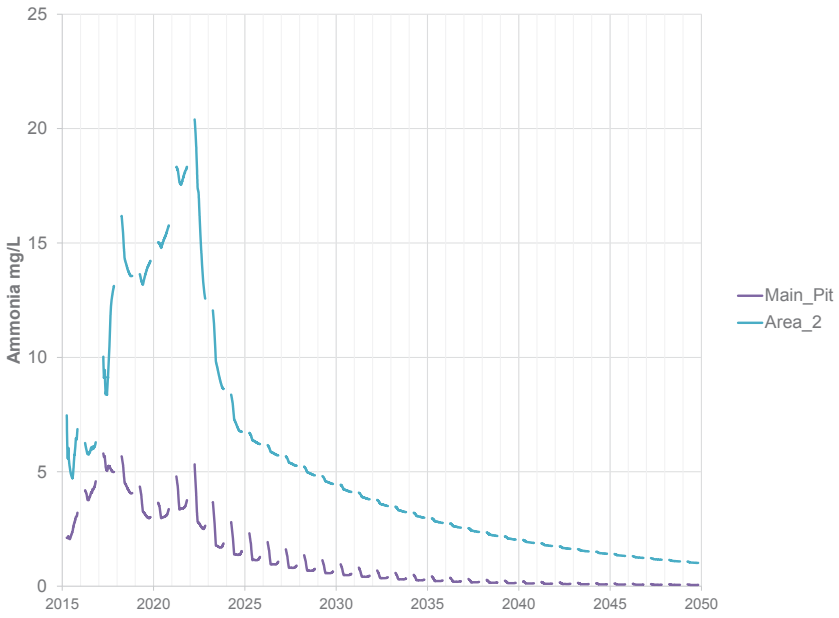


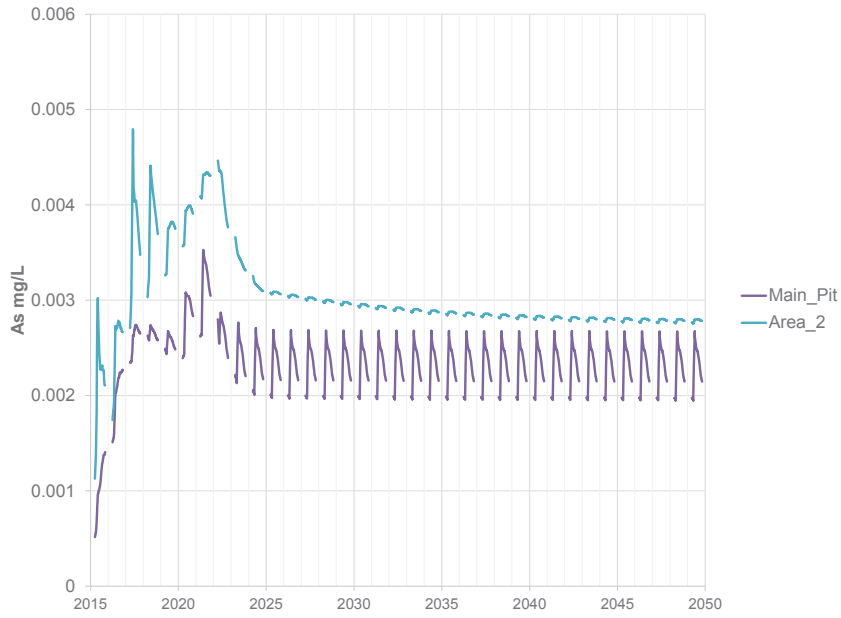


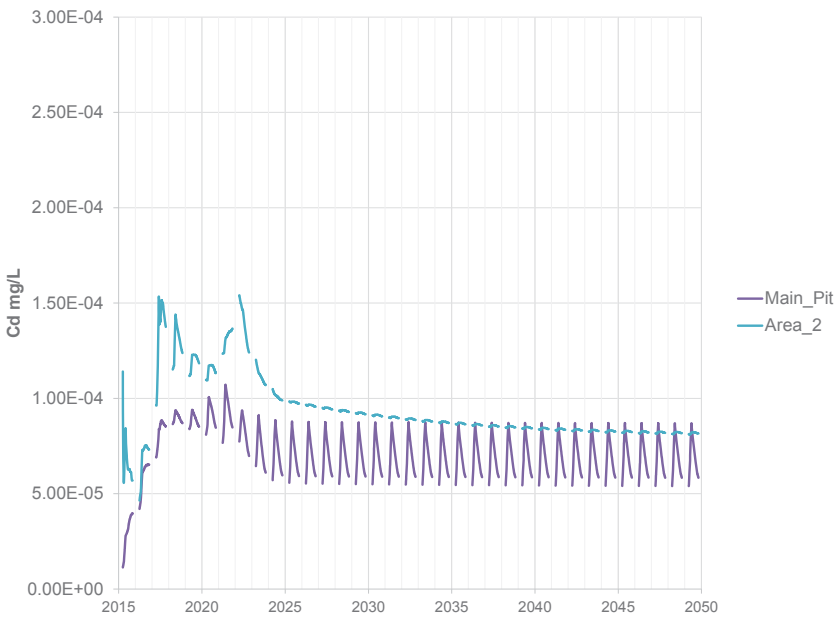


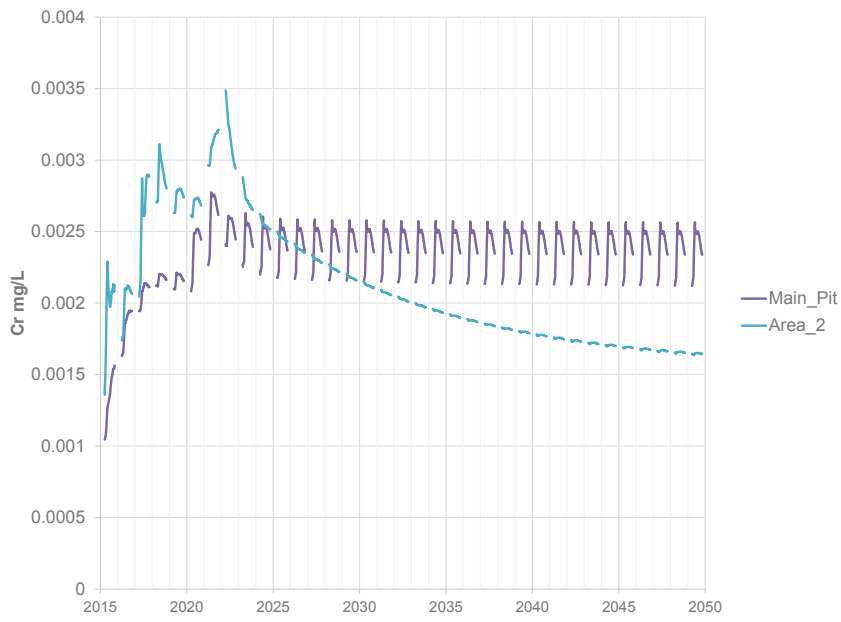


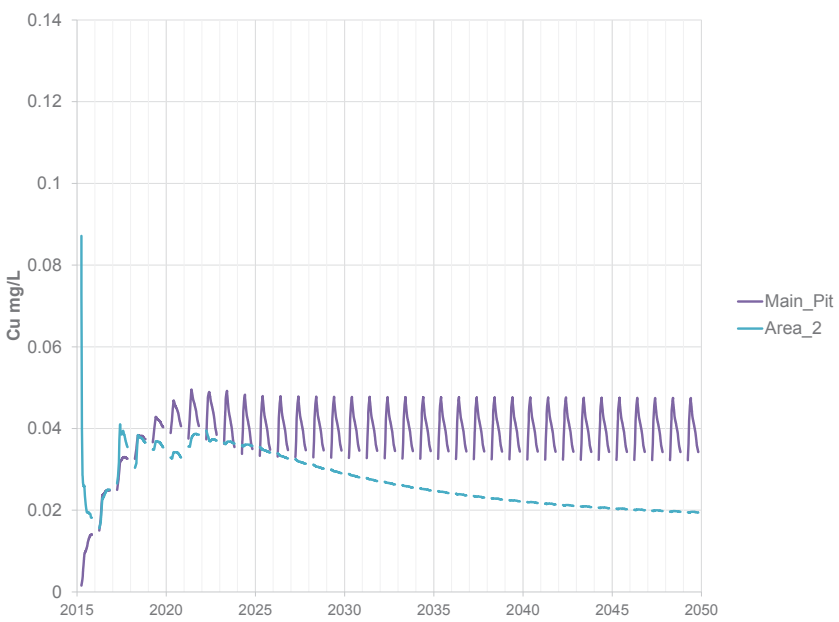


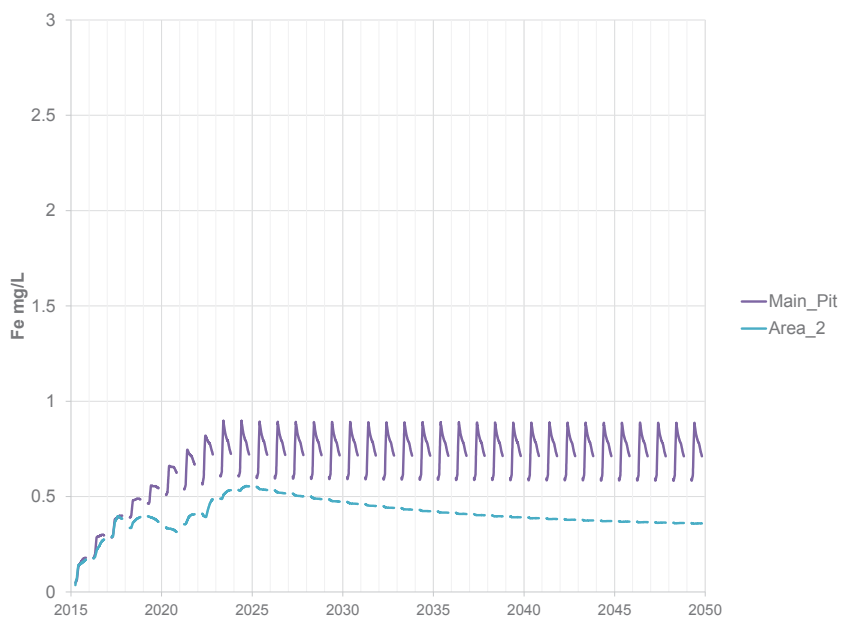


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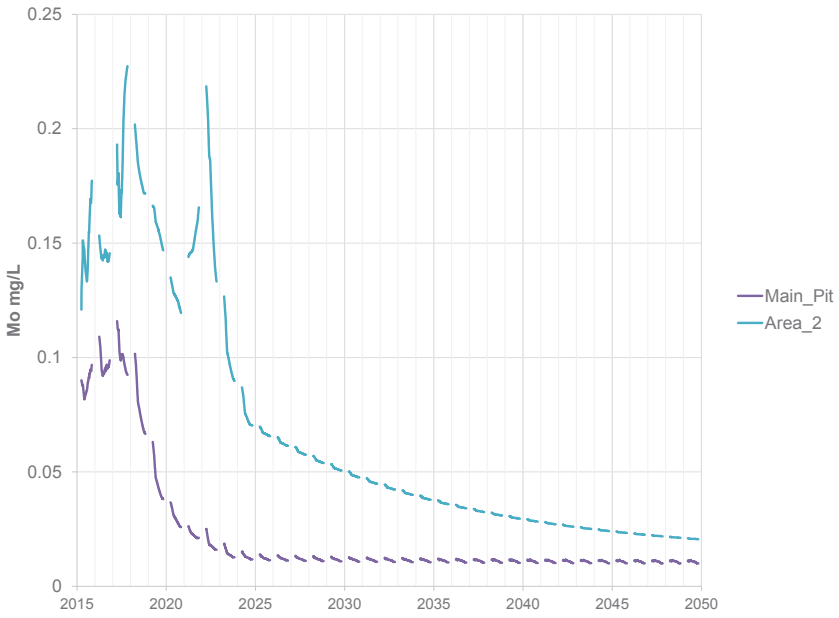


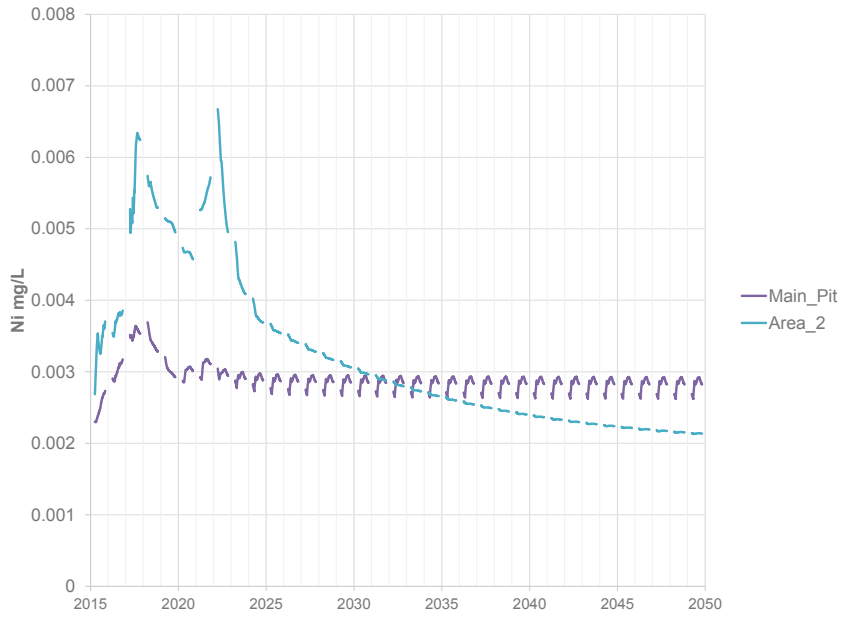


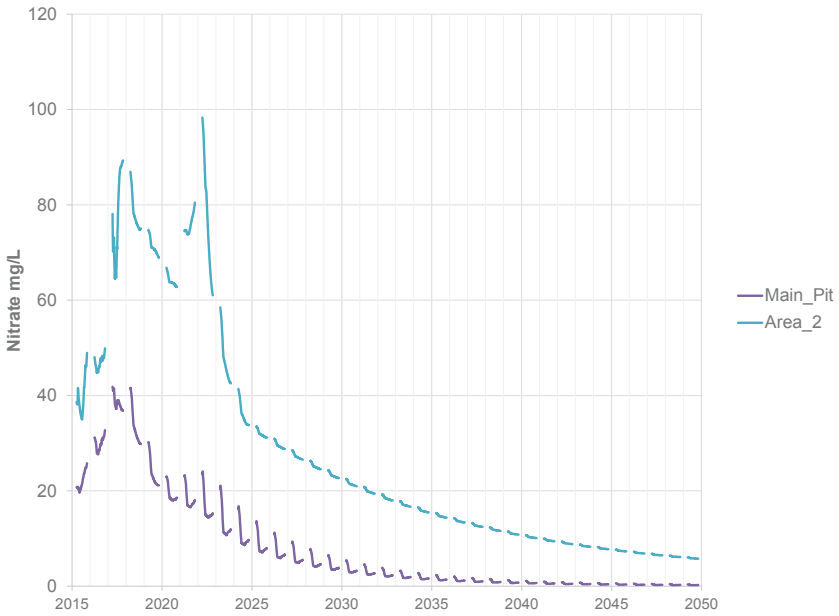


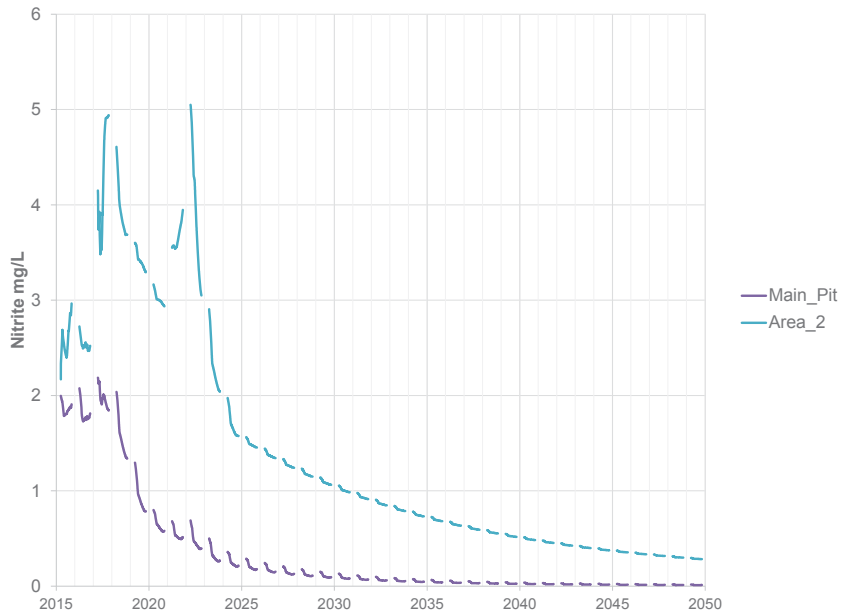


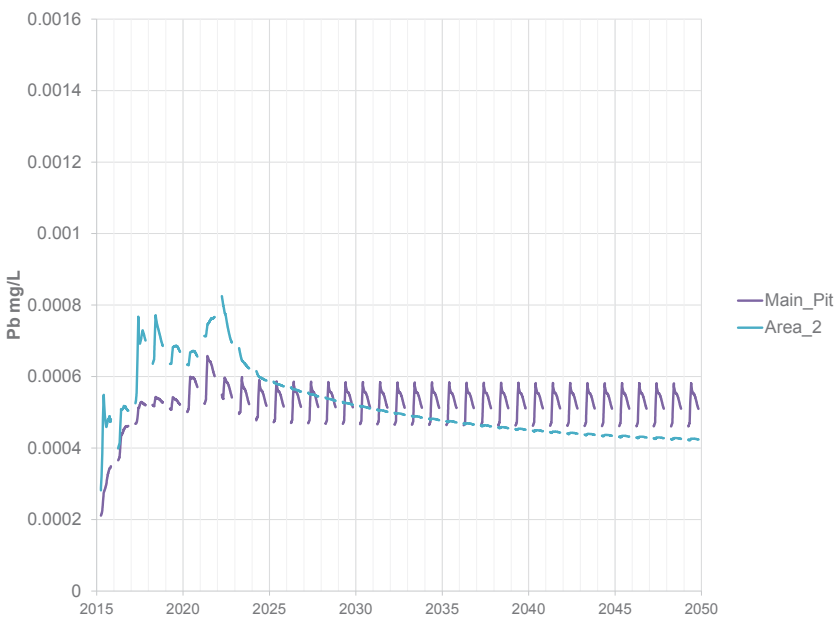


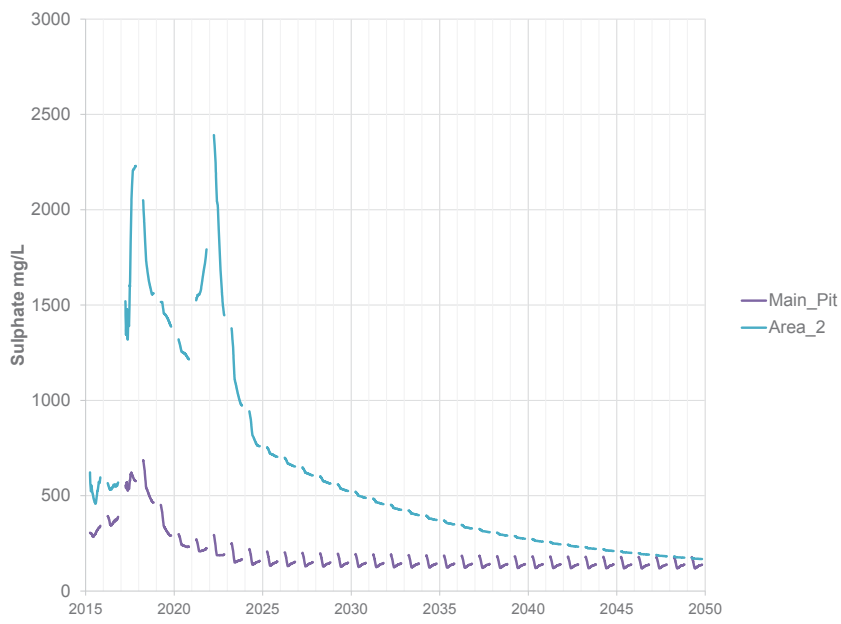


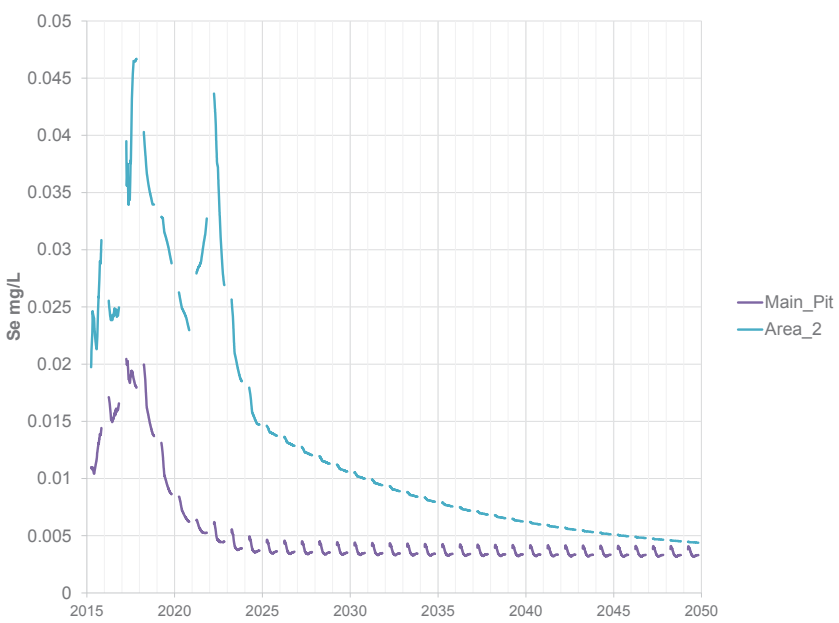


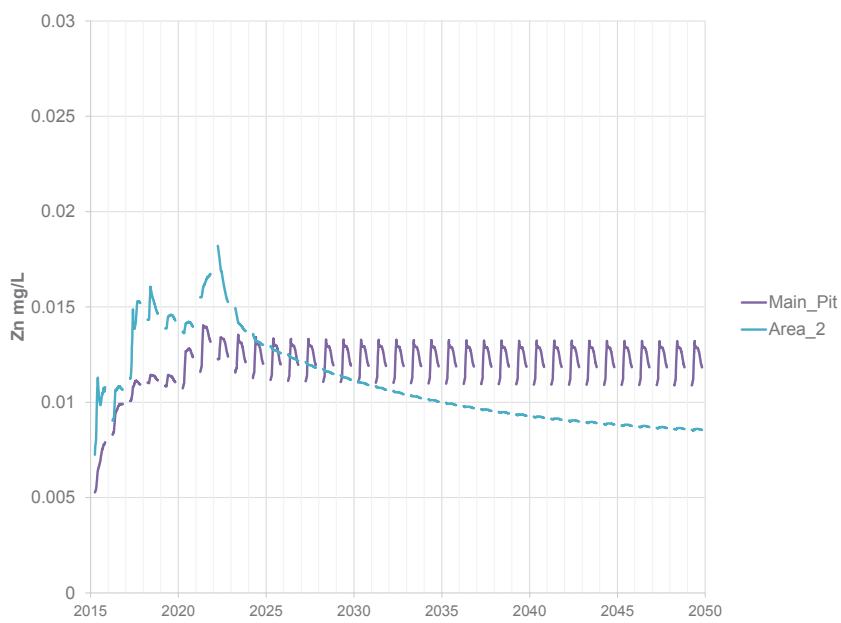


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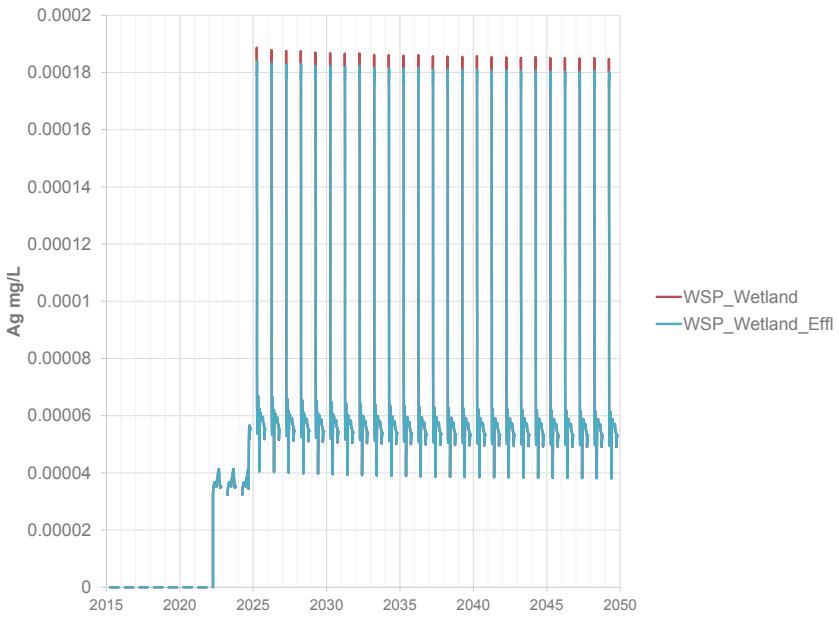


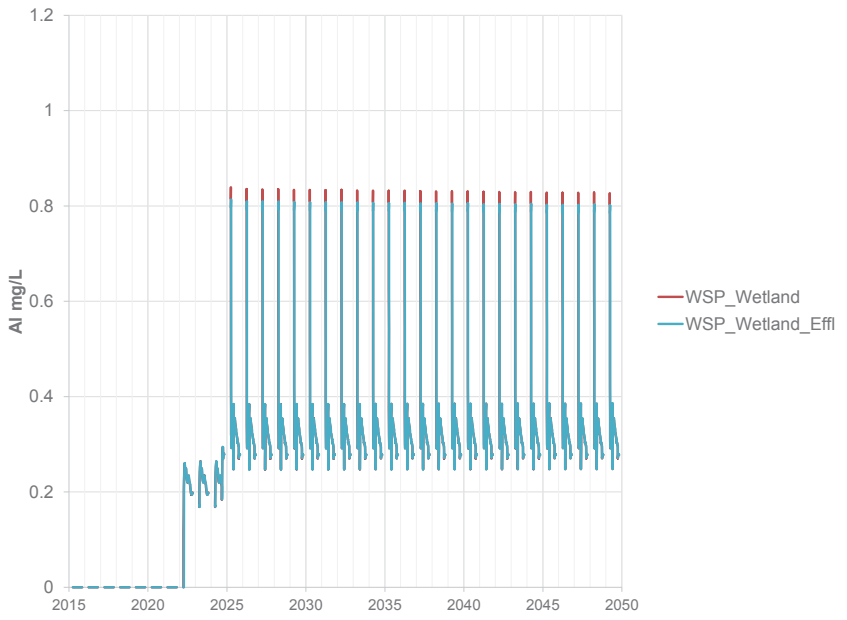


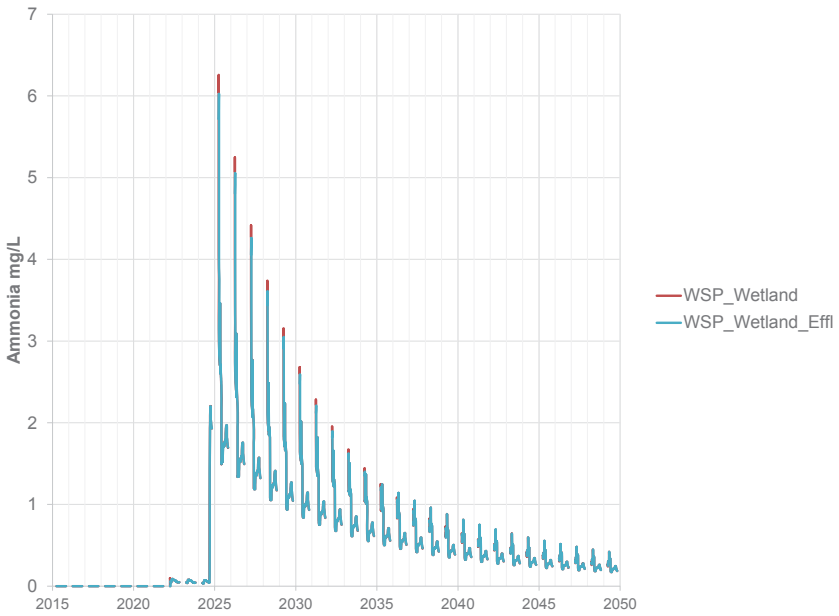


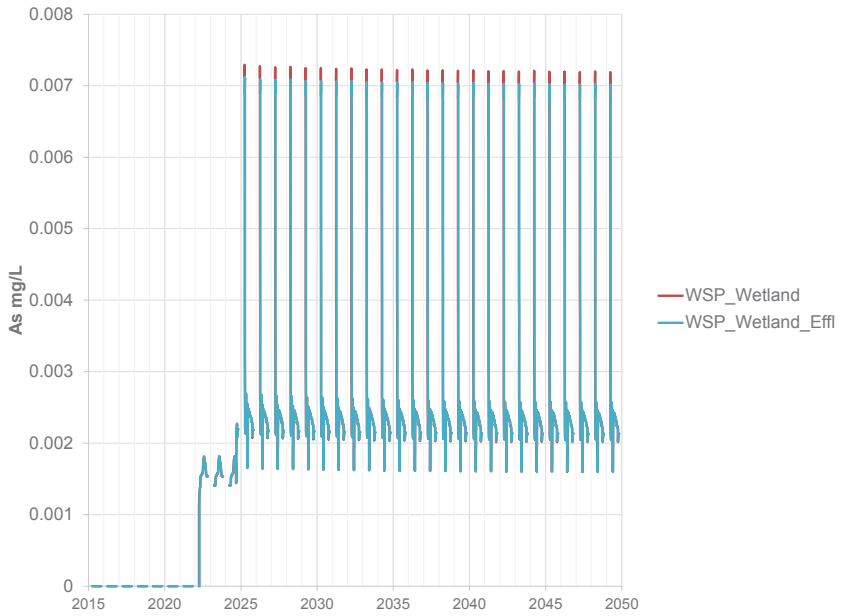


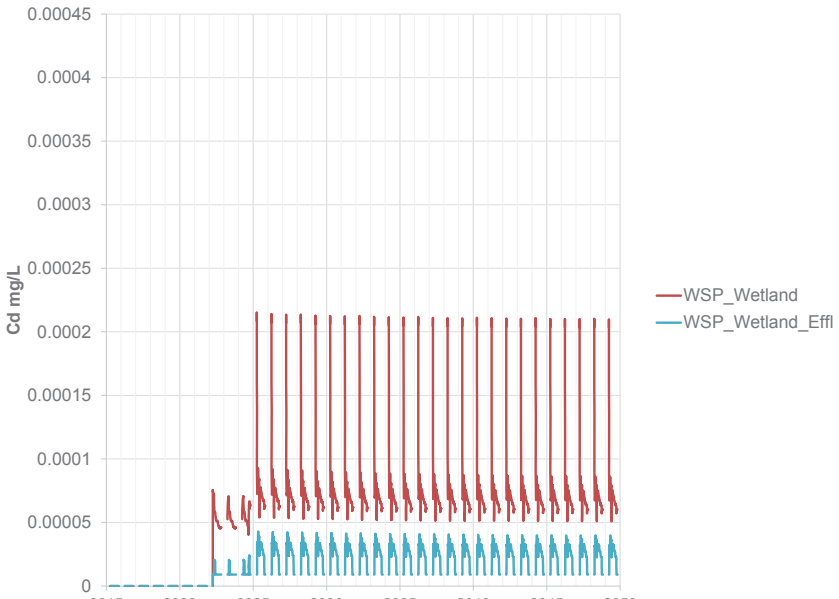


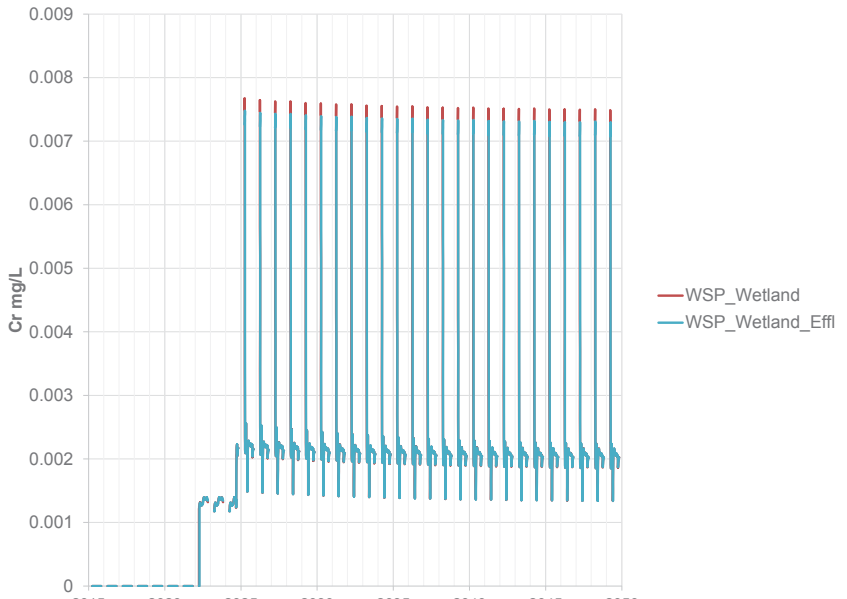


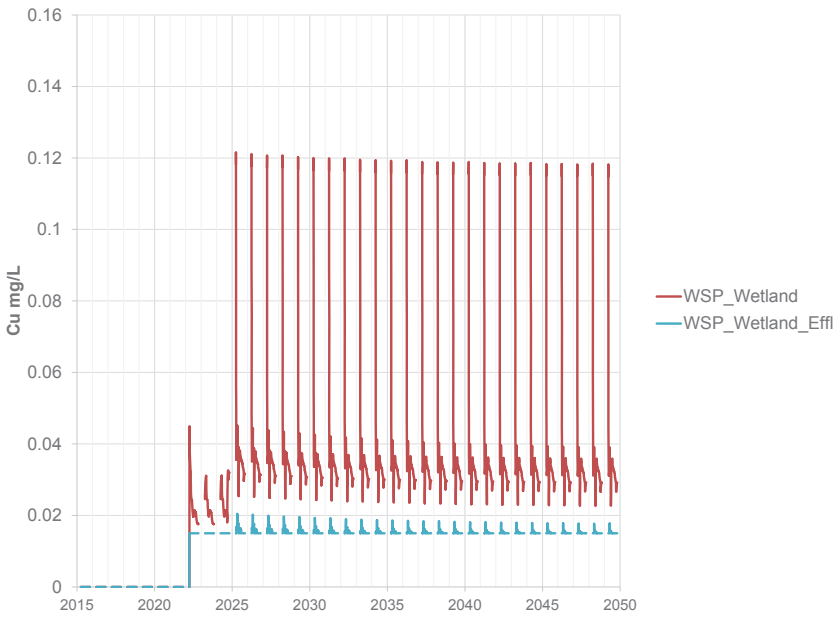


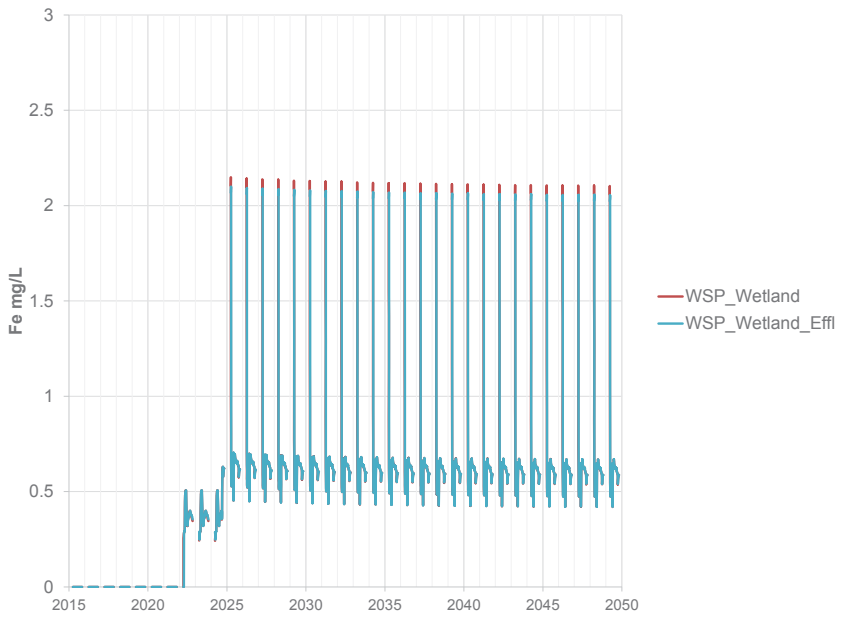


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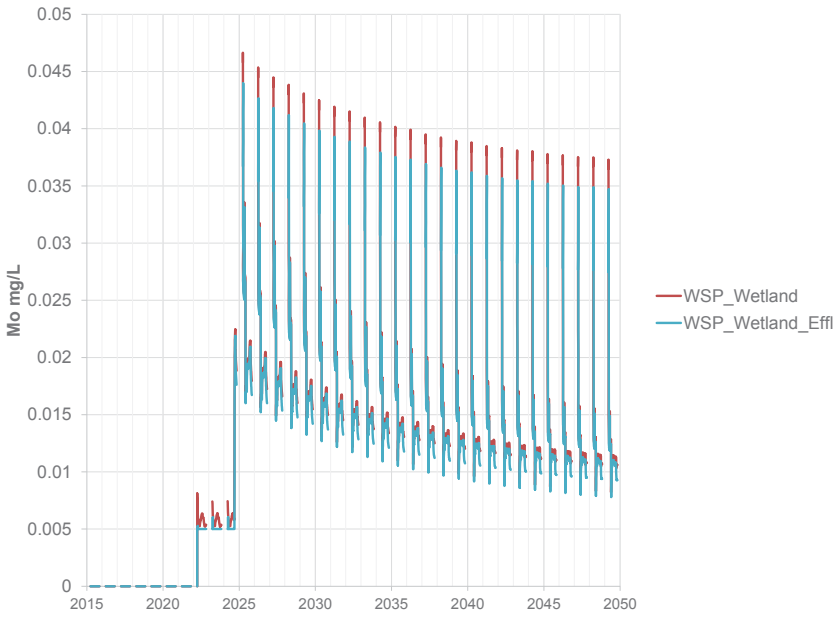


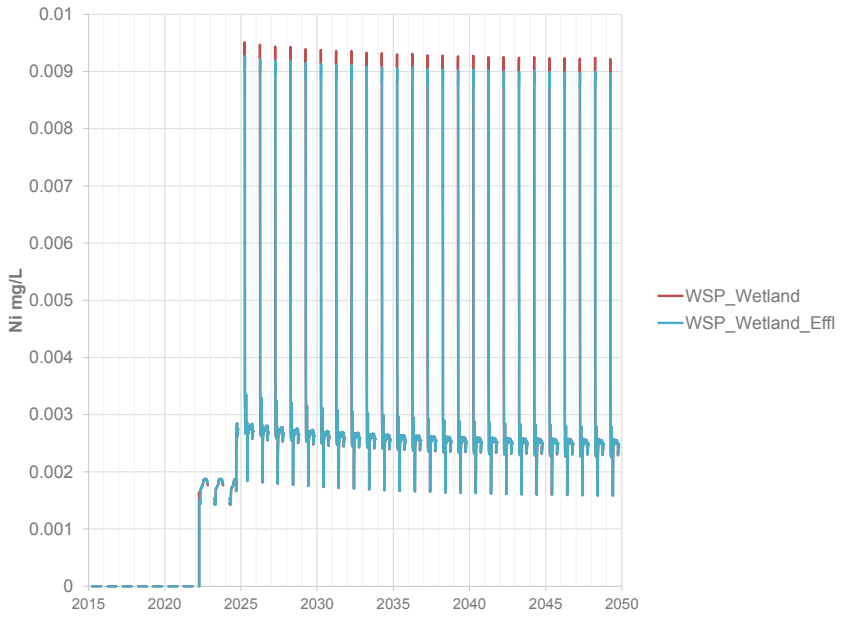


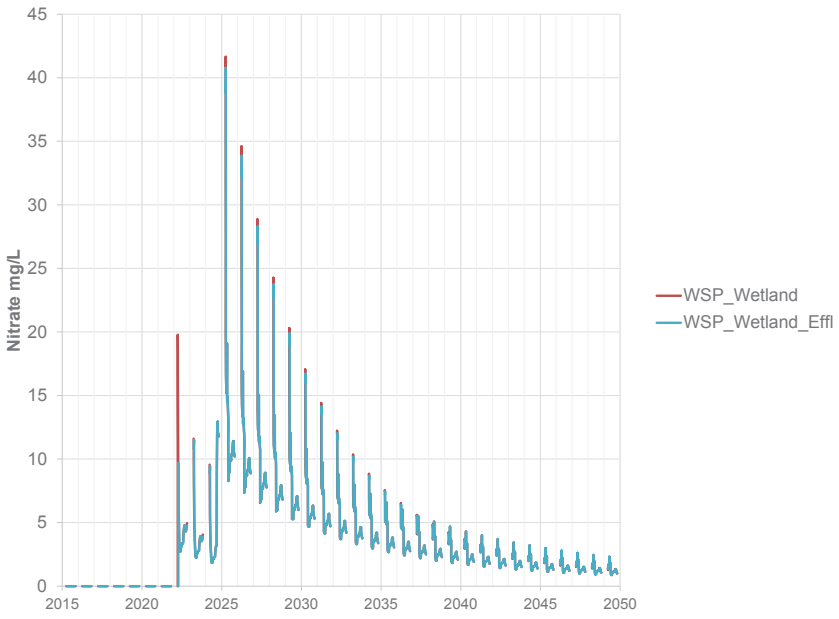


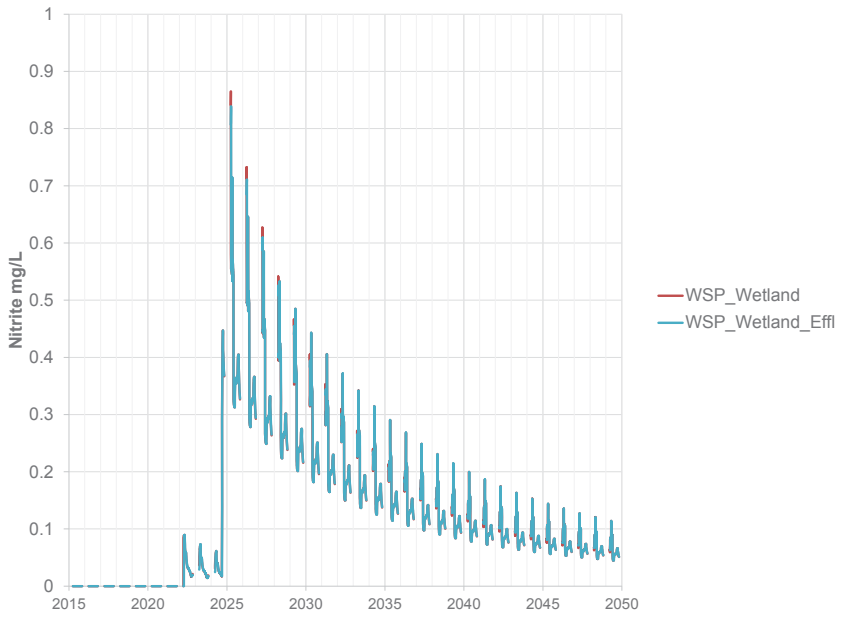


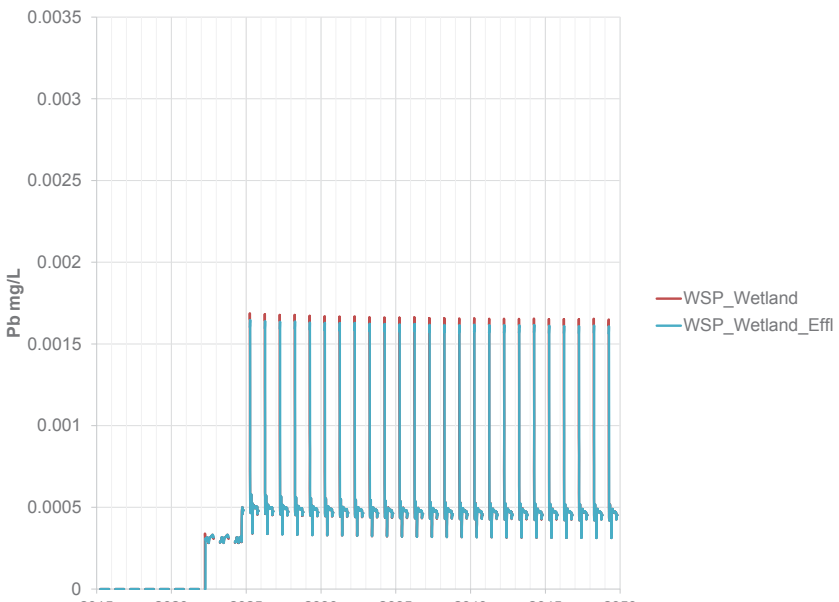


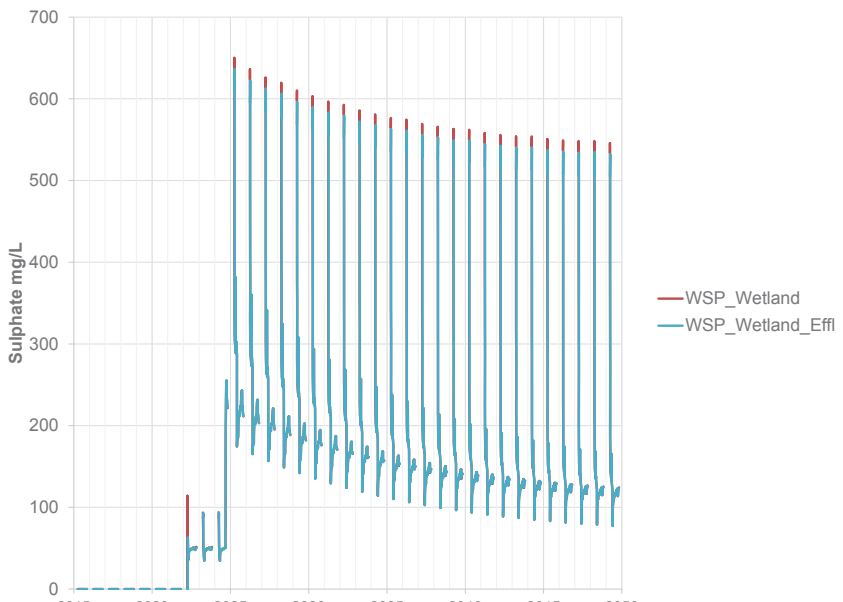


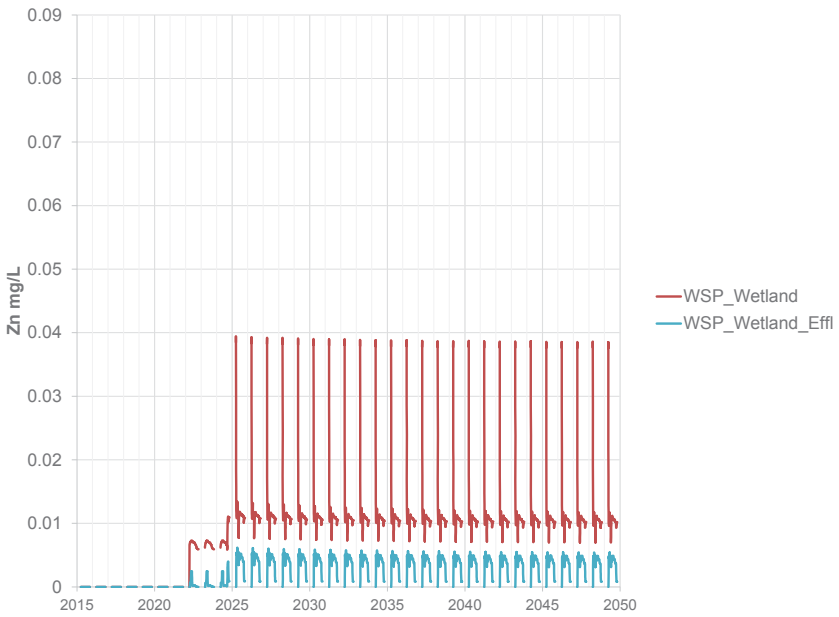


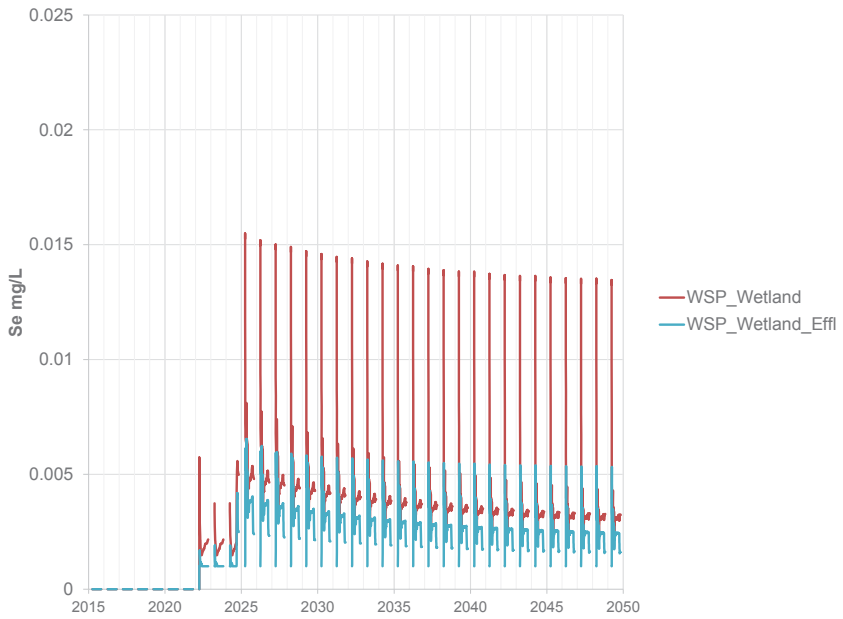


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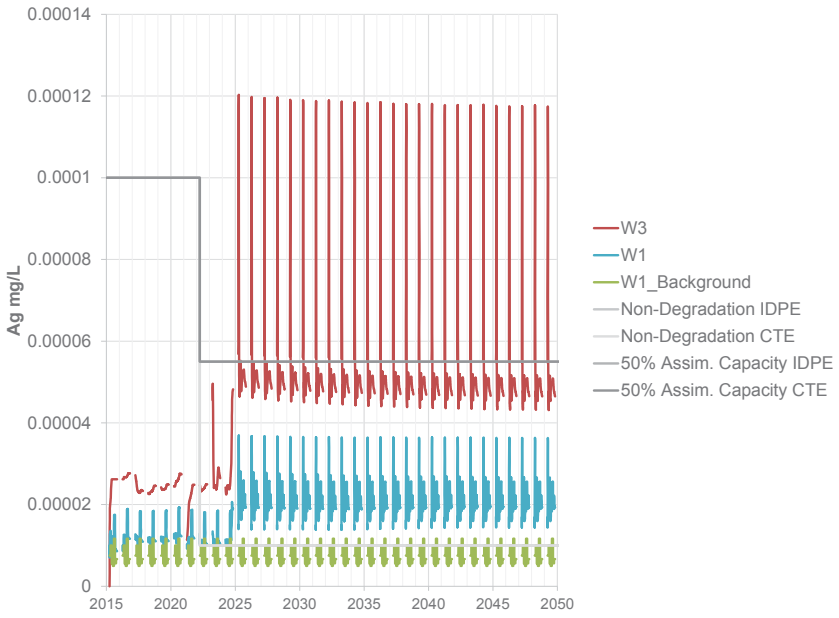


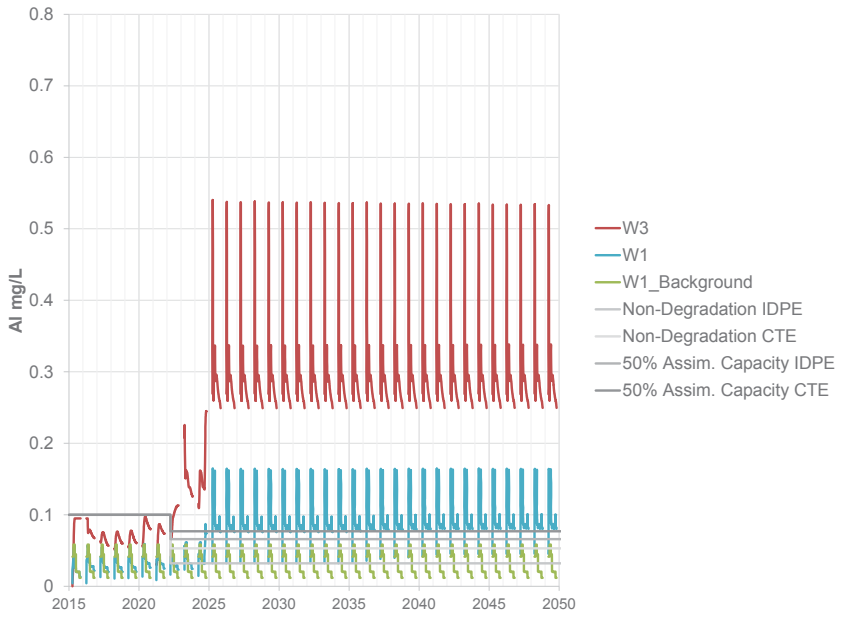


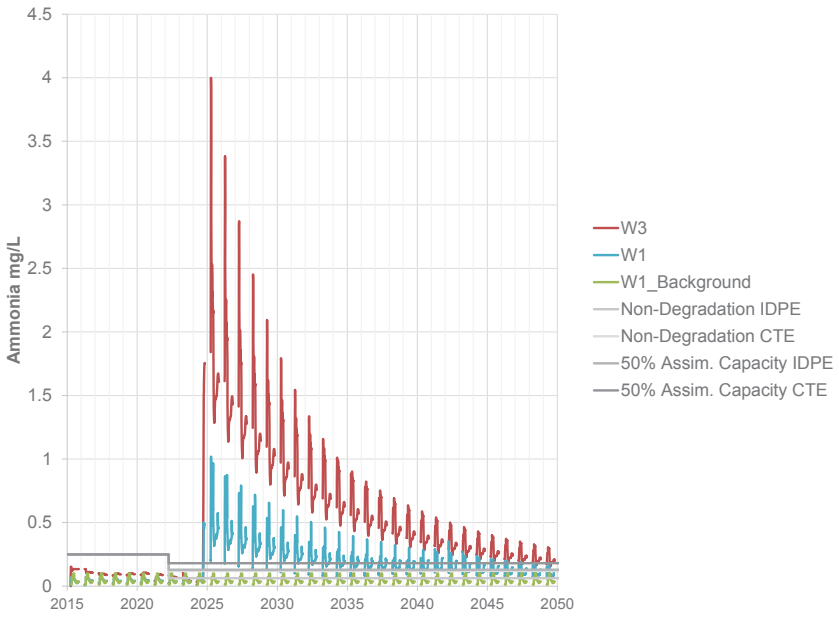


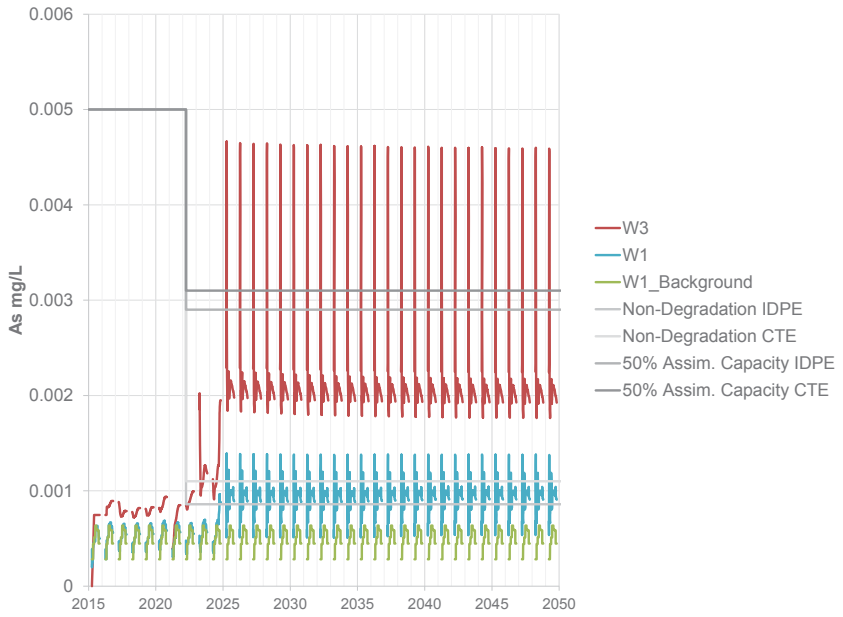


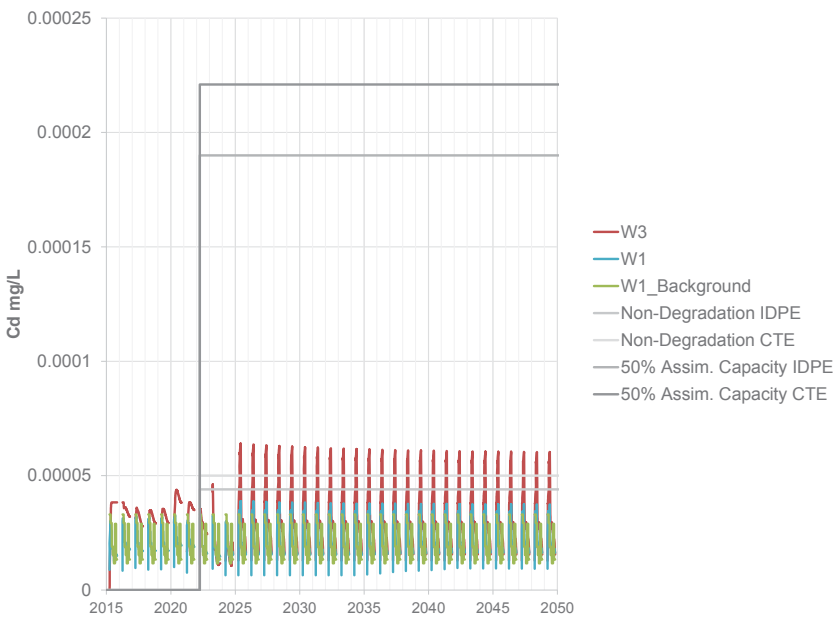


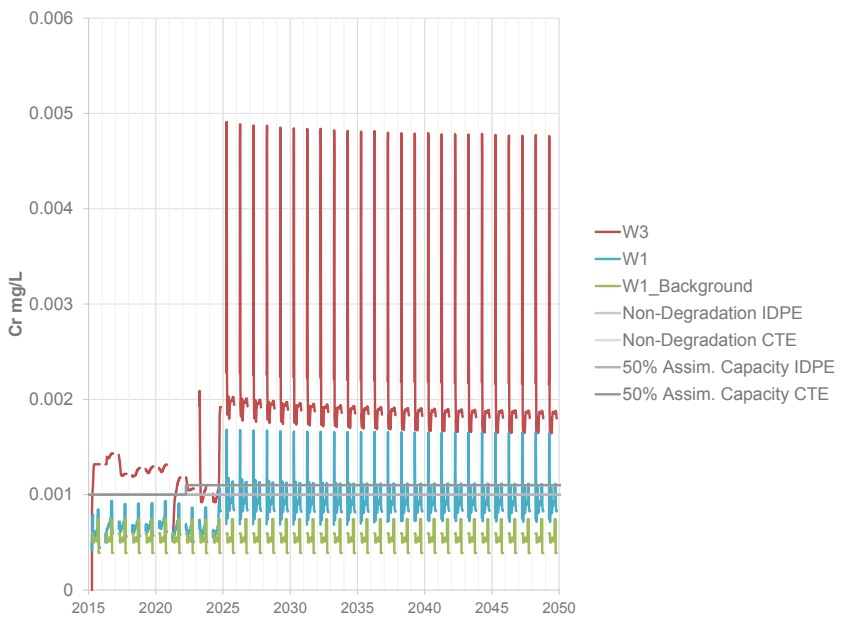


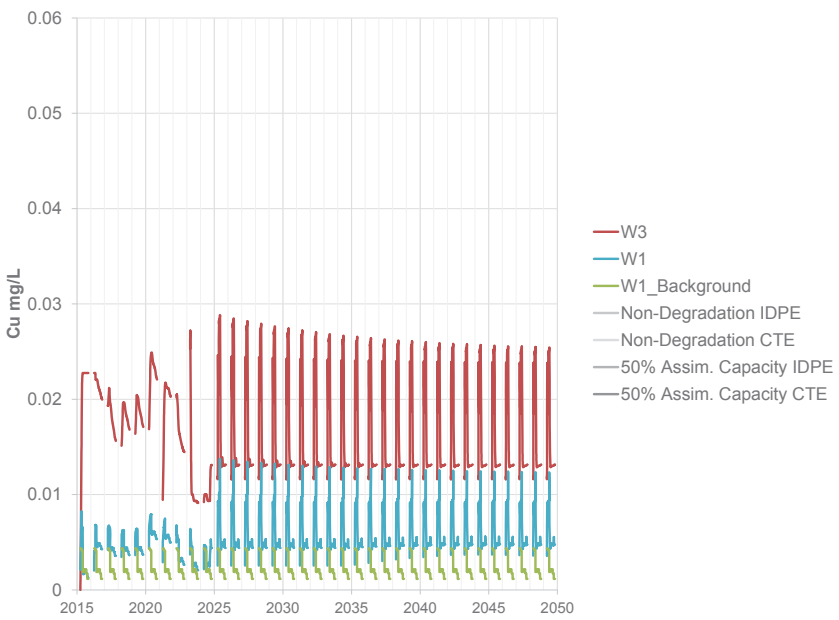


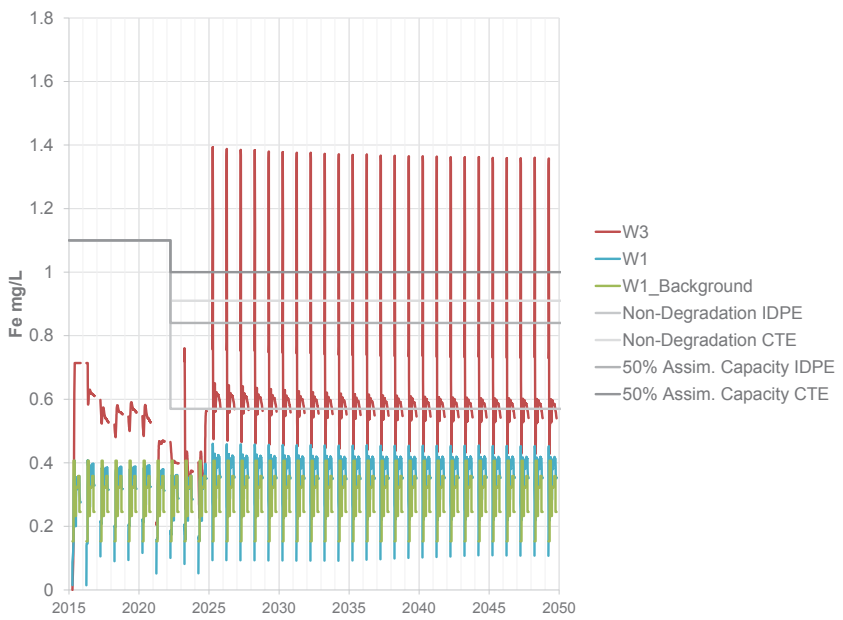


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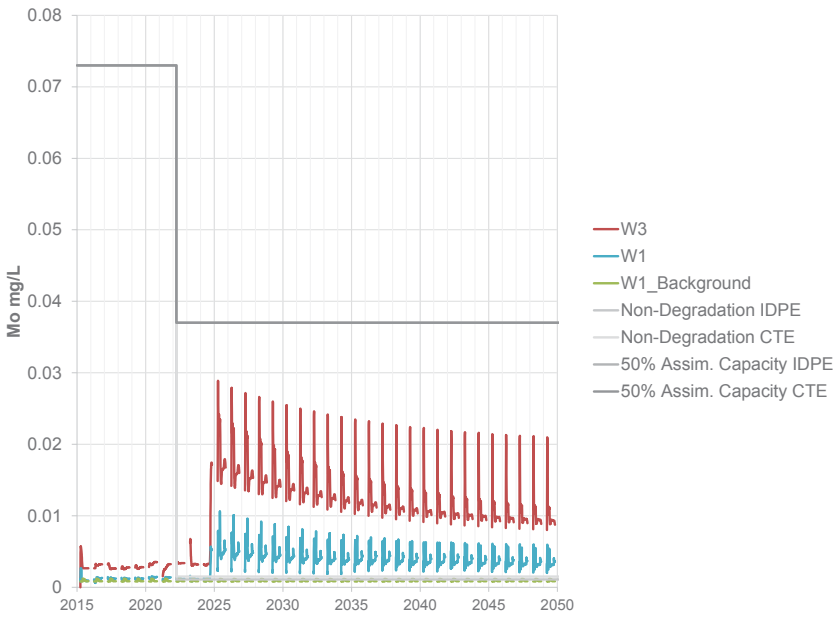


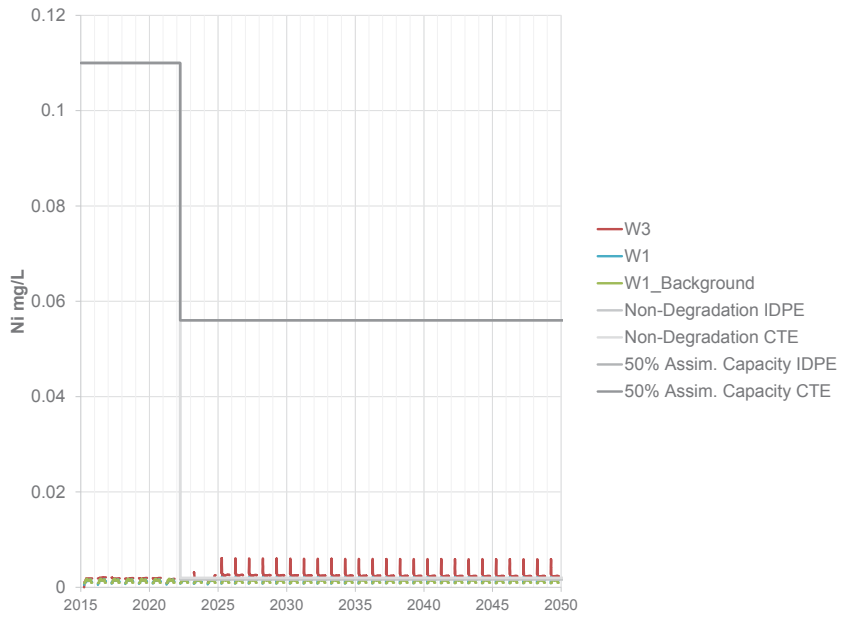


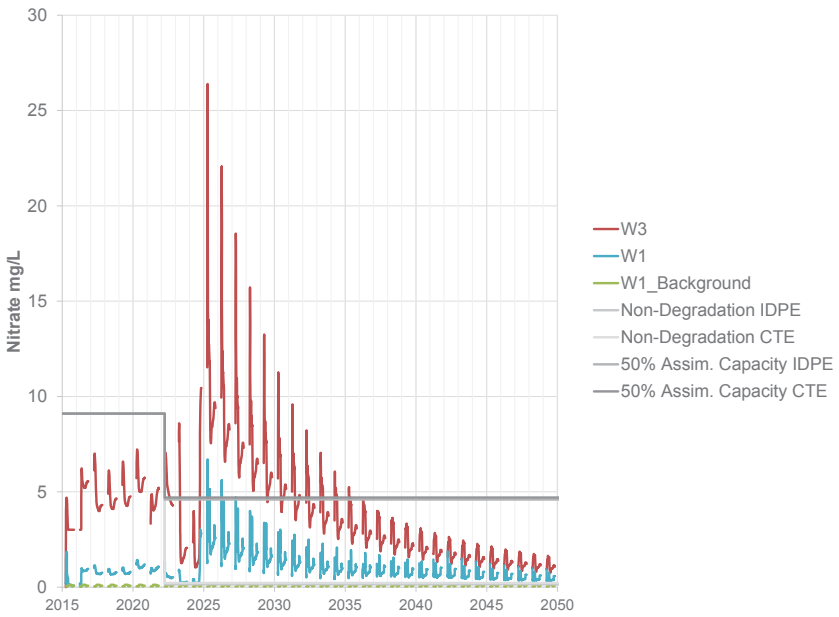


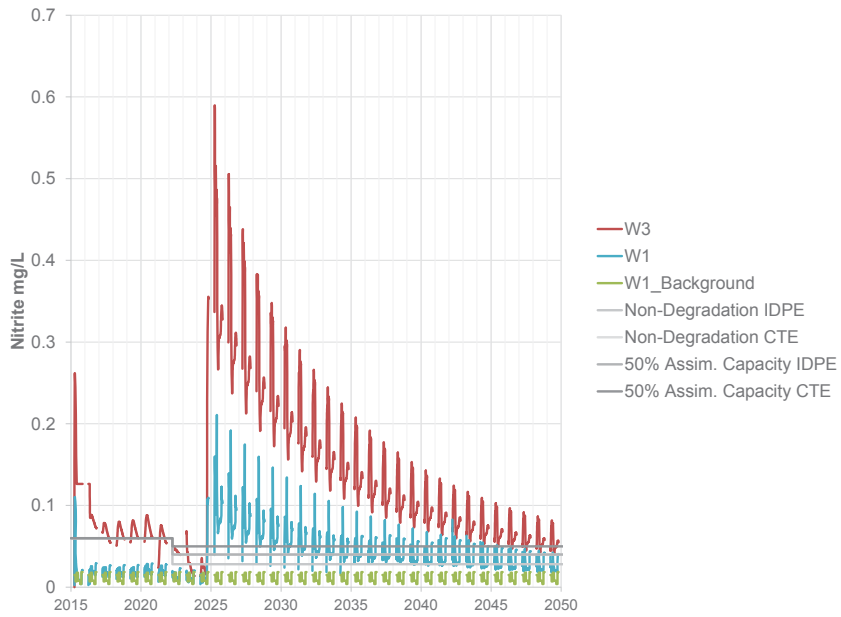


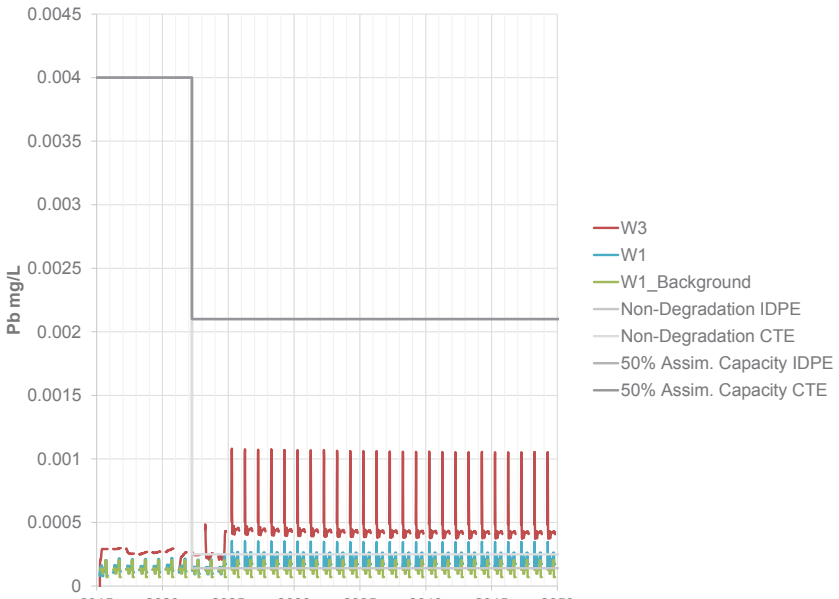


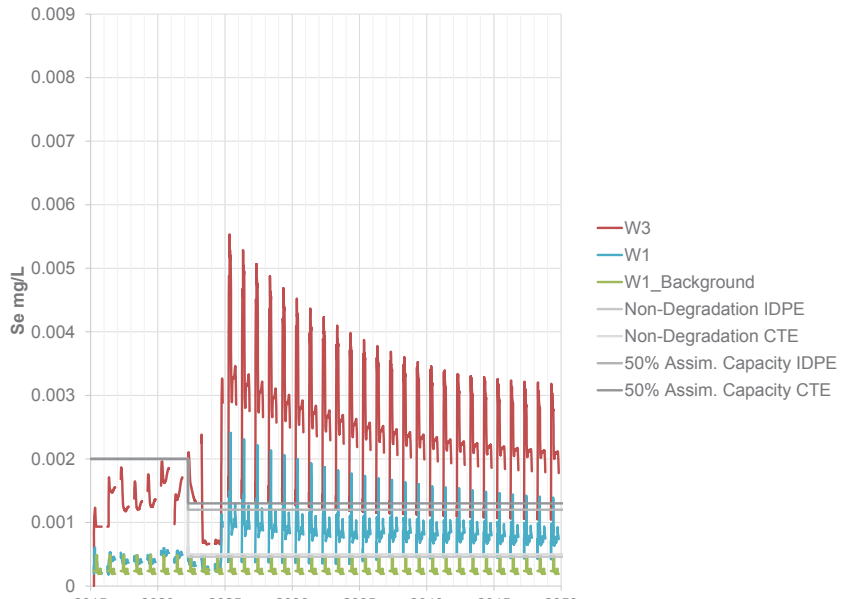


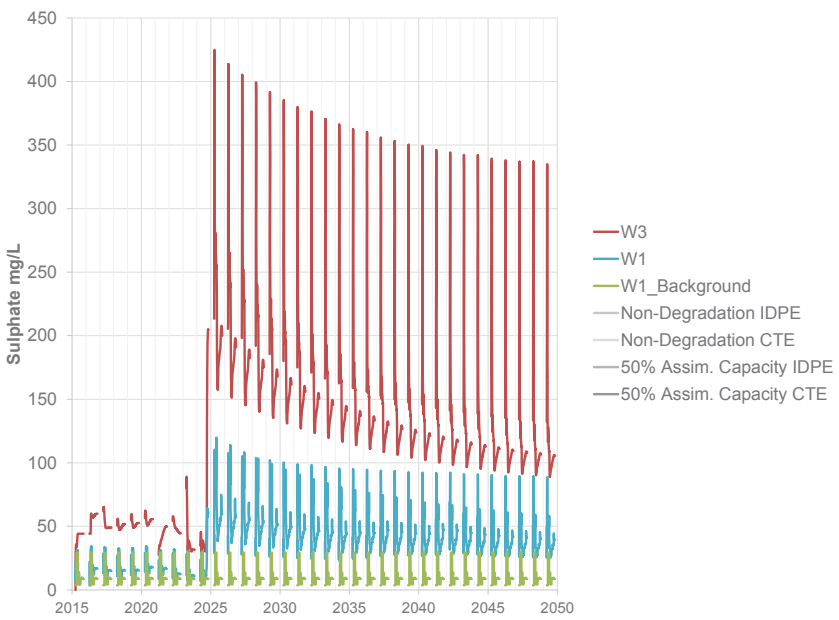


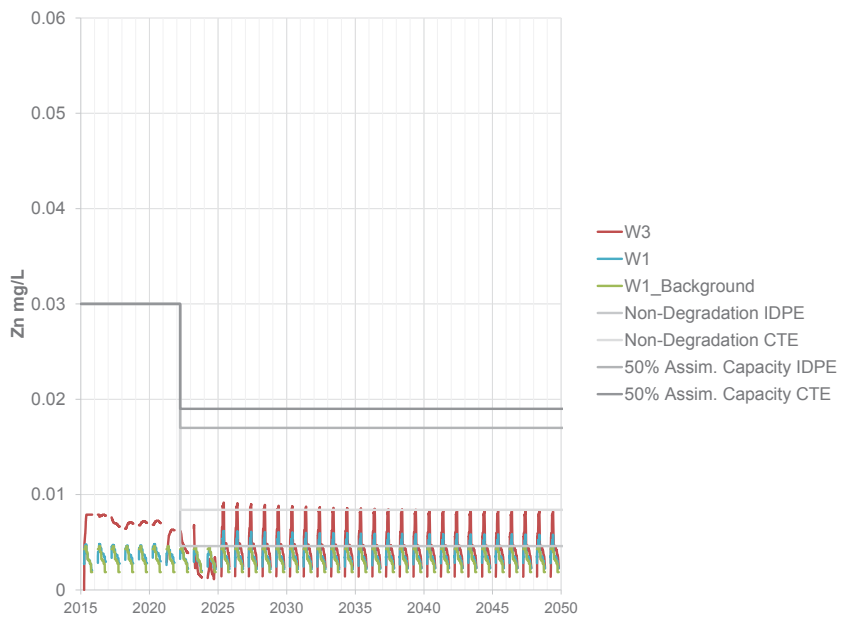


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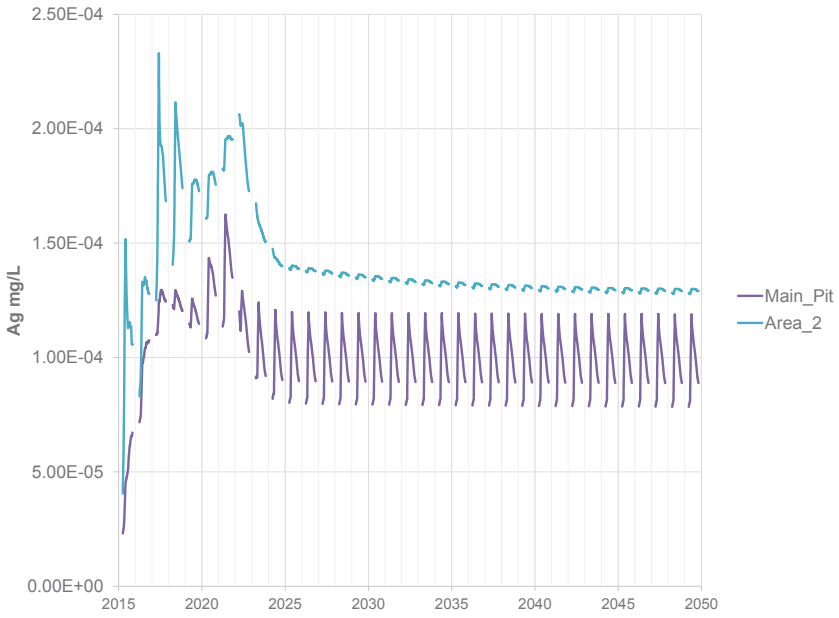
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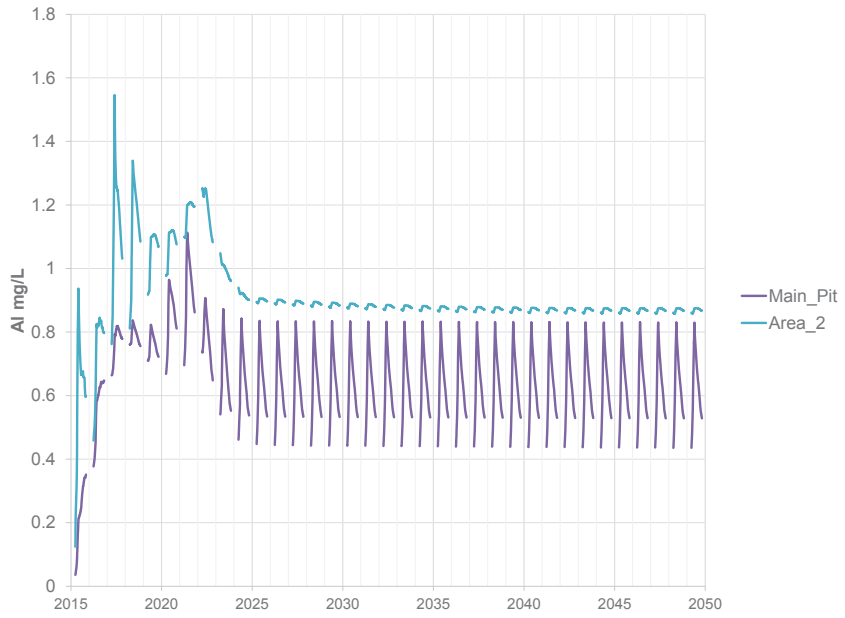
Main_Pit
Area_2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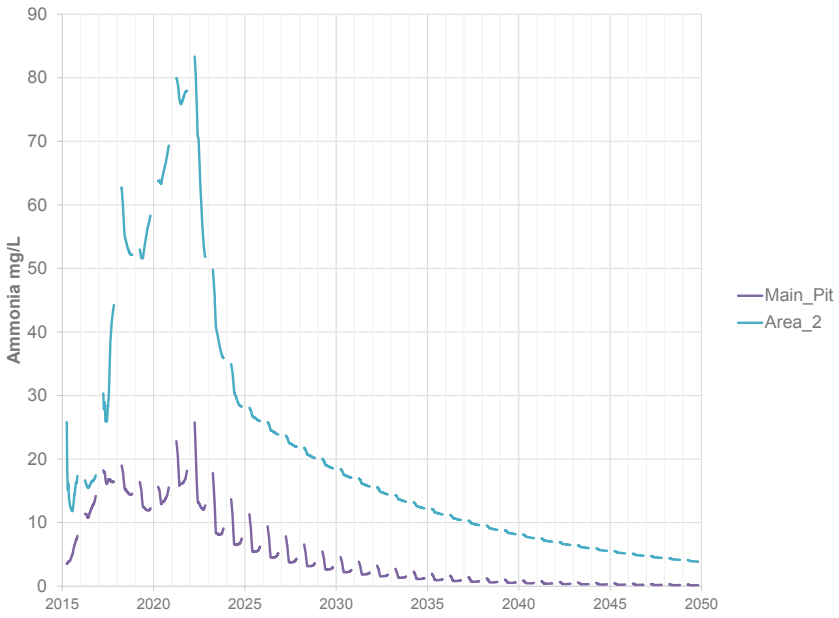
Ammonia mg/L
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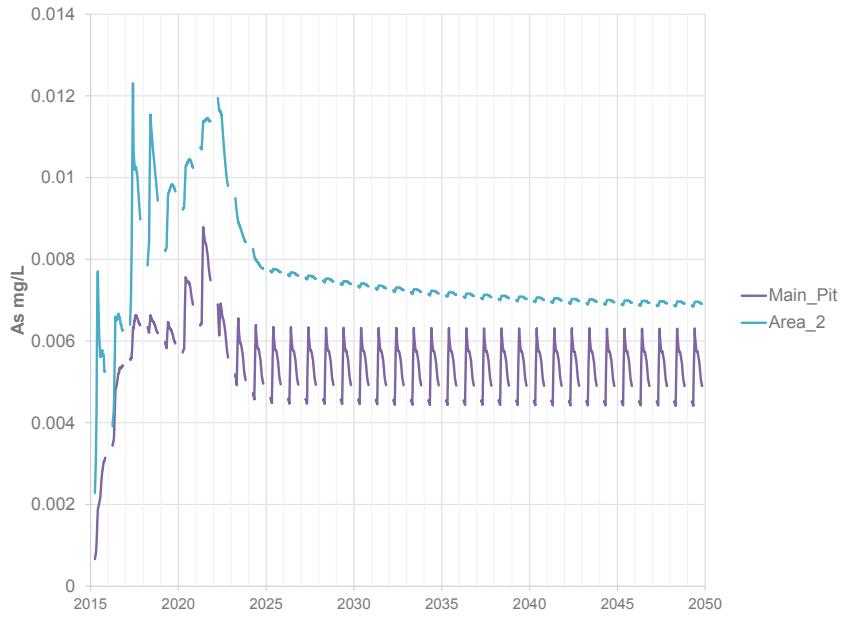
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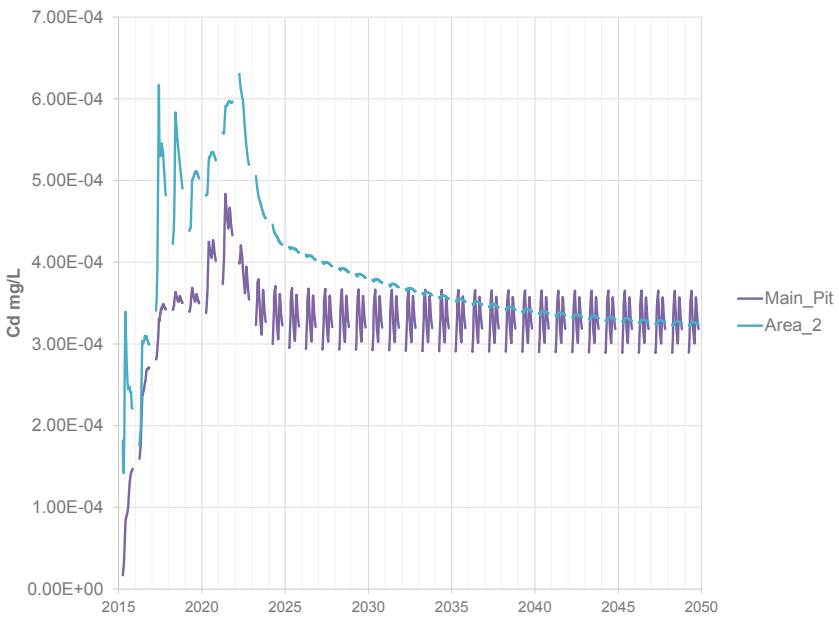
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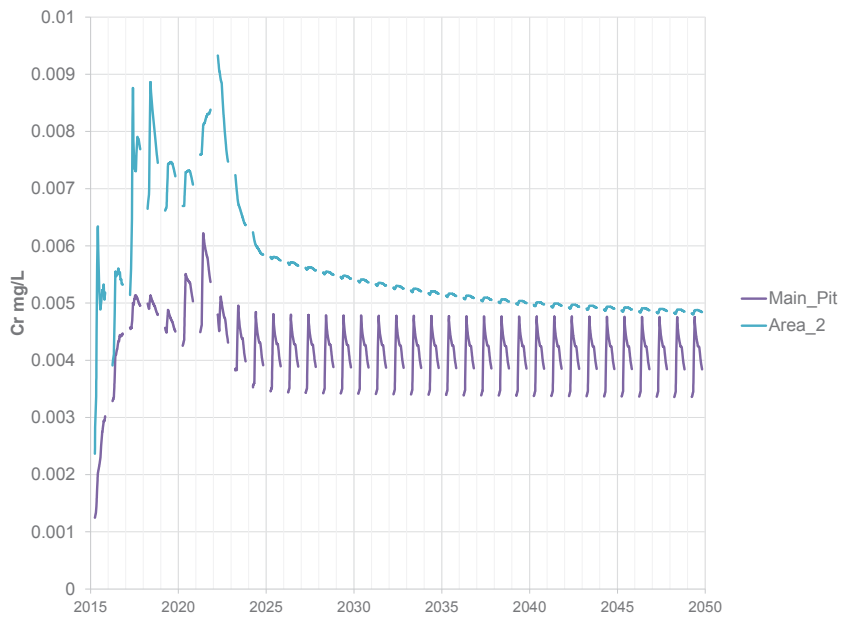
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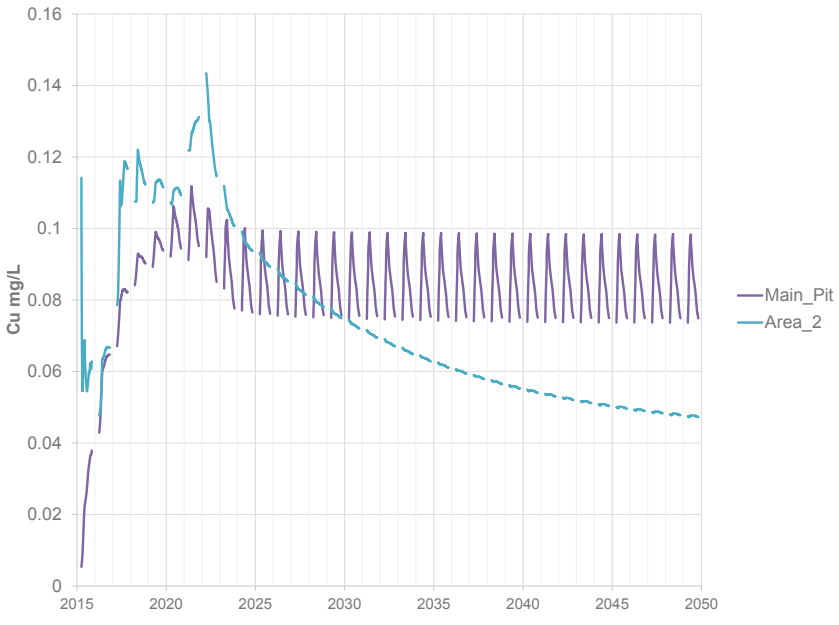
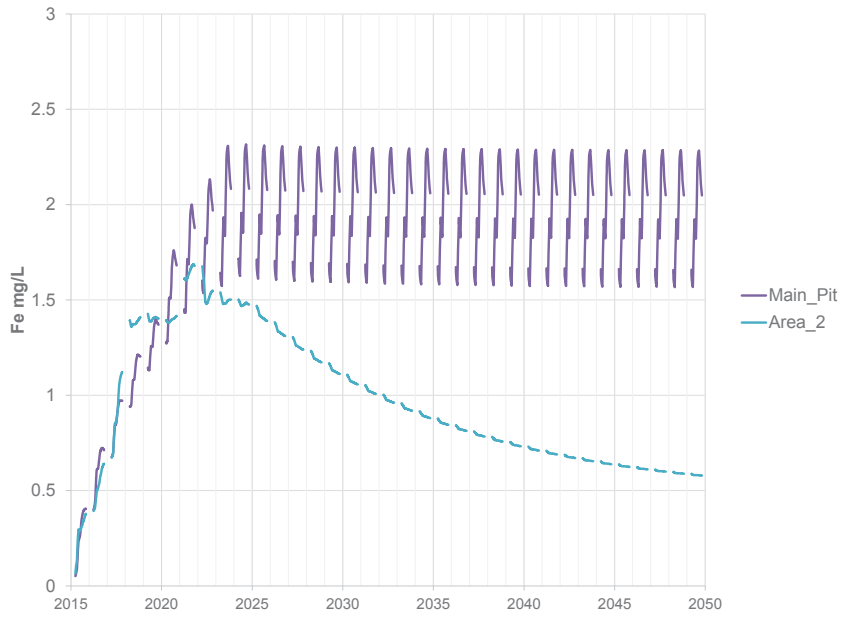
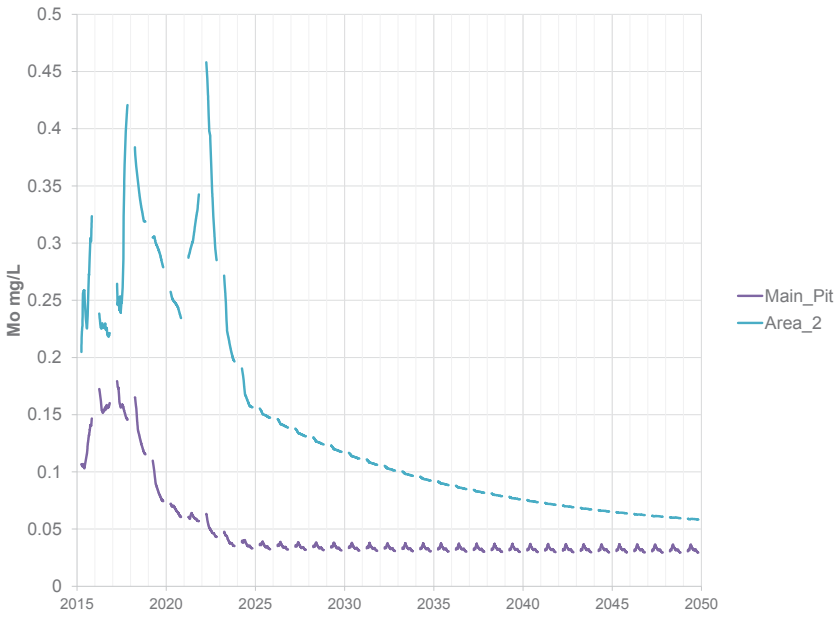
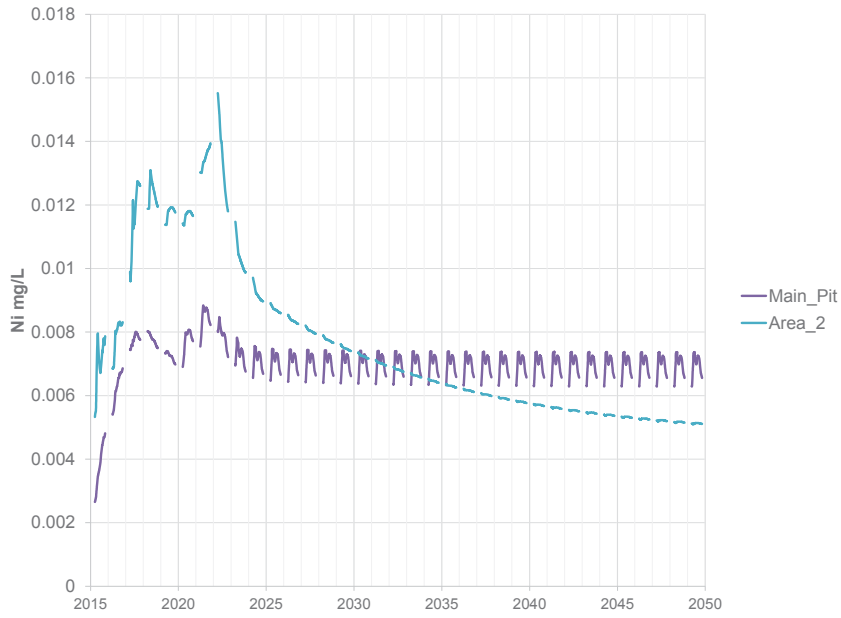
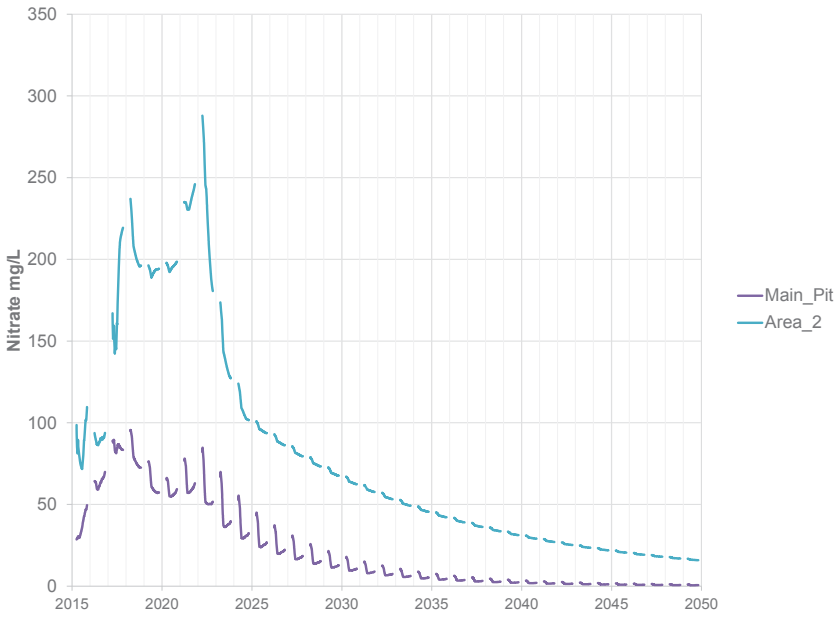
Main_Pit
Area_2

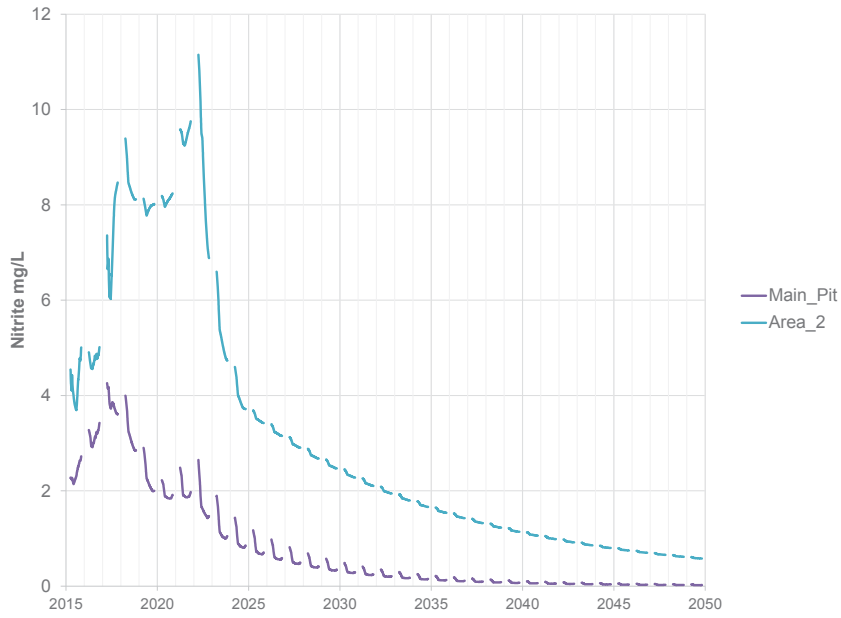

Cu mg/L
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2015
2020
2025
2030
2035
2040
2045
2050
Main_Pit
Area_2

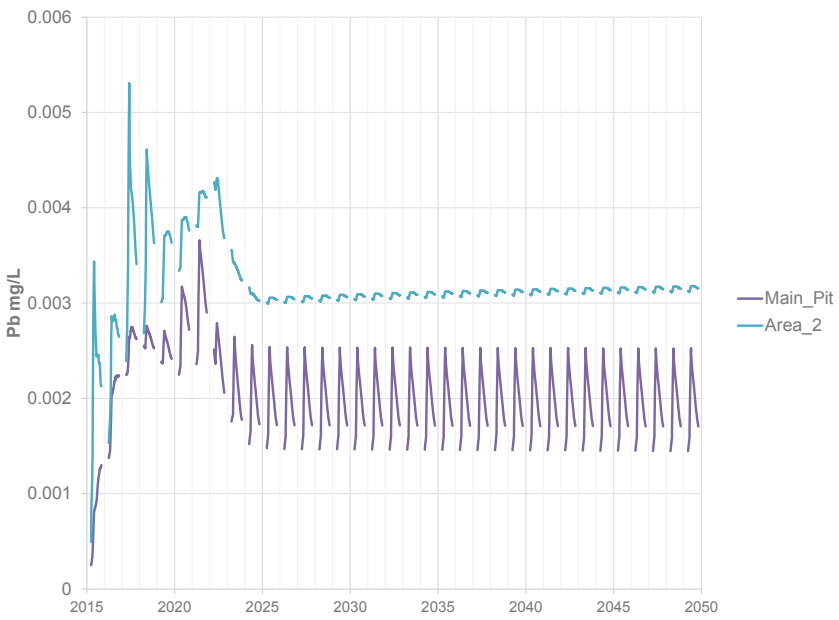

Fe mg/L
3
2.5
2
1.5
1
0.5
0
2015
2020
2025
2030
2035
2040
2045
2050
Main_Pit
Area_2

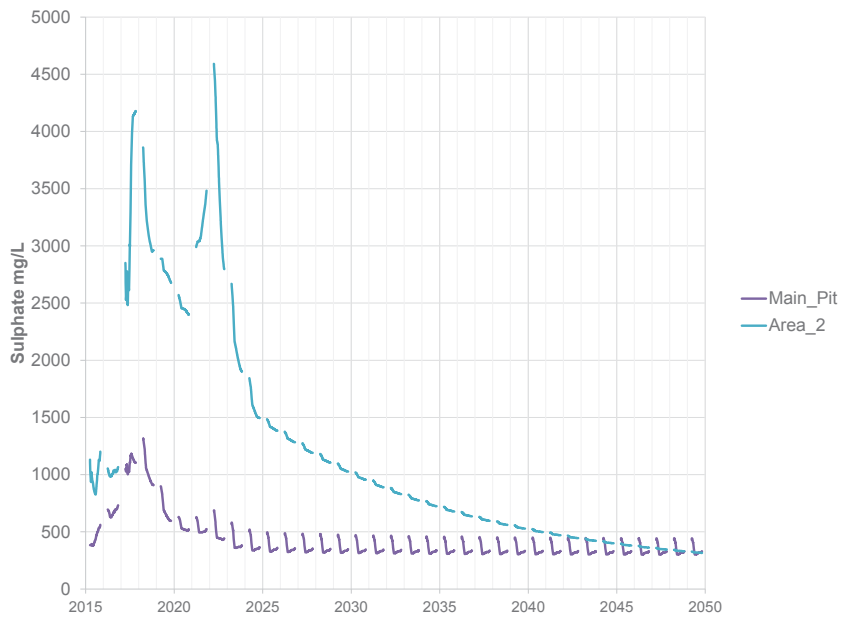


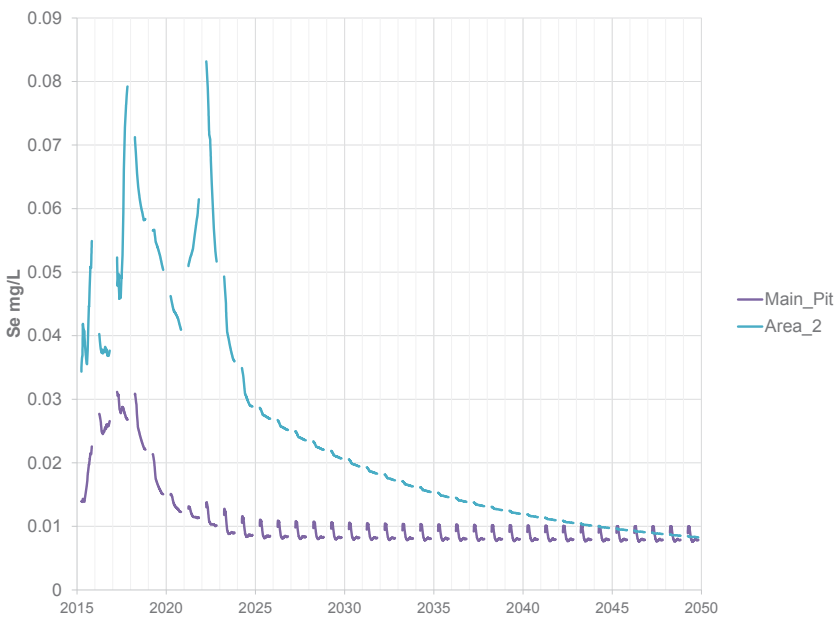



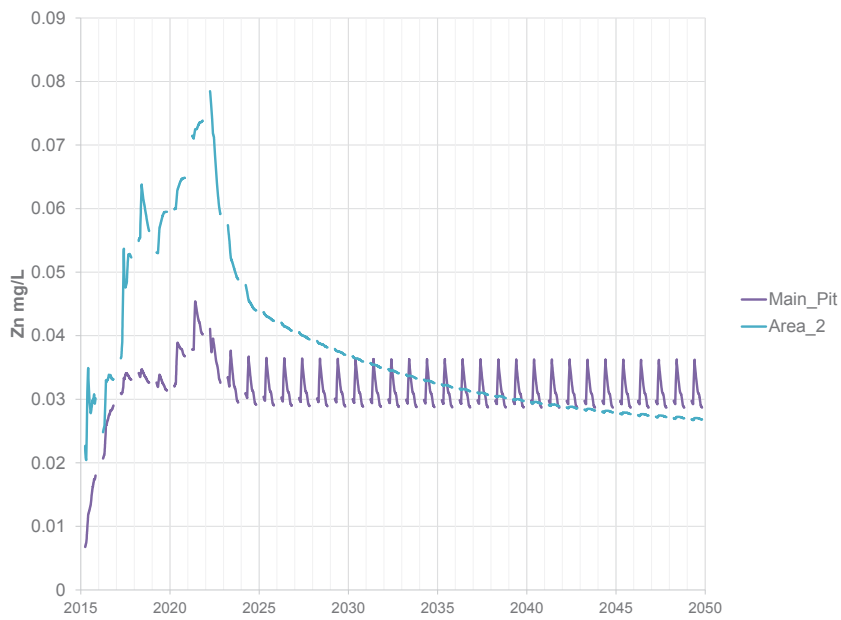

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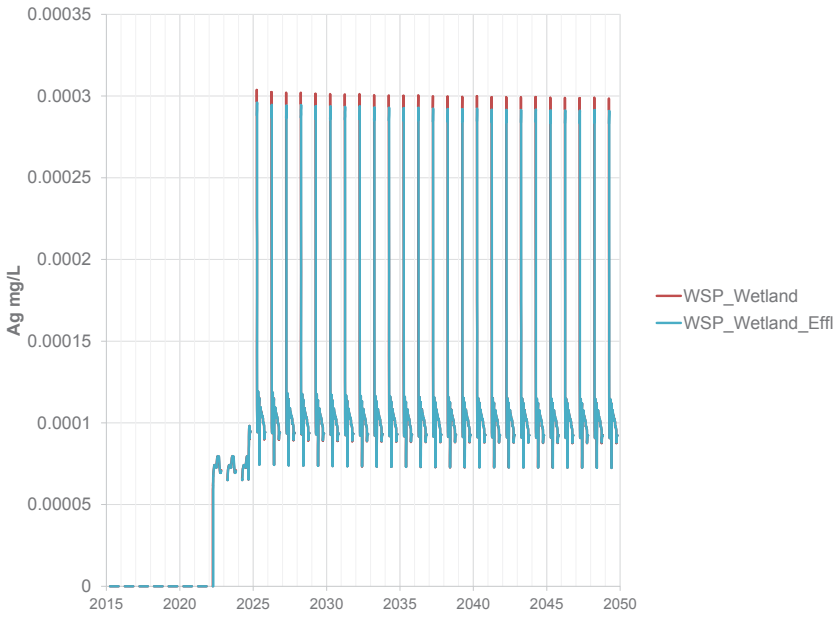
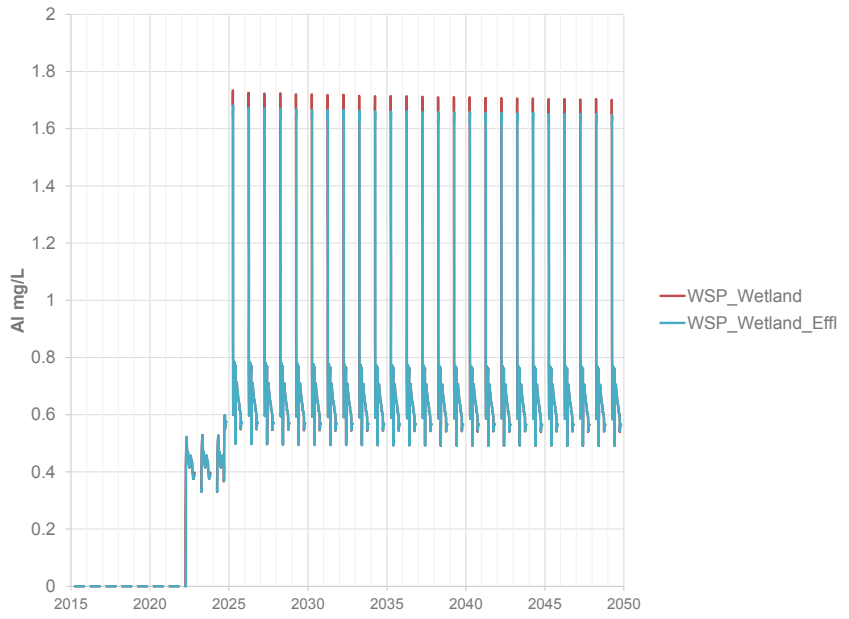
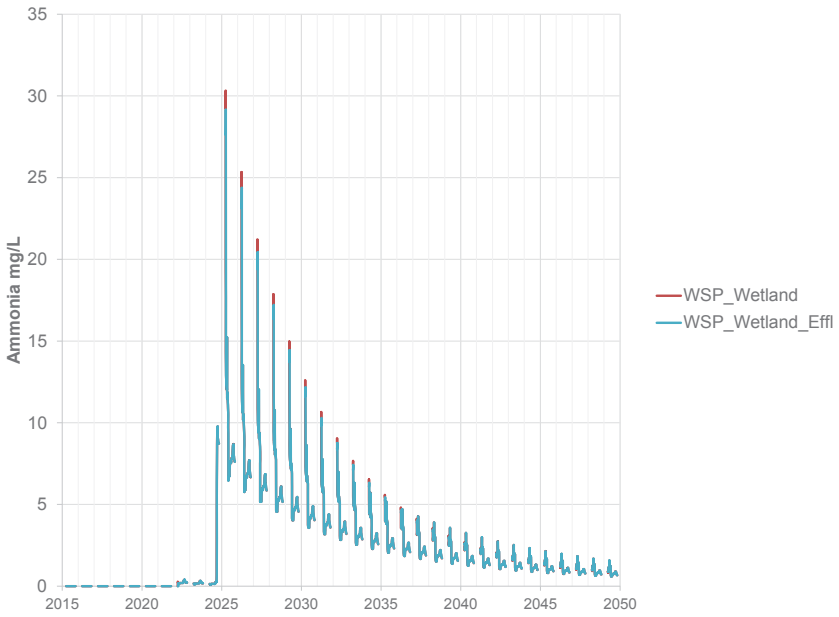
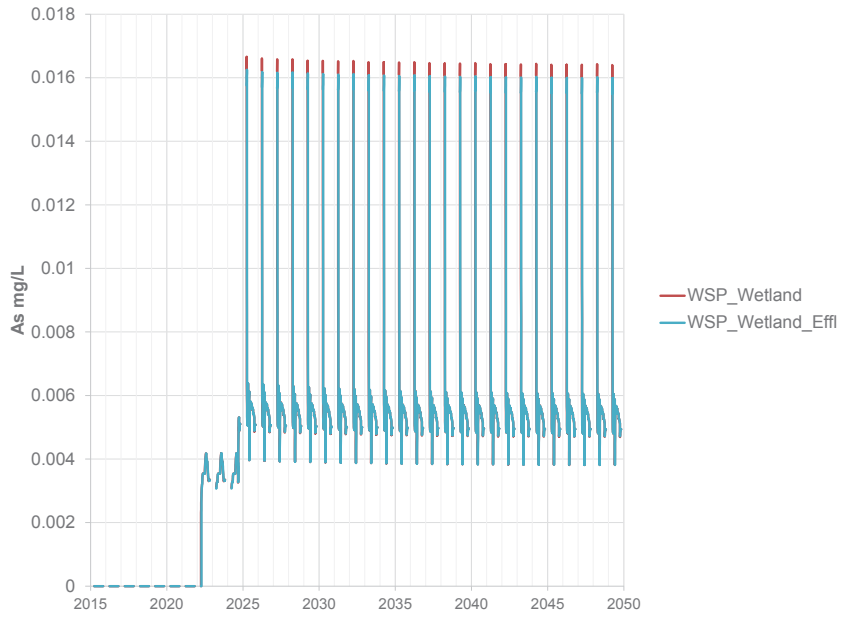

Ag mg/L
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

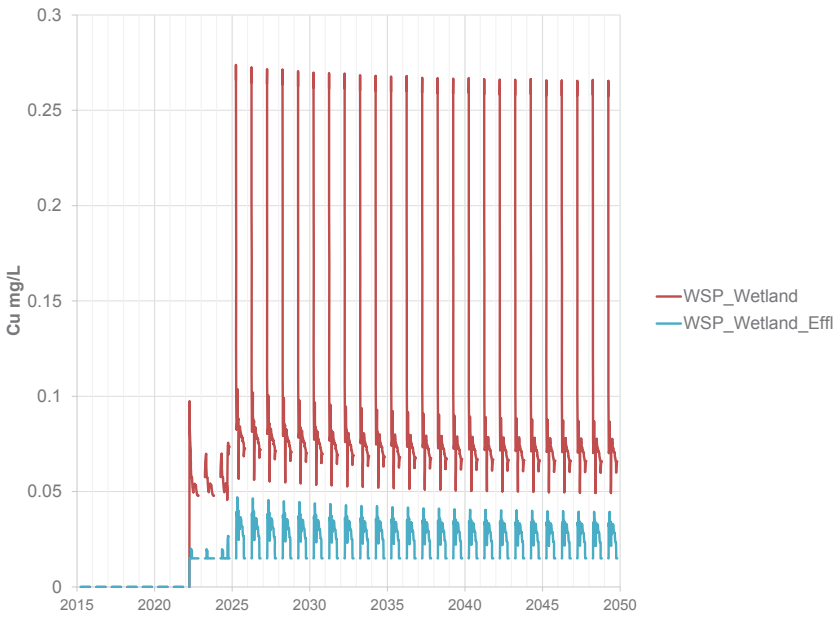

Al mg/L
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

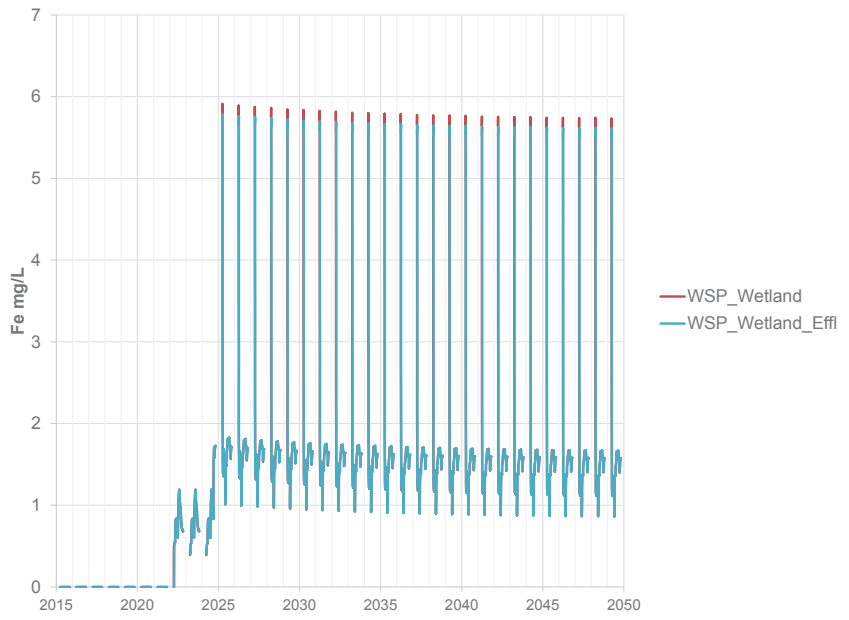

Ammonia mg/L
35
30
25
20
15
10
5
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

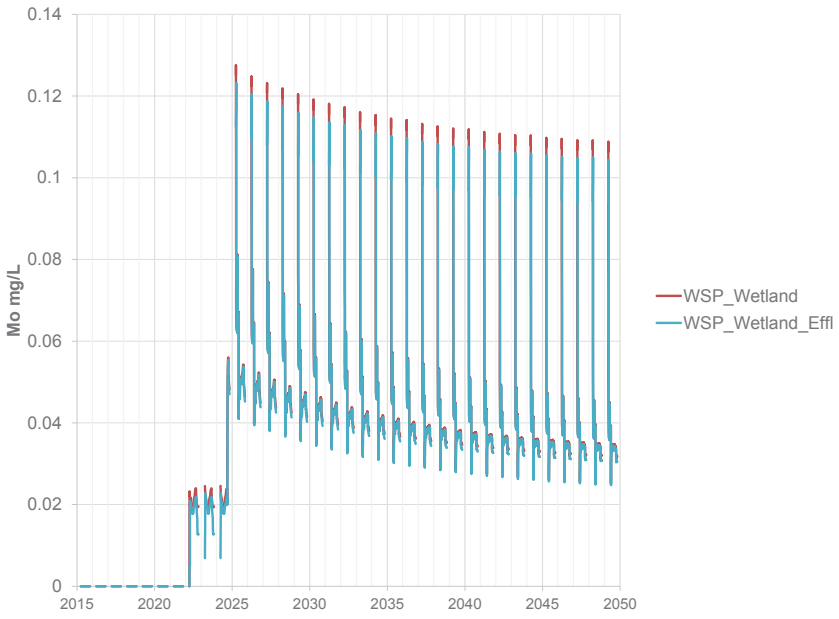

As mg/L
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

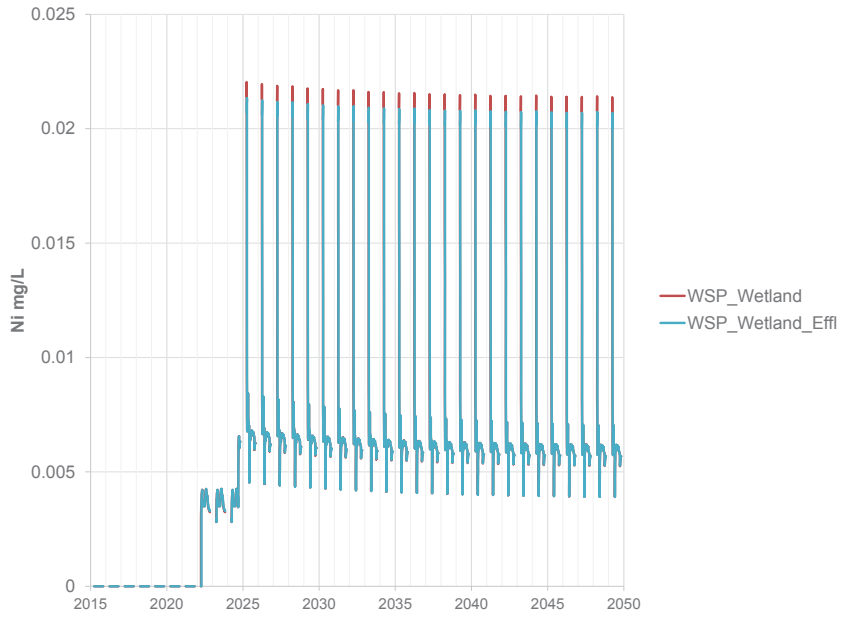

Cd mg/L
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

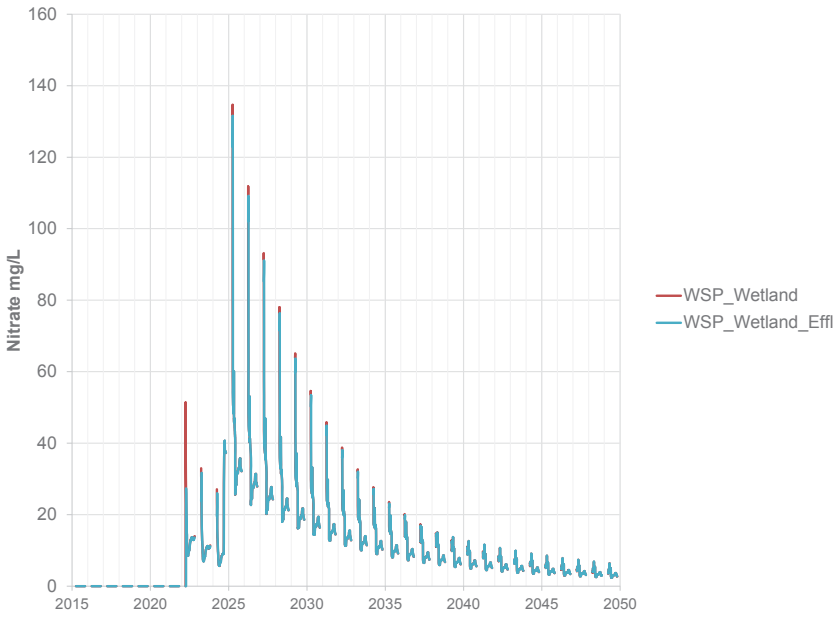

Cr mg/L
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

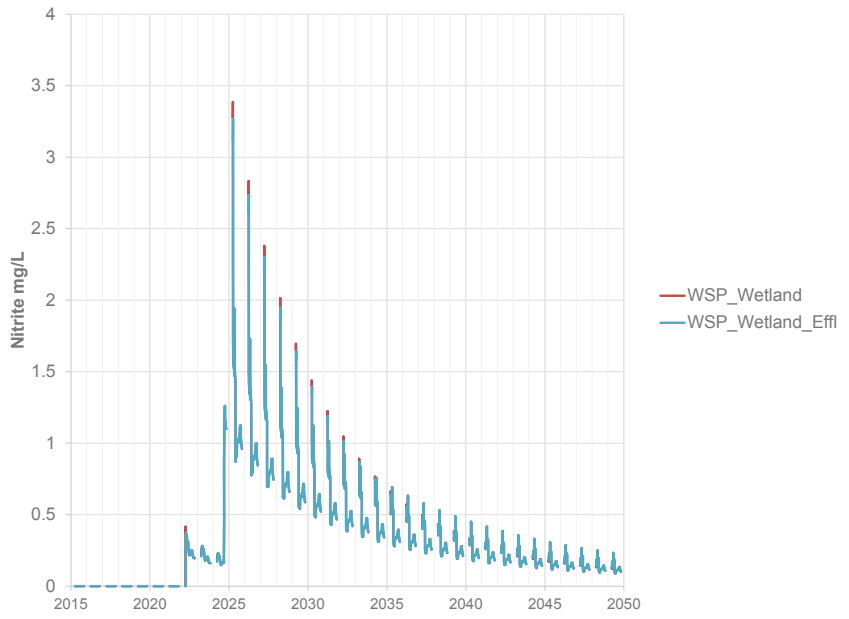

Cu mg/L
0.3
0.25
0.2
0.15
0.1
0.05
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

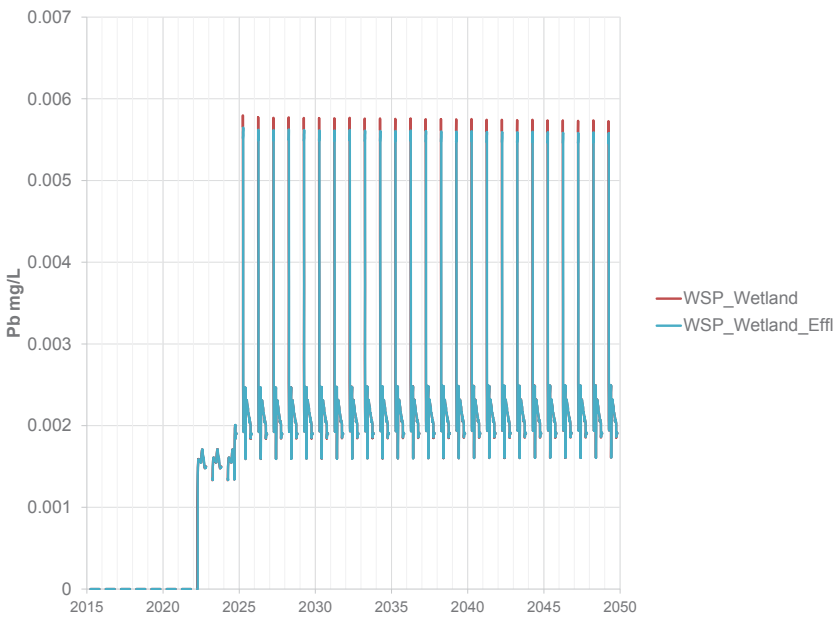

Fe mg/L
7
6
5
4
3
2
1
0
2015
2020
2025
2030
2035
2040
2045
2050
WSP_Wetland
WSP_Wetland_Effl

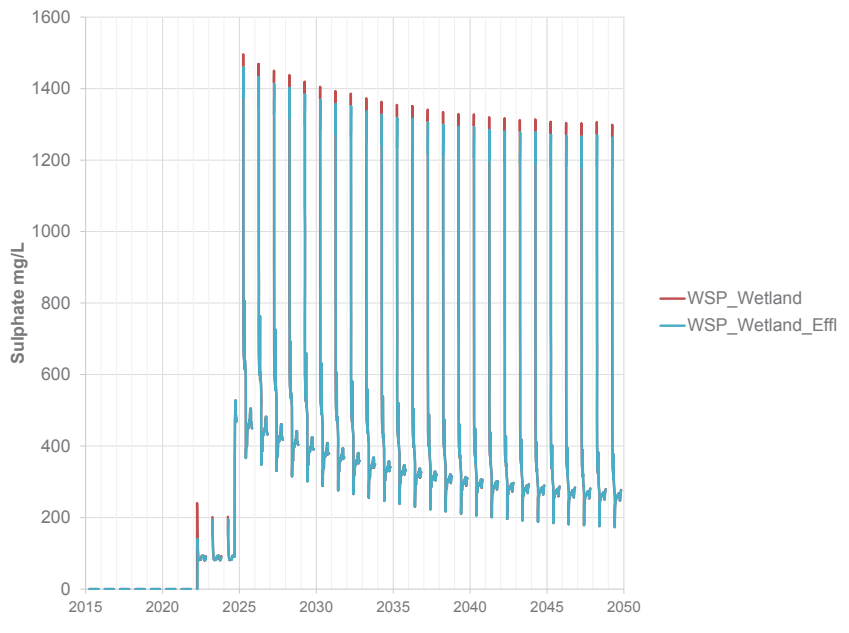


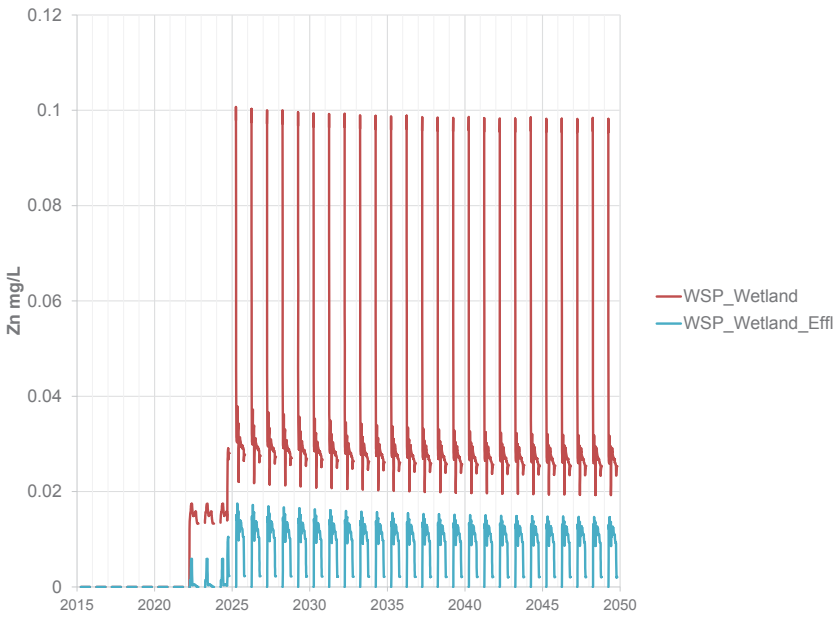



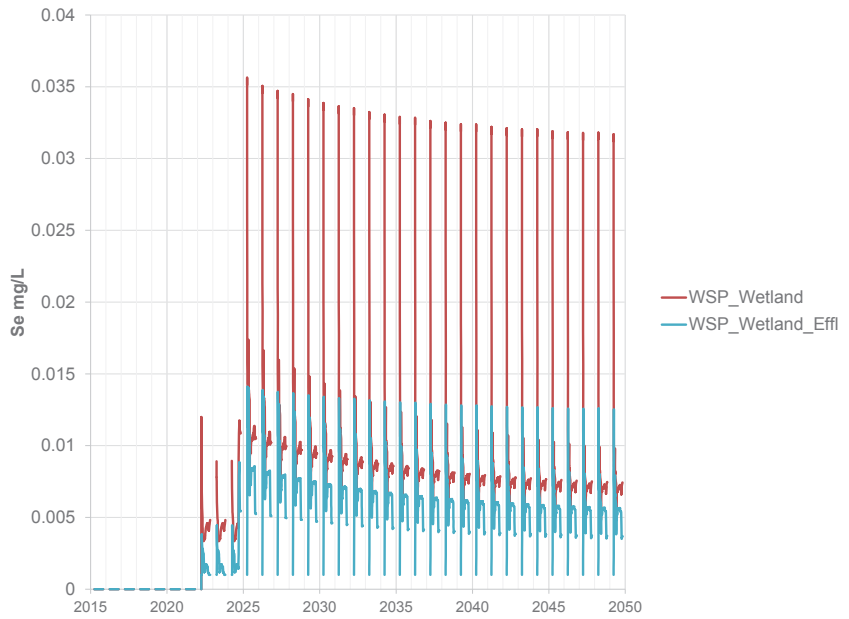

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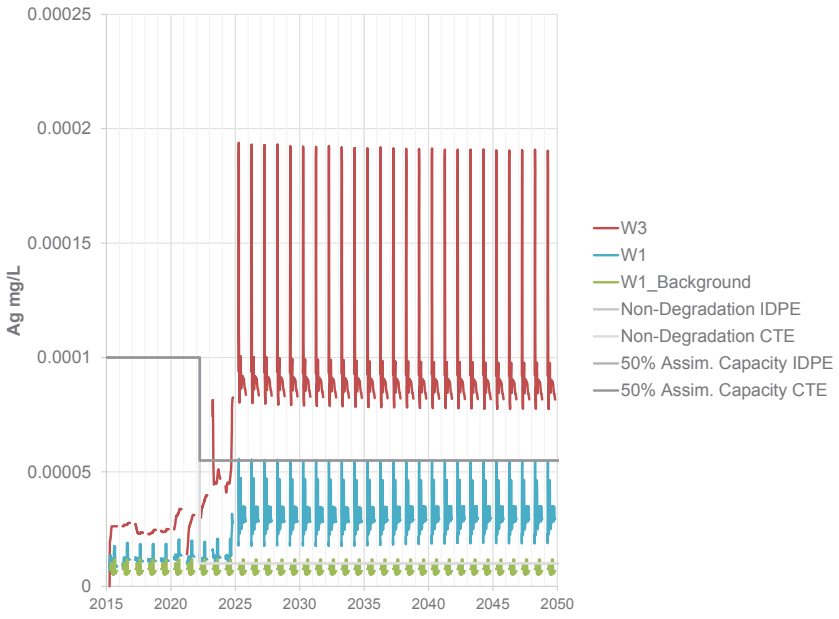


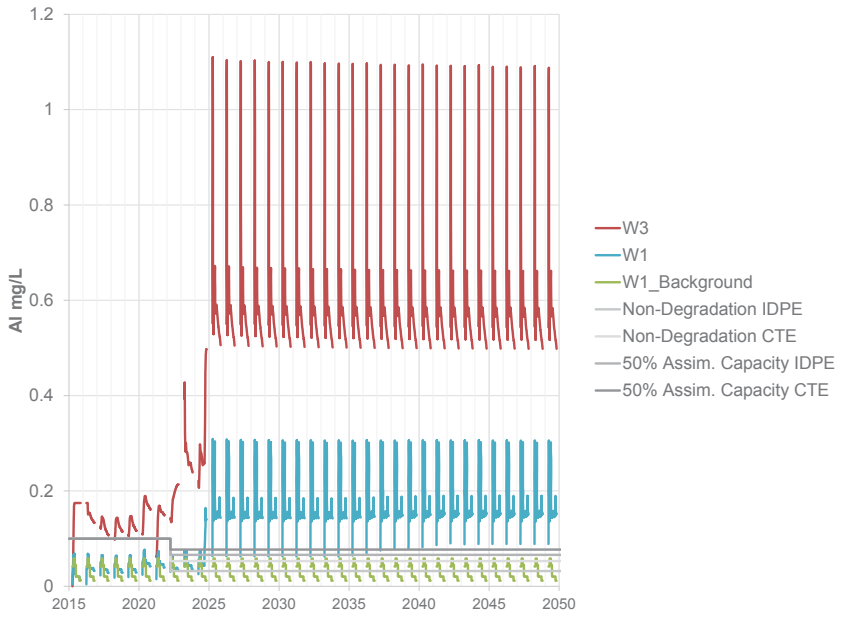


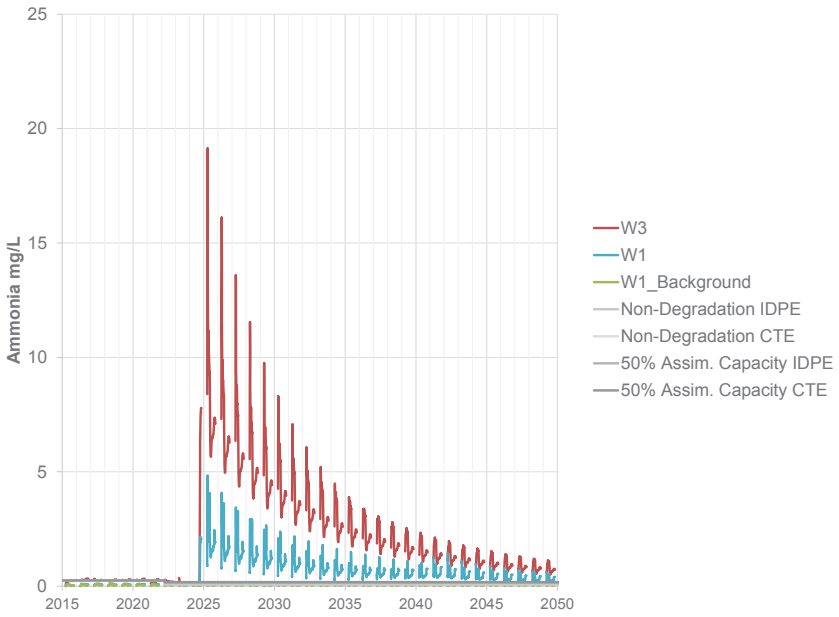


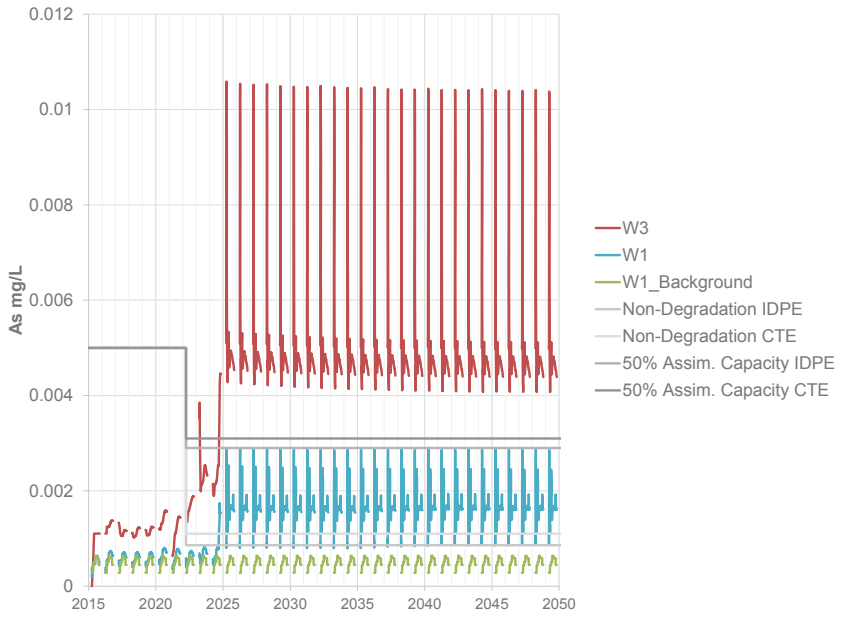


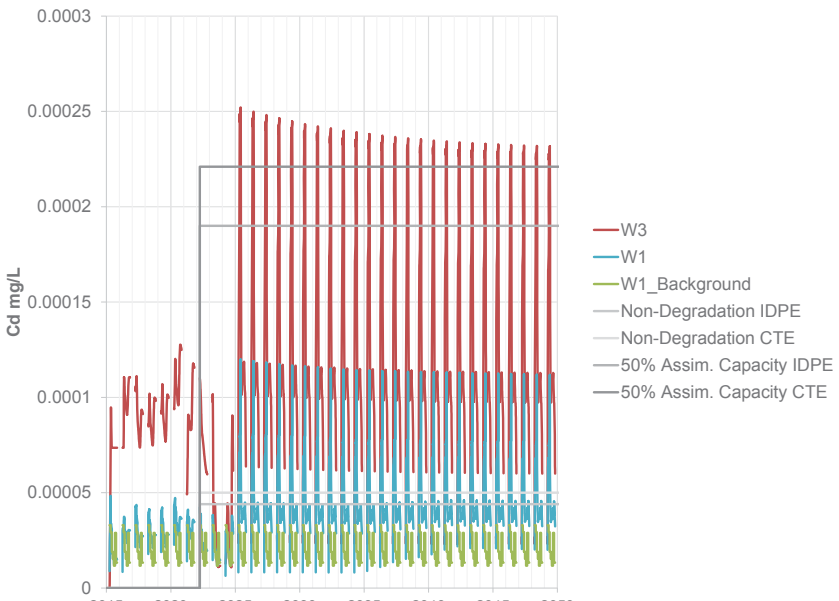


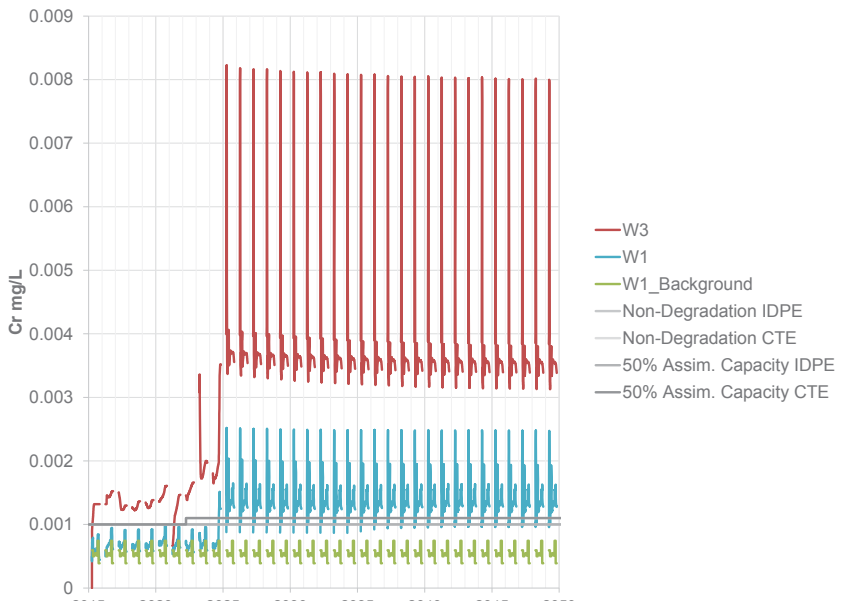


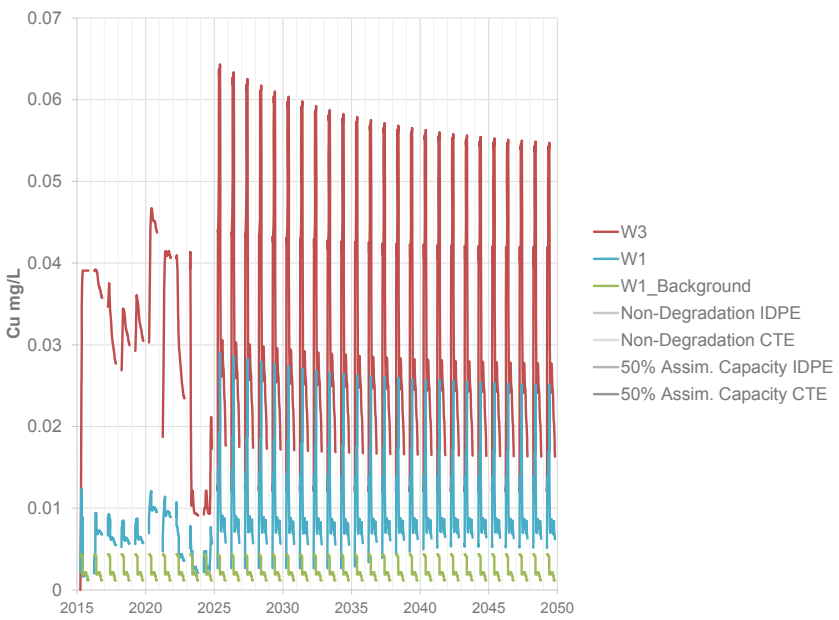


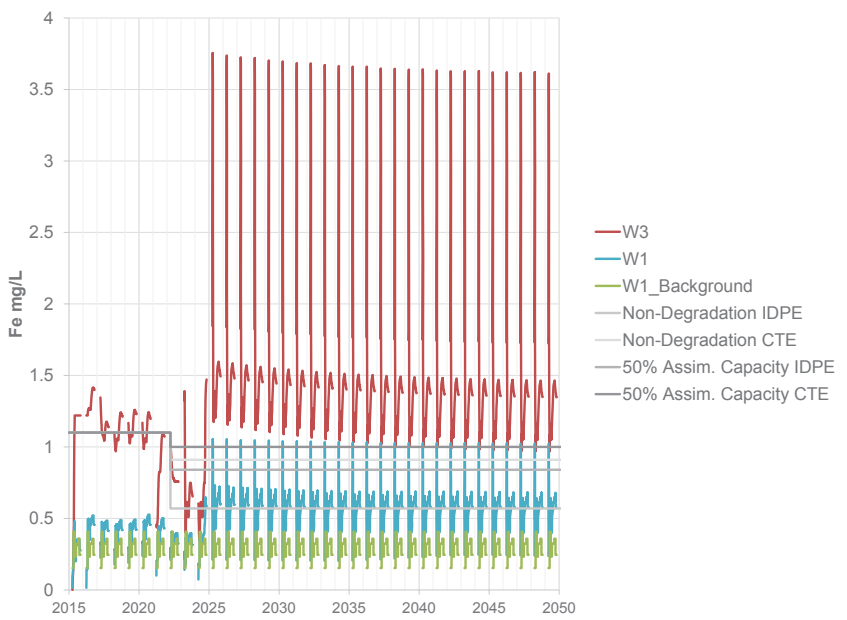


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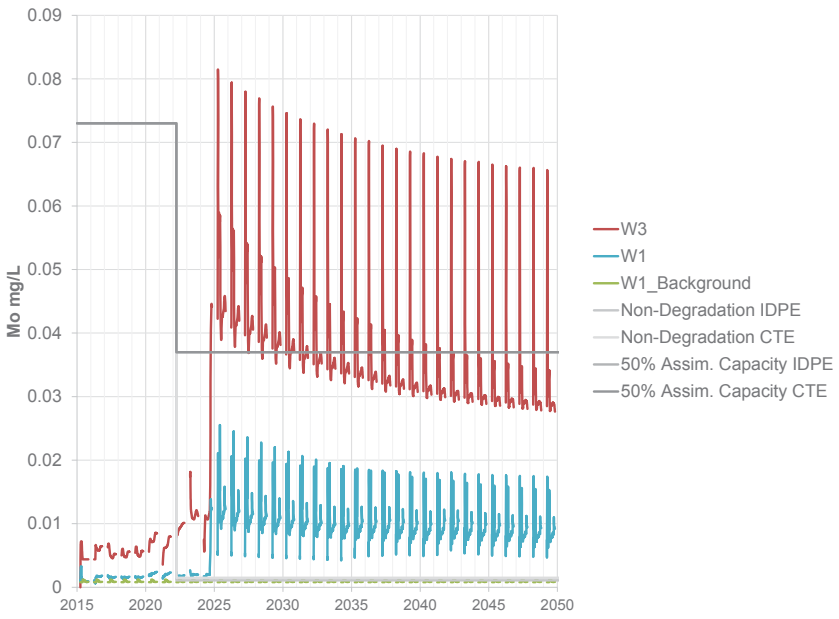


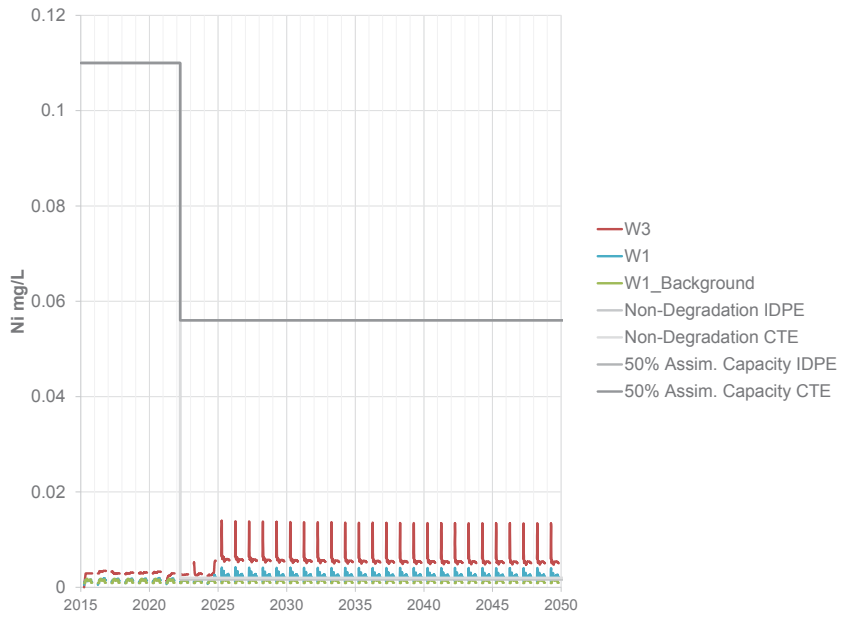


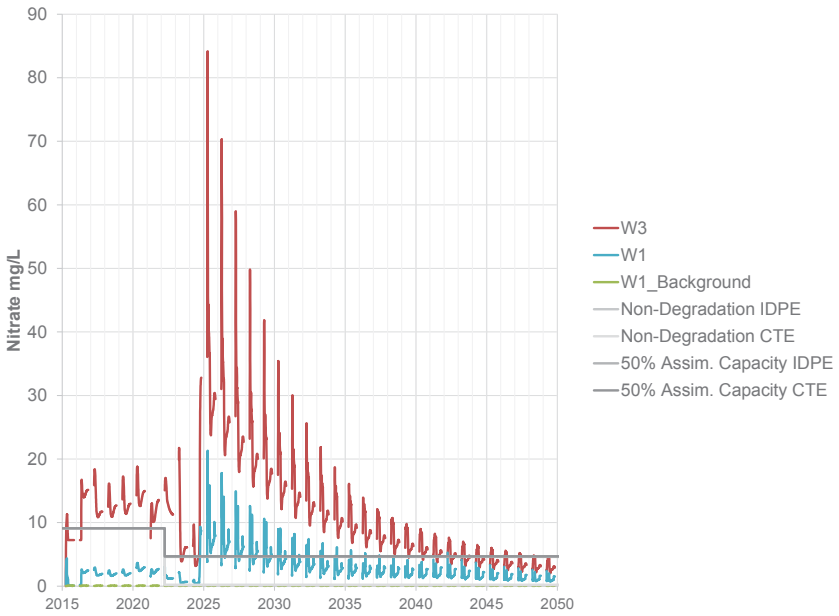


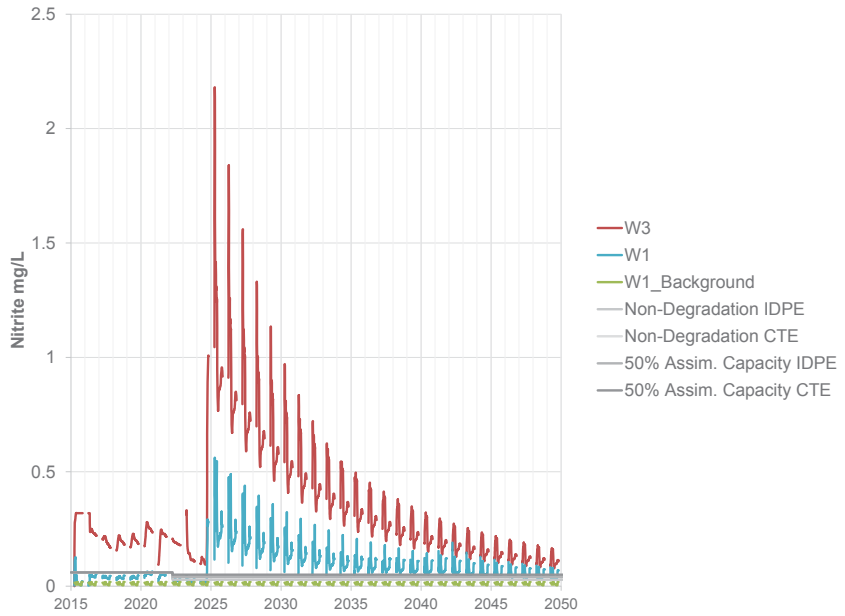


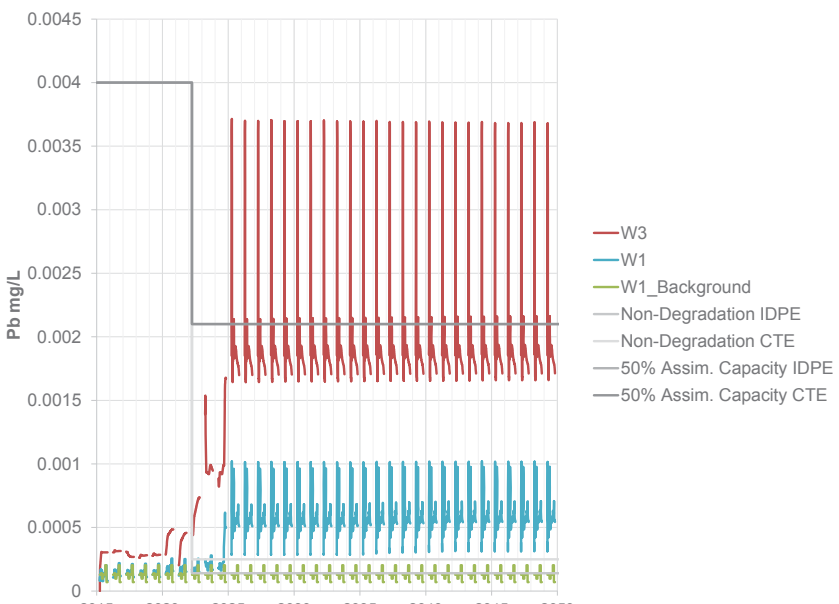


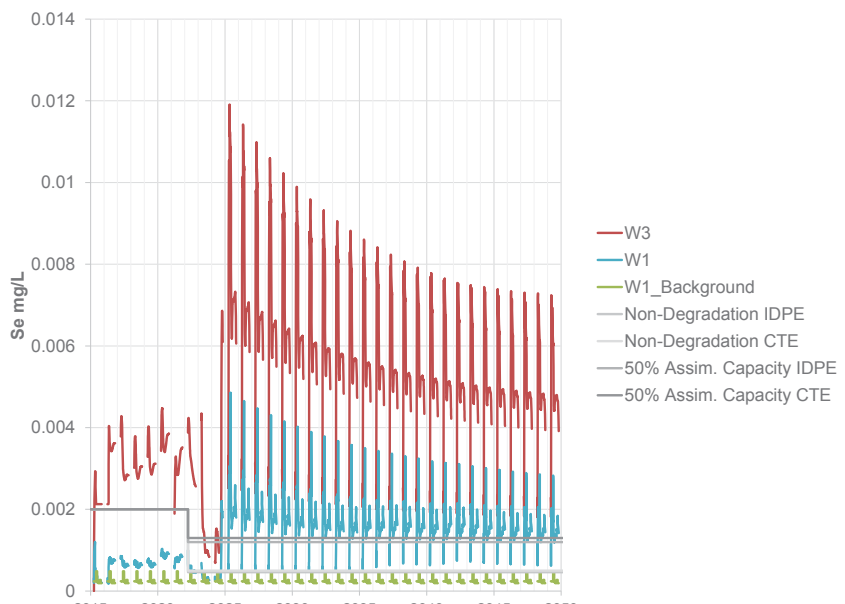


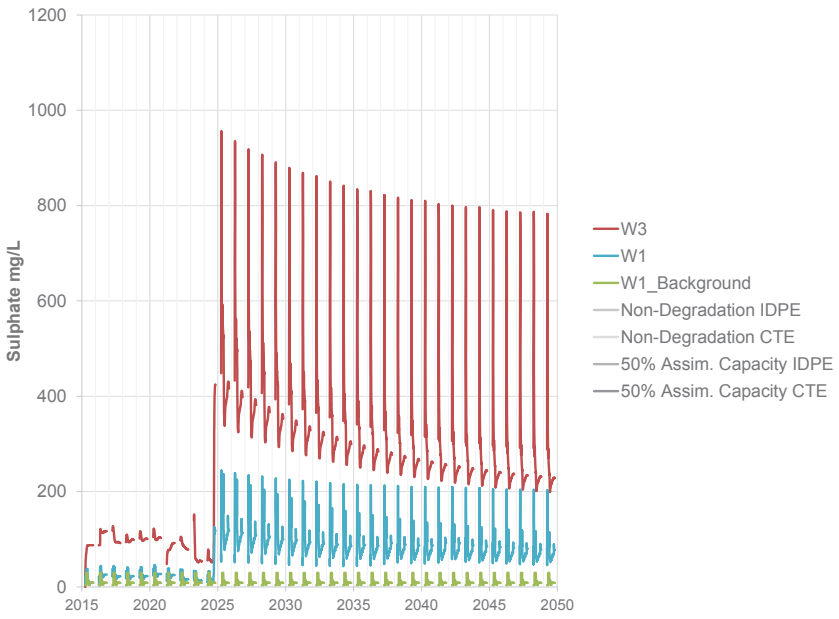


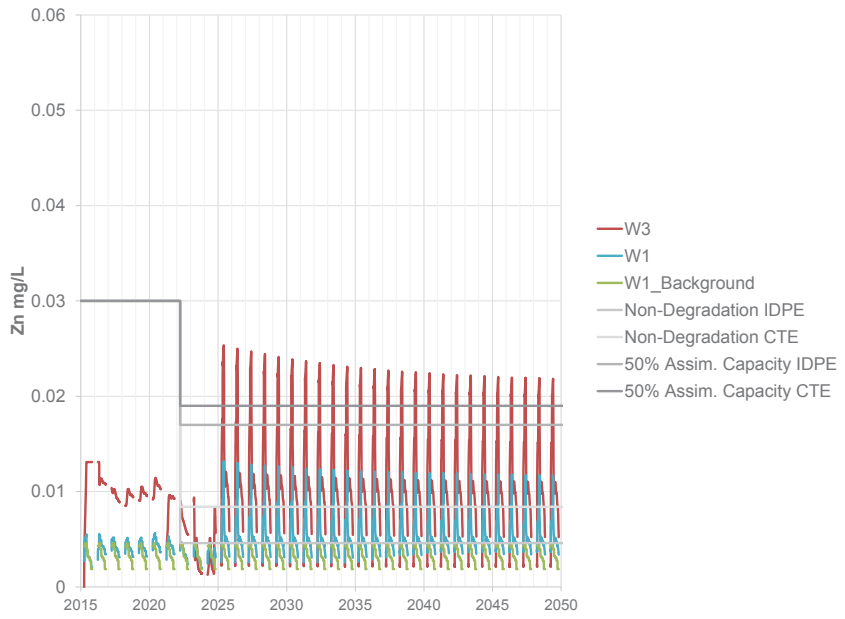


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Model: Minto_2017_1CM002.024_Rev71_SRJ_KNK, 2018/02/06, KNK

# Appendix B: Water and Load Balance Source Terms

**DSTSF Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/L | mg/L |
| Ag-D | 0.00002 | 0.0001 |
| Al-D | 0.01 | 0.069 |
| Ammonia | 0.12 | 0.98 |
| As-D | 0.0005 | 0.0009 |
| Cd-D | 0.00011 | 0.00024 |
| Cr-D | 0.001 | 0.002 |
| Cu-D | 0.094 | 0.32 |
| Fe-D | 0.089 | 0.39 |
| Mo-D | 0.007 | 0.038 |
| Na-D | 24 | 46 |
| Ni-D | 0.0018 | 0.005 |
| Nitrate | 22 | 84 |
| Nitrite | 0.12 | 2.5 |
| Se-D | 0.0039 | 0.014 |
| Sulphate | 120 | 200 |
| Zn-D | 0.005 | 0.01 |

**POX Ore Tailings Source Term (High Sulphate)**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/kg | mg/kg |
| Ag-D | 0.000016 | 0.00002 |
| Al-D | 0.036 | 0.097 |
| Ammonia | 6.3 | 20 |
| As-D | 0.00049 | 0.0018 |
| Cd-D | 0.000074 | 0.00016 |
| Cr-D | 0.00024 | 0.00048 |
| Cu-D | 0.0052 | 0.032 |
| Fe-D | 0.024 | 0.049 |
| Mo-D | 0.097 | 0.097 |
| Na-D | 250 | 660 |
| Ni-D | 0.0032 | 0.0032 |
| Nitrate | 52 | 150 |
| Nitrite | 3.8 | 3.8 |
| Se-D | 0.032 | 0.032 |
| Sulphate | 2300 | 4300 |
| Zn-D | 0.0024 | 0.0066 |

**Sulphide Ore Tailings Source Term**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/kg | mg/kg |
| Ag-D | 0.0000041 | 0.0000082 |
| Al-D | 0.016 | 0.066 |
| Ammonia | 1.5 | 2.8 |
| As-D | 0.00017 | 0.00019 |
| Cd-D | 0.0000034 | 0.0000052 |
| Cr-D | 0.000041 | 0.00041 |
| Cu-D | 0.00046 | 0.00087 |
| Fe-D | 0.0041 | 0.0041 |
| Mo-D | 0.04 | 0.047 |
| Na-D | 58 | 84 |
| Ni-D | 0.00061 | 0.0011 |
| Nitrate | 16 | 22 |
| Nitrite | 0.59 | 1.5 |
| Se-D | 0.0074 | 0.0093 |
| Sulphate | 160 | 300 |
| Zn-D | 0.00041 | 0.002 |

**Waste Rock Volume-based Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/m3/yr | mg/m3/yr |
| Ag-D | 0.0005 | 0.0005 |
| Al-D | 0.55 | 4 |
| Ammonia | 1.7 | 5.7 |
| As-D | 0.012 | 0.025 |
| Cd-D | 0.00035 | 0.0018 |
| Cr-D | 0.025 | 0.025 |
| Cu-D | 0.45 | 1.2 |
| Fe-D | 7 | 26 |
| Mo-D | 0.067 | 0.16 |
| Na-D | 250 | 550 |
| Ni-D | 0.025 | 0.064 |
| Nitrate | 150 | 940 |
| Nitrite | 1.1 | 7.5 |
| Se-D | 0.034 | 0.22 |
| Sulphate | 1400 | 4800 |
| Zn-D | 0.12 | 0.22 |

Note: load distributed over the year based on the mean hydrograph

**Waste Rock Area-based Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/L | mg/L |
| Ag-D | 0.000062 | 0.000062 |
| Al-D | 0.068 | 0.49 |
| Ammonia | 0.22 | 0.71 |
| As-D | 0.0015 | 0.0031 |
| Cd-D | 0.000043 | 0.00023 |
| Cr-D | 0.0031 | 0.0031 |
| Cu-D | 0.055 | 0.15 |
| Fe-D | 0.87 | 3.2 |
| Mo-D | 0.0083 | 0.02 |
| Na-D | 31 | 68 |
| Ni-D | 0.0031 | 0.0079 |
| Nitrate | 19 | 120 |
| Nitrite | 0.14 | 0.92 |
| Se-D | 0.0042 | 0.027 |
| Sulphate | 170 | 600 |
| Zn-D | 0.015 | 0.028 |

**Pit Walls**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/yr | mg/yr |
| Ag-D | 7,700 | 20,000 |
| Al-D | 73,000,000 | 140,000,000 |
| Ammonia | 0 | 0 |
| As-D | 390,000 | 1,100,000 |
| Cd-D | 9,900 | 49,000 |
| Cr-D | 160,000 | 700,000 |
| Cu-D | 2,300,000 | 6,000,000 |
| Fe-D | 8,400,000 | 25,000,000 |
| Mo-D | 1,400,000 | 5,800,000 |
| Na-D | 0 | 0 |
| Ni-D | 120,000 | 550,000 |
| Nitrate | 0 | 0 |
| Nitrite | 0 | 0 |
| Se-D | 290,000 | 550,000 |
| Sulphate | 3,300,000,000 | 6,600,000,000 |
| Zn-D | 740,000 | 3,500,000 |

Note: load distributed over the year based on the mean hydrograph

**Underground East Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/L | mg/L |
| Ag-D | 0.00002 | 0.00002 |
| Al-D | 0.0045 | 0.016 |
| Ammonia | 0.044 | 0.21 |
| As-D | 0.0005 | 0.0016 |
| Cd-D | 0.00001 | 0.000024 |
| Cr-D | 0.00097 | 0.001 |
| Cu-D | 0.0002 | 0.0031 |
| Fe-D | 0.04 | 3 |
| Mo-D | 0.001 | 0.007 |
| Na-D | 110 | 150 |
| Ni-D | 0.001 | 0.0011 |
| Nitrate | 0.023 | 0.052 |
| Nitrite | 0.053 | 0.27 |
| Se-D | 0.0001 | 0.00098 |
| Sulphate | 800 | 1200 |
| Zn-D | 0.005 | 0.027 |

**Underground South Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| | mg/L | mg/L |
| Ag-D | 0.00002 | 0.000031 |
| Al-D | 0.011 | 0.024 |
| Ammonia | 18 | 91 |
| As-D | 0.0016 | 0.0043 |
| Cd-D | 0.000017 | 0.00028 |
| Cr-D | 0.001 | 0.001 |
| Cu-D | 0.0074 | 0.067 |
| Fe-D | 0.012 | 0.076 |
| Mo-D | 0.018 | 0.042 |
| Na-D | 36 | 84 |
| Ni-D | 0.0023 | 0.0082 |
| Nitrate | 35 | 180 |
| Nitrite | 1.4 | 7.7 |
| Se-D | 0.00048 | 0.0044 |
| Sulphate | 370 | 1200 |
| Zn-D | 0.0061 | 0.058 |

**Upper and Lower Minto Creek Background Water Quality**

| Month | Ag-D | Al-D | Ammonia | As-D | Cd-D | Cr-D | Cu-D | Fe-D | Mn-D | Mo-D | Ni-D | Nitrate | Nitrite | Se-D | Sulphate | Zn-D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | Hg | mg/L | mg/L | mg/L | mg/L | mg/L |
| January | 0.00001 | 0.0053 | 0.005 | 0.00041 | 0.000035 | 0.0005 | 0.0011 | 0.094 | 0.034 | 0.0015 | 0.0005 | 0.32 | 0.0025 | 0.00043 | 24 | 0.0025 |
| February | 0.00001 | 0.021 | 0.006 | 0.00033 | 0.000064 | 0.0005 | 0.015 | 0.049 | 0.0071 | 0.0014 | 0.0005 | 0.29 | 0.0025 | 0.00034 | 12 | 0.0083 |
| March | 0.00001 | 0.0031 | 0.0067 | 0.00039 | 0.000005 | 0.0005 | 0.0012 | 0.012 | 0.0042 | 0.0011 | 0.0005 | 0.2 | 0.0025 | 0.00031 | 23 | 0.0025 |
| April | 0.0000087 | 0.038 | 0.012 | 0.00028 | 0.000031 | 0.00059 | 0.0041 | 0.15 | 0.041 | 0.00078 | 0.00084 | 0.035 | 0.015 | 0.00021 | 3.7 | 0.004 |
| May | 0.00001 | 0.05 | 0.06 | 0.00042 | 0.000024 | 0.0005 | 0.0039 | 0.36 | 0.095 | 0.00061 | 0.0013 | 0.031 | 0.0036 | 0.00018 | 29 | 0.0043 |
| June | 0.0000071 | 0.026 | 0.062 | 0.00047 | 0.000018 | 0.00055 | 0.0017 | 0.2 | 0.055 | 0.0011 | 0.0013 | 0.1 | 0.015 | 0.00037 | 14 | 0.0038 |
| July | 0.0000088 | 0.02 | 0.048 | 0.00061 | 0.000015 | 0.00059 | 0.002 | 0.32 | 0.068 | 0.001 | 0.0013 | 0.12 | 0.0091 | 0.00021 | 4.4 | 0.0032 |
| August | 0.000018 | 0.02 | 0.033 | 0.00063 | 0.000012 | 0.00063 | 0.0021 | 0.36 | 0.085 | 0.00096 | 0.0014 | 0.11 | 0.008 | 0.00021 | 9.2 | 0.0031 |
| September | 0.000009 | 0.02 | 0.024 | 0.00058 | 0.000016 | 0.00084 | 0.0017 | 0.36 | 0.079 | 0.00083 | 0.0016 | 0.046 | 0.0038 | 0.00027 | 9.5 | 0.0027 |
| October | 0.0000086 | 0.013 | 0.034 | 0.0005 | 0.000015 | 0.00044 | 0.0013 | 0.28 | 0.089 | 0.00095 | 0.0011 | 0.087 | 0.021 | 0.0002 | 8.6 | 0.002 |
| November | 0.00001 | 0.01 | 0.051 | 0.001 | 0.000011 | 0.00059 | 0.0013 | 1.7 | 1.1 | 0.0011 | 0.0017 | 0.12 | 0.005 | 0.00016 | 8.4 | 0.0025 |
| December | 0.00001 | 0.005 | 0.021 | 0.00054 | 0.0000065 | 0.0005 | 0.0017 | 0.046 | 0.068 | 0.001 | 0.00095 | 0.086 | 0.0025 | 0.0003 | 36 | 0.0025 |

**Minto North Background Water Quality**

| Month | Ag-D | Al-D | Ammonia | As-D | Cd-D | Cr-D | Cu-D | Fe-D | Mn-D | Mo-D | Ni-D | Nitrate | Nitrite | Se-D | Sulphate | Zn-D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | Hg | mg/L | mg/L | mg/L | mg/L | mg/L |
| January | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| February | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| March | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| April | 0.000005 | 0.041 | 0.038 | 0.00038 | 0.000027 | 0.00022 | 0.0026 | 0.13 | 0.0073 | 0.00038 | 0.00099 | 0.02 | 0.005 | 0.00009 | 0.5 | 0.0034 |
| May | 0.000005 | 0.028 | 0.0065 | 0.00038 | 0.0000085 | 0.0003 | 0.0024 | 0.16 | 0.0093 | 0.00046 | 0.0012 | 0.02 | 0.005 | 0.00013 | 0.5 | 0.0025 |
| June | 0.000005 | 0.014 | 0.019 | 0.00038 | 0.000006 | 0.0003 | 0.0019 | 0.097 | 0.0035 | 0.00082 | 0.001 | 0.06 | 0.005 | 0.00015 | 5.9 | 0.0018 |
| July | 0.000005 | 0.018 | 0.022 | 0.00042 | 0.00001 | 0.00033 | 0.0019 | 0.082 | 0.0017 | 0.00083 | 0.001 | 0.048 | 0.005 | 0.00015 | 3.2 | 0.0012 |
| August | 0.000005 | 0.022 | 0.02 | 0.00056 | 0.000007 | 0.0004 | 0.0019 | 0.2 | 0.0021 | 0.00086 | 0.0013 | 0.062 | 0.005 | 0.00013 | 2.8 | 0.00096 |
| September | 0.00002 | 0.019 | 0.02 | 0.00043 | 0.0000065 | 0.00035 | 0.0019 | 0.17 | 0.0067 | 0.00084 | 0.0012 | 0.042 | 0.005 | 0.00013 | 5.4 | 0.0011 |
| October | 0.000005 | 0.016 | 0.0093 | 0.00039 | 0.00001 | 0.0002 | 0.0016 | 0.11 | 0.0064 | 0.00085 | 0.00098 | 0.09 | 0.005 | 0.00017 | 6.8 | 0.0007 |
| November | 0.0000025 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Appendix C: Minto Mine 2016 Water Balance Update

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# Memo

| | | | |
|---|---|---|---|
| **To:** | Deborah Flemming, Ryan Herbert | **Client:** | Minto Explorations Ltd. |
| **From:** | Soren Jensen, Kaitlyn Kooy | **Project No:** | 1CM002.024 |
| **Cc:** | Dylan MacGregor (SRK) | **Date:** | March 28, 2017 |
| **Subject:** | 2016 Water Balance and Water Quality Model Summary for the Minto Mine Site | | |

# 1 Introduction and Background

This memorandum provides a summary of the 2016 water balance and water quality model updates for the Minto Mine site. The update covers the period January 1, 2016 through December 31, 2016.

The water balance update includes a review and summary of precipitation, flow and water inventory data for the Mine site. The water quality update includes a comparison of water quality data collected in 2016 to updated water quality model predictions for Phase V/VI of the Mine development. Updated water quality predictions for the Main Pit Tailings Management Facility (MPTMF) and the Water Storage Pond (WSP) are provided for the 2018 and for the post-closure period when predicted concentrations are the same from year to year (steady state concentrations).

# 2 Water Balance Update

## 2.1 Precipitation

Table 1 shows a summary of monthly precipitation measured at the Mine site between October 2015 and December 2016 along with precipitation data from the regional station at Carmacks, YT (Climate ID: 2100301)[1], which is located 77 km Southwest of the Minto Mine. In the past, the meteorological station at Pelly Ranch (Climate ID 2100880)[1] located 25 km north of Minto was used as a regional reference station. However, the published data record from Pelly Ranch ends in March 2015 so the Carmacks Station was used instead.

Approximately 242 mm of precipitation was collected at the Mine site in the 2016 hydrological year, which was nearly identical to the annual precipitation of 243 mm measured in 2015. A 242 mm annual total precipitation roughly corresponds to a 1 in 15 dry year.

[1] Pelly Ranch Data: obtained from Meteorological Service of Canada, Environment Canada.

**Table 1: Precipitation Records for the Minto Mine Site and Pelly Ranch**

| | | Campbell Scientific Station (Minto Mine) | | |
|---|---|---|---|---|
| **Year** | **Month** | **Tipping Bucket Gauge** | **Geonor Gauge[A]** | **Carmacks Ranch[B] (Climate ID 2100301)** |
| | | mm/month | mm/month | mm/month |
| 2015 | Oct | 14.7 | 27.7 | n/a |
| 2015 | Nov | 14.3 | 7.1 | n/a |
| 2015 | Dec | 9.5 | 11.5 | n/a |
| 2016 | Jan | 9.1 | 11.7 | 7.5 |
| 2016 | Feb | 6.9 | 7.8 | 12.2 |
| 2016 | Mar | 2.6 | 3.3 | 5.0 |
| 2016 | Apr | 14.7 | 14.7 | 13.1 |
| 2016 | May | 39.3 | 31.5 | 28.5 |
| 2016 | Jun | 30.2 | 22.2 | 17.1 |
| 2016 | Jul | 74.7 | 68.2 | 94.9 |
| 2016 | Aug | 46.0 | 35.9 | 26.1 |
| 2016 | Sept | 18.5 | 17.8 | 9.6 |
| 2016 | Oct | 6.7 | 9.8 | 8.4 |
| 2016 | Nov | 24.2 | 13.6 | 14.4 |
| 2016 | Dec | 7.4 | 14.1 | 17.5 |
| SUM Hydrological Year, Nov. 2015 to Oct. 2016 | | 273 | 242 | 256 |

Source: Minto Site Data: X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2015_Water_Balance_Update\Minto Water Balance\2016 Met Station Data Summary.xlsx

**Notes:**
A: Tipping bucket measurement used for month of November.
B: Data obtained from Meteorological Service of Canada, Environment Canada.
n/a: Not available at time of publication.

Minto's Campbell Scientific meteorological station measures total precipitation using a Geonor and a tipping bucket rain gauge. From October through May, the tipping bucket is equipped with a snowfall conversion adaptor, which allows it to measure snowfall as snow water equivalent. The Geonor precipitation gauge collects precipitation in a bucket and records precipitation by measuring the weight of the bucket. In the winter months, the bucket is partially filled with an antifreeze solution that melts any snow collected. Figure 1 shows monthly precipitation recorded by the two gauges as well as total precipitation recorded at Carmacks.

The total annual precipitation measured by the two gauges at Minto differ by 12%. Both gauges at Minto are within 6% of the total precipitation measured at Carmacks on an annual basis. The precipitation measured by the Geonor gauge at Minto was considered more reliable than the tipping bucket gauge and was therefore used for the hydrological analysis.

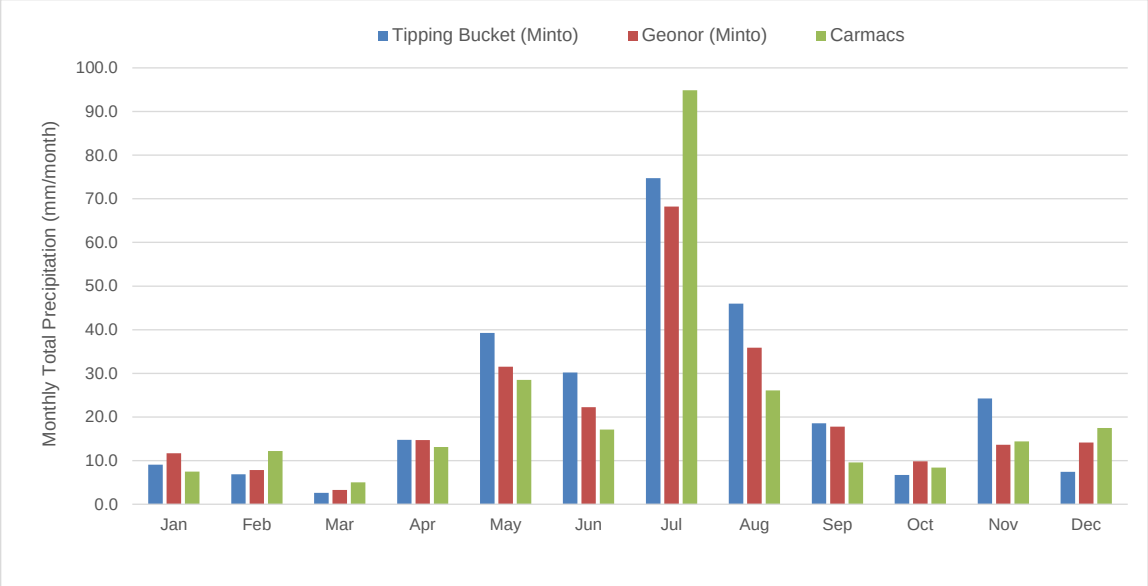


**Figure 1: 2015 Monthly Total Precipitation Measurements at Minto and at Carmacks in 2016**

## 2.2 Snow Course Data

Snow course surveys were completed at the three established snow survey stations at the Mine site in 2016. Table 2 shows a summary of the snow survey data (i.e. an average of the results from the three stations) from 2009 to 2016. The depth and water equivalent of the snow pack provides an indication of the volume of surface runoff that must be managed the following freshet. In April and May 2016, approximately 260,000 $m^3$ of surface runoff was collected from catchments at the Mine site upstream of the Water Storage Dam. This volume corresponds to roughly 25 mm of runoff, which was slightly greater than the estimated 22 mm of runoff observed in 2015.

**Table 2: Summary of Snow Survey Data for the Minto Mine Site**

| Year | February | | | March | | | April | | |
|---|---|---|---|---|---|---|---|---|---|
| | Snow Depth (cm) | Snow Density (%) | Water Equivalent (mm) | Snow Depth (cm) | Snow Density (%) | Water Equivalent (mm) | Snow Depth (cm) | Snow Density (%) | Water Equivalent (mm) |
| **2009** | 55.6 | 16.6 | 92.7 | 70.2 | 15.7 | 110.0 | 67.4 | 22.3 | 150.7 |
| **2010** | 60.5 | 17.8 | 107.7 | 58.1 | 20.7 | 120.7 | 40.4 | [A]13.9 | 56.0 |
| **2011** | 57.2 | 18.7 | 106.0 | 70.3 | 20.1 | 141.7 | 52.3 | 22.8 | 111.7 |
| **2012** | 54.7 | 20.3 | 111.0 | 64.6 | 19.6 | 127.0 | 61.3 | 21.5 | 132.7 |
| **2013** | 58.7 | 15.7 | 91.3 | 45.8 | 25.0 | 106.0 | 33.7 | 15.4 | 62.7 |
| **2014** | 44.3 | 19.0 | 84.3 | 45.8 | 22.3 | 99.7 | 41.0 | 25.7 | 67.3 |
| **2015** | 44.3 | 20.7 | 90.3 | 25.3 | 29.0 | 76.6 | 30.0 | 23 | 67.8 |
| **2016** | 40.7 | 19.0 | 80.3 | 42.3 | 23.0 | 80.7 | 15.5 | n/a | n/a |

Source: X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2016_Water_Balance_Update\MintoSnowMaster_2016.xlsx

**Notes:**

n/a – not available.
A: zero snow at #3, density is an average of snowpack at #1 and #2, average depth and water-equivalent is average of all three sites.

## 2.3 Water Management

Water that is suitable for release into Minto Creek is conveyed to the Water Storage Pond (WSP), while water collected from active mine areas is routed to the Main Pit Tailings Management Facility (MPTMF) or the Area 2 Pit Tailings Management Facility (A2PTMF). Since November 2012, the MPTMF has also been used for subaqueous deposition of tailings. Deposition of mine water and tailings (subaqueous) to the A2PTMF commenced in April 2015.

Other water management features on the Mine site include:

- W15 sump: collects surface runoff and seepage from:
  - The Southwest Waste Dump;
  - Part of the Main Waste Dump; and
  - Adjacent undisturbed catchments.

  In 2016, water collected at W15 was routed to the Main Pit TMF in early spring (March and most of April). Between April 27 and October 3, water from W15 was routed to the WSP. Approximately 50% of the catchment that report to W15 is covered by waste rock. Therefore, it is notable that water quality parameter concentrations are low enough that the water is suitable for discharge to Quarry Creek.

- W35a sump: collects surface runoff from the minimally disturbed southern catchments. Water collected at W35a in 2016 was piped to the Mai Pit in early April. From April 14 to October 3 the water was conveyed to the WSP. The remainder of the year the W35 water was routed to the Main Pit.

- W62 sump (formerly known as W36 or W37 sump): collects surface runoff and seepage from the mill valley, including contributions from the Dry Stack Tailings Storage Facility. Water collected at the W62 sump is pumped to the MPTMF.
- South Diversion Ditch: diverts water from minimally disturbed southern catchments to the WSP (can also be routed to the MPTMF).
- WSP: reservoir for water that meets discharge criteria and is destined for discharge to Minto Creek.

## 2.4 2016 Water Balance

Table 3 summarizes the monthly water and tailings inventory in Minto's MPTMF and A2PTMF as well as water inventory in the WSP. In 2016, the water inventory in the MPTMF was reduced by approximately 180,000 $m^3$, while the water inventory in A2PTMF increased by roughly 530,000 $m^3$. The increase in water inventory in the A2PTMF roughly corresponds to the volume of pore water in the sub-aqueously deposited tailings in 2016. The WSP water inventory was reduced by about 15,000 $m^3$ between January 1 and December 31, 2016.

Table 4 shows a summary of the 2016 water balance for the Mine site. The total surface runoff collected on site was estimated to be 590,000 $m^3$ based on the change in the water inventory and the known volume of water released to Minto Creek. Including an estimated inflow of 30,000 $m^3$ of groundwater, the total site-wide yield was estimated at about 620,000 $m^3$ for the year. The total catchment upstream of the Water Storage Dam measures approximately 1,040 ha. Therefore, 620,000 $m^3$ of runoff from 1,040 ha gives a unit yield of approximately 60 mm/year.

The water and load balance model used for forecasting surface runoff volumes uses a site-wide annual average runoff coefficient, which has been derived based on previous years' water balance results. The runoff coefficient is estimated based on the total annual precipitation as follows:

- For dry years with less than 190 mm total precipitation: runoff coefficient = 0.15.
- For average to wet years with more than 309 mm total precipitation: runoff coefficient = 0.30.
- Runoff coefficients for years with total precipitation between 190 mm and 309 mm: interpolated values between 0.15 and 0.30.

In 2016 (hydraulic year) the estimated total precipitation was 242 mm (Table 1), which corresponds to a modelled runoff coefficient of 0.22. The 2015 site-wide runoff coefficient, based on the 2015 water balance (measured flows, water inventory and total precipitation), is:

$$\textit{Annual Yield / Total Annual Precipitation} = \textit{Runoff Coefficient} \rightarrow \quad 60\ mm/243\ mm = \mathbf{0.25}$$

The calculated value for the annual site-wide runoff coefficient is slightly higher but close to the interpolated coefficient of 0.22. Overall, the agreement with site-wide runoff coefficients used for evaluating water management options is good and the model results can be expected to yield reliable estimates of the volume of water that must be managed on site on an annual basis.

**Table 3: 2015 Water Inventory and Release to Minto Creek**

| Month/ | MPTMF Volume Occupied (Water + Tailings)[A] | Change in MPTMF Water Inventory | Tailings Solids Deposition in MPTMF | A2PTMF Volume Occupied (Water + Tailings)[A] | Change in A2PTMF Water Inventory | Tailings Solids Deposition in A2PTMF | WSP Volume[A] | Change in WSP Water Inventory |
|---|---|---|---|---|---|---|---|---|
| Year | $m^3$ | $m^3$/month | BCM/month | $m^3$ | $m^3$/month | BCM/month | $m^3$ | $m^3$/month |
| Jan-16 | 4,108,000 | -81,000 | 0 | 1,024,000 | 83,000 | 45,000 | 82,000 | -3,000 |
| Feb-16 | 4,027,000 | -175,000 | 0 | 1,152,000 | 147,000 | 38,000 | 79,000 | -2,000 |
| Mar-16 | 3,852,000 | -211,000 | 0 | 1,337,000 | 160,000 | 47,000 | 77,000 | 10,000 |
| Apr-16 | 3,641,000 | 90,000 | 0 | 1,544,000 | 42,000 | 44,000 | 87,000 | 18,000 |
| May-16 | 3,731,000 | -29,000 | 0 | 1,629,000 | 23,000 | 49,000 | 105,000 | 55,000 |
| Jun-16 | 3,702,000 | 28,000 | 0 | 1,702,000 | -5,000 | 41,000 | 160,000 | 18,000 |
| Jul-16 | 3,730,000 | -28,000 | 0 | 1,737,000 | 52,000 | 45,000 | 177,000 | 23,000 |
| Aug-16 | 3,702,000 | -44,000 | 0 | 1,835,000 | 54,000 | 47,000 | 200,000 | 7,000 |
| Sep-16 | 3,658,000 | 90,000 | 0 | 1,936,000 | 13,000 | 44,000 | 207,000 | -85,000 |
| Oct-16 | 3,749,000 | 67,000 | 0 | 1,993,000 | -4,000 | 45,000 | 122,000 | -48,000 |
| Nov-16 | 3,815,000 | 63,000 | 0 | 2,034,000 | -18,000 | 42,000 | 74,000 | -3,000 |
| Dec-16 | 3,878,000 | 46,000 | 0 | 2,058,000 | -18,000 | 37,000 | 70,000 | -4,000 |
| Jan-17 | 3,924,000 | | | 2,077,000 | | | 67,000 | |
| SUM | | **-183,000** | **-** | | **529,000** | **524,000** | | **-15,000** |

Source: X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2016_Water_Balance_Update\2016 Water Balance Update REV00 KNK.xlsx

**Notes:**

A – on the first day of the month.

**Table 4: Water Balance Summary of the Minto Mine Site, 2016 (Jan to Dec)**

| | **Units** | **Main Pit TMF** | **Area 2 Pit TMF** | **WSP** |
|---|---|---|---|---|
| Volume Change 2016 (water + tailings) | $m^3$ | -183,000 | 1,053,000 | -15,000 |
| Tailings Deposited, total | BCM | - | 524,000 | - |
| Water Volume Change 2016 | $m^3$ | -183,000 | 529,000 | -15,000 |
| Estimated Groundwater Inflow | $m^3$ | - | 30,000 | - |
| **Total Water Inventory Increase in 2016** | **$m^3$** | 364,000 | | |
| Total Water Discharged to Minto Creek | $m^3$ | 254,000 | | |
| **Total Site-Wide Yield in 2016** | **$m^3$** | **617,000** | | |

Source: X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2016_Water_Balance_Update\2016 Water Balance Update REV00 KNK.xlsx

# 3 Water Quality Model Update

## 3.1 Solid Phase Geochemistry

The neutralization potential ratio (NPR) and copper content of waste rock and tailings were reviewed in order to identify any new trends in the solid phase geochemistry that may have developed since the last source term update. Significant changes in the solid phase geochemistry

would indicate a need for further analysis of the waste rock and tailings to generate new source terms that reflect the observed changes in the geochemistry.

The NPR and copper content of waste rock and tailings are shown in Figure 2 to Figure 5. No significant changes in geochemistry were observed in the properties of the materials produced in 2016 compared to similar materials produced in prior years. Therefore, no further evaluation of 2016 solid phase geochemistry was warranted.

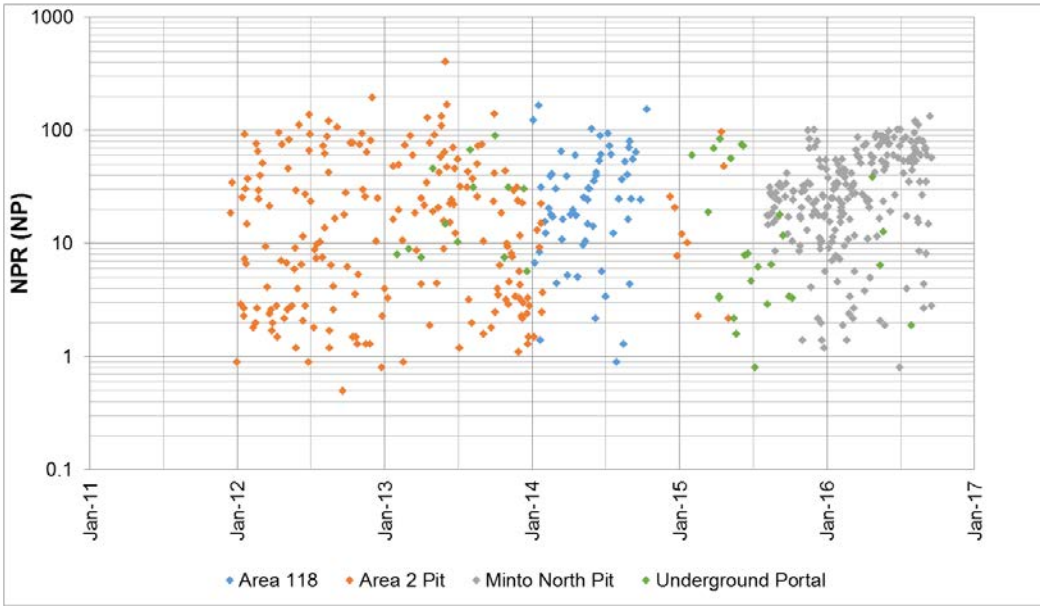


**Figure 2: Waste Rock Neutralization Potential Ratio over Time**

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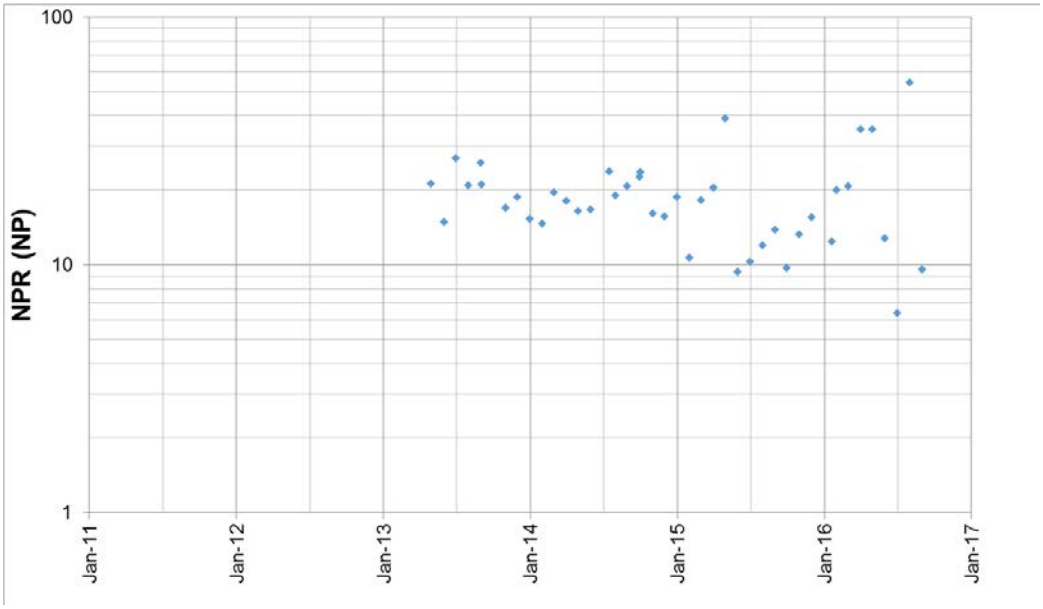


**Figure 3: Tailings Neutralization Potential Ratio over Time**

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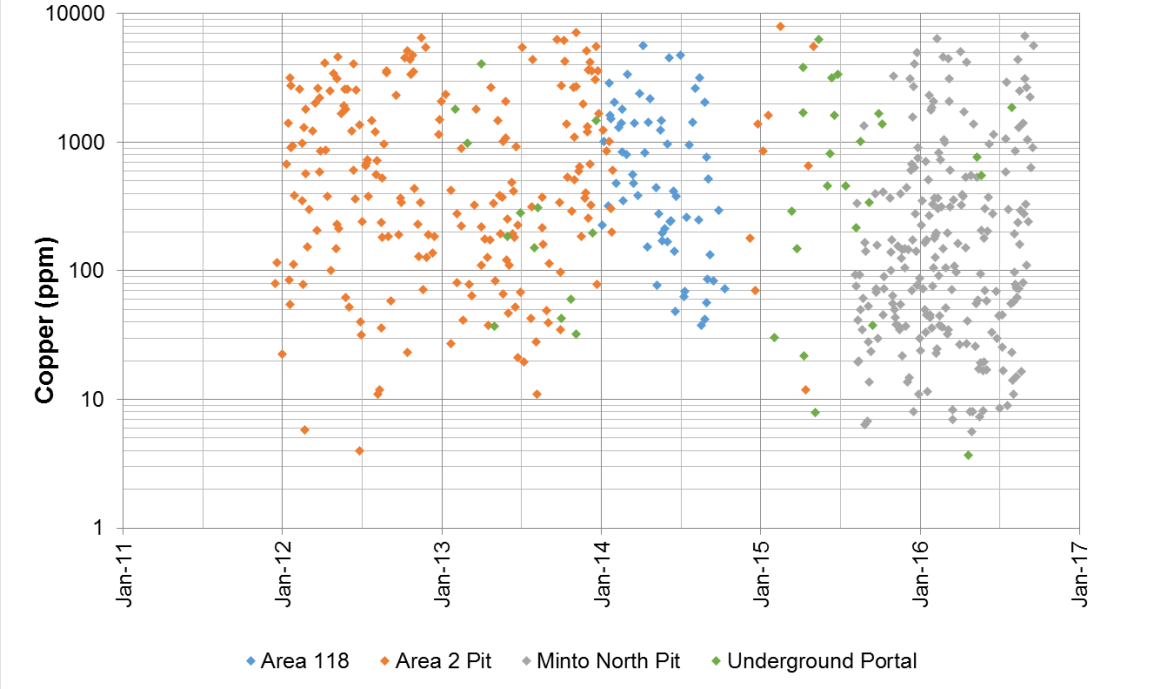


**Figure 4: Waste Rock Copper Concentration over Time**

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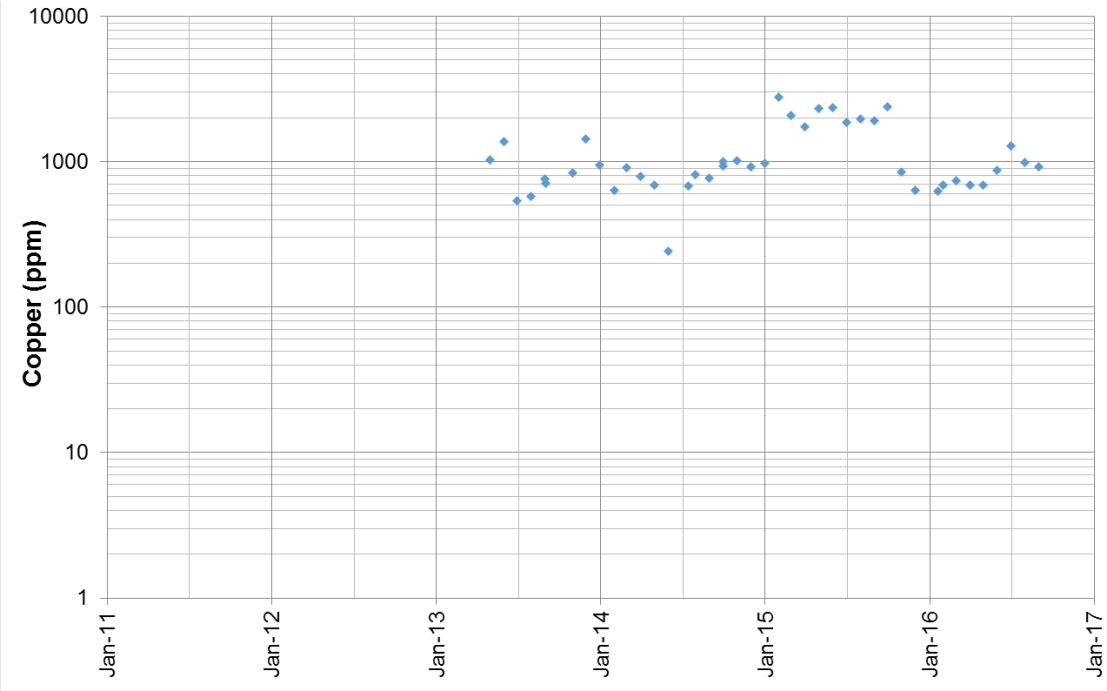


**Figure 5: Tailings copper concentration over time**

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## 3.2 Comparison of Measured Water Quality Data to Source Terms

### 3.2.1 Source Terms – Dry Stack Tailings Storage Facility

The Dry Stack Tailings Storage Facility (DSTSF) source terms used in the 2013 water and load balance model were developed based on the observed water chemistry at station W8. This station was chosen because it had the highest concentrations of copper, cadmium, selenium, and sulphate during the period of record available in 2013. The following points describe the source terms:

- Best Estimate source term: 50th percentile dissolved concentrations from W8 until 2013;
- Reasonable Worst Case source term: 95th percentile dissolved concentrations from W8 until 2013.

The Best Estimate and Reasonable Worst Case source terms were updated to include data to 2016 for comparison to the existing source terms. It was found that the updated source terms differed only marginally from the source terms used historically. Therefore, for consistency the 2013 DSTSF source terms will be used in the 2016 Updated Water Balance and Water Quality Model.

### 3.2.2 Source Terms – Waste Rock

The Main Waste Dump and the Southwest Waste Dump source terms used in the 2015 water and load balance model were defined based on the observed water chemistry at station W15, which collects runoff from the Southwest Waste Dump. Similar to the DSTSF source terms, the Best Estimate waste rock source term was the 50$^{th}$ percentile dissolved concentrations at W15 until 2015 and the Reasonable Worst Case waste rock source term was the 95$^{th}$ percentile dissolved concentrations from W15 until 2015.

The Best Estimate and Reasonable Worst Case source terms were updated to include data collected in 2016. Similar to the DSTSF source terms, the updated waste rock source terms differed only marginally from the source terms used historically. The 2015 waste rock source terms were therefore deemed acceptable and will be used in the 2016 Updated Water Balance and Water Quality Model for consistency.

### 3.2.3 Source Term – Tailings Slurry

A review of the mill influent water quality (reclaim water from the MPTMF, W12) and mill effluent water quality (Mill Thickener, W14) revealed that in 2015 and 2016 the processing of ore contributed greater loadings than in previous years. In light of this, the tailings slurry source term for the 2016 Updated Water Balance and Water Quality Model was updated as follows:

- Best Estimate source term: 50th percentile dissolved concentrations from W14 from 2015 and 2016 data only;
- Reasonable Worst Case source term: 95th percentile dissolved concentrations from W14 from 2015 and 2016 data only

However, the adjusted source terms for tailings slurry were not able to account for the greater-than-expected increase in parameter concentrations in the MPTMF. Similarly, adjustment of the waste rock source terms within limits of observed seepage concentrations were also not able to explain the concentration changes. One possible explanation for the additional observed load is that it is flushed from pit walls and waste rock as it is submerged by the rising water in the A2PTMF. This "first flush" effect is commonly observed and is caused by the buildup of weathering products as waste rock is exposed to the atmosphere for a period of time before becoming inundated. Once the A2PTMF has filled to capacity, this term is expected to become negligible. Ongoing monitoring and updates of the load balance will reveal whether flushing is indeed responsible for the additional loadings or if some other loading source not related to seepage or runoff characterized to date is the cause.

## 3.3 Water Quality Model Results

Table 6 and 7 show revised model outputs from the calibrated model of water quality in the Water Storage Pond (WSP) for 2016, 2018, and post-closure (best estimate and worst case) along with concentrations measured in 2016. Table 8 and 9 show revised model predictions of water quality in the MPTMF for 2016, 2018 and post-closure. Predictions for 2018 and post-closure were selected to provide representative short-term and long-term indications of water quality trends. Predictions are for average precipitation conditions. The Water Use Licence (QZ14-031) effluent limits are also listed in the tables. Model runs started on 1 January 2016 and ended on 1 January 2045, at which point concentrations in the model roughly have reached steady state.

The MPTMF was historically the primary water reservoir on site. In the model, the free water in the MPTMF and A2PTMF are more or less considered to belong to the same reservoir due to the high rate of flow between the two reservoirs. Reclaim water is drawn from the MPTMF and excess free water in the A2PTMF is pumped back to the MPTMF.

Therefore, a comparison of measured MPTMF water quality with concentrations predicted for pit water for the Phase V/VI environmental assessment provides a good measure of actual vs. expected geochemical performance of the site. Water collected in the WSP includes clean (non-contact) runoff and effluent from Minto's water treatment plant.

Median measured concentrations in the WSP in 2016 are comparable to the revised model predictions using best estimate source terms (Table 6). The favorable agreement indicates that the revised source terms are appropriate for describing the existing geochemical performance and the actual water management practices on site. Best estimate source terms are intended to provide an indication of the general trend in water quality parameter concentrations, but are not intended to capture maximum or outlier concentration values. Therefore, the median values of best estimate model predictions are compared to measured median values.

Revised model predictions using reasonable worst case source terms are generally higher than comparable median and maximum measured values for the WSP (Table 7).

Revised model predictions for water quality in the MPTMF (and by extension the A2PTMF) using the best estimate source terms are in good agreement with median measured concentrations in 2016 (Table 8) when the additional "first flush" load is included in the model. Water quality model predictions using reasonable worst case source terms are generally higher than measured

median and maximum concentrations, with the exception of dissolved copper. Median and maximum measured dissolved copper concentrations were both marginally higher than the concentrations predicted by the reasonable worst case source terms. The increase in dissolved copper concentration is not dramatic and may be caused by the flushing of rock that accompanied the inundation of the A2PTMF and related underground workings when deposition of tailings slurry was initiated. The source of the additional copper loadings (or increased copper solubility) will be evaluated based on water quality monitoring results in 2017.

**Table 5: WSP Water Quality Model Predictions and Measured Concentrations in 2016, Best Estimate**

| | | WUL Effluent Limits (QZ14-031) | WSP Measured Water Quality (Station W16) | Modelling Predictions of Quality in WSP (Station W16) | | |
|---|---|---|---|---|---|---|
| Year | | | 2016 | 2016 | 2018 | Post-Closure |
| | | | Median | Median | Median | Median |
| Ammonia | mg/L | 0.75 | 0.04 | 0.069 | 0.057 | 0.19 |
| $N\text{-}NO_2$ | mg/L | 0.18 | 0.033 | 0.034 | 0.022 | 0.053 |
| $N\text{-}NO_3$ | mg/L | 27.3 | 4.8 | 3.2 | 2 | 1.2 |
| Ag-Dissolved | mg/L | 0.0003 | 0.00001 | 0.000018 | 0.000013 | 0.000036 |
| Al-Dissolved | mg/L | 0.3 | 0.0066 | 0.034 | 0.032 | 0.14 |
| As-Dissolved | mg/L | 0.015 | 0.00034 | 0.00059 | 0.00048 | 0.0013 |
| Cd-Dissolved | mg/L | 0.0014[a] | 0.0000075 | 0.000021 | 0.00002 | 0.000049 |
| Cr-Dissolved | mg/L | 0.003 | 0.0001 | 0.00093 | 0.00069 | 0.0015 |
| Cu-Dissolved | mg/L | 0.06/0.039[b] | 0.018 | 0.012 | 0.0084 | 0.025 |
| Fe-Dissolved | mg/L | 3.3 | 0.027 | 0.37 | 0.31 | 0.49 |
| Pb-Dissolved | mg/L | 0.012 | 0.00005 | 0.00019 | 0.00015 | 0.00035 |
| Mo-Dissolved | mg/L | 0.219 | 0.0036 | 0.0021 | 0.0014 | 0.0076 |
| Ni-Dissolved | mg/L | 0.33 | 0.00066 | 0.0014 | 0.0012 | 0.002 |
| Se-Dissolved | mg/L | 0.006 | 0.0014 | 0.00084 | 0.00057 | 0.0025 |
| Zn-Dissolved | mg/L | 0.09 | 0.0013 | 0.005 | 0.0042 | 0.0081 |

Source: SRK, X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2015_Water_Balance_Update\All_Model_Results_for_WQ_Model_Comparison_for_2015_An_Report_SRJ_Rev00.xlsx

**Notes:**

Analytical data from Minto's water quality monitoring program.

a) at 50 mg/L hardness.

b) Cu effluent standard is 0.06 when [DOC] @ W2 > 10 mg/L and 0.039 when [DOC] @ W2 ≤ 10 mg/L.

**Table 6: WSP Water Quality Model Predictions and Measured Concentrations in 2016, Reasonable Worst Case**

| Year | | WUL Effluent Limits (QZ14-031) | WSP Measured Water Quality (Station W16) | | Modelling Predictions of Quality in WSP (Station W16) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2016 | | 2016 | | 2018 | | Post-Closure | |
| | | | Median | Max | Median | Max | Median | Max | Median | Max |
| Ammonia | mg/L | 0.75 | 0.04 | 0.31 | 0.16 | 0.23 | 0.11 | 0.21 | 0.31 | 0.41 |
| N-$NO_2$ | mg/L | 0.18 | 0.033 | 0.094 | 0.17 | 0.26 | 0.11 | 0.24 | 0.1 | 0.13 |
| N-$NO_3$ | mg/L | 27.3 | 4.8 | 5.7 | 20 | 30 | 12 | 29 | 3.4 | 4.5 |
| Ag-Dissolved | mg/L | 0.0003 | 0.00001 | 0.00002 | 0.000061 | 0.000089 | 0.00004 | 0.000085 | 0.00012 | 0.00019 |
| Al-Dissolved | mg/L | 0.3 | 0.0066 | 0.029 | 0.11 | 0.15 | 0.08 | 0.14 | 0.36 | 0.63 |
| As-Dissolved | mg/L | 0.015 | 0.00034 | 0.00088 | 0.00087 | 0.0011 | 0.00063 | 0.0011 | 0.0027 | 0.0047 |
| Cd-Dissolved | mg/L | 0.0014[a] | 0.0000075 | 0.000017 | 0.000067 | 0.000095 | 0.000048 | 0.00009 | 0.00018 | 0.00029 |
| Cr-Dissolved | mg/L | 0.003 | 0.0001 | 0.001 | 0.0015 | 0.002 | 0.001 | 0.0019 | 0.0031 | 0.0049 |
| Cu-Dissolved | mg/L | 0.06/0.039[b] | 0.018 | 0.026 | 0.029 | 0.043 | 0.019 | 0.041 | 0.062 | 0.089 |
| Fe-Dissolved | mg/L | 3.3 | 0.027 | 0.07 | 0.78 | 1.1 | 0.56 | 1 | 1.2 | 1.5 |
| Pb-Dissolved | mg/L | 0.012 | 0.00005 | 0.0002 | 0.00019 | 0.00025 | 0.00015 | 0.00024 | 0.001 | 0.0019 |
| Mo-Dissolved | mg/L | 0.219 | 0.0036 | 0.0051 | 0.0044 | 0.0063 | 0.0028 | 0.006 | 0.018 | 0.03 |
| Ni-Dissolved | mg/L | 0.33 | 0.00066 | 0.001 | 0.0024 | 0.0031 | 0.0017 | 0.003 | 0.0041 | 0.0058 |
| Se-Dissolved | mg/L | 0.006 | 0.0014 | 0.0016 | 0.004 | 0.006 | 0.0026 | 0.0057 | 0.0084 | 0.012 |
| Zn-Dissolved | mg/L | 0.09 | 0.0013 | 0.0063 | 0.0078 | 0.011 | 0.0059 | 0.01 | 0.016 | 0.025 |

Source: SRK, X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2015_Water_Balance_Update\All_Model_Results_for_WQ_Model_Comparison_for_2015_An_Report_SRJ_Rev00.xlsx

**Notes:**

Analytical data from Minto's water quality monitoring program.

a) at 50 mg/L hardness.

b) Cu effluent standard is 0.06 when [DOC] @ W2 > 10 mg/L and 0.039 when [DOC] @ W2 ≤ 10 mg/L.

**Table 7: MPTMF Water Quality Model Predictions and Measured Concentrations in 2016, Best Estimate**

| | | WUL Effluent Limits (QZ14-031) | MPTMF Measured Water Quality (Station W12) | Modelling Predictions of Quality in MPTMF (Station W12) | | |
|---|---|---|---|---|---|---|
| Year | | | 2016 | 2016 | 2018 | Post-Closure |
| | | | Median | Median | Median | Median |
| Ammonia | mg/L | 0.75 | 3.0 | 3.3 | 2.4 | 0.027 |
| $N\text{-}NO_2$ | mg/L | 0.18 | 1.5 | 1.7 | 0.91 | 0.0057 |
| $N\text{-}NO_3$ | mg/L | 27.3 | 26 | 22 | 18 | 0.14 |
| Ag-Dissolved | mg/L | 0.0003 | 0.00001 | 0.000037 | 0.000045 | 0.000045 |
| Al-Dissolved | mg/L | 0.3 | 0.011 | 0.13 | 0.18 | 0.15 |
| As-Dissolved | mg/L | 0.015 | 0.00045 | 0.0011 | 0.0015 | 0.0015 |
| Cd-Dissolved | mg/L | 0.0014[a] | 0.000016 | 0.000038 | 0.000055 | 0.000048 |
| Cr-Dissolved | mg/L | 0.003 | 0.0001 | 0.0016 | 0.0018 | 0.002 |
| Cu-Dissolved | mg/L | 0.06/0.039[b] | 0.025 | 0.017 | 0.029 | 0.031 |
| Fe-Dissolved | mg/L | 3.3 | 0.01 | 0.21 | 0.39 | 0.64 |
| Pb-Dissolved | mg/L | 0.012 | 0.00005 | 0.00035 | 0.00042 | 0.00043 |
| Mo-Dissolved | mg/L | 0.219 | 0.081 | 0.09 | 0.052 | 0.0061 |
| Ni-Dissolved | mg/L | 0.33 | 0.0017 | 0.0026 | 0.0025 | 0.0023 |
| Se-Dissolved | mg/L | 0.006 | 0.015 | 0.015 | 0.011 | 0.0023 |
| Zn-Dissolved | mg/L | 0.09 | 0.0037 | 0.008 | 0.0094 | 0.01 |

Source: SRK, X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2015_Water_Balance_Update\All_Model_Results_for_WQ_Model_Comparison_for_2015_An_Report_SRJ_Rev00.xlsx

**Notes:**

Analytical data from Minto's water quality monitoring program.

a) at 50 mg/L hardness.

b) Cu effluent standard is 0.06 when [DOC] @ W2 > 10 mg/L and 0.039 when [DOC] @ W2 ≤ 10 mg/L.

**Table 8: MPTMF Water Quality Model Predictions and Measured Concentrations in 2016, Reasonable Worst Case**

| | | WUL Effluent Limits (QZ14-031) | MPTMF Measured Water Quality (Station W12) | | Modelling Predictions of Quality in MPTMF (Station W12) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2016 | | 2016 | | 2018 | | Post-Closure | |
| | | | Median | Max | Median | Max | Median | Max | Median | Max |
| Ammonia | mg/L | 0.75 | 3 | 4.7 | 3.9 | 7.1 | 3.5 | 4.6 | 0.03 | 0.03 |
| N-$NO_2$ | mg/L | 0.18 | 1.5 | 4.3 | 1.9 | 2.5 | 1.4 | 1.7 | 0.0099 | 0.011 |
| N-$NO_3$ | mg/L | 27.3 | 26 | 29 | 34 | 45 | 45 | 49 | 0.65 | 0.78 |
| Ag-Dissolved | mg/L | 0.0003 | 0.00001 | 0.00002 | 0.00008 | 0.000096 | 0.00013 | 0.00014 | 0.00018 | 0.0002 |
| Al-Dissolved | mg/L | 0.3 | 0.011 | 0.018 | 0.27 | 0.34 | 0.42 | 0.44 | 0.43 | 0.46 |
| As-Dissolved | mg/L | 0.015 | 0.00045 | 0.0005 | 0.0021 | 0.0026 | 0.0031 | 0.0032 | 0.0031 | 0.0033 |
| Cd-Dissolved | mg/L | 0.0014[a] | 0.000016 | 0.000034 | 0.00012 | 0.00014 | 0.0002 | 0.0002 | 0.00022 | 0.00024 |
| Cr-Dissolved | mg/L | 0.003 | 0.0001 | 0.001 | 0.0026 | 0.0031 | 0.0035 | 0.0038 | 0.0041 | 0.0045 |
| Cu-Dissolved | mg/L | 0.06/0.039[b] | 0.025 | 0.053 | 0.039 | 0.05 | 0.073 | 0.078 | 0.082 | 0.091 |
| Fe-Dissolved | mg/L | 3.3 | 0.01 | 0.022 | 0.49 | 0.59 | 1 | 1.1 | 1.8 | 2 |
| Pb-Dissolved | mg/L | 0.012 | 0.00005 | 0.0002 | 0.00092 | 0.0011 | 0.0013 | 0.0013 | 0.001 | 0.0011 |
| Mo-Dissolved | mg/L | 0.219 | 0.081 | 0.087 | 0.098 | 0.13 | 0.071 | 0.087 | 0.018 | 0.019 |
| Ni-Dissolved | mg/L | 0.33 | 0.0017 | 0.0025 | 0.0038 | 0.0046 | 0.0049 | 0.0052 | 0.0055 | 0.006 |
| Se-Dissolved | mg/L | 0.006 | 0.015 | 0.017 | 0.019 | 0.028 | 0.019 | 0.022 | 0.011 | 0.013 |
| Zn-Dissolved | mg/L | 0.09 | 0.0037 | 0.0061 | 0.013 | 0.015 | 0.018 | 0.019 | 0.021 | 0.023 |

Source: SRK, X:\01_SITES\Minto\1CM002.024_Water_Balance_Support\2015_Water_Balance_Update\All_Model_Results_for_WQ_Model_Comparison_for_2015_An_Report_SRJ_Rev00.xlsx

**Notes:**

Analytical data from Minto's water quality monitoring program.

a) at 50 mg/L hardness.

b) Cu effluent standard is 0.06 when [DOC] @ W2 > 10 mg/L and 0.039 when [DOC] @ W2 ≤ 10 mg/L.

# 4 Closing

The summary of the 2016 Updated Water Balance and Water Quality Model for the Minto Mine was prepared in support of annual reporting. SRK would be pleased to address any questions or comments.

# Appendix D: Pit Water Quality Analysis and Source Term Update – Minto Mine

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# Memo

| | | | |
|---|---|---|---|
| **To:** | Ryan Herbert, Minto Explorations Ltd. | **Client:** | Minto Explorations Inc. |
| **From:** | Kaitlyn Kooy | **Project No:** | 1CM002.044 |
| **Cc:** | Dylan MacGregor, Soren Jensen, SRK Consulting | **Date:** | February 7, 2018 |
| **Subject:** | Pit Water Quality Analysis and Source Term Update- Minto Mine | | |

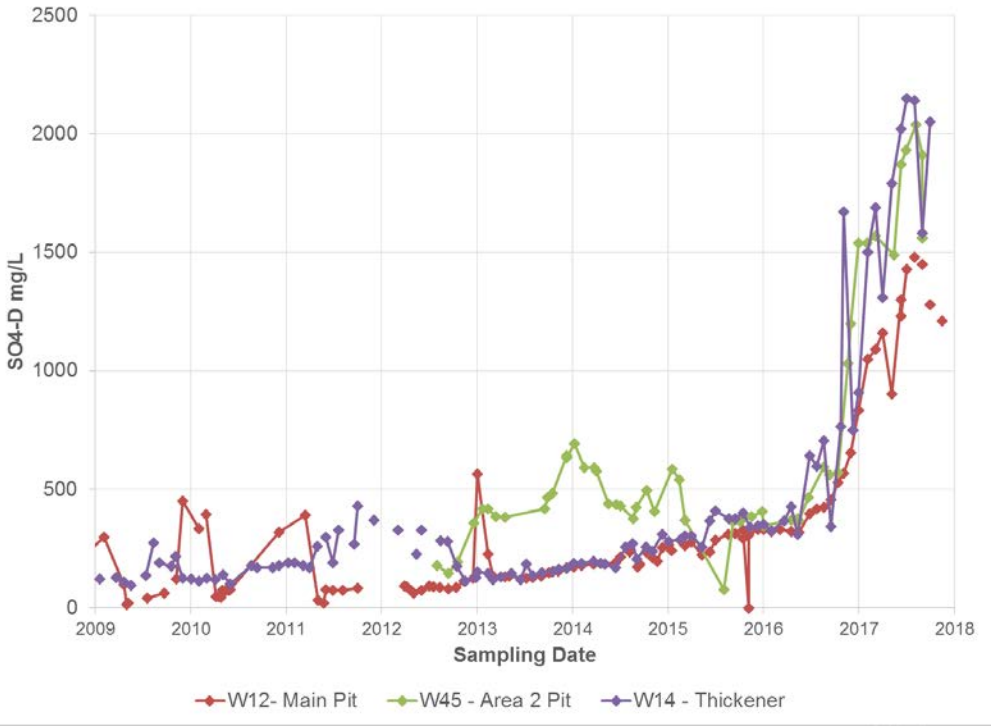
# 1 Introduction

Since the end of 2016, sulphate concentrations in the Main Pit and Area 2 Pit water have been increasing faster than observed previously. The resulting high sulphate concentrations have not been observed at any other surface source at the mine site and it has been unclear as to what has caused the observed sulphate concentrations. SRK was retained to review potential sources of sulphate at the Minto mine and to analyze the available data to determine a plausible explanation for the high concentrations of sulphate in the Main Pit and Area 2 Pit water. Results have contributed to the update of source terms used in the Water and Load Balance Model. This memo summarizes the methodology and results of that analysis and the source term update.

# 2 Background

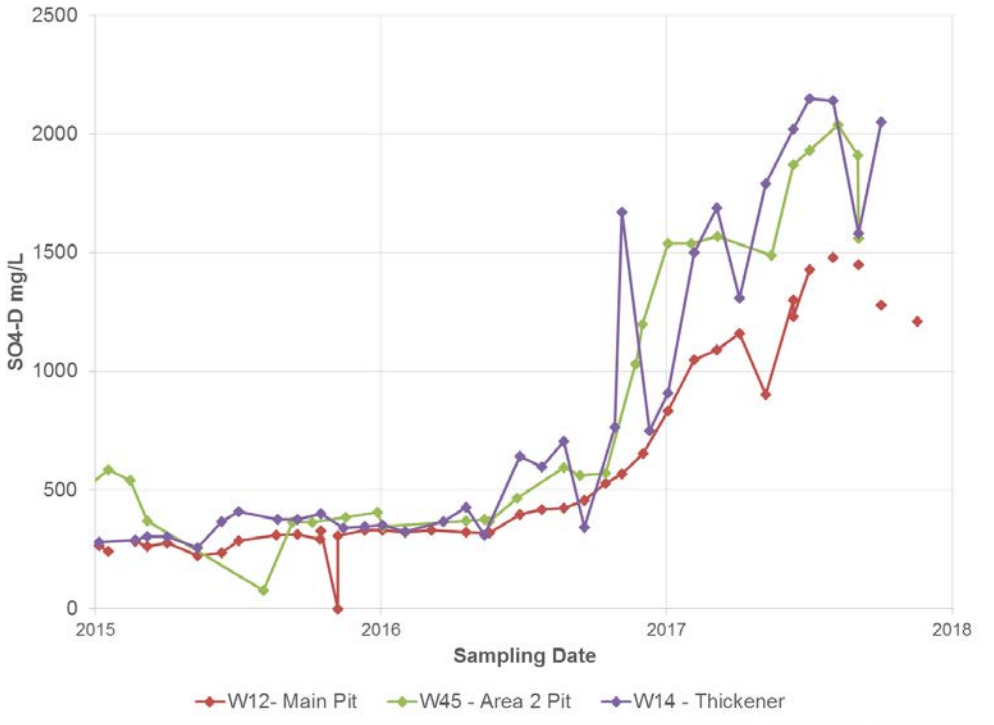
Steadily increasing sulphate concentrations have been observed in the Main Pit and Area 2 Pit water since the end of 2016. Both pits are Tailings Management Facilities (TMFs). Currently slurry tailings are pumped to the Area 2 Stage 2 Pit and reclaim water is drawn from the Main Pit free water. Water is actively pumped from Area 2 Pit to the Main Pit to maintain sufficient water levels in the Main Pit to meet the reclaim volume requirements. Since the Area 2 Pit became a TMF concentrations of most water quality constituents are higher in the Area 2 Pit than the Main Pit, as the Main Pit has a much larger catchment area and thus a much larger contribution of diluting waters. An aerial photograph taken in August of 2017 indicates that there is currently very little free water maintained in Area 2 as most of the free water is being pumped to the Main Pit.

Figure 1 shows the sulphate concentrations in both pits over time, and Figure 2 shows the sulphate concentrations in the pits over a shorter time scale (from 2015 to 2017). As shown in these figures, sulphate concentration in the pits has slowly increased from 2013 to mid-2016 before rising rapidly from the end of 2016 to the present day to a maximum of approximately 2000 mg/L in the Area 2 Pit and 1500 mg/L in the Main Pit. It appears as though sulphate levels in the Main Pit have decreased slightly in November and December of 2017 but it is unclear at this time if it will continue to trend downward.




Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\Raw Data Timeseries\MP_A2_Tails_UG_W15_TimeSeries_REV01_knk

**Figure 1: Sulphate Concentrations in Main Pit, Area 2 Pit, and Tailings Thickener over time**




Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\Raw Data Timeseries\MP_A2_Tails_UG_W15_TimeSeries_REV01_knk

**Figure 2: Sulphate Concentrations in Main Pit, Area 2 Pit, and Tailings Thickener from 2015 to 2017**

Since very little dilution occurs in the Area 2 Pit and the sulphate concentration is very similar to that of the tailings thickener, the Area 2 Pit sulphate loading was not directly analysed and is considered as a pathway only for sulphate loading in the Main Pit for the purposes of this analysis. The increase in sulphate load in the Main Pit is the primary focus of this analysis. Table 1 summarizes the annual sulphate loading in the Main Pit for the last three years.

**Table 1: Sulphate Load in the Main Pit**

| Year | Sulphate Load in Main Pit at Year End (kg)[(1)] | Annual Load Increase (kg) |
|---|---|---|
| 2015 | 437,324 | 135,694 |
| 2016 | 955,458 | 518,261 |
| 2017 | 1,601,671 | 639,825 |
| | **Total** | **1,293,781** |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\ Main_Pit_Sulphate_Review_Compliled_Calcs_Rev00_knk

**Notes:**

1. Includes sulphate load in free water only

# 3 Previous Source Terms

Past water quality predictions at the site have been based on source terms generated either by measured water quality at the site or laboratory humidity cell tests (e.g. SRK 2016). The source terms used in previous versions of the Water and Load Balance Model did not forecast the sulphate concentrations that are currently being observed in the open pits. In past modeling efforts in general, there were two groups of source term inputs that were modelled as reporting to the Main Pit and Area 2 Pit: contact water runoff and tailings slurry.

Table 2 below shows the modelled sulphate load reporting to the open pits annually from runoff based on the previous sulphate source terms (SRK 2016). The Best Estimate case is based on source terms generated from the 50th percentile of measured data while the Worst Case scenario is based on source terms generated from the 95th percentile of measured data.

Load from the tailings slurry is highly variable and is discussed further in Section 5.5.

**Table 2: Typical Annual Main Pit Loading based on previous source terms**

| Catchment Type | Total Area Contributing Runoff to Open Pits (ha) | Annual Sulphate Runoff Load - Best Estimate (kg) | Annual Sulphate Runoff Load - Worst Case (kg) |
|---|---|---|---|
| Undisturbed | 661 | 23,503 | 23,503(1) |
| Pit Walls | 44 | 6,653 | 13,312 |
| Dry Stack Tailings Storage Facility | 19 | 2,285 | 3,808 |
| Waste rock | 196 | 43,039 | 157,401 |
| Ore Stockpiles | 13 | 1,735 | 1,788 |
| Mill Area | 16 | 870 | 1,740 |
| **Total** | **950** | **78,085** | **201,552** |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\ Main_Pit_Sulphate_Review_Compliled_Calcs_Rev00_knk

**Notes:**

1. The Best Estimate undisturbed source term is used for both the Best Estimate and Worst Case predictions

# 4 Sulphate Source Review: Pre-Screening

There are several possible sources of increased sulphate loading at the site. In order to determine the most likely source that is increasing sulphate loading in the system, all the potential sulphate sources were compiled and a screening process was carried out to eliminate sources that are unlikely to produce sulphate load of any appreciable magnitude. Table 3 summarizes all of the potential sources and whether or not they were carried forward for further evaluation. Figure 3 shows the simplified water routing assumptions used for the purposes of this analysis.

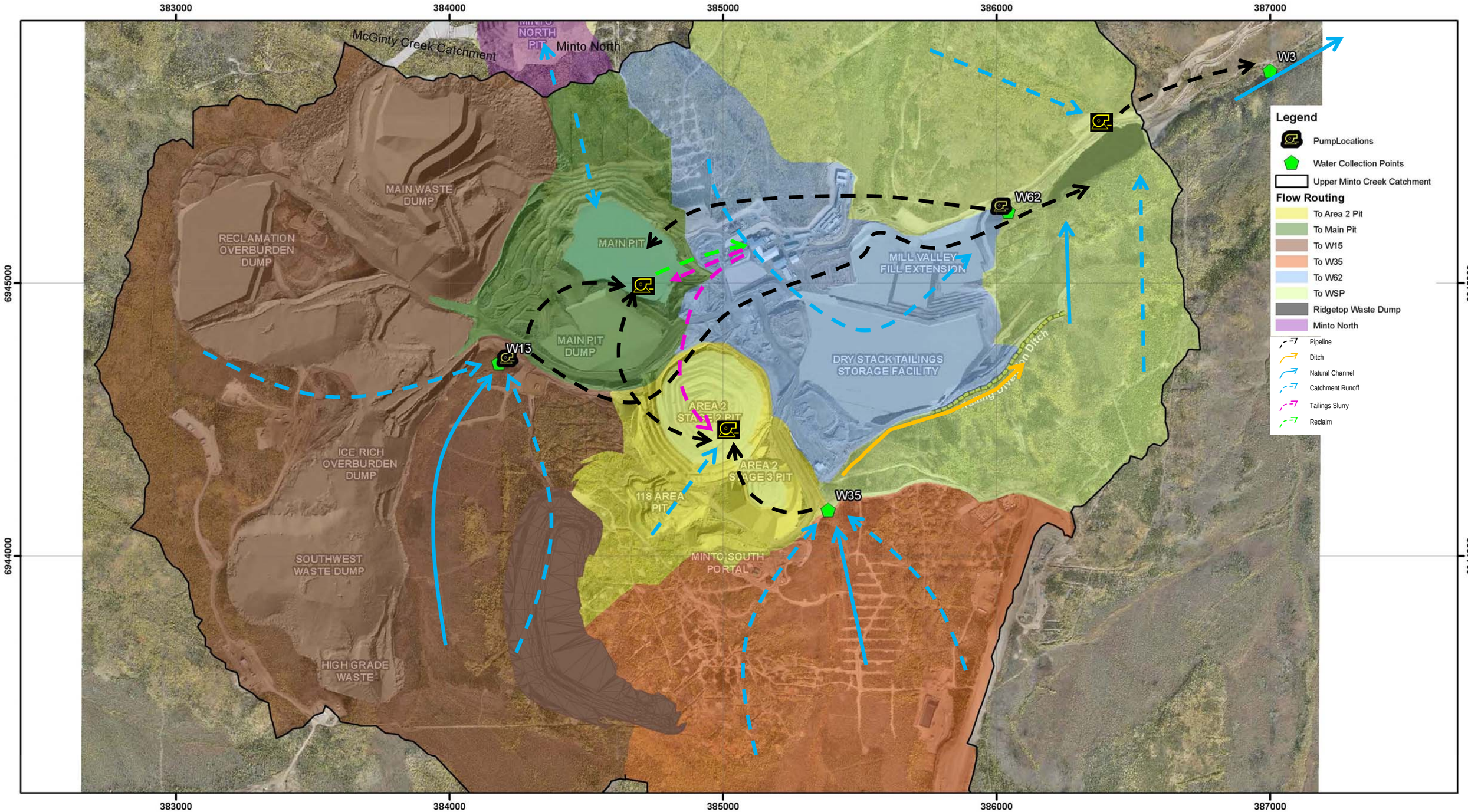
The sources carried forward from pre-screening are the Pit Walls, Main Pit SAT Dump, Underground Dewatering, Tailings Slurry, and Unsaturated Tailings.

**Table 3: Potential Sulphate Source Pre-Screening Summary**

| Potential Sulphate Source | Water Quality Directly Monitored | Observed Increase in Sulphate Concentration | Carried Forward | Comment |
|---|---|---|---|---|
| Southwest Waste Dump | Yes | No | No | Measured water quality at station W15 and waste rock dump seepage monitoring points indicates no increase in sulphate levels |
| Main Pit SAT | No | N/A | **Yes** | Not currently monitored, cannot confirm sulphate loading from source has not increased |
| Dry Stack Tailings Storage Facility | Yes | No | No | Measured water quality at station W8A indicates no increase in sulphate levels |
| Unsaturated Tailings | No | N/A | **Yes** | Not currently monitored, cannot confirm sulphate loading from source has not increased |
| Pit Walls | No | N/A | **Yes** | Not currently monitored, cannot confirm sulphate loading from source has not increased |
| Tailings Slurry | Yes | Yes | **Yes** | Measured water quality in the tailings thickener (station W14) indicates an increase in sulphate concentration |
| Underground Mine | Yes | Yes | **Yes** | Measured water quality in the underground dewatering sump (station UG1) indicates an increase in sulphate concentration |
| Ore Stockpile | Yes | No | No | Measured water quality at ore stockpile seepage monitoring points indicates no increase in sulphate levels |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\Main_Pit_Sulphate_Review_Compliled_Calcs_Rev00_knk

**Figure 3: Water Routing Assumptions**




Note: Adapted from Figure 4.2 in SRK (2018)

# 5 Potential Sulphate Source Evaluation

## 5.1 Main Pit SAT

The Main Pit SAT that is stored within the South Wall Buttress and overlying Main Pit Dump has been identified as a potential source because the dump contains waste rock with neutralization potential ration values less than three and there is currently no data available on the water quality of seepage from the dump.

The Main Pit SAT will be covered or submerged under water in the Main Pit at closure. There are currently no seepage monitoring locations (or opportunities) at the dump. There is no data available directly regarding the water quality of runoff from the dump and seepage from the dump may be a contributing factor to the higher than expected levels of sulphate in the open pits. The previous source terms regarding the water quality of the SAT seepage are based upon measured water quality at station W15.

Due to the lack of water quality data directly from the Main Pit SAT, the evaluation of the material as a potential sulphate source is conceptual in nature and has been undertaken in a conservative manner. In general, the evaluation methodology involved making estimates of maximum potential sulphate concentrations (based on industry experience at other mines) and then calculating the maximum possible sulphate load that may originate from the Main Pit SAT based on applying the mean annual precipitation (MAP) and assumed runoff coefficient to the assumed catchment area. A summary of the evaluation is shown in Table 4.

**Table 4: Maximum Potential Load from Main Pit SAT Dump**

| Annual Runoff Volume ($m^3$)(1) | Maximum Potential Sulphate Concentration (mg/L)(2) | Maximum Annual Load (kg) |
|---|---|---|
| 7,400 | 6,000 | 44,400 |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\Main_Pit_Sulphate_Review_Compliled_Calcs_Rev00_knk

**Notes:**

1. Based on a SAT catchment area of 7.45 ha, mean annual precipitation (MAP) of 329 mm and runoff coefficient of 0.3
2. Maximum potential sulphate concentration is not expected but is used to conservatively illustrate the scale of potential loading

In general it was concluded that the Main Pit SAT is unlikely to be the sole source of sulphate in the open pits since its potential annual maximum load is less than a tenth of the sulphate loading observed in the Main Pit over the first eight months of 2017. If a more in-depth refinement of this scoping evaluation is carried out in future, it is expected that the estimate of the maximum possible annual load would decrease. The volume of runoff that comes into contact with the dump is too small to carry the load required to reasonably explain the increase of sulphate in the Main Pit and Area 2 Pit.

## 5.2 Open Pit TMF Unsaturated Tailings

The Main Pit TMF and Area 2 TMF unsaturated tailings have been identified as a potential sulphate source because residual sulphide minerals contained in unsaturated tailings can weather over time and generate sulphate-bearing seepage, and there is currently no data available on the water quality of runoff from the unsaturated tailings beaches.

Based on the aerial photograph taken in August of 2017, the Main Pit currently has a relatively small tailings beach (approximately 11,000 $m^2$ as of August 2017) while the Area 2 Pit TMF has a relatively larger tailings beach (approximately 35,000 $m^2$ as of August 2017) since most of the free water in the Area 2 Pit is pumped to the Main Pit.

Similar to the Main Pit SAT evaluation, the unsaturated tailings evaluation remains conceptual and conservative due to the limited data available. The same methodology was used in this case by adopting estimates of maximum potential sulphate concentrations (based on industry experience at other mines) and calculating the maximum possible sulphate load that may originate from the unsaturated tailings in the Main Pit TMF and Area 2 Pit TMF. A summary of the calculations is shown in Table 5.

**Table 5: Maximum Potential Plausible Load from Unsaturated Tailings in the Pit TMFs**

| Annual Main Pit and Area 2 Pit Tailings Beach Runoff Volume ($m^3$)(1) | Maximum Potential Sulphate Concentration (mg/L)(2) | Maximum Annual Load (kg) |
|---|---|---|
| 4,600 | 6,000 | 27,600 |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\Main_Pit_Sulphate_Review_Compliled_CaIcs_Rev00_knk

**Notes:**

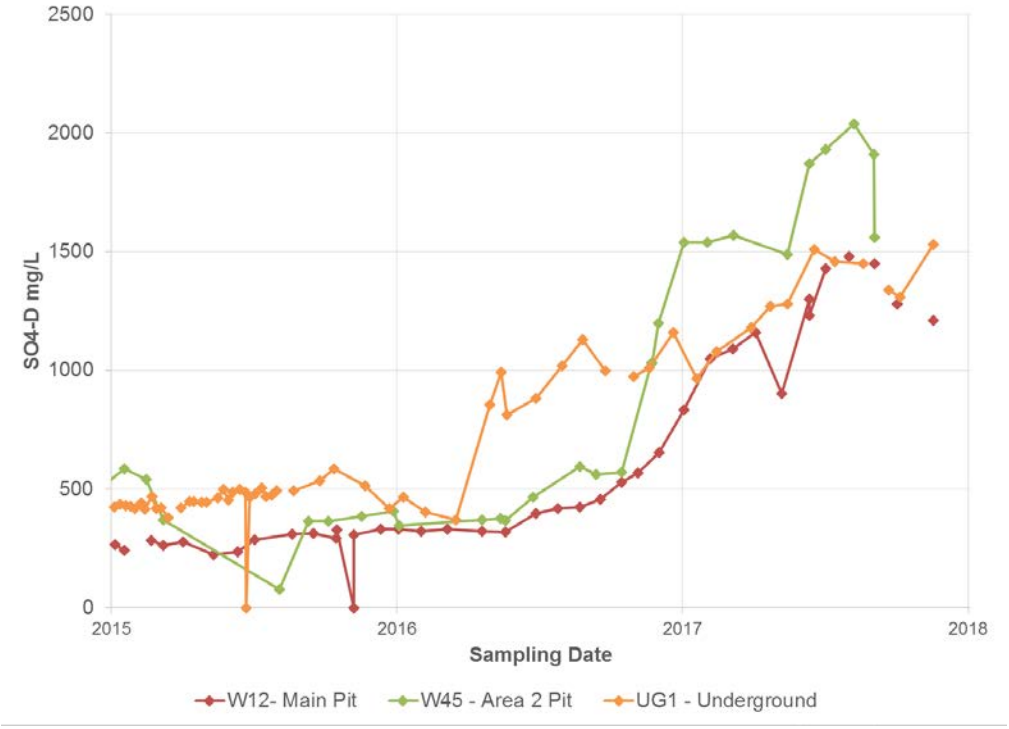
1. Based on the combined Main Pit and Area 2 Pit tailings beach catchment area of 4.6 ha approximated from the August 2017 aerial photo, mean annual precipitation (MAP) of 329 mm and runoff coefficient of 0.3
2. Maximum potential sulphate concentration is not expected but is used to illustrate the scale of potential loading

In general it was concluded that the unsaturated tailings is unlikely to be the sole source of sulphate in the open pits. The volume of runoff that comes into contact with the tailings beach is too small to carry the load required to reasonably explain the increase in sulphate concentrations in the Main Pit and Area 2 Pit. If a more in-depth refinement of this scoping evaluation is carried out in future, it is expected that the estimate of the maximum possible annual load would decrease.

## 5.3 Underground Mine

The underground mine dewatering was identified as a potential source because the observed water quality data had not previously been analysed in detail for this purpose, and sulphate concentrations in the underground mine discharge have increased markedly since mid-2016.

Water reporting to the underground workings is actively pumped or trucked to either the Main Pit or the Area 2 Pit. Water Quality is monitored monthly at the underground sump. Sulphate levels had remained relatively steady at approximately 500 mg/L prior to May 2016. After May 2016 sulphate concentrations in the underground mine have increased to a maximum of approximately 1500 mg/L. Figure 4 shows the sulphate concentrations in the underground mine over time as well as the sulphate concentrations in the Main Pit and Area 2 Pit for comparison.




Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\Raw Data Timeseries\MP_A2_Tails_UG_W15_TimeSeries_REV01_knk

**Figure 4: Sulphate Concentrations in Main Pit, Area 2 Pit, and the Underground Mine from 2015 to 2017**

The pumping rates from the underground mine sump is tracked, and that allowed the annual sulphate load conveyed from the underground mine to the pits to be calculated. The annual load from the underground is shown in Table 6.

**Table 6: Total Water Volume and Sulphate Load Pumped from Underground from 2015 to 2017**

| Year | Annual Water Pumped ($m^3$)(1) | Annual Sulphate Load (kg)(2) |
|---|---|---|
| 2015 | 39,492 | 19,035 |
| 2016 | 23,728 | 23,074 |
| 2017(3) | 39,632 | 49,532 |
| **Total** | **102,852** | **91,641** |

Source: \\VAN-SVR0\Projects\01_SITES\Minto\!020_Site_Wide_Data\Water Management Data\Underground_Dewatering_Rev00_knk.xlsm

**Notes:**

1. Daily pumping rates derived from monthly averages and added together to calculate the annual total
2. Load calculated from interpolated sulphate concentration records
3. 2017 totals are up to and including data from August 8, 2017

The pumping rates from the underground to the pits are relatively low. A groundwater discharge to the pits from underground is unlikely as the underground workings are lower elevation than the pit bottoms, and groundwater modelling carried out on both the Main Pit and the Area 2 Pit indicates that there is a net seepage from the each pit to groundwater of tens of $m^3$/day (SRK 2018). It would be reasonable to conclude that there is no inflow of elevated sulphate groundwater seeping into the pits as the net groundwater flux is outward seepage from the open pits.

Is it important to note that the increase in sulphate in the underground mine occurred prior to the increase in sulphate in either of the open pits. This timing relationship makes it unlikely that the elevated levels of sulphate in the pits could have caused the elevated sulphate levels in the underground mine.

In general is was concluded that the underground mine discharge is a relatively small source of sulphate in the system, and cannot account for all of the sulphate inventory increase in the open pits.

## 5.4 Open Pit Walls

The open pit walls have been identified as a potential source of sulphate loading because there is currently no data available on the water quality of runoff from the pit walls. The current assumptions regarding the water quality of the pit walls runoff are based upon laboratory humidity cell tests that had been carried out in 2013.

Due to the lack of water quality data from the pit walls runoff, the evaluation of the pit walls as a potential sulphate source is conceptual and conservative in nature. In general, the evaluation methodology involved making estimates of maximum potential sulphate concentrations (based on the 95$^{th}$ percentile values observed in Minto waste rock seepage) and then calculating the maximum possible sulphate load that may originate from the pit walls based on the mean annual precipitation (MAP) and assumed runoff coefficient. A summary of the evaluation is shown in Table 7.

**Table 7: Maximum Potential Load from Open Pit Walls**

| Annual Main Pit and Area 2 Pit Runoff Volume ($m^3$)(1) | Maximum Potential Sulphate Concentration (mg/L)(2) | Maximum Annual Load (kg) |
|---|---|---|
| 32,400 | 600 | 19,440 |

Source: Z:\01_SITES\Minto\!020_Site_Wide_Data\ML-ARD\Source_Terms_PhV_VI\Waste_Rock\SourceTerm_2017review\Pit Chemistry KNK WORKING\ Main_Pit_Sulphate_Review_Compliled_Calcs_Rev00_knk

**Notes:**

1. Based on a mean annual precipitation (MAP) of 329 mm and runoff coefficient of 0.3
2. Maximum potential sulphate concentration is not expected but is used to illustrate the scale of potential loading

In general it was concluded that the open pit walls are unlikely to be the sole source of sulphate in the open pits since the maximum possible annual sulphate load is less than a twentieth of the sulphate loading observed in the Main Pit in 2017. The volume of runoff that comes into contact

with the pit walls is too small to carry the load required to reasonably explain the increase of sulphate in the Main Pit and Area 2 Pit.

## 5.5 Tailings Slurry

The tailings slurry has been identified as a potential source of sulphate loading because the concentration of sulphate in the tailings thickener has increased significantly since mid-2016 and the tailings slurry water quality significantly influences the water quality in the open pits due to the relatively high volumes of tailings slurry pumped out of the mill.

### 5.5.1 Mill Process Sulphate Loading

Figure 5 shows the sulphate concentration in the Main Pit, Tailings Thickener, and the process water feed tank over time. Mill process water is typically pulled from the Main Pit but there was a brief period of time in the fall of 2016 where treated water from the water treatment plant effluent was used as reclaim water. Figure 6 shows the tailings thickener and reclaim sulphate concentrations from 2015 to 2017 and demonstrates that the difference between the two has increased significantly in 2016 and 2017. The blue shading in Figure 6 highlights this difference and represents the sulphate that is added to the system from the mill.

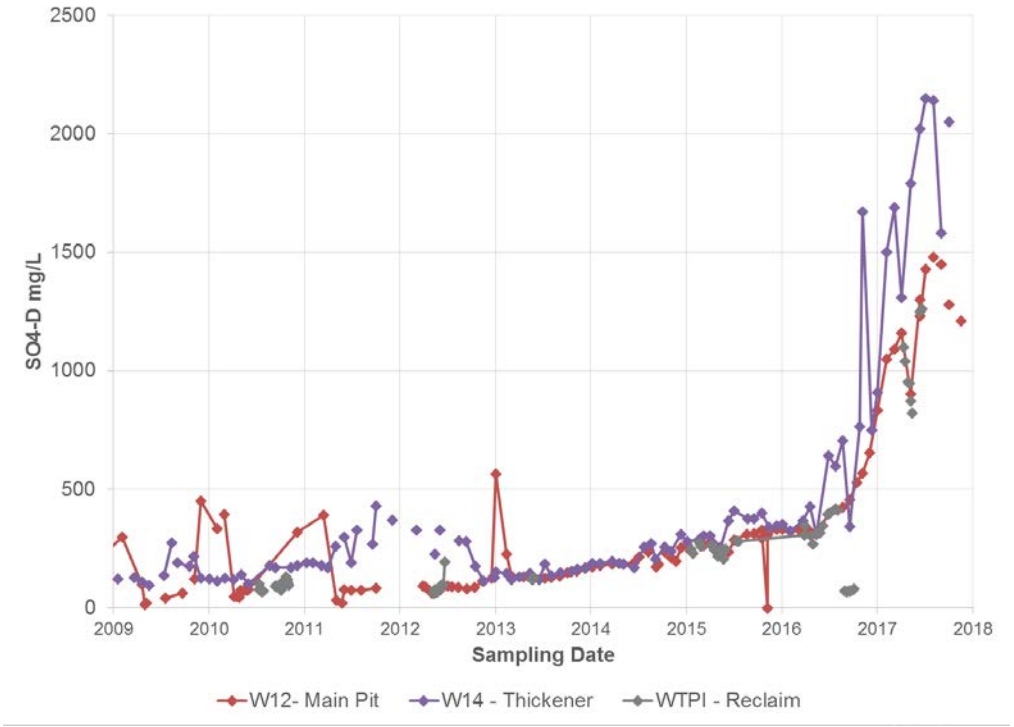



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**Figure 5: Sulphate Concentrations in Main Pit, Tailings Thickener, and Reclaim Water over time**

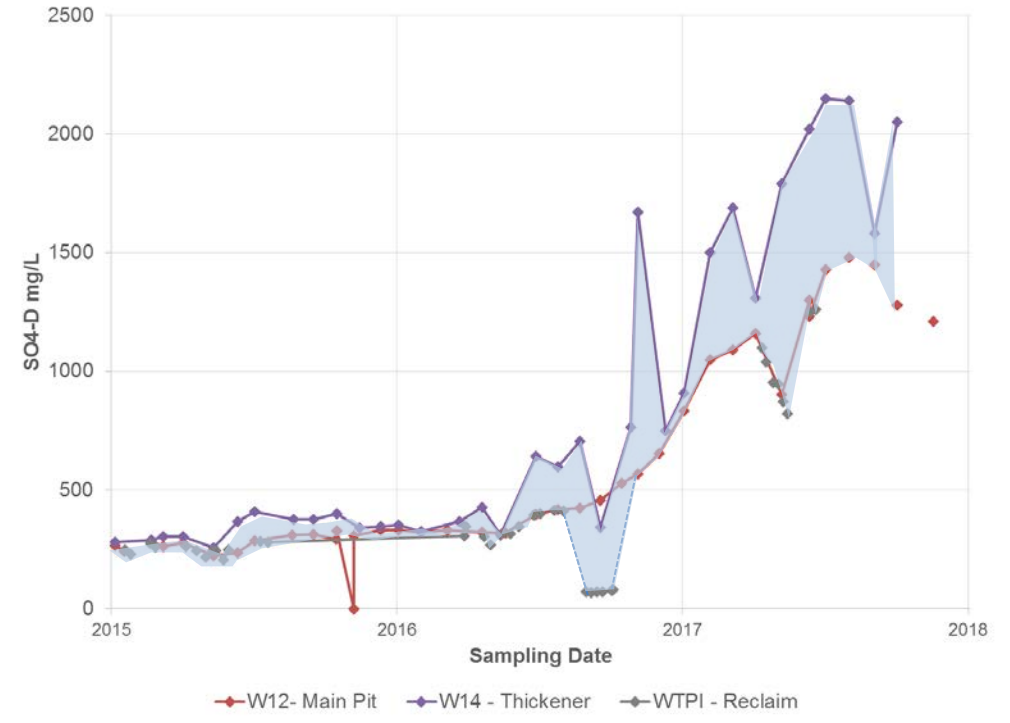


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**Figure 6: Sulphate Concentrations in Main Pit, Tailings Thickener, and Reclaim Water from 2015 to 2017**

Figure 7 demonstrates that the higher loading rates in the mill (orange line) coincide with the increase in sulphate concentration in the Main Pit (blue line). The sulphate loading rate in the mill was never previously as high as it was in late 2016 and 2017. Table 8 shows the total additional sulphate load to free water from the tailings slurry from 2015 to 2017.

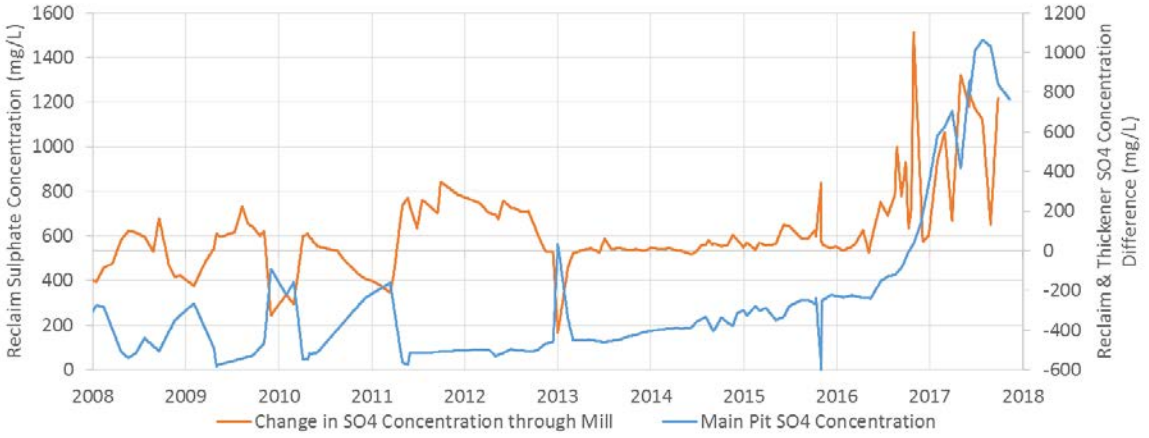


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**Figure 7: Sulphate Concentrations in Reclaim Water and Concentration Change in Mill Tailings Process Water over Time**

**Table 8: Annual Sulphate Loading to Pits from the Mill since 2015**

| Year | Annual Sulphate Load Increase in Mill Process (kg)[1] | Assumed load Increase to Tailings Pores (kg)[2] | Annual Sulphate Load Increase to Free Water (kg)[3] |
|---|---|---|---|
| 2015 | 135,457 | 40,490 | 94,966 |
| 2016 | 398,068 | 156,335 | 241,732 |
| 2017[4] | 588,413 | 219,654 | 368,759 |

**Notes:**

1. Difference between sulphate load in Main Pit reclaim water and thickener discharge sulphate load
2. Based on the proportion of water that is lost to tailings pores
3. Based on remaining water volume that reports to open water pond (i.e. is not lost to pores)
4. Up to and including August 2017

### 5.5.2 Sulphide Ore & POX Blend

The type and grade of ore processed in the mill is variable over time. The ore is classified as either sulphide ore or POX (partially oxidized) ore. The degree of oxidation of POX ore is variable and has a variable effect on the water quality of the mill effluent. Figure 8 shows the type of ore milled from 2015 to 2017. Sulphide ore was milled from January to October of 2016 and a blend of sulphide ore and POX was milled in 2015 and from November 2016 to present.

Typically, the milling of purely sulphide ore does not result in high sulphate loading which is evidenced by the record of low sulphate concentrations in the mill effluent. The milling of POX, depending on the grade, can periodically have a significant influence on the water quality of the mill effluent as shown by the 2017 sulphate loading rates.

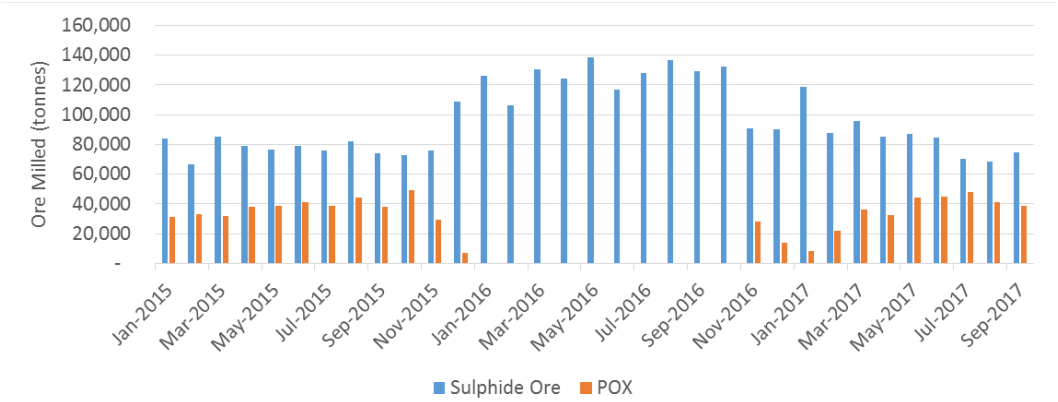


**Figure 8: Ore Type Milled from 2015 to 2017**

When POX ore is being milled, sodium sulphide is used in the mill process. Figure 9 shows the sodium sulphide use in the mill from 2015 to 2017. Sodium sulphide introduces sulphide ions into the system which eventually oxidize to sulphate in surface water, and therefore represents an imported source of sulphur to the system. However, until that oxidation occurs, the sulphur remains in sulphide form- that sulphur would be reported in a total sulphur analysis, but not in a routine sulphate analysis.

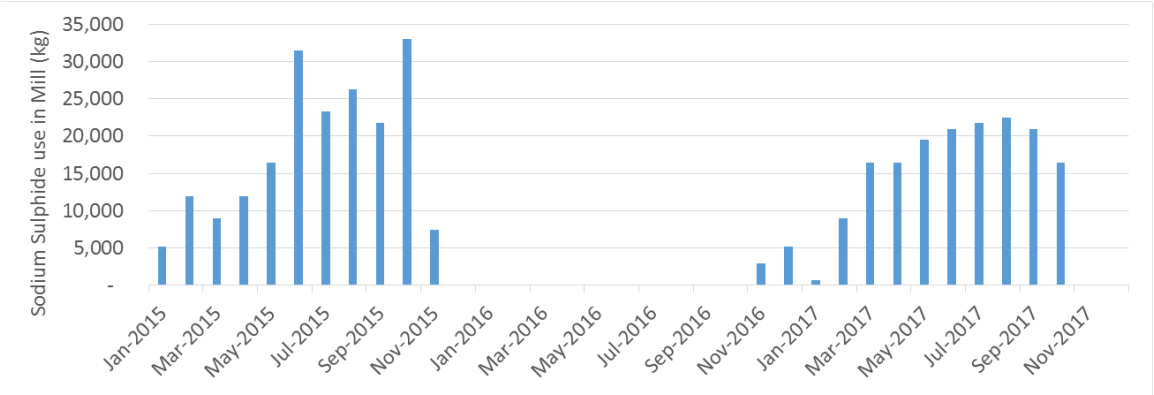


**Figure 9: Sodium Sulphide use in the Mill from 2015 to 2017**

The introduction of sodium sulphide into the process system in 2015 did not result in any observed increase in sulphate loading in the mill while sodium sulphide use in 2017 coincides with a significant increase in observed sulphate loading. This suggests that the POX being milled in 2015 and 2017 had very different soluble sulphate contents and have responded quite differently to the mill process and addition of sodium sulphide. This is further evidenced by the

higher levels of unoxidized total sulphur observed in the tailings thickener, Area 2 Pit, and Main Pit in late 2016 and 2017. Typically the total sulphur observed in the open pits and tailings thickener is nearly entirely in the form of sulphate. However, in late 2016 and 2017 levels of unoxidized sulphur are periodically elevated higher than have been observed previously. Figure 10 shows the concentration of unoxidized sulphur in the tailings thickener, Area 2 Pit, and Main Pit over time. Equation 1 shows the method for calculating unoxidized sulphur.

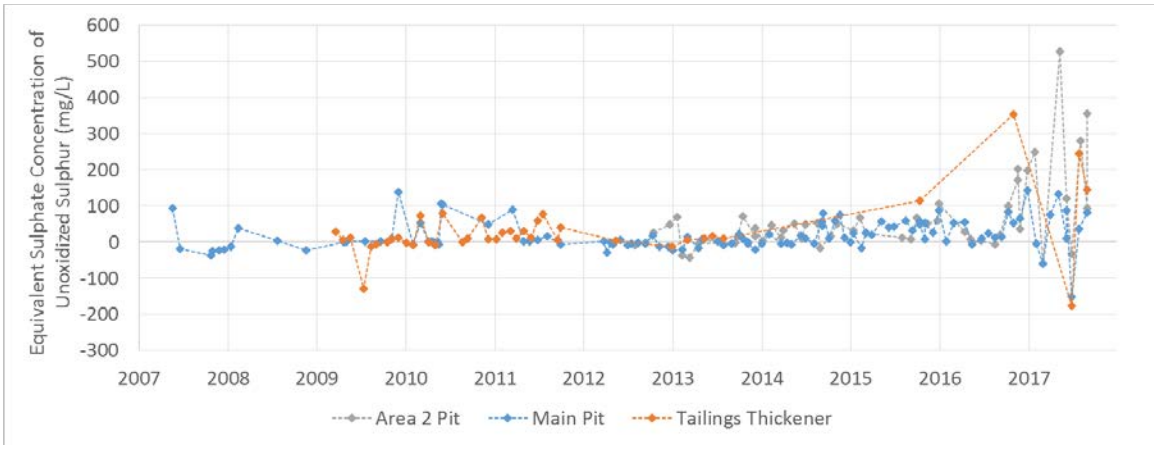


**Figure 10: Unoxidized Sulphur Converted to Sulphate Equivalent**

**Equation 1: Unoxidized sulphur calculation.**

$$Sulphur\ Concentration\ x\ \frac{Sulphate\ molar\ mass}{Sulphur\ molar\ mass} - Sulphate\ Concentration = Unoxidized\ Sulphur$$

Unoxidized sulphur appears to decline as the water is pumped from the mill to the Area 2 Pit to the Main Pit. This indicates that there is further additional sulphate generation occurring in the system as sulphur oxidizes. The total sulphur concentration data at the tailings thickener is somewhat limited so further review of the data may provide additional insight as more data becomes available.

The contrast in unoxidized sulphur and sulphate concentration observed in the tailings thickener and open pits in 2015 and 2017, both years where POX was milled, speaks to the variability of the mill ore feed and inherent difficulty in predicting the mill effluent water quality.

### 5.5.3 Mill Reclaim Residence Time

Currently mill reclaim water is sourced from the Main Pit, slurry tailings are deposited in the Area 2 Pit, and the excess free water in the Area 2 Pit is pumped back to the Main Pit. This circular system has a residence time that is a function of the available free water in the two open pits. Based on the water level record in the open pits, the tailings production schedule, and modelled runoff water volumes, the mill reclaim system residence time has been steadily decreasing since 2015 as water is lost to tailings pores and subaqueous waste rock pores. Figure 11 shows the approximate predicted residence time in the open pit ponds during operations. The available free water and subsequently the residence time in the pits appears to reach a local minimum in early

2017 and then begins to climb. The predicted increase in residence time immediately following the minimum is due to the overall volume in the open pits increasing due to accumulation of runoff and minimal discharge of any water from the system.

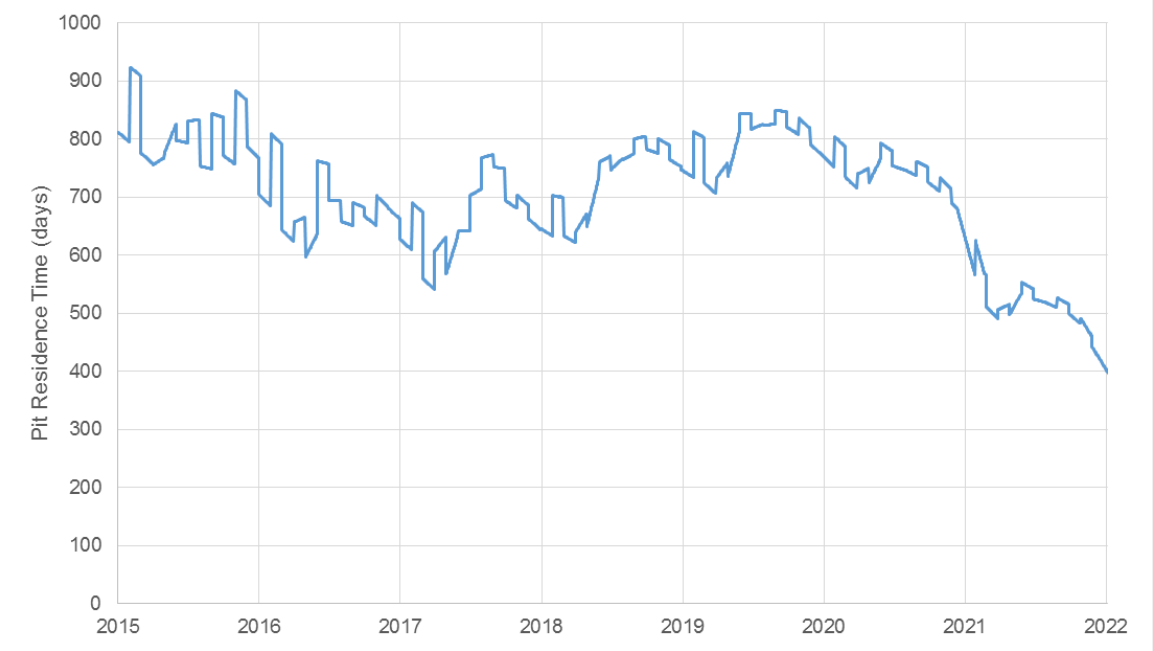


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**Figure 11: Predicted Mill Reclaim/TMF System Residence Time**

The predicted minimum residence time approximately coincides with the maximum observed sulphate concentration in the Main Pit and Area 2 Pit. The observed sulphate concentration in the open pits is beginning to trend downward as the predicted residence time in the open pits begins to increase. The effects of the higher mill sulphate loading rates observed recently have likely been pronounced by the relatively low pit residence time.

In general it was concluded that the tailings slurry is a significant source of sulphate at the Minto Mine and is highly sensitive to the ore feed and reagents used in the mill process. Water management and residence time in the open pits also has an effect on the water quality

# 6 Source Term Update

The underground and tailings slurry source terms have been updated to reflect the findings of the analysis and observed current conditions. The other potential sulphate sources reviewed as part of this analysis will not require a source term update as there is no measured data to substantiate any change from previous assumptions.

## 6.1 Underground Source Term

The underground source terms were generated as follows:

- **South Portal Best Estimate** – 50th Percentile of available water quality data from the underground sump (stations UG1 and W44); applies to Area 118 Underground, Area 2 Underground, and Copper Keel Underground
- **South Portal Worst Case** – 95th Percentile of available water quality data from the underground sump (stations UG1 and W44); applies to Area 118 Underground, Area 2 Underground, and Copper Keel Underground
- **Minto East Best Estimate** – 50th Percentile of available water quality data groundwater monitoring wells with observed elevated sulphate concentrations (stations MW12-05-01, MW12-05-02, MW12-05-03, MW17-12-01, and MW17-12-02); applies to Minto East Underground, Minto East 2 Underground, and Minto North Underground
- **Minto East Worst Case** – 95th Percentile of available water quality data groundwater monitoring wells with observed elevated sulphate concentrations (stations MW12-05-01, MW12-05-02, MW12-05-03, MW17-12-01, and MW17-12-02); applies to Minto East Underground, Minto East 2 Underground, and Minto North Underground

Since the water quality in the groundwater monitoring wells used to generate the Minto East underground source terms are not affected by active underground mining (i.e. do not have nitrogen species concentrations originating from explosive residues) the ammonia, nitrate, and nitrite South Portal source term values were also used for the Minto East underground source term. The underground source terms are provided in Attachment 1.

## 6.2 Tailings Slurry Source Term

The tailings slurry source terms were generated as follows:

- **Sulphide Ore Source Term Best Estimate** – 50th percentile of monthly average load generated per kg of sulphide ore milled from January to October 2016 (no POX milled during this period)
- **Sulphide Ore Source Term Worst Case** – 95th percentile of monthly average load generated per kg of sulphide ore milled from January to October 2016 (no POX milled during this period)
- **POX Low Sulphate Source Term Best Estimate** – 50th percentile of monthly average load generated per kg of POX ore milled in 2015
- **POX Low Sulphate Source Term Worst Case** – 95th percentile of monthly average load generated per kg of POX ore milled in 2015
- **POX High Sulphate Source Term Best Estimate** – 50th percentile of monthly average load generated per kg of POX ore milled from November 2016 to September 2017
- **POX High Sulphate Source Term Worst Case** – 95th percentile of monthly average load generated per kg of POX ore milled from November 2016 to September 2017

The tailings slurry source terms are provided in Attachment 2.

# 7 Discussion

The review has identified that the source of the increased sulphate concentration in the Main Pit and Area 2 Pit water is primarily soluble sulphate loadings from POX ore being processed in the mill, and the use of sodium sulphide to process the POX ore. Underground dewatering is also a source of sulphate loading but to a comparatively lesser extent presently; loadings from underground dewatering will increase over the period of mining in Minto East and Minto East 2. The revised sulphide ore, POX ore and underground discharge source terms presented herein should be incorporated into the next update to the Water and Load Balance.

SRK Consulting (Canada) Inc.



Kaitlyn Kooy, EIT
Staff Consultant

reviewed by



Dylan MacGregor, PGeo
Principal Consultant

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# 8 References

SRK Consulting 2016. Water and Load Balance Model Report 2016. Prepared for Minto Explorations Ltd. August 2016.

SRK Consulting 2018. Minto Groundwater Characterization and Hydrogeologic Conceptual Model Update Report. Prepared for Minto Explorations Ltd. January 2018.

# Attachment 1: Underground Source Terms

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# Memo

| | | | |
|---|---|---|---|
| **To:** | File | **Client:** | Minto Explorations Inc. |
| **From:** | Kaitlyn Kooy | **Project No:** | 1CM002.044 |
| **Cc:** | Dylan MacGregor, Soren Jensen, SRK Consulting | **Date:** | February 5, 2018 |
| **Subject:** | Underground discharge source terms: 2018 update | | |

# 1 Cover

Updated source terms for the underground discharge were developed in 2018, as described in SRK (2018).

> SRK Consulting 2018. Pit Water Quality Analysis and Source Term Update. Prepared for Minto Explorations Ltd. February 2018

**South Portal Underground Discharge Source Term**

| | Expected Case | Worst Case |
|---|---|---|
| **Parameter** | **mg/L** | **mg/L** |
| Ag-D | 0.00002 | 0.0000306 |
| Al-D | 0.0106 | 0.0242 |
| Ammonia | 18 | 91.4 |
| As-D | 0.00156 | 0.00426 |
| Cd-D | 0.0000165 | 0.000275 |
| Cr-D | 0.001 | 0.001 |
| Cu-D | 0.00742 | 0.0673 |
| Fe-D | 0.012 | 0.0758 |
| Mn-D | 0.132 | 0.205 |
| Mo-D | 0.0176 | 0.0419 |
| Ni-D | 0.0023 | 0.00817 |
| Nitrate | 35.1 | 181 |
| Nitrite | 1.44 | 7.65 |
| Se-D | 0.000475 | 0.00441 |
| Sulphate | 366 | 1170 |
| Zn-D | 0.00605 | 0.0583 |

**Minto East Underground Discharge Source Term**

| | Site Monitoring Data | |
|---|---|---|
| | **Expected Case** | **Worst Case** |
| **Parameter** | **mg/L** | **mg/L** |
| Ag-D | 0.00002 | 0.00002 |
| Al-D | 0.0045 | 0.016 |
| Ammonia* | 18 | 91.4 |
| As-D | 0.0005 | 0.00161 |
| Cd-D | 0.00001 | 0.0000235 |
| Cr-D | 0.000965 | 0.001 |
| Cu-D | 0.0002 | 0.00313 |
| Fe-D | 0.0395 | 3.04 |
| Mn-D | 0.713 | 2.6 |
| Mo-D | 0.001 | 0.00695 |
| Ni-D | 0.001 | 0.00112 |
| Nitrate* | 35.1 | 181 |
| Nitrite* | 1.44 | 7.65 |
| Se-D | 0.000101 | 0.000981 |
| Sulphate | 795 | 1160 |
| Zn-D | 0.005 | 0.0269 |

*Nitrogen species are based on South Portal water quality

# Attachment 2: Tailings Slurry Source Terms

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# Memo

| | | | |
|---|---|---|---|
| **To:** | File | **Client:** | Minto Explorations Inc. |
| **From:** | Kaitlyn Kooy | **Project No:** | 1CM002.054 |
| **Cc:** | Dylan MacGregor, Soren Jensen, SRK Consulting | **Date:** | February 7, 2018 |
| **Subject:** | Tailings slurry source terms: 2018 update | | |

# 1 Cover

Updated source terms for the tailings slurry were developed in 2018, as described in SRK (2018).

> SRK Consulting 2018. Pit Water Quality Analysis and Source Term Update. Prepared for Minto Explorations Ltd. February 2018

**Tailings Slurry Sulphide Ore Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| Parameter | **mg/kg** | **mg/kg** |
| Ag-D | 0.0000041 | 0.00000819 |
| Al-D | 0.0159 | 0.0663 |
| Ammonia | 1.53 | 2.77 |
| As-D | 0.000172 | 0.000188 |
| Cd-D | 0.00000338 | 0.00000522 |
| Cr-D | 0.000041 | 0.00041 |
| Cu-D | 0.000463 | 0.00087 |
| Fe-D | 0.0041 | 0.0041 |
| Mn-D | 0.0382 | 0.0649 |
| Mo-D | 0.0399 | 0.0472 |
| Ni-D | 0.000606 | 0.00112 |
| Nitrate | 16.2 | 22. |
| Nitrite | 0.592 | 1.45 |
| Se-D | 0.0074 | 0.00933 |
| Sulphate | 163. | 302. |
| Zn-D | 0.00041 | 0.00205 |

**Tailings Slurry Low Sulphate POX Ore Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| Parameter | **mg/kg** | **mg/kg** |
| Ag-D | 0.0000163 | 0.0000413 |
| Al-D | 0.101 | 0.194 |
| Ammonia | 6.82 | 15.7 |
| As-D | 0.000565 | 0.00252 |
| Cd-D | 0.0000151 | 0.0000563 |
| Cr-D | 0.00122 | 0.00372 |
| Cu-D | 0.00477 | 0.055 |
| Fe-D | 0.0149 | 0.0659 |
| Mn-D | 0.144 | 0.771 |
| Mo-D | 0.166 | 0.425 |
| Ni-D | 0.00159 | 0.0053 |
| Nitrate | 39.3 | 129. |
| Nitrite | 2.02 | 3.7 |
| Se-D | 0.0356 | 0.079 |
| Sulphate | 438. | 1280. |
| Zn-D | 0.0062 | 0.0186 |

**Tailings Slurry High Sulphate POX Ore Source Terms**

| | Expected Case | Worst Case |
|---|---|---|
| Parameter | **mg/kg** | **mg/kg** |
| Ag-D | 0.0000159 | 0.0000202 |
| Al-D | 0.0359 | 0.0967 |
| Ammonia | 6.3 | 20. |
| As-D | 0.000489 | 0.0018 |
| Cd-D | 0.0000741 | 0.000157 |
| Cr-D | 0.000243 | 0.000479 |
| Cu-D | 0.00523 | 0.0324 |
| Fe-D | 0.0243 | 0.0492 |
| Mn-D | 1.41 | 2.29 |
| Mo-D | 0.0974 | 0.0974 |
| Ni-D | 0.00325 | 0.00325 |
| Nitrate | 52. | 149. |
| Nitrite | 3.83 | 3.83 |
| Se-D | 0.0325 | 0.0325 |
| Sulphate | 2340. | 4320. |
| Zn-D | 0.00243 | 0.00661 |




# Minto Mine

# Operations Adaptive Management Plan

2018-01

Prepared by:
Minto Explorations Ltd.
Minto Mine
January 2018

**Minto Mine Operations Adaptive Management Plan**

**First Issue: June 2014**
**Version History**

| Version Number | Issue Date | Description and Revisions Made |
|---|---|---|
| 2014-01 | June 2014 | First Issue |
| 2015-01 | December 2015 | Revisions made as per requirements of WUL QZ14-031 and QML-0001 |
| 2016-01 | May 2016 | Revisions made as per AMP comments from the Yukon Government, Selkirk First Nation and QML-0001 conditions |
| 2017-01 | January 2017 | Revisions made as per Yukon Water Board and Yukon Government review comments. |
| 2017-02 | April 2017 | Revisions made as per Yukon Water Board Reasons for Decisions (April 3, 2017). |
| 2018-01 | January 2018 | Revised thresholds in Minto Creek Surface Water AMP, and made minor modifications to AMP responses and groundwater evaluation frequencies. |

**Table of 2018-01 Revisions**

| Section Revised | Description of Revision |
|---|---|
| 2.1.3 | Revisions include the following changes:<br>• Revision to Specific Performance Thresholds and Responses in Table 2-1.<br>• Revision to Specific Performance Thresholds at W2 in Table 2-2. |

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# 1 Introduction

## 1.1 Overview

Minto Explorations Ltd. (Minto), a wholly owned subsidiary of Capstone Mining Corp. (Capstone), owns and operates the Minto copper mine. Minto Mine is located within Selkirk First Nation (SFN) Category-A Settlement Land (Parcel R-6A), and is approximately 240 km northwest of Whitehorse, Yukon Territory. The Minto mine commenced commercial operations in October 2007.

The Yukon Government's Decision Document (Yukon Government, 2014) following the YESAA review of Minto's Phase V/VI project proposal (file # 2013-0100, (Minto Explorations Ltd., 2013)) required an Adaptive Management Plan (AMP) for the mine operations. As an outcome of the Phase V/VI mine licensing processes, Minto is required to update the AMP with additional information outlined in its Quartz Mining License QML-0001 (QML) and Water Licence QZ14-031 (WL).

AMPs are tools used to address uncertainty or conditions beyond those anticipated in mining operations. AMPs outline a range of possible but unexpected outcomes and the responses that will be undertaken to curb possible negative impacts associated with these unexpected situations.

Mining activities are highly managed operations, with very prescriptive and detailed management plans required for both operational control and regulatory approval. More mature mines such as Minto have management plans which benefit from the operational experience at the site, and uncertainty in the range of conditions expected is reduced through this operational experience.

Minto has developed a number of operational management plans which describe the management and response actions for expected conditions at the site. These plans currently include:

- Solid Waste Management Plan;
- Environmental Monitoring, Surveillance, Reporting Plan;
- Wildlife Protection Plan;
- Spill Contingency Plan;
- Sediment and Erosion Control Plan;
- Mine Development and Operations Plan;
- Underground Mine Development and Operations Plan;
- Mill Operations Plan;
- Water Management Plan;
- Tailings Management Plan;
- Waste Rock and Overburden Management Plan;
- Emergency Response Plan;
- Heritage Resources Protection Plan; and

- Reclamation and Closure Plan

This AMP is intended to provide a framework for responses to conditions beyond those expected and identified in these decision-based management plans. Consequently, this AMP addresses a limited range of components.

## 1.2 Adaptive Management Planning

Adaptive management is an approach to environmental management that is appropriate when a mitigation measure may not function as intended or when broad-scale environmental change is possible. Adaptive management plans are precautionary in nature, and provide a level of security in long term environmental planning. Adaptive management plans also allow for the inclusion of improved science into mitigation measures as they are continually revised.

Adaptive management has been evolving since its emergence in the 1970s. Adaptive approaches include an ability to incorporate knowledge into the management plan as the knowledge is gleaned and circumstances change. Eberhard et al. (Eberhard, et al., 2009) described the categories of knowledge that may trigger changes to water quality management plans; system understanding, measuring progress and anticipating changes. These categories allow for the inclusion of knowledge and adaptation of management to changed conditions. Embedding adaptation into environmental plans involves thinking about how the results of monitoring will change management actions. Adaptive management plans are a way to accept uncertainties and build a structured framework to respond to changing conditions.

Adaptive management conducts a flexible path with actions to take when specific triggers occur. AMPs are a formalization of a plan for performance monitoring and project re-evaluation in the future. The general structure of adaptive management can be described by the following steps:

1. Identify risk triggers associated with vulnerabilities or uncertainties;
2. Quantify impacts and uncertainties;
3. Evaluate strategies and define implementation path that allows for multiple options at specific triggers;
4. Monitor the performance and critical variables in the system; and
5. Implement or re-evaluate strategies when triggers are reached.

Although there are no widely used AMP terms, the steps listed above are representative of typical AMP processes. Within AMPs, triggers provide decision points in a stepwise decision-making framework that identifies how and when management action should be taken. A key characteristic of adaptive management is monitoring, which is used to advance scientific understanding and to adjust management policies in an iterative process. Adaptive management is a rigorous method for addressing uncertainties in ecosystem management.

## 1.3 Adaptive Management Plan Objectives

An AMP is a management tool wherein a framework is provided to make quick and effective decisions to guide responses to unforeseen events. This document identifies areas of uncertainty within the operational phase of the Minto Mine life and provides an AMP framework for each. For each component the AMP describes monitoring commitments, thresholds, triggers and responses to underperforming elements or emerging risks within the

component. The steps laid out in the AMP framework are precautionary, and therefore they provide the confidence that action will be taken before adverse environmental impacts are observed.

Response planning, and results for anticipated events are contained within site management plans while AMPs guide responses to unforeseen or contingency events. This AMP provides a framework to guide responses to unanticipated monitoring results and to potential but low probability events where uncertainty exists.

It is difficult to predict the specific environmental condition that may arise which requires a response from management and, therefore, the AMP does not provide specific detailed descriptions of responses to a situation. The AMP provides a range of possible responses to use as a guide to respond to specific environmental conditions encountered. Management should use the information provided in the AMP and undertake the appropriate response.

### 1.3.1 Updated AMP Objectives

This version of the AMP has been updated to include the requirements of the QML and WL.

The QML was issued December 18, 2014 and was accompanied by a letter entitled outlining the components required in an Adaptive Management Plan (Yukon Government - Energy, Mines and Resources, 2014). The AMP includes the requirements outlined in the letter with the exception of Cover Systems, as they are more appropriately addressed in the Closure Adaptive Management Plan which forms part of the Reclamation and Closure Plan. Additionally, two conditions have been adopted into this plan as part of the March 2nd, 2016 EMR approval of the AMP.

The WL was issued August 5, 2015 and the requirements for the AMP are outlined in clause 109 (Yukon Water Board, 2015).

Clause 109 details and the sections in the AMP where these are addressed are summarized in Table 1-1.

**Table 1-1: QZ14-031 Concordance table**

| 109) The Licensee shall submit to the Board for Review and Approval an updated Operational Adaptive Management Plan. This plan shall be submitted by December 18, 2015, and shall be implemented once approved. The updated plan shall include, without limitation: | Section addressed |
|---|---|
| a) a surface water quality Adaptive Management Plan for McGinty Creek; | 2.2 |
| b) groundwater quality Adaptive Management Plans, including establishment of thresholds, for the Minto Creek and McGinty Creek watersheds; | 2.3, 2.4 |
| c) freeboard thresholds for each water storage facility; | 2.5 |
| d) WQOs, as stated in clause 8; (note: Clause 8 is presumed to be incorrect reference, and therefore W2 WQOs from licence have been included) | 2.1 |
| e) specifications for Monthly Reports that will include, but not be limited to the activities carried out under the Adaptive Management Plan, and | 3.1 |
| f) specifications for the Annual Report to include but not be limited to:<br>i. activities undertaken in relation to the Adaptive Management Plan;<br>ii. trend analysis and water levels in Minto and McGinty creeks;<br>iii. proposed updates and revisions to the Adaptive Management Plan, and<br>iv. any other revisions | 3.1, 3.2 |

## 1.4 Adaptive Management Plan Approach

In addition to the conclusions drawn from research, the approach presented in this AMP follows the Environmental Code of Practice for Metal Mines, Section 4.1.17 on Adaptive Management:

"Mine owners/operators should use adaptive management methods to revise and refine the environmental management strategy. Adaptive management should consider a wide range of factors, including:

- The results of environmental audits or other evaluation activities;
- The results of environmental monitoring;
- The results of monitoring of the performance or condition of environmental infrastructure, such as containment structures, water management systems or treatment facilities;
- Technological developments; and
- Changing environmental conditions." (Environment Canada, 2009)

In addition to the guidance provided by the Environmental Code of Practice for Metal Mines, the AMP serves to meet the Yukon Government's Decision Document following the YESAA review of Minto's Phase V/VI project proposal which identifies some areas that an AMP for operations should be prepared to address including "*water quality, physical stability, covers, water treatment, and water management;".* Though some covers are anticipated to be placed as part of progressive reclamation, they are not an operational feature and therefore have not been included in this AMP.

### 1.4.1 AMP Components

The following AMP components have been identified as having the potential for unexpected conditions during the operational period for which the Operational Management Plans may not provide adequate mitigation against potential effects to the environment or human health and safety:

- Surface water quality;
- Groundwater quality;
- Water Management, and
- Physical Stability

The specific AMP framework for these components is described in subsequent sections.

### 1.4.2 AMP Framework

The AMPs for each component are laid out using a common element approach to create consistency in implementation of the AMP protocol for all components as illustrated in Figure 1-1. The common elements are:

1. Description of the component
   - *Description* - description and understanding of the component leads to risk narrative and specific performance thresholds.
   - *Risk Narrative* describe the possible environmental impacts and environmental conditions that implementation of the AMP will prevent.
2. Monitoring the component

- *Specific Indicators* are the environmental or physical parameters to be monitored and assessed. Specific indicators are measurable or observable, and are indicative of changes from the designed or expected condition.
- *Monitoring Requirements* describes the monitoring regime for the component including frequency, type of data required and interpretation of results.
- *Specific Performance Thresholds* define the conditions, in terms of specific indicators, when action is triggered. Performance thresholds are staged to accommodate levels of concern and a diversity of actions. To the extent possible, specific performance thresholds will include early warning thresholds so that timely and informative responses are initiated before higher impact thresholds are triggered. Trend analysis at early warning thresholds are included to determine the potential of triggering subsequent thresholds.

3. Responding to unexpected conditions of the component

   *Specific Responses* are staged according to specific performance thresholds describes the actions to be implemented if specific performance thresholds are crossed. They are provided in the following categories:

   a) Notification
   b) Review
   c) Evaluation
   d) Action

4. Annual Reporting and Review

   Annual Reporting reflects annual changes made to the AMP as the site conditions change. The AMP should be modified whenever unexpected circumstances are encountered and the protocol is implemented or when additional proven science or technology becomes available. The annual review will include a review of the relevant monitored data and AMP elements. Updates, amendments, performance thresholds crossed, and trigger(s) activated will be provided to the appropriate governmental (including SFN) organizations as required and will be part of the annual report.

   Additional reporting is described further in section 3.1.

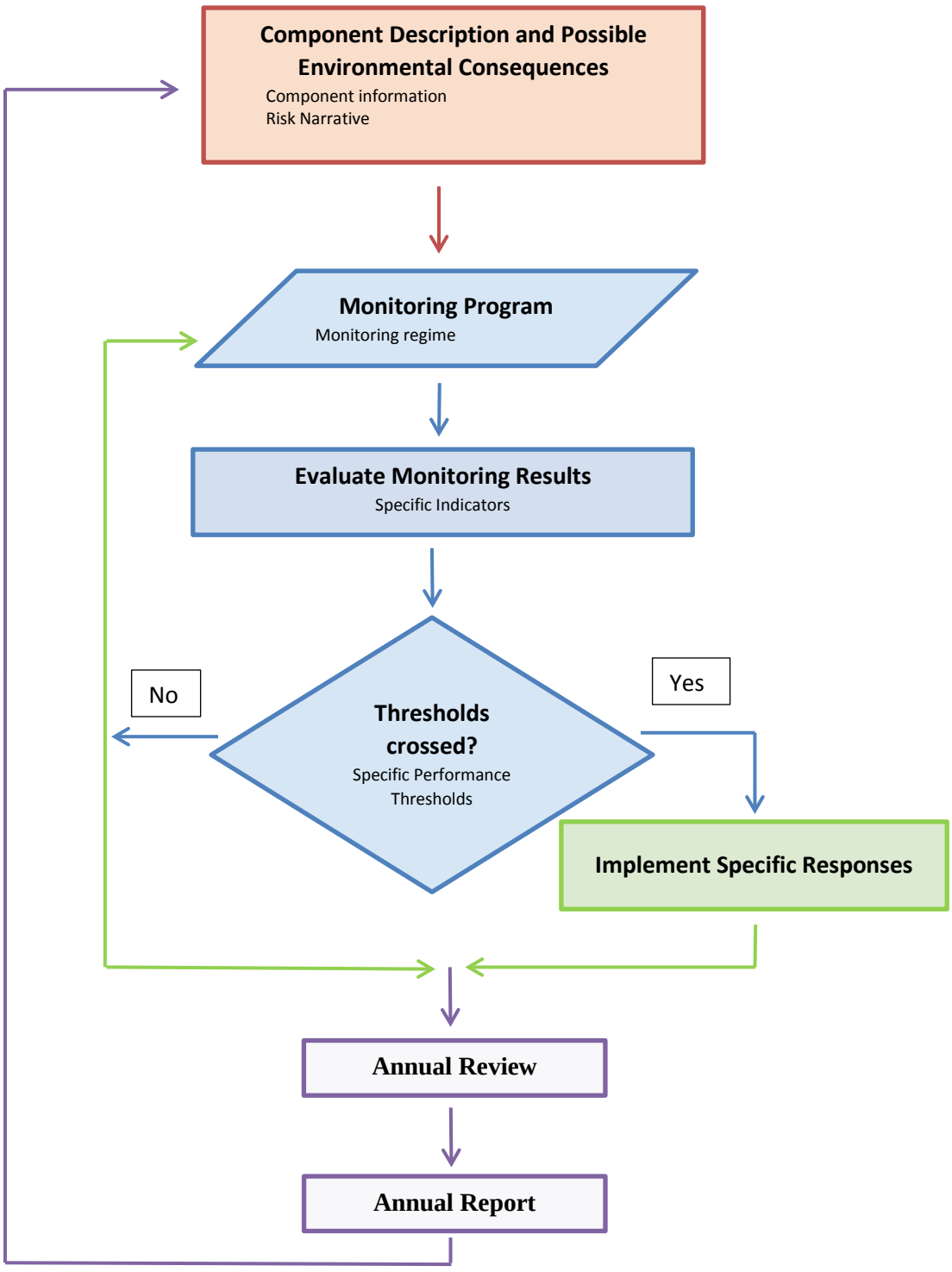


**Figure 1-1: Sequential Components of the AMP (Adapted from AECOM 2010)**

# 2 Adaptive Management Plans for Mine Components

## 2.1 Minto Creek Surface Water Quality

### 2.1.1 Description

Station W50 is considered the main control point on Minto Creek. It is also the last surface monitoring point on the mine site property and is considered a discharge compliance point under the current water licence. Additional key surface water monitoring locations upgradient of W50 and within the mine footprint are located at W16, W17, W15, W35, and W37.

As described in the Water Management Plan (Minto Explorations Ltd., 2015), Minto maintains substantial flexibility over the control and management of site runoff. The conveyance, storage and treatment systems are oriented to adequately manage site water to meet the current and proposed discharge standards at W50.

The W2 monitoring point near the Yukon River is beyond the final mine water discharge point controlled by Minto, and is subject to a broad range of influences from tributaries and catchment areas that are beyond Minto's control. However, Minto is committed to monitoring the water quality at W2 and responding to changing water quality in lower Minto Creek as appropriate. The AMP framework below compliments the operational water management plan at the mine site with a decision-based structure for ensuring that negative impacts to lower Minto Creek from mining activities are avoided.

### 2.1.2 Risk Narrative

Increase in contaminant concentrations from the mine causes adverse effects to aquatic resources in the receiving environment (lower Minto Creek) despite adherence to discharge standards.

### 2.1.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to water quality and the monitoring program are provided below in Table 2-1. Specific thresholds are identified in Table 2-2. Specific thresholds are based on 70 and 85 percent of the WQO for each parameter, as indicators and triggers for action before WQOs are reached.

The monitoring results that will be evaluated and utilized in this component of the AMP are a requirement of the Surface Water Surveillance Program of the Environmental Monitoring, Surveillance and Reporting Plan (EMSRP) (Minto Explorations Ltd., 2016). The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which samples were collected) - this corresponds to the existing monthly reporting schedule.

**Table 2-1: Specific Indicators, Performance Thresholds and Responses for Surface Water Quality at Station W2 in lower Minto Creek.**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous Concentrations at Station W2 for the following parameters with water quality objectives<br><br>Parameters:<br>• $NH_4$-N<br>• $NO_2$-N<br>• $NO_3$-N<br>• pH<br>• Quarterly Bioassay<br><br>Dissolved<br>• Aluminum<br>• Arsenic<br>• Cadmium<br>• Chromium<br>• Copper<br>• Iron<br>• Lead<br>• Molybdenum<br>• Nickel<br>• Silver<br>• Selenium<br>• Zinc<br><br>(See Table **2-2** below for specific threshold values) | **Specific Threshold 1**<br><br>• Exceedance of ST1 value in two consecutive samples **(scheduled or re-sample)** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with W3 results<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• If comparison with W3 result indicates mine loadings are responsible for exceedance then:<br>o Expedite results for subsequent sampling and review the data to see if the exceedance continues or if no other sample has been collected then re-sample within 24-hour of original sample result review.<br>• Actions will continue until performance thresholds are no longer exceeded. |
| | **Specific Threshold 2**<br><br>• Exceedance of ST2 value in two consecutive samples **(scheduled or re-sample) at W2** where evaluation confirmed mine loading responsible for first exceedance | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with W3 results. If comparison with W3 result indicates that mine loadings are responsible for exceedance; and validation confirms original result, then:<br>o Evaluate causes for load contributions and develop investigation plan.<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• Implement investigation plan, including at a minimum:<br>o Expedite results for subsequent sampling and review the data to see if the exceedance continues or if no other sample has been collected then re-sample within 24-hour of original sample result review; and<br>o Site investigation of candidate load contributions.<br>• Review results of investigation and prepare recommendations if appropriate.<br>• Implement recommendations.<br>• Actions will continue until performance thresholds are no longer exceeded.<br>• If trend analysis suggests WQO exceedance within one year, then initiate actions for Specific Threshold 3. |
| | **Specific Threshold 3**<br><br>• WQO exceeded at W2 in a single sample | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol.<br>o Review laboratory QA/QC report.<br>o Verify original result, or re-run sample if laboratory error indicated.<br>**Evaluation**<br>• Compare with W3 results. If comparison with W3 result indicates mine loadings responsible for exceedance – and verification confirms original result – then:<br>o Evaluate candidate causes for load contributions and develop investigation plan (or review/revise as appropriate). |

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | | • A trend analysis will be conducted by Minto's senior level environmental personnel.<br><br>**Action**<br>• Maintain weekly monitoring at W2 and W3.<br>• Implement investigation plan, including any reviews/revisions, and at a minimum:<br>o Expedite results for subsequent sampling and review the data to see if the exceedance continues or if no other sample has been collected then re-sample within 24-hour of original sample result review.<br>o Site investigation of candidate load contributions; and<br>o Engage a qualified individual for the evaluation of potential effects to aquatic resources (i.e. Compare to Predicted No Effect Concentration (PNEC) and apply Biotic Ligand Model (BLM) for D-Cu, invertebrate tissue for Se, compare with calculated acute guideline for D-Cd.) This may include but not be limited to the evaluation of existing data and results from effluent toxicity, surface water toxicity, sediment chemistry, sediment toxicity, benthic invertebrate community structure and fish health testing/programs.<br><br>• Review results of investigation and prepare recommendations if appropriate.<br>• Implement recommendations.<br>• Actions will continue until performance thresholds are no longer exceeded. |
| | **Specific Threshold 4**<br><br>• WQO or PNEC exceeded in **2 consecutive samples (scheduled or re-sample) at W2** where evaluation confirmed mine loading responsible for first exceedance | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Compare with W3 results<br>• Follow QA/QC investigative protocol<br>**Evaluation**<br>• Compare with W3 results. If comparison with W3 result indicates mine loadings responsible for exceedance; and verification confirms original result, then:<br>o Evaluate candidate causes for load contributions and develop investigation plan (or review/revise as appropriate).<br>o Provide investigation plan to SFN/YG Inspector.<br>• Evaluate potential for mine loadings to cause adverse effects to aquatic resources (i.e. redo BLM modeling).<br>• Consider ongoing WQ monitoring results in development of investigation plan.<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• Maintain weekly monitoring and collect samples at greater frequency as required.<br>• Develop investigation plan, including at a minimum:<br>o Expedite results for subsequent sampling and review the data to see if the exceedance continues or if no other sample has been collected then re-sample within 24-hour of original sample result review.<br>o Site investigation of load contributions; and<br>o Evaluation of potential effects to aquatic resources.<br>• Review results of investigation and prepare recommendations.<br>• Implement recommendations arising from investigations.<br>• Implement necessary reasonable and practical measures to reduce contaminant loading from mine to Minto Creek.<br>• Suspend discharge from the mine until water quality is appropriate for discharge.<br>• Actions will continue until performance thresholds are no longer exceeded.<br><br>**If threshold consistently exceeded for 2 months**, then:<br>• Develop revised forecast for near-term (12 months) water quality in Minto Creek.<br>• Develop and implement any additional mitigation measures to reduce loading from mine site, if necessary, with appropriate regulatory approvals.<br>• Actions will continue until performance thresholds are no longer exceeded. |

**Table 2-2: Specific Performance Thresholds for Surface Water Quality in Lower Minto Creek (W2)**

| | Specific Threshold 1 (ST1) (70% of WQO) | Specific Threshold 2 (ST2) (85% of WQO) | W2 Water Quality Objective (WQO) |
|---|---|---|---|
| | mg/L | mg/L | (mg/L) |
| Ammonia - N, mg/L | 0.175 | 0.2125 | 0.25 |
| Nitrite - N, mg/L | 0.042 | 0.051 | 0.06 |
| Nitrate - N, mg/L | 6.37 | 7.735 | 9.1 |
| Aluminum (dissolved), mg/L | 0.07 | 0.085 | 0.1 |
| Arsenic (dissolved), mg/L | 0.0035 | 0.00425 | 0.005 |
| Cadmium (dissolved), µg/L | $0.7*e^{(0.736(\ln(\text{hardness})-4.943)}$ | $0.85*e^{(0.736(\ln(\text{hardness})-4.943)}$ | $e^{(0.736(\ln(\text{hardness})-4.943)}$ |
| Chromium (dissolved), mg/L | 0.0007 | 0.00085 | 0.001 |
| Copper (dissolved), mg/L (when [DOC] @ W2 >10 mg/L) | 0.014 | 0.017 | 0.02 |
| Copper (dissolved), mg/L (when [DOC] @ W2 ≤10 mg/L) | 0.0091 | 0.01105 | 0.013 |
| Iron (dissolved), mg/L | 0.77 | 0.935 | 1.1 |
| Lead (dissolved), mg/L | 0.0028 | 0.0034 | 0.004 |
| Molybdenum (dissolved), mg/L | 0.0511 | 0.06205 | 0.073 |
| Nickel (dissolved), mg/L | 0.077 | 0.0935 | 0.11 |
| Silver (dissolved), mg/L | 0.00007 | 0.000085 | 0.0001 |
| Selenium (dissolved), mg/L | 0.0014 | 0.0017 | 0.002 |
| Zinc (dissolved), mg/L | 0.021 | 0.0255 | 0.03 |
| pH (pH units) | n/a | n/a | 6.0 – 9.0 |

Water Use Licence QZ14-031 identifies the WQO Station as:

- Station W2 during the period when flow is encountered at stations W15 and W35; or
- Station W50 during the period when flow is not encountered at stations W35 and W15.

Clause 11 of the licence identifies the water quality objectives (above in Table 2-2) for Minto Creek, and states that “any exceedances of these at the defined WQO Station shall trigger the Operations Adaptive Management Plan.” The AMP framework in this section ensures that action under the Operational AMP is triggered in advance of exceedances of WQOs at station W2. In the event of the WQO station being W50 (no flow at stations W35 and W15), it is assumed that this would be under winter conditions, and that there will be no contributing flow from the rest of the Minto Creek catchment downstream of the mine. In this case, Minto would adhere to the simple AMP outline listed below:

**Table 2-3: Specific Indicators, Performance Thresholds and Responses for Surface Water Quality at Station W50 in Minto Creek.**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous Concentrations at Station W50 for the following parameters with water quality objectives<br><br>Parameters:<br>• $NH_4$-N<br>• $NO_2$-N<br>• $NO_3$-N<br><br>Dissolved<br>• Aluminum<br>• Arsenic<br>• Cadmium<br>• Chromium<br>• Copper<br>• Iron<br>• Lead<br>• Molybdenum<br>• Nickel<br>• Silver<br>• Selenium<br>• Zinc<br><br>(See Table **2-2** above for specific threshold values) | **Specific Threshold**<br>• Exceedance of WQO for in a single sample | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Action**<br>• Suspend discharge from the mine until water quality is appropriate for discharge. |

Minto will evaluate and respond to toxicity testing in mine effluent as outlined in Table 2-4 below:

**Table 2-4: Specific Indicators, Performance Thresholds and Responses for Toxicity Testing at Stations W3 and W50 in Minto Creek.**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| • Licensed Bioassay test and analysis (acute or chronic) at W3 or W50 | **Specific Threshold**<br>• Failure of any licensed effluent bioassay test | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Action**<br>• If not already initiated, collect Bioassay samples at W2: 7-day rainbow trout test (Lazorchak and Smith 2007), 7-day for *Ceridaphnia dubia* (EPS 1/RM/21), and continue quarterly until directed by a qualified professional to stop. |

## 2.2 McGinty Creek Surface Water Quality

### 2.2.1 Description

The Minto North deposit is an extension of the mineralized corridor being mined within the Minto Creek catchment. It is within the McGinty Creek catchment area, to the north of Minto Creek. Minto has been monitoring surface water quality in the McGinty Creek catchment since 2009, and the results from monitoring program (until the end of 2015) are presented in McGinty Creek Water Quality Characterization, July 2016 (AEG, 2016).

As described in the Water Management Plan (Minto Explorations Ltd., 2015), during the recently completed active mining of Minto North, Minto actively managed water directly impacted by open pit mining with pump trucks. With surface mining in Minto North now complete, there is no active water management, with runoff and meteoric water now allowed to accumulate in the pit.

The AMP framework below provides a decision-based structure with the goal of avoiding changes to background water quality in lower McGinty Creek that result from completed mining activities at Minto North. Station MN-4.5 is the monitoring station on the lower main stem of McGinty Creek, after the north and south tributaries converge, and near the confluence of McGinty Creek with the Yukon River. Surface water quality at the MN-4.5 monitoring point is subject to periodic TSS influences from catchment area that are beyond Minto's control, so dissolved metals concentrations will be used to track influences from the Minto North development.

### 2.2.2 Risk Narrative

Increase in contaminant concentrations from completed Minto North mining activities causes unacceptable changes to surface water quality in McGinty Creek.

### 2.2.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to water quality and the monitoring program are provided below in Table 2-6. The specific indicators are total suspended solids and contaminant (nitrogen species and dissolved metals/metalloids) concentrations for parameters identified in the Water Use Licence QZ14-031 Table 2 – Water Quality Objectives. Thresholds are all based on a proposed water quality objective (WQO), and the specific indicators station, as identified above, is MN-4.5. The discussion below applies to data collected from this station. The selection of this indicator station, along with other aspects of the AMP framework, is consistent with the approach taken for closure water quality objective development in Minto Creek (i.e. downstream indicator station, non-degradation water quality objectives, and a focus on dissolved metal concentrations.)

Essentially, Minto has adopted the statistical definitions of non-degradation (from the discussions and agreement with SFN regarding Minto Creek closure water quality objectives) as the basis of developing these revised McGinty Creek Water Quality Objectives. Monthly monitoring has continued in the McGinty Creek catchment, and the background dataset has been updated to include all monitoring data from initiation of the program in May 2009 until July 2015 (stripping of the Minto North Pit began in August 2015.) Similar to the data treatment used in Minto Creek, data from monitoring stations were collapsed into monthly results (most monitoring has been undertaken monthly anyway, and this was only required for May 2009 when sampling was weekly.) All monthly data were then used to calculate the 95th percentile, for use as the maximum water quality objective, or individual data point evaluator (IDPE). The monthly data were then also grouped by year, and the annual medians were calculated. The 95th percentile of these annual medians was calculated for each station to generate the central tendency evaluator (CTE).

These objectives form the basis of the AMP thresholds. Values lower than the WQOs have been selected as early warning thresholds (ST 1) prior to the WQOs themselves forming the higher level specific thresholds (ST2 and ST3). For these thresholds, the 85th percentile of the same data selected. Utilizing a statistic such as this is more effective and reliable than using a percentage (e.g. 75%) of maximum value, as it considers the actual statistical distribution of the background data.

The actual calculated threshold values are presented in Table 2-5.

The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Surface Water Surveillance Program of the EMSRP (Minto Explorations Ltd., 2016). The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which samples were collected) - this corresponds to the existing monthly reporting schedule.

**Table 2-5: Specific Thresholds for McGinty Creek, Station MN-4.5**

| Analytes | Specific Threshold 1 (85th percentile) | Water Quality Objectives (Specific Thresholds 2 and 3) | |
|---|---|---|---|
| | | Individual Data Point Evaluator ($95^{th}$ percentile) | Central Tendency Evaluator (95th percentile of annual medians) |
| Total Suspended Solids (mg/L) | 52.0 | 269 | 32.0 |
| Ammonia (mg/L) | 0.040 | 0.12 | 0.046 |
| Nitrite (mg/L) | 0.006 | 0.05 | 0.005 |
| Nitrate (mg/L) | 0.200 | 0.232 | 0.083 |
| Dissolved Aluminum (µg/L) | 48.6 | 135.0 | 47.0 |
| Dissolved Arsenic (µg/L) | 0.55 | 0.61 | 0.54 |
| Dissolved Cadmium (µg/L) | 0.026 | 0.041 | 0.015 |
| Dissolved Chromium (µg/L) | 1.0 | 1.0 | 1.0 |
| Dissolved Copper (µg/L) | 2.9 | 3.5 | 2.8 |
| Dissolved Iron (µg/L) | 334 | 403 | 358 |
| Dissolved Lead (µg/L) | 0.20 | 0.20 | 0.20 |
| Dissolved Molybdenum (µg/L) | 1.0 | 1.0 | 1.0 |
| Dissolved Nickel (µg/L) | 1.6 | 1.8 | 1.6 |
| Dissolved Selenium (µg/L) | 0.17 | 0.20 | 0.16 |
| Dissolved Silver (µg/L) | 0.020 | 0.020 | 0.020 |
| Dissolved Zinc (µg/L) | 5.0 | 5.2 | 5.0 |

**Table 2-6: Specific Indicators, Performance Thresholds and Responses for Surface Water Quality in McGinty Creek**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous Concentrations at Station MN-4.5 for parameters with Water Quality Objectives.<br><br>(See Table 2-5 above for Water Quality Objective and threshold values.) | **Specific Threshold 1**<br><br>• Exceedance of ST1 value in two consecutive samples **(scheduled or re-sample)** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with MN-1.5 results<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• If comparison with other results suggests that Minto North loading may be responsible for exceedance and validation confirms original result, then:<br>o Evaluate causes for load contributions, and<br>o If trend analysis suggests WQO exceedance within one year, then initiate actions for threshold 2. |
| | **Specific Threshold 2**<br><br>• Exceedance of the WQO (grab vs. IDPE, or 12-month moving average vs. CTE) | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Measures from ST1, and<br>• Engage a qualified professional to evaluate potential effects to aquatic resources<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• If comparison with results suggests that Minto North loadings are responsible for exceedance and validation confirms original result, then:<br>o Re-sample MN-1.5 and MN-4.5 within **two weeks** of original sample result review; and<br>o Evaluate causes for load contributions<br>o Develop a mitigation strategy with recommendations based on the findings of the potential effects to aquatic resources evaluation<br>• Actions will continue until performance thresholds are no longer exceeded. |
| | **Specific Threshold 3**<br><br>• Exceedance of the WQO (as defined above) in **2 consecutive samples (scheduled or re-sample)** where evaluation confirmed mine loading responsible for first exceedance | **Notification**<br>• Notify management, SFN and YG<br>• include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Measures from ST2<br>**Action**<br>• If comparison with results (evaluation, above) suggests that Minto North loadings are STILL responsible for exceedance; and validation confirms original result, then:<br>o If not already implemented, increase monitoring frequency.<br>o Implement recommendations from mitigation strategy (threshold 2 response). This could include batch water treatment in the Minto North pit if determined feasible and appropriate.<br>o Actions will continue until performance thresholds are no longer exceeded. |

## 2.3 Groundwater Quality in Minto Creek Watershed

### 2.3.1 Description

Groundwater quality has the potential to be important in terms of contributions to surface water quality. Groundwater contributes to streamflow as baseflow, which is typically most important during the autumn/winter low flow season when surface water flows are minimal.

All mine workings and waste facilities within in the Minto Creek catchment are located upgradient (and west) of the Water Storage Pond (WSP). The monitoring supporting the AMP framework is defined and described in the Groundwater Monitoring Plan (GMP) (Minto Explorations Ltd., 2016). Groundwater is monitored both upgradient (west) and downgradient (east) of the WSP; upgradient monitoring is carried out via a multi-level monitoring well at MW12-06, and downgradient monitoring is carried out via a multi-level monitoring well at MW12-05. Surface water downgradient of the WSP is monitored at several stations including station W3, which is located immediately adjacent to MW12-05.

As described in the 2015 Groundwater Model Update (SRK 2015a), groundwater coming from the mine area (the western and highest elevation portion of the Minto Creek catchment) is expected to discharge to surface water in the vicinity of the Water Storage Pond (i.e. upgradient of monitoring well MW12-05). Minimal groundwater from the mine area is expected to discharge to Minto Creek down gradient of the Water Storage Pond. MW12-05 and MW12-06 are optimally located to monitor expected groundwater flow paths.

The W2 surface water monitoring station is located at approximately 600 m from the Yukon River and is 6 km downstream of the Minto lease boundary. Water reporting to W2 is subject to influences from groundwater and surface water outside the mine area. Minto is committed to monitoring groundwater quality at MW12-05 and MW12-06 and surface water quality at W2 as required by Water Use Licence QZ14-031, and responding to changing water quality in groundwater and lower Minto Creek as appropriate.

The operational AMP framework below complements the operational water management plan at the mine site with a decision-based structure for ensuring that negative impacts to lower Minto Creek from mining activities are avoided.

### 2.3.2 Risk Narrative

Flux of geochemical load from the mine via groundwater pathways causes surface water quality objectives to be in exceeded in Minto Creek at station W2.

### 2.3.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to groundwater quality in Minto Creek watershed are provided in Table 2-7. Specific Performance Thresholds (SPTs) are defined for each of the Effluent Quality Standards (EQS) parameters identified in Clause 9 (a), Table 1 of Water Use Licence QZ14-031, with the exception of pH, oil and grease, iron and nitrite (as discussed later in this section). Additionally, although it is not specified in Clause 9(a), sulphate has been included in the SPTs. Table 2-8 compiles the concentration of background groundwater for each Specific Indicator and the Specific Performance Threshold values.

The concentrations of the background groundwater are based on the respective median parameter concentrations at monitoring well MW09-03 (including all monitoring ports). At present (January 2017), the MW09-03 monitoring record is considered to be the most representative indicator of the baseline groundwater

conditions for the entire project site. MW09-03 was installed in 2009 and monitored to collect baseline data downgradient of the Minto North ore body- this well is located near the southern limit of the McGinty Creek catchment close to the surface water divide with Minto Creek. Pre-mining groundwater concentrations for certain parameters such as cadmium and iron have been relatively high, likely due to the adjacent highly mineralized zone. Mining of this ore body began in Q3 2015 and as such the monitoring record prior for the 2009-2015 period reflects baseline conditions. Another groundwater well (nominally MW16-08, likely MW2017-08 when completed) will be installed in 2017 to allow groundwater quality monitoring within the Minto Creek catchment upgradient of any mine disturbances. Once an adequate record of the groundwater quality from MW16-08 becomes available, the groundwater quality at MW09-03 and MW16-08 will be compared by a qualified professional to verify and assess if background groundwater concentrations used in the current operational AMP remain appropriate. Minto expects that an adequate record will be available after 3 years of monitoring. Other new wells that are planned for installation in 2017 will be monitored in accordance with Minto's EMSRP, but will not be included in the AMP.

Iron and nitrite have been excluded from the Specific Indicators for groundwater quality because of the magnitude of the natural variability observed in groundwater at Minto. In addition, pH as also been excluded as a Specific Indicator for groundwater quality because it is not as useful an early warning indicator as sulphate and metal/ metalloid concentrations, and Oil & Grease has been excluded because it is not relevant as a specific indicator for groundwater. Although iron, nitrite and pH are excluded from the Specific Indicator list, these three constituents are monitored and would be included in the review of groundwater quality if an SPT was exceeded.

Three SPTs have been defined for the Minto Creek watershed. Rationale for development of the SPTs is as follows:

- SPT-1 corresponds to a trend-based assessment designed to flag a potential rapid increase in groundwater loadings that has not yet exceeded concentration-based thresholds. The assessment is structured to determine if an indicator has increased significantly compared to the last sampling event. The assessment will be performed as followed:

  $$((C_n - C_{n-1})/( C_{SPT-2} – C_n) > 0.2$$

  Where:

  - $C_n$ = the parameter concentration of groundwater from the latest sampling event;
  - $C_{n-1}$ = the parameter concentration of groundwater from the last sampling event ;
  - $C_{SPT-2}$ = the parameter concentration for the SPT-2;

  The SPT-1 provides a conservative threshold considering that it is weighted against the concentration for the SPT-2. The SPT-1 will be increasingly sensitive to change in concentrations between two sampling events as groundwater approaches the SPT-2, since the size of the denominator decreases as the SPT-2 value is approached.

- SPT-2 generally corresponds to the EQS concentrations defined in Clause 9 (a), Table 1 of Water Use License QZ14-031 (with four exceptions (Cr-D, Cu-D, Ni-D and sulphate) as indicated in the notes to Table 2-7). The EQS are defined for surface water discharge, and the mine is not permitted to discharge water that exceeds any EQS guidelines to surface water. As SPT-2 applies to groundwater (not surface water) concentrations in single zone, this is a highly conservative threshold.

- SPT-3 generally corresponds to the estimated concentrations in groundwater that would be necessary to cause exceedance of the Water Quality Objectives in lower Minto Creek, at W2, under long term steady state conditions (exceptions are listed in the notes to Table 2-7). These concentrations were determined by conducting a mass loading calculation to determine the groundwater concentrations that would be necessary to cause exceedance of WQOs in lower Minto Creek during low flow periods where all streamflow is derived from groundwater discharge. The mass loading calculation was structured to represent a low-flow period when all surface flows in lower Minto Creek originate from groundwater discharge to the creek. The calculation was done using the following formula:

$$C_{gw\text{-}mine\_max} = ((Q_{W2} \times C_{W2\text{-}WQO}) - (Q_{gw\text{-}bgrnd} \times C_{gw\text{-}bgrnd}))/Q_{gw\text{-}mine}$$

Where:

- $C_{gw\text{-}mine\_max}$ = the indicator parameter concentration of all groundwater upgradient of MW12-05 that reports to Minto Creek that would be required to cause surface water to exceed the WQO at station W2.
- $Q_{W2}$ = the combined groundwater flow discharging to Minto Creek (total groundwater discharge to Minto Creek from the 2015 groundwater model update) during low flow periods
- $C_{W2\text{-}WQO}$ = the WQO parameter concentration for surface water at W2
- $Q_{gw\text{-}bgrnd}$ = background groundwater flow discharging to Minto Creek (groundwater discharge down gradient of the Water Storage Pond from the 2015 groundwater model update) during low flow periods
- $C_{gw\text{-}bgrnd}$ = background groundwater concentration (based on median concentrations from the 2009-2015 baseline monitoring period in MW09-03)
- $Q_{gw\text{-}mine}$ = the estimated groundwater flow from the mine at the Water Storage Pond (from the 2015 groundwater model update)

If groundwater concentration of one indicator reached the SPT-3 in an individual port, the quality of the lower Minto Creek at W2 would not yet exceed the Water Quality Objective due to the contribution of groundwater from un-impacted areas of the Minto Creek watershed and the fact that groundwater concentrations at a specific monitoring well port represents only a portion of the flow and not the whole groundwater flow field. The SPT-3 provides therefore a conservative threshold for action before any significant effect would be observed in surface water.

The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Groundwater Monitoring Program of the EMSRP (Minto Explorations Ltd., 2016). The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which samples were collected) - this corresponds to the existing monthly reporting schedule. The evaluation of new AMP triggers will be done by the qualified professional (QP) with the monthly data review as indicated in the response Table 2-7. If however, the exceedance is an on-going trigger, then the review by the QP will be quarterly for that parameter in the specific zone.

Examples of actions that may arise from recommendations include:

- Continuation of monitoring;

- Continuation monitoring with an increase in monitoring frequency;
- Development of additional monitoring points and monitoring of those newly-established monitoring locations;
- Completion of appropriate risk assessment;
- Development and execution of a focused study to better understand the cause of exceedance.

**Table 2-7: Specific Indicators, Performance Thresholds and Responses for Groundwater Quality in Minto Creek**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous concentrations in samples collected from multi-level groundwater monitoring wells MW12-05 or MW12-06 for the following parameters with water quality objectives:<br>• Dissolved Aluminum<br>• Dissolved Arsenic<br>• Dissolved Cadmium<br>• Dissolved Chromium<br>• Dissolved Copper<br>• Dissolved Iron<br>• Dissolved Lead<br>• Dissolved Molybdenum<br>• Dissolved Nickel<br>• Dissolved Silver<br>• Dissolved Selenium<br>• Dissolved Zinc<br>• $NH_4$-N<br>• $NO_3$-N<br>• Sulphate | **SPT-1**<br>• Exceedance of SPT-1 for any sample collected during routine monitoring from multilevel groundwater monitoring wells MW12-05 or MW12-06. | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (trend analysis included) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>Include the trend analysis in scheduled reporting<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator |
| | **SPT-2**<br>• Exceedance of SPT-2 concentrations in 2 consecutive samples (scheduled or re-sampled) collected during routine monitoring from multilevel groundwater monitoring wells MW12-05 or MW12-06. | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (including trend analysis) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>o Timing: initiate within 1 week of QA/QC review validating original results<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator |

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | **SPT-3**<br>• Exceedance of SPT-3 in 2 consecutive samples (Scheduled or re-sampled) collected during routine monitoring from multilevel groundwater monitoring wells MW12-05 or MW12-06. | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (including a trend analysis) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>o Timing: initiate within 1 week of QA/QC review validating original results<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator<br>• Increase monitoring frequency to monthly sampling of all monitored zones in the affected multi-level well for a period to be defined by qualified professional. |

**Table 2-8: Background concentrations and SPTs for the groundwater monitoring in the Minto Creek watershed**

| Minto Creek | *Concentrations (mg/L)* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ag-D | Al-D | As-D | Cd-D | Cr-D | Cu-D | Pb-D | Mo-D | Ni-D | Se-D | Zn-D | N-NO3 | Ammonia | Sulphate[2] |
| SPT-3 [1] | 0.00046 | 0.48 | 0.025 | 0.0060 | 0.0030 | 0.060 | 0.020 | 0.34 | 0.33 | 0.0093 | 0.13 | 45 | 1.0 | 4951 |
| SPT-2 | 0.00030 | 0.30 | 0.015 | 0.0030 | 0.0015[4] | 0.030 [4] | 0.012 | 0.22 | 0.165[4] | 0.0060 | 0.090 | 27 | 0.75 | 1000 |
| Background Groundwater[3] | 0.00001 | 0.0045 | 0.0001 | 0.00002 | 0.00050 | 0.0014 | 0.0001 | 0.006 | 0.001 | 0.0002 | 0.006 | 0.07 | 0.051 | 12 |

Notes:

1: For most Specific Indicators, SPT-3 is the calculated concentration that all groundwater from the mine catchment must attain to reach the Operational Water Quality Objectives at W2. Model flows were based on 2015 Groundwater Model Update. 15 L/s is the total groundwater discharging to Minto Creek. 3 L/s is the estimated groundwater flow from the Minto Creek catchment up gradient of the Water Storage Pond. The exceptions are dissolved chromium, dissolved copper and dissolved nickel, for which SPT-3 is equal to the Effluent Quality Standard value that applies to surface water discharge from the mine site.

2: There is no Effluent Quality Standard for sulphate. For the SPT-2, the guideline for Aquatic Life from the Contaminated Site Regulation Schedule 3 was used as a replacement.

3: The background concentration in groundwater is calculated as the median of concentrations observed at groundwater monitoring well MW09-03.

4: SPT-2 for dissolved copper, dissolved chromium and dissolved nickel set at one-half (50%) of Effluent Quality Standard (SPT-2 for all remaining parameters (other than sulphate) is equal to (100% of) the Effluent Quality Standard).

## 2.4 Groundwater Quality in McGinty Creek Watershed

### 2.4.1 Description

The mine workings in the McGinty Creek catchment are limited to the Minto North Pit- the pit and the overall catchment are described in Section 2.2.1. The catchment area of the Minto North Pit is roughly 15 ha and the catchment area of the McGinty Creek watershed is roughly 3400 ha (SRK 2013); in other words, the Minto North Pit catchment is roughly 0.4% of the total McGinty Creek catchment area. While a groundwater model encompassing the full extent of the McGinty Creek catchment has not been developed, it is clear that only a very small proportion of the groundwater in the McGinty Creek watershed can be affected by the Minto North Pit.

The monitoring supporting the AMP framework is defined and described in the Groundwater Monitoring Plan (part of the EMSRP ( (Minto Explorations Ltd., 2016)). Groundwater in the McGinty Creek catchment downgradient of the Minto North Pit is monitored at multi-level monitoring well MW09-03.

### 2.4.2 Risk Narrative

Flux of geochemical load from the Minto North Pit via groundwater pathways causes surface water quality objectives to be in exceeded in McGinty Creek at station MN4.5.

### 2.4.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to groundwater quality in McGinty Creek watershed are provided below in Table 2-9. SPTs are defined for each of the EQS parameters identified in Clause 9 (a), Table 1 of Water Use License QZ14-031, with the exception of pH, Oil & Grease, iron and nitrite (for reasons described in the Minto Creek groundwater section (Section 2.3). Additionally, although it is not specified in Clause 9(a), sulphate has been included in the SPTs. The concentration of background groundwater and the Specific Performance Threshold values for each Specific Indicator and each zone (i.e. individual well port) of MW09-03 are compiled in Table 2-10.

As stated above, at present, MW09-03 is considered to be the most representative of the baseline groundwater conditions for the entire project site. MW09-03 was installed in 2009 and monitored to collect baseline data downgradient of the Minto North ore body- this well is located near the southern limit of the McGinty Creek catchment close to the surface water divide with Minto Creek. Pre-mining groundwater concentrations for certain parameters such as cadmium and iron have been relatively high, likely due to the adjacent highly mineralized zone. Mining of this ore body began in Q3 2015 and as such the prior monitoring record from the 2009-2015 period reflects baseline conditions.

Two Specific Performance Thresholds have been defined for McGinty Creek watershed groundwater- both are conservative given the application of the thresholds at individual ports, the small proportion of McGinty Creek catchment groundwater that will be influenced by the mine workings and the expected slow rates of groundwater movement. Rationale for development of the two specific performance thresholds is as follows:

- SPT-1: Three consecutive exceedances of the 75$^{th}$ percentile background level in a single monitoring port.
    - The specification of three consecutive exceedances is intended to avoid triggering the AMP unnecessarily, but to ensure that any sustained increase from baseline conditions receives appropriate scrutiny.
- SPT-2: Three consecutive exceedances of the 95$^{th}$ percentile background level in a single monitoring port.

- The specification of three consecutive exceedances is intended to avoid triggering the AMP unnecessarily, but to ensure that any sustained increase from baseline conditions receives appropriate scrutiny.

The monitoring results that are evaluated for this component of the AMP are an obligation of the Groundwater Monitoring Program of the EMSRP. The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which samples were collected) - this corresponds with the existing monthly reporting schedule. The evaluation of new AMP triggers will be done by the qualified professional (QP) with the monthly data review as indicated in the response Table 2-9. If however, the exceedance is an on-going trigger, then the review by the QP will be quarterly for that parameter in the specific zone.

Examples of actions that may arise from recommendations include:

- Continuation of monitoring;
- Continuation monitoring with an increase in monitoring frequency;
- Development of additional monitoring points and monitoring of those newly-established monitoring locations;
- Completion of appropriate risk assessment;
- Development and execution of a focused study to better understand the cause of exceedance.

**Table 2-9: Specific Indicators, Performance Thresholds and Responses for Groundwater Quality in McGinty Creek**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous concentrations in samples collected from multi-level groundwater monitoring well MW09-03 for the following parameters:<br>• Dissolved Aluminum<br>• Dissolved Arsenic<br>• Dissolved Cadmium<br>• Dissolved Chromium<br>• Dissolved Copper<br>• Dissolved Lead<br>• Dissolved Molybdenum<br>• Dissolved Nickel<br>• Dissolved Silver<br>• Dissolved Selenium<br>• Dissolved Zinc<br>• $NH_4$-N<br>• $NO_3$-N<br>• Sulphate | **Specific Threshold 1**<br>• Three consecutive exceedances of the 75$^{th}$ percentile value* from the baseline period (2009-2015) in routine monitoring results from a single monitoring port in MW09-03.<br><br>*values provided in Table 2-9 | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original results, or re-run samples if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (including trend analysis) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>o Timing: initiate within 1 week of QA/QC review validating original results<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator<br>• Trend analysis to be included in scheduled reporting |
| | **Specific Threshold 2**<br>• Three consecutive exceedances of the 95$^{th}$ percentile value* from the baseline period (2009-2015) in routine monitoring results from a single monitoring port in MW09-03.<br><br>*values provided in Table 2-9 | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original results, or re-run samples if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (including trend analysis) to be undertaken by a qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>o Timing: initiate within 1 week of QA/QC review validating original results<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator<br>• Increase monitoring frequency to monthly sampling of all monitored zones in the affected multi-level well for a period to be defined by qualified professional.<br>• Trend analysis to be included in scheduled reporting |

**Table 2-10: Background concentrations and SPTs for the groundwater monitoring in the McGinty Creek watershed**

| Minto Creek | | *Concentrations (mg/L)[1]* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ag-D[3] | Al-D | As-D | Cd-D | Cr-D[3] | Cu-D | Pb-D[3] | Mo-D | Ni-D | Se-D | Zn-D | N-NO3 | $NH_4$-N | Sulphate |
| MW09-03-01 | 95th Percentile | 0.000016 | 0.0101 | 0.00081 | 0.000272 | 0.000575 | 0.00625 | 0.0003 | 0.026 | 0.0060 | 0.0015 | 0.022 | 0.28 | 0.133 | 38 |
| | 75th Percentile | 0.000010 | 0.0065 | 0.00011 | 0.000075 | 0.000500 | 0.00155 | 0.0001 | 0.005 | 0.0021 | 0.0001 | 0.013 | 0.13 | 0.067 | 24 |
| | Median[2] | 0.000010 | 0.0045 | 0.00005 | 0.000022 | 0.000500 | 0.00031 | 0.0001 | 0.004 | 0.0015 | 0.0001 | 0.006 | 0.07 | 0.045 | 22 |
| MW09-03-02 | 95th Percentile | 0.000034 | 0.0095 | 0.00092 | 0.000272 | 0.000796 | 0.01080 | 0.0002 | 0.062 | 0.0026 | 0.0040 | 0.015 | 0.07 | 0.282 | 67 |
| | 75th Percentile | 0.000018 | 0.0073 | 0.00074 | 0.000031 | 0.000500 | 0.00263 | 0.0001 | 0.018 | 0.0009 | 0.0005 | 0.010 | 0.03 | 0.230 | 7 |
| | Median[2] | 0.000010 | 0.0062 | 0.00067 | 0.000026 | 0.000500 | 0.00122 | 0.0001 | 0.017 | 0.0005 | 0.0002 | 0.008 | 0.01 | 0.210 | 1 |
| MW09-03-03 | 95th Percentile | 0.000010 | 0.0075 | 0.00014 | 0.000069 | 0.000500 | 0.00500 | 0.0003 | 0.018 | 0.0011 | 0.0004 | 0.011 | 0.54 | 0.058 | 13 |
| | 75th Percentile | 0.000010 | 0.0047 | 0.00005 | 0.000023 | 0.000500 | 0.00247 | 0.0001 | 0.006 | 0.0005 | 0.0004 | 0.008 | 0.50 | 0.020 | 12 |
| | Median[2] | 0.000010 | 0.0025 | 0.00005 | 0.000015 | 0.000500 | 0.00174 | 0.0001 | 0.005 | 0.0005 | 0.0003 | 0.003 | 0.48 | 0.012 | 11 |

Notes:

1: For monitoring results where concentrations were below the analytical detection limits, a concentration of half the detection limit was adopted for calculation purposes.

2: For AMP purposes, the background concentration in groundwater at MW09-03 is defined as the median concentration observed in each port over the 2009-2015 baseline monitoring period.

3: For Ag-D, Cr-D and Pb-D, most 2009-2015 concentrations were at the limit of analytical detection, and as such the calculated 75th and 95th percentile values are skewed low.

## 2.5 Water Management

### 2.5.1 Description

The Minto Mine site has a positive water balance. Therefore, it is necessary to release water from site from time to time to prevent accumulation of excess water. The primary objective of Minto's water management strategy is to ensure that water can be released from site in a way that protects the water quality in Minto Creek. Details concerning water management for Phase V/VI are provided in the Minto Mine Phase V/VI Water Management Plan as amended from time to time (Minto Explorations Ltd., 2015).

The strategy can be summarized as follows:

- Runoff from developed mine areas (mine water) will be collected and stored in the Main Pit Tailings Management Facility (MPTMF) and the Area 2 Pit Tailings Management Facility (A2PTMF). Mine water will be used for ore processing.
- The site water balance will be used to define mine water inventory targets and targets for volumes to be released to Minto Creek. Inventory targets will be defined on an annual basis and reported in the annual water balance update.
- To the extent possible, water will be released from site by collecting and diverting discharge-compliant (clean) runoff to the water storage pond (WSP) and from there to Minto Creek.
- If collection, diversion and release of clean water does not move enough water off site then Minto has the option of treating and releasing mine water.

The water management strategy is able to deal with most foreseeable conditions that may be encountered though the mine development. However, certain unforeseen conditions may require an adaptive response as described below.

Based on observations and studies conducted for Phase V/VI licensing it is not expected that the Minto North Pit will fill to a surface spilling point during operations. It is a reasonable expectation given the location of the Minto North Pit within the watershed (located near the surface water divide between the McGinty Creek and Minto Creek catchments, with a small catchment reporting to the Minto North Pit).

### 2.5.2 Risk Narrative

The existing water treatment plant is not able to treat and discharge enough mine water, and as a result the mine water inventory exceeds the target.

### 2.5.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to water management are provided below in Table 2-11. The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Water Inventory Tracking of the Water Management Plan (Minto Explorations Ltd., 2015). The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which the data were collected) - this corresponds with the existing monthly reporting schedule.

**Table 2-11: Specific Indicators, Performance Thresholds and Responses for Water Management**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Water inventory in the Main Pit Tailings Management Facility or the Area 2 Pit Management Facility exceeds target inventory | **Specific Threshold 1**<br><br>• Water inventory target is exceeded for a period of three months. The water storage capacity still exceeds 1,000,000 $m^3$. | **Notification**<br>• Minto Management<br>• Include in monthly report<br><br>**Review**<br>• Review site water balance<br>• Review recent water management and water treatment practices<br><br>**Evaluation**<br>• Evaluate the water inventory targets. For example, how much water can be stored in the pits for how long? Can the inventory target safely be changed to accommodate the excess volume of water?<br><br>**Action**<br>• Develop plan to address the water excess inventory such that the target can be met within 6 months. The plan may include:<br>o An adjustment of the target inventory,<br>o Diverting more clean water to the WSP,<br>o Modifying or expanding water treatment.<br>o Trend analysis to determine when or if SPT2 will be triggered |
| | **Specific Threshold 2**<br><br>• The water storage capacity is less than 1,000,000 $m^3$. | **Notification**<br>• Minto Management, SFN and YG Inspector.<br>• Include in scheduled Water Use Licence reporting.<br><br>**Review**<br>• Review site water balance.<br>• Review recent water management and water treatment practices.<br><br>**Evaluation**<br>• Evaluate the water inventory targets. For example, how much water can be stored in the pits for how long? Can the inventory target safely be changed to accommodate the excess volume of water?<br>• Evaluate treatment requirements and determine if the exiting water treatment plant has sufficient capacity to meet the requirements.<br><br>**Action**<br>• Immediately develop and implement a plan to address the lack of storage capacity such that the capacity can be restored prior to subsequent freshet.<br>o The plan may include, modifying or expanding the water treatment plant.<br>o Plans to bring mobile treatment equipment to site may be considered.<br>o Trend analysis to determine when or if SPT3 will be triggered |

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | **Specific Threshold 3**<br><br>• The water storage capacity is less than 500,000 $m^3$. | **Notification**<br>• Minto Management, SFN, YG Inspector and Regulators.<br>• Include in Water Use Licence reporting.<br>**Review**<br>• Review site water balance.<br>• Review recent water management and water treatment practices.<br>**Evaluation**<br>• Evaluate treatment requirements and determine if the existing water treatment plant has sufficient capacity to meet the requirements.<br>**Action**<br>• Immediately make plans to bring mobile treatment equipment to site, if existing plant does not have sufficient capacity.<br>• Conduct trend analysis to determine duration until spilling |

### 2.5.4 Freeboard Thresholds for Water Storage Facilities

The water storage facilities authorized under the WL include the Water Storage Pond, the Mill Water Pond, the Ridgetop North Pit, the Main Pit and the Area 2 Pit. With the exception of the Ridgetop North Pit, all of these facilities have documents associated with their design.

**Table 2-12: Freeboard Limits for Storage Facilities**

| Storage Facility | Freeboard limit (m) from spill elevation |
|---|---|
| Water Storage Pond | 1 |
| Main Pit Tailings Management Facility | 2 |
| Area 2 Pit Tailings Management Facility | 5 |

All of the water storage facilities water levels and volumes are managed through permanent pumping and piping systems.

The mill water pond was decommissioned in 2016 and is therefore not included in this AMP.

## 2.6 Physical Stability

### 2.6.1 Description

The physical stability of the waste rock, tailings and water storage facilities are monitored according to the Physical Monitoring Plan, which forms part of the Environmental Monitoring, Surveillance and Reporting Plan (Minto Explorations Ltd., 2016). The document describes the inspection and instrumentation data collection frequencies, instrument locations, installation details, as well as the data collection procedures.

The purpose of the monitoring program is to identify physical changes to the conditions of the facilities which may lead to future instability and to allow the mine to mitigate these conditions prior to any occurrence of instability. The facilities have been separated into two sets of geotechnical thresholds and response criteria (Table 2-13).

**Table 2-13: Physical Stability Categories**

| Category | Facility |
|---|---|
| 1 | • Dry Stack Tailings Storage Facility and Mill Valley Fill Extension (Stage 1 and 2)<br>• Southwest Waste Dump<br>• South Wall Buttress / Main Pit Dump |
| 2 | • Main Waste Dump and Main Waste Dump Extension<br>• Reclamation Overburden Dump<br>• Ice-Rich Overburden Dump<br>• Water Storage Pond Dam |

Category 1 facilities are founded in areas of ice-rich periglacial foundations that have previously experienced deep seated foundation movement. The Mill Valley Fill Extension (MVFE) and South Wall Buttress (SWB) are designed to mitigate movements in the Dry Stack Tailings Storage Facility (DSTSF) and Main Pit South Wall areas,

respectively. Additional monitoring inspection and response requirements for the DSTSF are detailed in the Operations, Maintenance, and Surveillance Manual (OMS) for the facility (Minto Explorations Ltd., 2014).

Category 2 facilities consist of all the remaining waste rock dumps and the Water Storage Pond Dam. These waste dumps are located in areas with good foundation conditions that avoid areas underlain by ice-rich overburden. Additional monitoring inspection and response requirements for the Water Storage Pond Dam are detailed in the Operations, Maintenance, and Surveillance Manual (OMS) for the facility (Tetra Tech EBA, 2014).

### 2.6.2 Risk Narrative

A mass failure of one of the waste facilities has the potential to endanger the health and safety of site employees or visitors, or lead to an increase in contaminant loadings from the mine and subsequent adverse effects to aquatic resources in the receiving environment (lower Minto Creek).

### 2.6.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to Category 1 and Category 2 Facilities are provided in Table 2-14 and Table 2-15, respectively. The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Physical Monitoring Program of the EMSRP (Minto Explorations Ltd., 2016). The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which the data were collected) - this corresponds with the existing monthly reporting schedule.

**Table 2-14: Specific Indicators, Performance Thresholds and Responses for Category 1 Facilities**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| • Mass movement indicated by monitoring of geotechnical instrumentation<br>• Visual observations of physical damage<br>• Visual observations of evidence that could suggest mass movement<br>• Occurrence of seismic events | **Specific Threshold 1**<br><br>• Observation of unusual occurrence including:<br>  • tension cracks, settlement, or sloughing;<br>  • a seismic event that exceeds the 1:475 return period event[1];<br>  • abnormal seepage from any area of the slopes;<br>  • increased turbidity from seepage; or,<br>  • physical damage.<br><br>This threshold applies to all Category 1 facilities. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br><br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br><br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results for additional evidence of instability.<br><br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Follow any recommendations of the Geotechnical Engineer/EIT. At a minimum, the Engineer/EIT will consider the need for:<br>  o An increase in the frequency of routine inspections and monitoring.<br>  o Additional inspection, instrumentation, monitoring, or analyses.<br><br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 2**<br><br>• One survey hub or inclinometer reading indicating an increase in the movement rate greater than the long-term trend and outside the range of instrumentation error.<br><br>This threshold applies to all Category 1 facilities. | **Notification**<br>• Geotechnical Engineer/EIT<br><br>**Review**<br>• Review existing instrumentation data.<br><br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results and complete a trend analysis.<br><br>**Action**<br>• Retake reading.<br>• If the reading was accurate, increase the survey hub or inclinometer frequency.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |

[1] This size of a seismic event would be felt by most people on site. It would shake buildings, and rattle or break dishes, hanging objects, etc. Earthquake information may also be found online at: http://www.earthquakescanada.nrcan.gc.ca/index-eng.php

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | **Specific Threshold 3**<br><br>• For DSTSF and MVFE piezometers 13-DSP-05a, 13-DSP-06, 15-DSP-07, and 15-DSP-08, and all SWD piezometers, an increase in piezometric pressures under unfrozen or thawing conditions such that Ru[2] exceeds 0.43. Conversions of Ru to equivalent water elevations for each instrument are contained in Table 2-15.<br><br>• For MVFE2 piezometer 15-DSP-10, an increase in piezometric pressure under unfrozen or thawing conditions such that the equivalent water elevation is 3 m above the original ground surface.<br><br>Or<br><br>• Temperature greater than zero at a depth of 2 m below original ground *(all SWD ground temperature cables, and DSTSF ground temperature cables DST-10, DST-11, and DST-14 only)* | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results and complete a trend analysis.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• If the piezometric pressure threshold is exceeded: immediately increase frequency to **twice-weekly** or as directed by the Engineer/EIT until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer/EIT.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 4**<br><br>• For DSTSF and MVFE piezometers 13-DSP-05, 13-DSP-06, 15-DSP-07, and 15-DSP-08, and all SWD piezometers, an increase in piezometric pressures under unfrozen or thawing conditions such that Ru exceeds 0.6. Conversions of Ru to equivalent water elevations for each instrument are contained in Table 2-15.<br><br>• For MVFE2 piezometer 15-DSP-10, an increase in piezometric pressure under unfrozen or thawing conditions such that the equivalent water elevation is 10 m above the original ground surface. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results and complete a trend analysis.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Immediately increase piezometric pressure monitoring and data review frequency to **daily** or as directed by the Engineer/EIT until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer/EIT. At a minimum, the Engineer/EIT will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses.<br>o Modifications to the waste placement/construction practices.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately.<br>• Trend analysis will be included in scheduled reporting |

[2] Ru is the pore water pressure coefficient which is the ratio of piezometric pressure to the overburden pressure. A pore water pressure ratio of 0.5 would be similar to the effect of a groundwater table at surface. Conversions from Ru to equivalent water elevation are contained in Table 2-16.
[3] Piezometer 13-DSP-5b exceeded this trigger on April 2015. A review of the data and stability analysis was completed and documented in the 2015 annual geotechnical inspection report and found no stability issue and recommended continued monthly monitoring.

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | **Specific Threshold 5**<br><br>• Three consecutive survey hub or inclinometer readings indicating an increase in the movement rate movement greater than the long-term trend.<br>Or<br>• Three consecutive survey hub readings indicating a change in horizontal direction of movement greater than 15 degrees from the long term trend.<br><br>This threshold applies to all Category 1 facilities. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results and complete a trend analysis.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to monitor any future displacement.<br>• Immediately increase survey hub monitoring and data review frequency to **twice-weekly** or as directed by the Engineer/EIT until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer/EIT. At a minimum, the Engineer/EIT will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses.<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately.<br>• Trend analysis will be included in scheduled reporting. |

**Table 2-15: Specific Indicators, Performance Thresholds and Responses for Category 2 Facilities**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| • Mass movement indicated by monitoring of geotechnical instrumentation<br>• Visual observations of physical damage<br>• Visual observations of evidence that could suggest mass movement<br>• Occurrence of seismic events | **Specific Threshold 1**<br><br>• Observation of unusual occurrence including:<br>  • tension cracks, settlement, or sloughing;<br>  • a seismic event that exceeds the 1:475 return period event;<br>  • abnormal seepage from any area of the slopes;<br>  • increased turbidity from seepage;<br>  • physical damage.<br><br>This threshold applies to all Category 2 facilities. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br><br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br><br>**Evaluation**<br>Geotechnical Engineer/EIT to compare recent monitoring results against older results for additional evidence of instability.<br><br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Follow any recommendations of the Geotechnical Engineer/EIT. At a minimum, the Engineer/EIT will consider the need for:<br>  o An increase in the frequency of routine inspections and monitoring.<br>  o Additional inspection, instrumentation, monitoring, or analyses.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 2**<br><br>**WSP Dam:**<br>• One survey hub reading indicating an increase of movement outside range of instrumentation error.<br><br>**All other Category 2 Facilities:**<br>• Survey hub cumulative displacements between 150 mm and 500 mm. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br><br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br><br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results for additional evidence of instability and complete a trend analysis.<br>**Action**<br>• Retake reading<br>• If the reading is accurate, inspect the area for any signs of instability.<br>• Immediately increase survey hub reading frequency to **twice-monthly** or as directed by the Engineer/EIT until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer/EIT.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | **Specific Threshold 3**<br><br>**WSP Dam:**<br>• One piezometer reading outside of its long-term trend (in comparison to the reservoir pond elevation).<br><br>**All other Category 2 Facilities:**<br>• Survey hub cumulative displacements greater than 500 mm. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br><br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br><br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results for additional evidence of instability and complete a trend analysis.<br><br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to allow for a stability assessment to be completed (if required by the Engineer), and to monitor any future displacement.<br>• Immediately increase monitoring and data review frequency until determined unnecessary:<br>o If survey hub threshold exceeded: increase frequency to **twice-weekly** or as directed by the Engineer/EIT.<br>o If piezometric pressure threshold exceeded: increase frequency to **daily** or as directed by the Engineer/EIT.<br>• Follow any additional recommendations of the Geotechnical Engineer/EIT. At a minimum, the Engineer/EIT will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 4**<br><br>**WSP Dam:**<br>• Three consecutive survey hub readings indicating increase in movement outside range of instrumentation error. | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer/EIT<br>• Chief Engineer<br>• Include in annual report<br><br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature and survey data.<br><br>**Evaluation**<br>• Geotechnical Engineer/EIT to compare recent monitoring results against older results for additional evidence of instability and complete a trend analysis. |

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| | | **Action**<br><br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to allow for a stability assessment to be completed (if required by the Engineer/EIT), and to monitor any future displacement.<br>• Immediately increase survey hub reading frequency to **twice-weekly** or as directed by the Engineer/EIT until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer/EIT. At a minimum, the Engineer/EIT will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses.<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |

**Table 2-16: Equivalent Water Elevations for Piezometric Pressure Thresholds**

| Instrument | Facility | Threshold 1 | Threshold 2 | Threshold 3 | Threshold 4 | Threshold 5 |
|---|---|---|---|---|---|---|
| DSP-05a | DSTSF | n/a | n/a | 785.03 m | 794.82 m | n/a |
| DSP-06a | DSTSF | n/a | n/a | 784.18 m | 791.49 m | n/a |
| DSP-06b | DSTSF | n/a | n/a | 783.06 m | 791.81 m | n/a |
| DSP-07 #1 | DSTSF | n/a | n/a | 777.89 m | 781.13 m | n/a |
| DSP-07 #2 | DSTSF | n/a | n/a | 775.65 m | 781.77 m | n/a |
| DSP-07 #3 | DSTSF | n/a | n/a | 773.69 m | 782.33 m | n/a |
| DSP-07 #4 | DSTSF | n/a | n/a | 772.85 m | 782.57 m | n/a |
| DSP-07 #5 | DSTSF | n/a | n/a | 772.29 m | 782.73 m | n/a |
| DSP-07 #6 | DSTSF | n/a | n/a | 771.17 m | 783.06 m | n/a |
| DSP-08 #1 | DSTSF | n/a | n/a | 774.32 m | 786.20 m | n/a |
| DSP-08 #2 | DSTSF | n/a | n/a | 752.75 m | 756.35 m | n/a |
| DSP-08 #3 | DSTSF | n/a | n/a | 751.35 m | 756.75 m | n/a |
| DSP-08 #4 | DSTSF | n/a | n/a | 749.86 m | 757.07 m | n/a |
| DSP-08 #5 | DSTSF | n/a | n/a | 748.46 m | 757.47 m | n/a |
| DSP-08 #6 | DSTSF | n/a | n/a | 745.67 m | 758.27 m | n/a |
| DSP-10 | DSTSF | n/a | n/a | 722.47 m | 725.10 m | n/a |
| SDP-2A | SWD | n/a | n/a | 846.40 m | 847.90 m | n/a |
| SDP-2B | SWD | n/a | n/a | 846.21 m | 847.96 m | n/a |
| SDP-3A | SWD | n/a | n/a | 859.10 m | 861.52 m | n/a |
| SDP-3B | SWD | n/a | n/a | 858.90 m | 861.57 m | n/a |
| SDP-4A | SWD | n/a | n/a | 860.47 m | 861.46 m | n/a |
| SDP-4B | SWD | n/a | n/a | 860.28 m | 861.52 m | n/a |

# 3 Reporting and Review

Reporting and review represent an essential part of the Adaptive Management Framework, as described in section 1.4.2, and reporting on adaptive management is included in the notification component of all specific responses described in section 2.

## 3.1 Monthly and Annual Reporting

Monthly reports are required to be submitted to the Yukon Water Board under Water Licence QZ14-031, and annual reports are required for submission under both the Water Licence and the Quartz Mining License. Both licenses require reporting on adaptive management.

Monthly reporting includes all activities carried out under the Adaptive Management Plan. The monthly report will include a comparison of monitoring results to AMP thresholds as well as status of responses implemented due to thresholds triggered.

Annual reporting will include summaries of all activities carried out under the Adaptive Management Plan, including a summary of the comparisons conducted monthly and any actions taken. The annual report will also include follow: water levels, a trend analysis (where applicable) for all parameters that triggered responses and a yearly comparison summary of all physical stability monitoring results to AMP thresholds.

The Annual Water Licence Report will also include a comparison of the data collected under this monitoring with predicted water quality estimates. This will be undertaken as part of the annual review of the Water and Load Balance Model.

## 3.2 Annual Review

The AMP may be modified when unexpected circumstances are encountered and the protocol is implemented or when additional understanding becomes available. An annual review of the AMP will take place prior to annual reporting, and Annual Reports will include a summary of proposed updates and revisions to the Adaptive Management Plan and include a revised Adaptive Management Plan, if warranted.

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# Minto Mine

# Closure Adaptive Management Plan

2018-01

Prepared by:
Minto Explorations Ltd.
Minto Mine
February 2018

**Minto Mine Closure Adaptive Management Plan**

**AMP Version History**

| AMP Version | Issue Date | Description and Revisions Made |
|---|---|---|
| 2014-01 | June 2014 | First Issue |
| 2016-01 | August 2016 | Revisions made as per requirements of WUL QZ14-031 and QML-0001 |
| 2017-01 | February 2017 | Revisions made to reflect finalization of closure water quality objectives with SFN, with associated updates and adjustments |
| 2018-01 | February 2018 | Revisions made based on YWB review and subsequent information requests. |

**2017-01 Revisions**

| AMP Section | Description of Revision |
|---|---|
| 1 | Included a description of all three closure periods. Included a recommendation to revise the AMP prior to implementation. |
| 2.1 | Included an introduction paragraph which provides context by explaining how the surface water quality AMP components are integrated. Also, included Table 2-1, which clarifies what AMP component applies to a given closure period. |
| 2.1.1.1 | Included clarification regarding what closure period the Mine Site AMP Component applies. |
| 2.1.1.3 | Revised all of the values in Table 2-2 (formerly 2-1) so that they actually represent maximum predicted concertation for the Post Closure II period. Revised Table 2-3 (formerly 2-2) to include applicable closure period to each specific threshold and revised wording to improve clarity. |
| 2.1.2.1 | Included explanation for when the CWTS AMP component applies. |
| 2.1.2.3 | Revised Table 2-5 (formerly 2-4) to include applicable closure period to each specific threshold. |
| 2.1.3.1 | Significant revisions made to describe how the Minto Creek AMP component will apply to the PCI period. |
| 2.1.3.2 | Significant revisions made to separate out risk narrative for PCI and PCII periods. |
| 2.1.3.3 | Significant revisions made to incorporate a PCI specific AMP component for Minto Creek. Includes the addition of Table 2-6 for the PCI period. Significant revisions made to the PCII specific AMP component to incorporate the finalized WQOs. Table 2-7 (formerly Table 2-5) revised with WQOs. Revisions specific threshold 1 of Table 2-8 (formerly Table 2-6). Revisions to Table 2-9 (formerly Table 2-7) to incorporate central tendency WQO, revised resample frequency in specific threshold 1 response, included applicable closure period to each specific threshold and revised specific threshold 5. |
| 2.1.4 | Significant revisions to match what is in the updated operational AMP (2016-02). |
| 2.2.1.3 | Significant revisions to match what is in the updated operational AMP (2016-02). |

**2018-01 Revisions**

| AMP Section | Description of Revision |
|---|---|
| 1 | Corrected errors in Table 1-2 |
| 2.1.1 | Added details on the investigation/evaluation in response to SPT-1 in Table 2-3. |
| 2.1.2 | Included specific definition in SPT-3 in Table 2-5. |
| 2.1.3 | Included details on the application of trend analysis (both annual and the proposed monthly methods) in Table 2-6.<br>Corrected errors in Table 2-7.<br>Included trend analysis and more details on investigation/evaluation elements in Table 2-8. |
| 2.1.4 | Specified a 12-month moving average for comparison with the CTE in Table 2-11. |
| 2.3.1 | Included a list of specific facilities to which the Water Management Infrastructure AMP applies. |
| 2.5.2 | New section, AMP for Minto North Pit Water Levels |

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# 1 Introduction

Minto Explorations Ltd. (Minto), a wholly owned subsidiary of Capstone Mining Corp. (Capstone), owns and operates the Minto copper mine. Minto Mine is located within Selkirk First Nation (SFN) Category-A Settlement Land (Parcel R-6A), and is approximately 240 km northwest of Whitehorse, Yukon Territory. The Minto mine commenced commercial operations in October 2007.

As an outcome of the Phase V/VI mine licensing processes, Minto was required to update the mine Reclamation and Closure Plan (RCP) for the updated mine plan and with additional information outlined in its Quartz Mining License QML-0001 (QML) and Water Use Licence QZ14-031 (WUL) and approval letters. Both authorizations required the updating of the Adaptive Management Plan (AMP) for the closure and post-closure periods. AMPs are tools used to address uncertainty or conditions beyond those expected in reclamation and closure. AMPs outline a range of possible but unexpected outcomes and the responses that will be undertaken to curb possible negative impacts associated with these unexpected situations.

Closure failure modes and effects analyses (FMEA) have been conducted to determine both the probability and severity of postulated component failures at the Minto mine site and the associated infrastructure and environmental management systems. The FMEAs have been used to determine potential failure modes with the greatest risk rating, and identified components and scenarios where uncertainty and attendant risk could be reduced through adaptive management.

Mining activities are highly managed operations, with very prescriptive and detailed management plans required for both operational control and regulatory approval. More mature mines such as Minto have management plans which benefit from the operational experience at the site, and uncertainty in the range of conditions expected is reduced through this operational experience.

Minto has developed and implemented an operational Adaptive Management Plan to address uncertainty in site performance during the operational period (MEL, 2016). Uncertainty is reduced in the operational period through the development and implementation of operational management plans. Minto has developed a number of operational management plans which describe the management and response actions for expected conditions at the site during operations. These plans currently include:

- Solid Waste Management Plan;
- Environmental Monitoring, Surveillance, Reporting Plan;
- Wildlife Protection Plan;
- Spill Contingency Plan;
- Sediment and Erosion Control Plan;
- Mine Development and Operations Plan;
- Underground Mine Development and Operations Plan;
- Mill Operations Plan;
- Water Management Plan;

- Tailings Management Plan;
- Waste Rock and Overburden Management Plan;
- Emergency Response Plan; and
- Heritage Resources Protection Plan.

For the closure and post closure periods, planning and management of site activities are guided by the Minto Mine Reclamation and Closure Plan (RCP). This includes the identification of distinct closure periods with defined activities and performance expectations:

1. Active Closure (AC) - includes the implementation and construction of the large majority of the selected closure measures. Closure measures completed during this period include, but are not limited recontouring, soil placement, closure water conveyance construction, revegetation, construction of passive water treatment facilities and partial decommissioning of the Water Storage Dam, demobilization and demolition. Further details regarding the planned closure measures can be found in Section 7 of the RCP. During the AC period, operational water quality objectives/effluent standards and AMP will still apply and active treatment is expected to be the primary source of water treatment. The AC period is expected to span three years but may be completed sooner as closure measures are completed.
2. Post Closure I (PCI) - The PCI period is intended to provide time which allows the closure measures to establish and assessments to be completed on the performance of the chosen closure measure. During this period, maintenance on soil covers will be ongoing as vegetation begins to establish. Water conveyance features will be commissioned along with the passive treatment system. The passive treatment system is expected to take two years to reach design performance expectations. A pump back system will be established from the passive treatment system to the water treatment plant as there is potential that water quality will not meet effluent standards without active treatment. During PCI, operational water quality objectives/effluent standards will still apply. Passive treatment will be commissioned over the first two years of PCI and will become the primary water treatment system utilizing active treatment as required to meet operational water quality objectives and manage site water inventory. During the PCI period the Operational AMP and Closure AMP will both apply to specific components and are identified in this AMP.
3. Post Closure II (PCII) - is intended as a confirmatory period which will monitor that the closure measures continue to perform as expected. PCII is primarily a monitoring phase with maintenance activities as required. During PCII the closure water quality objectives will apply and passive treatment will be the primary water treatment onsite. The Closure AMP will be the sole AMP in PCII and will cover all of the components detailed in this plan.

This AMP is intended to provide a framework for responses to conditions beyond those expected and identified in the RCP for primarily the Post Closure I and II (PCI and PCII) periods. It has been constructed to meet the licensing requirements under both main authorizations, and has benefited from an initial adequacy review by the Yukon Water Board (version 2017-01), with updates included based on that review in this version 2018-01.

Given the complexities of this AMP and the duration until implementation, it is recommended that this plan be reviewed and revised as required prior to implementation.

## 1.1 Adaptive Management Overview

Adaptive management is an approach to environmental management that is appropriate when mitigation measures may not function as intended or when broad-scale environmental change is possible. Adaptive management plans are precautionary in nature, and provide a level of security in long term environmental planning. Adaptive management plans also allow for the inclusion of improved science into mitigation measures as they are continually revised.

Adaptive management has been evolving since its emergence in the 1970s. Adaptive approaches include an ability to incorporate knowledge into the management plan as the knowledge is gleaned and circumstances change. Embedding adaptation into environmental plans involves thinking about how the results of monitoring will change management actions. Eberhard et al. (Eberhard, et al., 2009) described the categories of knowledge that may trigger changes to water quality management plans; system understanding, measuring progress and anticipating changes. These categories allow for the inclusion of knowledge and adaptation of management to changed conditions. Adaptive management plans are a way to accept uncertainties and build a structured framework to respond to changing conditions.

Adaptive management conducts a flexible path with actions to take when specific triggers occur. AMPs are a formalization of a plan for performance monitoring and project re-evaluation in the future. The general structure of adaptive management can be described by the following steps:

1. Identify risk triggers associated with vulnerabilities or uncertainties;
2. Quantify impacts and uncertainties;
3. Evaluate strategies and define implementation path that allows for multiple options at specific triggers;
4. Monitor the performance and critical variables in the system; and
5. Implement or re-evaluate strategies when triggers are reached.

Although there are no widely used AMP terms, the steps listed above are representative of typical AMP processes. Within AMPs, triggers provide decision points in a stepwise decision-making framework that identifies how and when management action should be taken. A key characteristic of adaptive management is monitoring, which is used to advance scientific understanding and to adjust management policies in an iterative process. Adaptive management is a rigorous method for addressing uncertainties in ecosystem management.

## 1.2 Adaptive Management Plan Objectives

An AMP is a management tool wherein a framework is provided to make quick and effective decisions to guide responses to unforeseen events. This document identifies areas of uncertainty within the post closure phases of the Minto Mine life and provides an AMP framework for each. For each component the AMP describes thresholds, triggers and responses to underperforming elements or emerging risks within the component. The steps laid out in the AMP framework are precautionary, and therefore they provide the confidence that action will be taken before adverse environmental impacts are observed.

Response planning, and results for anticipated events are contained within site management plans while AMPs guide responses to unforeseen or contingency events. This AMP provides a framework to guide responses to unanticipated monitoring results and to potential but low probability events where uncertainty exists.

It is difficult to predict the specific environmental condition that may arise which requires a response from management and, therefore, the AMP does not provide specific detailed descriptions of responses to a situation. The AMP provides a range of possible responses to use as a guide to respond to specific environmental conditions encountered. Management should use the information provided in the AMP and undertake the appropriate response.

### 1.2.1 Updated AMP Objectives

The 2016-01 version of the AMP was updated to include the requirements of the QML and WUL.

The QML was issued December 18, 2014 and was accompanied by a letter entitled outlining the components required in an Adaptive Management Plan (Yukon Government - Energy, Mines and Resources, 2014). The AMP includes the requirements outlined in the letter, which have also been addressed in the Operational AMP (the QML approval letter is non-specific as to the mine phase, so the requirements have been included in both AMPs). The QML approval letter requirements and where the items are addressed in the AMP are presented in the following concordance Table 1-1.

**Table 1-1**: QML Approval Letter Concordance Table

| 1. Adaptive Management Plan<br>An adaptive management plan must include: | Section addressed |
|---|---|
| (a) key pathways and events that lead to uncertainty about site performance, including but not limited to: | 1.3<br>2.1 – 2.5 |
| o water quality | 2.1 |
| o physical stability | 2.2 |
| o cover systems | 2.3.1 |
| o water treatment, and | 2.1, 2.5 |
| o water management | 2.5 |
| (b) detailed descriptions of effective indicators of performance, monitoring programs, triggers for adaptive management responses, and actions that will be taken for each event or pathway. Triggers and actions should be defined and described for various levels of response, initially requiring investigation of causes and proceeding to implementation of appropriate contingency measures; and | 2.1 – 2.5 |
| (c) detailed descriptions of procedures for investigating causes of adaptive management trigger exceedances, and corrective actions should be provided. These should demonstrate that actions can be taken prior to causing unacceptable effects | 2.1 – 2.5 |

The WUL was issued August 5, 2015 and the requirements for the Closure AMP are outlined in clause 110 e) (Yukon Water Board, 2015).

Clause 110 e) details and the sections in the AMP where these are addressed are summarized in Table 1-2.

**Table 1-2: QZ14-031 Concordance Table**

| 110) The updated RCP shall include, but not necessarily be limited to, the following:<br>e) an updated Closure AMP including, but not necessarily be limited to, the following: | Section addressed |
|---|---|
| i) numerical values of thresholds for each parameter for each specific threshold for each AMP component | all |
| ii) consideration of statistical trend analysis to provide future forecasting of potential exceedances; | 2.1 |
| iii) thresholds for action and responses related to potential poor performance of the Main Pit Dam; and | n/a[1] |
| iv) management measures to responds to changing conditions in: | 2.1 |
| • McGinty Creek | 2.1.4 |
| • water quality at internal monitoring locations | 2.1.1 |
| • pit water quality | 2.1.1 |
| • passive treatment system performance; and | 2.1.2 |
| • water levels in open pits | 2.5.2 |

[1] Main Dam is no longer part of the proposed Mine Plan

## 1.3 Adaptive Management Plan Approach

In addition to the conclusions drawn from research, the approach presented in this AMP follows the Environmental Code of Practice for Metal Mines, Section 4.1.17 on Adaptive Management:

"Mine owners/operators should use adaptive management methods to revise and refine the environmental management strategy. Adaptive management should consider a wide range of factors, including:

- The results of environmental audits or other evaluation activities;
- The results of environmental monitoring;
- The results of monitoring of the performance or condition of environmental infrastructure, such as containment structures, water management systems or treatment facilities;
- Technological developments; and
- Changing environmental conditions." (Environment Canada, 2009)

### 1.3.1 AMP Components

The following AMP components have been identified as having the potential for unexpected conditions during the operational period for which the Operational Management Plans may not provide adequate mitigation against potential effects to the environment or human health and safety, therefore, these components have been carried over into the AMP for the closure periods:

- Surface water quality;
- Groundwater quality;
- Water Management Infrastructure;
- Physical Stability; and
- General Reclamation Measures

The specific AMP framework for these components is described in Sections 2.1 through 2.5.

### 1.3.2 AMP Framework

The AMPs for each component are laid out using a common element approach to create consistency in implementation of the AMP protocol for all components as illustrated in Figure 1-1. The common elements are:

1. Description of the component
   - *Description* - description and understanding of the component leads to risk narrative and specific performance thresholds.
   - *Risk Narrative* describe the possible environmental impacts and environmental conditions that implementation of the AMP will prevent.
2. Monitoring the component

- *Specific Indicators* are the environmental or physical parameters to be monitored and assessed. Specific indicators are measurable or observable, and are indicative of changes from the designed or expected condition.
- *Monitoring Requirements* describes the monitoring regime for the component including frequency, type of data required and interpretation of results – outlined in the Minto RCP document.
- *Specific Performance Thresholds* define the conditions, in terms of specific indicators, when action is triggered. Performance thresholds are staged to accommodate levels of concern and a diversity of actions. To the extent possible, specific performance thresholds will include early warning thresholds.

3. Responding to unexpected conditions of the component

   *Specific Responses* are staged according to specific performance thresholds describes the actions to be implemented if specific performance thresholds are crossed. They are provided in the following categories:

   a) Notification

   b) Review

   c) Evaluation

   d) Action

4. Annual Reporting and Review

   Annual Reporting reflects annual changes made to the AMP as the site conditions change. The AMP should be modified whenever unexpected circumstances are encountered and the protocol is implemented or when additional proven science or technology becomes available. The annual review will include a review of the relevant monitored data and AMP elements. Updates, amendments, performance thresholds crossed, and trigger(s) activated will be provided to the appropriate governmental (including SFN) organizations as required and will be part of the annual report.

   Additional reporting is described further in section 3.

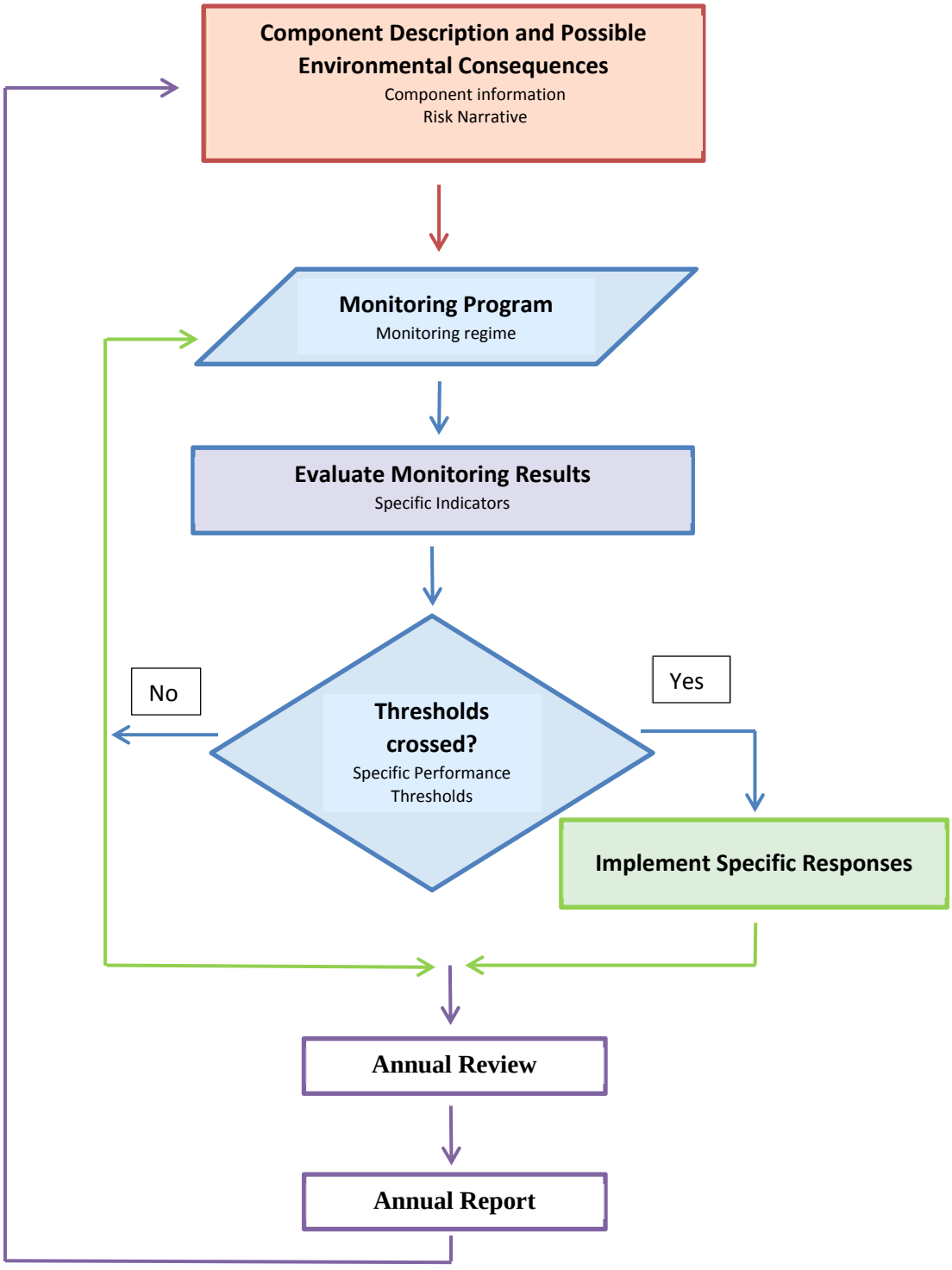


**Figure 1-1: Sequential Components of the AMP (Adapted from AECOM 2010)**

# 2 Adaptive Management Plans for Mine Components

## 2.1 Surface Water Quality

The Surface Water Quality section of this AMP aims to integrate the mine site (Area 2 and Main Pits) water quality with the performance of the CWTS to reach the overall goal of meeting water quality objectives (WQO) in Minto Creek's receiving environment (W2). The McGinty Creek AMP component is also included but does not have the same source control uncertainty as Minto Creek and is therefore not integrated with other AMP components. The Surface Water Quality components are intended to address the uncertainty that arise in specific closure periods and are therefore not completely inclusive of PCI and PCII closure periods. The applicable closure periods will be identified to the corresponding components in the sections below. A summary of the closure periods and corresponding AMP components is broken down in Table 2-1 below.

**Table 2-1: Surface water AMP components and corresponding closure period**

| AMP Component | Applicable Closure Period | Exceptions |
|---|---|---|
| Mine Site | PCII | No exceptions |
| Constructed Wetland Treatment Systems (CWTS) | PCI and PCII | Applies after the CWTS commissioning period only |
| Minto Creek | PCI and PCII | Only applies in PCI after the CWTS is preforming as expected |
| McGinty Creek | PCI and PCII | No exceptions |

### 2.1.1 Mine Site

#### *2.1.1.1 Description*

During the closure and post-closure period, the management of runoff and site water will become increasingly more passive, as described in the RCP. Attention to the quality of site runoff and surface water at some key locations will be important indicators of reclamation success of site facilities, and will provide an indication of potential water quality issues upstream of the passive treatment installation at the former water storage pond footprint. In particular, attention to the water quality in the two upstream pit outflows (Main Pit – W12, Area 2 Pit – W45) will provide site managers with indications of water quality that may lead to passive treatment performance problems, and possibly to water quality objectives not being attained further downstream in the receiving environment of Minto Creek (W2).

As active water treatment will be employed and utilized in Active Closure as well as available during the PCI period, with a high degree of certainty around effluent quality, the AMP framework for the mine site facilities below are relevant to the post closure PCII period only.

#### *2.1.1.2 Risk Narrative*

Increasing concentrations of contaminants from closed site facilities and flooded open pits lead to passive treatment challenges, exceedance of downstream water quality objectives, and/or adverse effects to aquatic resources in the receiving environment (lower Minto Creek).

#### *2.1.1.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to water quality and the monitoring program are provided below in Table 2-3, and the specific thresholds are identified in Table 2-2. The monitoring results that will be evaluated and utilized in this component of the AMP are outlined in Section 7.11 of the Minto Mine RCP (2018-01).

**Table 2-2: Specific Performance Thresholds for Mine Site Stations**

| Parameter | Worst Case Maximum Predicted Concentration for Post-Closure II Period | | | | | |
|---|---|---|---|---|---|---|
| | W45 (Area 2 Pit) | | | W12 (Main Pit) | | |
| | May | July | Sept | May | July | Sept |
| Ammonia - N, mg/L | 0.79 | 0.77 | 0.77 | 0.13 | 0.12 | 0.12 |
| Nitrite - N, mg/L | 0.55 | 0.54 | 0.54 | 0.12 | 011 | 0.10 |
| Nitrate - N, mg/L | 30 | 29 | 29 | 12 | 11 | 10 |
| Aluminum (dissolved), mg/L | 0.42 | 0.42 | 0.42 | 0.37 | 0.36 | 0.35 |
| Arsenic (dissolved), mg/L | 0.0029 | 0.0029 | 0.0029 | 0.0027 | 0.0026 | 0.0026 |
| Cadmium (dissolved), µg/L | 0.00018 | 0.00018 | 0.00018 | 0.00018 | 0.00017 | 0.00017 |
| Chromium (dissolved), mg/L | 0.0033 | 0.0032 | 0.0032 | 0.0033 | 0.0031 | 0.0031 |
| Copper (dissolved), mg/L | 0.045 | 0.045 | 0.045 | 0.061 | 0.056 | 0.056 |
| Iron (dissolved), mg/L | 0.85 | 0.85 | 0.84 | 1.3 | 1.2 | 1.2 |
| Lead (dissolved), mg/L | 0.0013 | 0.0013 | 0.0013 | 0.0010 | 0.00095 | 0.00094 |
| Molybdenum (dissolved), mg/L | 0.049 | 0.048 | 0.048 | 0.016 | 0.015 | 0.015 |
| Nickel (dissolved), mg/L | 0.0046 | 0.0045 | 0.0045 | 0.0045 | 0.0042 | 0.0042 |
| Silver (dissolved), mg/L | 0.00011 | 0.00010 | 0.00010 | 0.00013 | 0.00012 | 0.00012 |
| Selenium (dissolved), mg/L | 0.023 | 0.022 | 0.022 | 0.0083 | 0.0076 | 0.0075 |
| Zinc (dissolved), mg/L | 0.017 | 0.017 | 0.017 | 0.017 | 0.016 | 0.016 |

**Table 2-3: Specific Indicators, Performance Thresholds and Responses for Mine Site Monitoring Locations**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| Dissolved metal parameters in Table 2-2. | **Specific Threshold 1**<br>Worst Case Maximum water quality prediction is exceeded<br><br>**AND**<br><br>Potential or existing challenges to passive treatment are identified as a result of pit water quality | **PCII** | **Notification**<br>• Minto Management<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with previous results and evaluate if concentrations are trending upwards<br>• review all other available monitoring results (e.g. W15) and assess whether results show evidence of related conditions.<br>• test appropriate other pit inflow locations to help isolate the source<br>• Depending on which pit and parameters show elevated concentrations, evaluate the scale (single station, site- wide, specific facility, etc.)<br>**Action**<br>• If result is validated, **AND**<br>• concentrations are trending upwards significantly, then:<br>o Re-sample within one month of triggering ST1 |
| Dissolved metal parameters in Table 2-2. | **Specific Threshold 2**<br>Subsequent exceedance of ST1 in subsequent sampling (resampled or routine) and evaluation confirms upward trend in concentrations<br><br>**AND**<br><br>Potential or existing challenges to passive treatment are identified as a result of pit water quality | **PCII** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• All evaluation measures identified in ST1<br>**Action**<br>• Increase sampling frequency to monthly<br>• Engage qualified professional to evaluate potential for passive treatment challenges from pit outflow concentrations<br>• Retain qualified expert to develop mitigation plan, including recommendations. This could include, for example, consideration of the use of batch treatment to mitigate water quality in pits. |
| Dissolved metal parameters in Table 2-2. | **Specific Threshold 3**<br>Continued exceedance of ST2 in subsequent sampling<br><br>**AND**<br><br>Potential or existing challenges to passive treatment are identified as a result of pit water quality | **PCII** | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol<br>o Review laboratory QA/QC report<br>o Verify original result, or re-run sample if laboratory error indicated<br>**Evaluation**<br>• All evaluation measures for ST2<br>**Action**<br>• Implement recommendations from Mitigation Plan<br>• Maintain monthly sampling frequency |

### 2.1.2 Constructed Wetland Treatment Systems

#### *2.1.2.1 Description*

The RCP describes how surface water quality will be managed during the post closure period. This includes the construction and operation of a constructed wetland treatment system (CWTS) in the footprint of the existing water storage pond. Based on site specific research, it is expected that the CWTS will take at least 2 full years before the wetland will be performing as designed. Research to date, also outlined in the RCP, on wetland performance at the Minto site suggests that a constructed wetland treatment system can be expected to mitigate certain water quality constituent loading during some months of the year, particularly during base flow summer months. Although some routine maintenance is expected for this facility, there also exists some remaining uncertainty regarding how the wetland will perform in decreasing aqueous constituent loads.

Section 2.1.1 above outlines how contributing loads from upstream sources will be managed adaptively, and section 2.3 outlines how an adaptive management approach will be used to respond to changing conditions related to the physical integrity of the CWTS as a water management infrastructure component. This section outlines how unexpected changes in the performance of the CWTS related to aqueous constituent load reduction will be identified and responded to after the expected commissioning period (two years after construction).

The CWTS AMP framework will provide a response towards continuous improvement of the system during PCI period and will address unexpected performance in PCII. The CWTS will mature as a treatment installation during the first two years of PCI – the Commissioning Period – and after it will be transitioned to the primary water treatment component for the duration of PCI (as long as Operational WQO can be met) and for the entirety of PCII. The CWTS AMP framework below applies to the third year of PCI and through the entire duration of PCII.

#### *2.1.2.2 Risk Narrative*

Aqueous constituent load reduction does not meet expectations or design criteria, resulting in downstream water quality objectives not being met, and/or adverse effects to aquatic resources in the receiving environment (lower Minto Creek).

#### *2.1.2.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to performance of the CWTS are provided below in Table 2-5. Specific thresholds are identified in Table 2-4. The monitoring results that will be evaluated and utilized in this component of the AMP are outlined in the Minto Mine RCP (2018-01) (Section 7.11).

**Table 2-4: Specific Performance Thresholds for Mine Site stations**

| Specific Indicator | Specific Threshold Value | Basis/rationale for threshold value |
|---|---|---|
| CWTS Soil Redox Probe reading | -100 mV | Desired range for optimal performance is -250 to -100 mV. Performance can still be expected as high as -50, so -100 as threshold is conservative |
| **Treatment rate coefficient** | | |
| Cadmium (dissolved) | 0.078 (first order) | Treatment rate coefficients should be evaluated as an annual average, based on inflow and outflow concentrations, and retention time within the CWTS (formulae are provided in CTWS Design Document, appended to Minto RCP). The threshold values here are from the design basis, based on expected performance from reclamation research to date, with an added range of 20% to allow for variation. |
| Copper (dissolved) | 0.060 (first order) | |
| Selenium (dissolved) | 0.00012 (zero order) | |

**Table 2-5: Specific Indicators, Performance Thresholds and Responses for CWTS performance.**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| Soil Redox | **Specific Threshold 1**<br>average of all probes trending upwards and out of ideal range (-250 to -100) over 3 consecutive sampling events<br><br>**OR**<br><br>25% of all probes reading > -100 in any sampling event | **Year 3 of PCI and all of PCII** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Validate redox results<br>o Confirm water depth around probes in question<br>**Evaluation**<br>• Consider installation of duplicate probes to confirm readings<br>• Consider sampling of soil in vicinity of probes in question for total organic carbon (TOC) and nutrients (NPK).<br>**Action**<br>• If probe readings confirmed and TOC is low, add organic carbon as directed by qualified expert<br>• If probe readings confirmed and soil nutrients are low, add fertilizer as directed by qualified expert<br>• If water depths less that design amount, mitigate as recommended by qualified expert |
| Treatment rate coefficient | **Specific Threshold 2**<br>Target treatment rate coefficient for specific aqueous constituent is not achieved in any year of monitoring | **Year 3 of PCI and all of PCII** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Increase sampling frequency of influent/effluent to monthly (if not already implemented)<br>• Sample between cells to isolate problem cell(s)<br>• Consider analysis for interfering/facilitating issues (e.g. iron/Sulphur)<br>**Action**<br>• Retain qualified expert to develop mitigation plan, including recommendations |
| Treatment rate coefficient | **Specific Threshold 3**<br>Target treatment rate coefficient for specific aqueous constituent is not achieved for **3 consecutive years**<br><br>**AND**<br><br>Applicable downstream water quality objectives have been exceeded as defined by: SPT-3 (or higher) is triggered from Minto Creek AMP in Table 2-9. | **Year 3 of PCI and all of PCII** | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol<br>o Review laboratory QA/QC report<br>o Verify original result, or re-run sample if laboratory error indicated<br>**Evaluation**<br>• All evaluation measures for ST2<br>**Action**<br>• Implement recommendations from Mitigation Plan |

### 2.1.3 Minto Creek

#### *2.1.3.1 Description*

The majority of the Minto Mine footprint (with the exception of the Minto North pit) is in the headwaters of the catchment area for Minto Creek. The W2 monitoring point on lower Minto Creek near the Yukon River is beyond the final mine water discharge point (W50) controlled by Minto, and is subject to a broad range of influences from tributaries and catchment areas that are beyond Minto's control. However, Minto is committed to monitoring the water quality at W2 and responding to changing water quality in lower Minto Creek as appropriate. The AMP frameworks below compliment the closure water management plan at the mine site with a decision-based structure for ensuring that negative impacts to lower Minto Creek from mining activities are avoided.

The monitoring results that will be evaluated and utilized in this component of the AMP are outlined in section 7.11 of the Minto Mine RCP (2018-01). The Operational Water Quality Objectives will continue to be employed in the Active Closure and PCI periods. As such, the Minto Mine Operational AMP is relevant and will be utilized during the Active Closure and PCI periods. To address the uncertainty of meeting the post closure water quality objectives (PC-WQO) within the expected 5-year duration of the PCI period, a PCI AMP framework has been developed for Minto Creek and is intended to be used as a supplement to the Operational AMP.

The PCI period AMP framework was developed to guide continuous improvement towards meeting PC-WQO after the CTWS has reached the expected performance and will only apply during the PCI period. The portion of the Minto Creek AMP that applies to the PCII period is intended to respond to uncertainty regarding meeting both non-degradation and 50% of assimilative capacity WQOs.

In the sections below, the PCI period AMP framework and the PCII period AMP framework for Minto Creek have been separated to simplify what AMP frameworks apply to what closure period.

#### *2.1.3.2 Risk Narrative*

*Post Closure I Period*

The CWTS performs as designed, however, the water quality in the receiving environment is not trending towards meeting PC-WQO by the end of the expected PCI period.

*Post Closure II Period*

Increase in contaminant concentrations from the mine causes exceedance of the PC-WQO in the receiving environment (lower Minto Creek).

#### *2.1.3.3 Indicator, Specific Performance Thresholds and Responses*

*Post Closure I Period*

The indicator, performance thresholds and responses specific to continuous improvement of water quality during the PCI period are provided in Table 2-6. The AMP framework for the PCI period applies to the receiving environment of Minto Creek (W2) and utilizes the results of trend analysis of routine monitoring to guide responses to improving water quality towards meeting the post closure water quality objectives prior to the expected completion of the PCI period (5 years total). Specifically this AMP only applies after the CWTS has met the designed performance for a period of one year and water quality at W2 is not meeting post closure water quality objectives.

**Table 2-6: Continuous improvement for water quality at W2 during the PCI period.**

| Indicator | Specific Performance Threshold | Stage | Specific Responses |
|---|---|---|---|
| Complete an annual Trend Analysis of receiving environment water quality data (Minto Creek Station W2) to determine if water quality meets or is trending towards meeting PC-WQOs. To be initiated after successful establishment of the CWTS (PCI Years 3,4,5 at minimum).<br><br>And<br><br>Complete an ongoing analysis with monthly W2 data to detect deviation from prediction limits. | Annual analysis shows trending towards meeting PC-WQO and will likely meet them before end of PCI. | **PCI** | **Action:**<br>• Re-evaluate in subsequent years and confirm or repudiate previous year's results |
| | Annual analysis shows trending towards meeting PC-WQO but will likely not meet before end of PCI. | **PCI** | **Notification:**<br>• Minto Management<br>**Review:**<br>• Follow QA/QC investigative protocol:<br>- Review laboratory QA/QC report<br>- Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation:**<br>• Review site water quality results - e.g. does pit water quality exceed expected concentrations?<br>• Compare with W50 and/or CWTS results. If comparison indicates elevated site concentrations are responsible for exceedance; and validation confirms original result, then:<br>- Engage qualified expert(s) to develop mitigation plan<br>**Action:**<br>• Review results of investigations/evaluations and implement recommendations if appropriate.<br>• Re-evaluate in subsequent years and confirm or repudiate previous year's results |
| | Annual analysis shows water quality stable, neither trending towards nor away from PC-WQO<br><br>OR<br><br>Monthly Analysis shows 2 or more consecutive results above the upper prediction limit. | **PCI** | **Notification**:<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review:**<br>• Follow QA/QC investigative protocol:<br>- Review laboratory QA/QC report<br>- Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation:**<br>• Review site water quality results - e.g. does pit water quality exceed expected concentrations?<br>• Compare with W50 and/or CWTS results. If comparison indicates elevated site concentrations are responsible for exceedance; and validation confirms original result, then:<br>- Engage qualified expert(s) to develop mitigation plan<br>**Action:**<br>• Review results of investigations/evaluations and prepare recommendations if appropriate.<br>• Engage SFN and Regulators<br>• Re-evaluate in subsequent years and confirm or repudiate previous year's results |
| | Annual analysis shows trending away from meeting PC-WQO<br><br>OR<br><br>Monthly Analysis shows 3 or more consecutive results above the upper prediction limit. | **PCI** | **Notification:**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review:**<br>• Follow QA/QC investigative protocol:<br>- Review laboratory QA/QC report<br>- Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation:**<br>• Review site water quality results - e.g. does pit water quality exceed expected concentrations?<br>• Compare with W50 and/or CWTS results. If comparison indicates elevated site concentrations are responsible for exceedance; and validation confirms original result, then:<br>- Engage qualified expert(s) to develop mitigation plan<br>**Action:**<br>• Review results of investigations/evaluations and prepare recommendations if appropriate.<br>• Engage SFN and Regulators<br>• Re-assess Passive treatment option<br>• Re-evaluate in subsequent years and confirm or repudiate previous year's results |

*Post Closure II Period*

Indicators, performance thresholds and responses specific to water quality and the monitoring program are provided below in Table 2-8. Specific thresholds for the PCII period AMP framework are identified in Table 2-7. This portion of closure AMP for Minto Creek water quality utilizes the post closure water quality objectives (WQOs) at station W2 as the basis for specific thresholds.

To apply these WQOs as the basis of specific performance thresholds in this plan, the following abbreviations, definitions and assumptions are being used:

**BGWQ:** Background Water Quality, as compiled and outlined in Appendix A (Minnow, 2016) of Appendix 1-3 (Surface Water Quality) of Appendix H (Site Characterization Plan) of the RCP 2018-01.

**ND**: Non-degradation of water quality, statistically unchanged from BGWQ

**NDIDPE-WQO**: Non-degradation Maximum water quality objective, as defined by the 95$^{th}$ percentile of the BGWQ data set

**NDCT-WQO**: Non-degradation Central Tendency water quality objective, as defined as the 95$^{th}$ percentile of the annual medians of the BGWQ data set.

**50IDPE-WQO**: 50% of assimilative capacity Individual Data Point Evaluator water quality objective, as calculated using the 95$^{th}$ percentile of background concentrations and the Post Closure WQO formula outlined in Section 3.1.3.1 of RCP 2018-01.

**50CT-WQO**: 50% of assimilative capacity Central Tendency water quality objective, as calculated using the NDCT-WQO as background and the Post Closure WQO formula outlined in Section 3.1.3.1 of RCP 2018-01.

**75%-STI**: Specific Threshold One value, as calculated using 75 percent of the 50IDPE-WQO and is intended to be an early warning threshold for the 50% of assimilative capacity WQO.

**Table 2-7: Specific Performance Thresholds for Surface Water Quality in Lower Minto Creek (W2)**

| Parameter | Non-Degradation - Individual Data Point Evaluator | Non-Degradation - Central Tendency | 75% of 50% Assimilative Capacity Individual Data Point Evaluator | 50% Assimilative Capacity - Individual Data Point Evaluator | 50% Assimilative Capacity - Central Tendency |
|---|---|---|---|---|---|
| | Water Quality Objective | Water Quality Objective | STP-1 | Water Quality Objective | Water Quality Objective |
| | (NDIDPE-WQO) | (NDCT-WQO) | Table 2-8 | (50IDPE-WQO) | (50CT-WQO) |
| Ammonia - N, mg/L | 0.12 | 0.06 | 0.14 | 0.18 | 0.13 |
| Nitrite - N, mg/L | 0.04 | 0.03 | 0.04 | 0.05 | 0.04 |
| Nitrate - N, mg/L | 0.22 | 0.15 | 3.5 | 4.7 | 4.6 |
| Aluminum (dissolved), mg/L | 0.053 | 0.032 | 0.058 | 0.077 | 0.066 |
| Arsenic (dissolved), mg/L | 0.0011 | 0.0009 | 0.0023 | 0.0031 | 0.0029 |
| Cadmium[1] (dissolved), µg/L | 0.00005 | 0.000044 | 0.00017 | 0.00022 | 0.00019 |
| Chromium (dissolved), mg/L | 0.0011 | 0.0010 | 0.0008 | 0.0011 | 0.0010 |
| Copper (dissolved), mg/L (when [DOC] @ W2 >10 mg/L) | 0.0054 | 0.0029 | 0.010 | 0.013 | 0.011 |
| Copper (dissolved), mg/L (when [DOC] @ W2 ≤10 mg/L) | 0.0054 | 0.0029 | 0.0069 | 0.0092 | 0.0079 |
| Iron (dissolved), mg/L | 0.91 | 0.57 | 0.75 | 1.0 | 0.84 |
| Lead (dissolved), mg/L | 0.00025 | 0.00014 | 0.0016 | 0.0021 | 0.0021 |
| Molybdenum (dissolved), mg/L | 0.0015 | 0.0011 | 0.028 | 0.037 | 0.037 |
| Nickel (dissolved), mg/L | 0.0020 | 0.0016 | 0.042 | 0.056 | 0.056 |
| Selenium (dissolved), mg/L | 0.00050 | 0.00046 | 0.0010 | 0.0013 | 0.0012 |
| Silver (dissolved), mg/L | 0.00001 | 0.00001 | 0.000041 | 0.000055 | 0.000055 |
| Zinc (dissolved), mg/L | 0.008 | 0.005 | 0.014 | 0.019 | 0.017 |

[1]Cadmium value calculated using 95th percentile hardness (225.2 mg/L) in Operational Stage WQO calculation. Actual objective for comparison with monitoring results will be calculated with observed hardness.

Table 2-8 below presents the specific thresholds and actions proposed to respond to changing water quality, i.e. deviation from a non-degradation condition, in lower Minto Creek, as measured at water quality station W2.

**Table 2-8: Specific Indicators, Performance Thresholds and Responses for Surface Water Quality at Station W2 in lower Minto Creek during Post Closure II, using Non-Degradation Water Quality Objectives.**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous Concentrations at Station W2 for parameters with water quality objectives<br><br>(See Table **2-7** above for specific threshold values) | **Specific Threshold 1**<br><br>• Exceedance of 2 consecutive NDIDPE-WQOs<br><br>**OR**<br><br>• Exceedance of NDCT-WQO once | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Review site water quality results – e.g. does pit water quality exceed expected concentrations?<br>• Conduct a trend analysis<br>• Compare with site water quality results, including W3, CWTS results, potential groundwater inflows, and contributions from the bypass channel if applicable. If comparison indicates either elevated site concentrations or poor CWTS performance are responsible for exceedance; and validation confirms original result, then:<br>o Engage qualified expert(s) to develop mitigation plan<br>**Action**<br>• Review results of investigations/evaluations and prepare recommendations if appropriate. This could include a recommendation that certain parameters be immediately subject to the AMP framework in Table 2-9 – 50%AC-WQOs if concentrations are determined by a qualified expert are unlikely to achieve ND-WQOs.<br>• if trend analysis suggests a continued (sustained) exceedance of Threshold 1 within one year, then initiate actions from SPT-2<br>• Actions will continue until performance thresholds are no longer exceeded. |
| | **Specific Threshold 2**<br><br>• Continued Exceedance of Threshold 1 in subsequent sampling | **Notification**<br>• Minto Management, SFN<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• All review measures for ST1<br><br>**Evaluation**<br>All evaluation measures from ST1<br>**Action**<br>• Implement recommendations from mitigation plan<br>• Actions will continue until performance thresholds are no longer exceeded. |
| | **Specific Threshold 3**<br>• Continued exceedance of Threshold 1 for 3 years | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• All review measures for ST2<br>**Evaluation**<br>• All evaluation measures for ST2<br>**Action**<br><br>• If all results are confirmed, then non-degradation is declared unattainable, and the specific indicator (i.e. parameter) is then subject to the AMP framework in Table 2-7 (50%AC-WQOs). |

In the case of the non-degradation condition being declared unattainable for any given specific indicator through the decision framework above, that parameter will be subject only to the following AMP framework which applies the 50% of assimilative capacity water quality objectives. Until such time, the specific indicators will be subject to both frameworks to ensure that actions are implemented in the case where 50% assimilative capacity WQOs are approached or exceeded early in the post closure period. The definition of attainment, of the closure WQOs are detailed in the RCP 2018-01 and is used as the basis for Specific Threshold 4 in Table 2-9, below. Specifically, as outlined in greater detail in the RCP, attainment is considered to be achieved if Specific Threshold 4 is not triggered.

**Table 2-9: Specific Indicators, Performance Thresholds and Responses for Surface Water Quality at Station W2 in Minto Creek, using the 50% Assimilative Capacity Water Quality Objectives.**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| Aqueous Concentrations at Station W2 for parameters with water quality objectives<br><br>(See Table **2-7** above for specific threshold values) | **Specific Threshold 1**<br>• Exceedance of SPT1 from Table 2-7 | **PCII** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with W3/CWTS results<br>**Action**<br>• On next scheduled sampling event, ensure sampling conducted at mine site stations W12 and W45 (open pits) if not already scheduled. |
| | **Specific Threshold 2**<br>• Exceedance of SPT1 in **2 consecutive samples at W2** where evaluation confirmed mine loading responsible for first exceedance | **PCII** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with W3 results. If comparison with W3 result indicates that mine loadings are responsible for exceedance; and validation confirms original result, then:<br>o Evaluate causes for load contributions and develop investigation plan; and<br>o A trend analysis will be conducted by a qualified person.<br>**Action**<br>• Implement investigation plan, including at a minimum:<br>o Re-sampling both W2 and W3 within **one month** of original sample result review; and<br>o Site investigation of candidate load contributions.<br>• Review results of investigation and prepare recommendations if appropriate.<br>• If trend analysis suggests WQO exceedance within one year, then initiate actions for Specific Threshold 3. |
| | **Specific Threshold 3**<br>• 50IDPE-WQO exceeded at W2 in a single sample where evaluation confirms that mine loading is responsible for exceedance. | **PCII** | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol<br>o Review laboratory QA/QC report<br>o Verify original result, or re-run sample if laboratory error indicated<br>**Evaluation**<br>• Compare with W3 results. If comparison with W3 result indicates mine loadings responsible for exceedance – and verification confirms original result – then:<br>o Evaluate candidate causes for load contributions and develop investigation plan (or review/revise as appropriate)<br>**Action**<br>• Implement investigation plan, including any reviews/revisions, and at a minimum:<br>o Re-sampling both W2 and W3 within **two weeks** of original sample result review; and<br>o Site investigation of candidate load contributions<br>• Review results of investigation and prepare recommendations if not already prepared from ST2.<br>• Implement recommendations from above. |
| | **Specific Threshold 4**<br>• Exceedance of 50IDPE-WQO in **2 consecutive samples (scheduled or re-sample) at W2** | **PCII** | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in scheduled Water Use Licence reporting<br>**Review** |

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | **or twice in one year** where evaluation confirmed mine loading responsible for first exceedance<br><br>**Or**<br><br>• 50CT-WQO exceeded at W2 by a 3 year rolling average value<br><br>(ST-4 = Attainment as defined in the RCP 2018-01) | | • Compare with W3 results<br>• Follow QA/QC investigative protocol<br>**Evaluation**<br>• Compare with W3 results. If comparison with W3 result indicates mine loadings responsible for exceedance; and verification confirms original result, then:<br>o Evaluate candidate causes for load contributions and develop investigation plan (or review/revise as appropriate)<br>o Provide investigation plan to SFN/YG Inspector<br>• Engage a qualified individual for the evaluation of potential effects to aquatic resources (i.e. Compare to Predicted No Effect Concentration (PNEC) and apply Biotic Ligand Model (BLM) for D-Cu, invertebrate tissue for Se, compare with calculated acute guideline for D-Cd.) This may include but not be limited to the evaluation of existing data and results from effluent toxicity, surface water toxicity, sediment chemistry, sediment toxicity, benthic invertebrate community structure and fish health testing/programs.<br>**Action**<br>• Implement monthly monitoring at W2 and W3/CWTS if recommended by qualified individual evaluating for the potential for effects at aquatic resources.<br>• Revise investigation plan, including at a minimum:<br>o Re-sampling both W2 and W3 within **one week** of original sample result review; and<br>o Additional site investigation of load contributions<br>• Review results of investigation and prepare additional recommendations<br>• Implement recommendations arising from investigations. |
| | **Specific Threshold 5**<br>• 50IDPE-WQO exceeded in **3 consecutive samples (scheduled or re-sample) at W2** where evaluation confirmed mine loading responsible for exceedances | **PCII** | **Notification**<br>• Minto Management, SFN, YG Inspector<br>• Include in Water Use Licence reporting<br>**Review**<br>• Compare with W3/CWTS results and any other WQ data as appropriate<br>• Follow QA/QC investigative protocol<br>**Evaluation**<br>• All evaluation measures for ST4<br>**Action**<br>• Maintain monthly monitoring and collect samples at greater frequency as required.<br>• Review and revise mitigation plans with qualified individuals, and Implement necessary reasonable and practical measures to reduce contaminant loading from mine to Minto Creek. This could include consideration of: additional passive treatment installations.<br>• Actions will continue until performance thresholds are no longer exceeded. |

### 2.1.4 McGinty Creek

#### *2.1.4.1 Description*

The Minto North deposit is an extension of the mineralized corridor being mined within the Minto Creek catchment. It is within the McGinty Creek catchment area, to the north of Minto Creek. Minto has been monitoring surface water quality in the McGinty Creek catchment since 2009, and the results from monitoring program (until the end of 2015) are presented in McGinty Creek Water Quality Characterization, July 2016 (AEG, 2016).

As described in the Water Management Plan (Minto Explorations Ltd., 2015), during the recently completed active mining of Minto North, Minto actively managed water directly impacted by open pit mining with pump trucks. With surface mining in Minto North now complete, there is no active water management, with runoff and meteoric water now allowed to accumulate in the pit.

The AMP framework below provides a decision-based structure with the goal of avoiding changes to background water quality in lower McGinty Creek that result from completed mining activities at Minto North. Station MN-4.5 is the monitoring station on the lower main stem of McGinty Creek, after the north and south tributaries converge, and near the confluence of McGinty Creek with the Yukon River. Surface water quality at the MN-4.5 monitoring point is subject to periodic TSS influences from catchment area that are beyond Minto's control, so dissolved metals concentrations will be used to track influences from the Minto North development.

#### *2.1.4.2 Risk Narrative*

Increase in contaminant concentrations from completed Minto North mining activities causes unacceptable changes to surface water quality in McGinty Creek.

#### *2.1.4.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to water quality and the monitoring program are provided below in Table 2-11. The specific indicators are total suspended solids and contaminant (nitrogen species and dissolved metals/metalloids) concentrations for parameters identified in the Water Use Licence QZ14-031 Table 2 – Water Quality Objectives. Thresholds are all based on a proposed water quality objective (WQO), and the specific indicators station, as identified above, is MN-4.5. The discussion below applies to data collected from this station. The selection of this indicator station, along with other aspects of the AMP framework, is consistent with the approach taken for closure water quality objective development in Minto Creek (i.e. downstream indicator station, non-degradation water quality objectives, and a focus on dissolved metal concentrations.)

Essentially, Minto has adopted the statistical definitions of non-degradation (from the discussions and agreement with SFN regarding Minto Creek closure water quality objectives) as the basis of developing these revised McGinty Creek Water Quality Objectives. Monthly monitoring has continued in the McGinty Creek catchment, and the background dataset has been updated to include all monitoring data from initiation of the program in May 2009 until July 2015 (stripping of the Minto North Pit began in August 2015.) Similar to the data treatment used in Minto Creek, data from monitoring stations were collapsed into monthly results (most monitoring has been undertaken monthly anyway, and this was only required for May 2009 when sampling was weekly.) All monthly

data were then used to calculate the 95th percentile, for use as the maximum water quality objective, or individual data point evaluator (IDPE). The monthly data were then also grouped by year, and the annual medians were calculated. The 95th percentile of these annual medians was calculated for each station to generate the central tendency evaluator (CTE).

These objectives form the basis of the AMP thresholds. Values lower than the WQOs have been selected as early warning thresholds (ST 1) prior to the WQOs themselves forming the higher level specific thresholds (ST2 and ST3). For these thresholds, the 85th percentile of the same data selected. Utilizing a statistic such as this is more effective and reliable than using a percentage (e.g. 75%) of maximum value, as it considers the actual statistical distribution of the background data.

The actual calculated threshold values are presented in Table 2-10.

The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Surface Water Surveillance Program of the EMSRP (Minto Explorations Ltd., 2016). The monitoring data will be compared to the specific performance thresholds monthly (by the end of the month following the month in which samples were collected) - this corresponds to the existing monthly reporting schedule.

**Table 2-10: Specific Thresholds for McGinty Creek, Station MN-4.5**

| Analytes | Specific Threshold 1 (85th percentile) | Water Quality Objectives (Specific Thresholds 2 and 3) | |
|---|---|---|---|
| | | Individual Data Point Evaluator ($95^{th}$ percentile) | Central Tendency Evaluator (95th percentile of annual medians) |
| Total Suspended Solids (mg/L) | 52.0 | 269 | 32.0 |
| Ammonia (mg/L) | 0.040 | 0.12 | 0.046 |
| Nitrite (mg/L) | 0.006 | 0.05 | 0.005 |
| Nitrate (mg/L) | 0.200 | 0.232 | 0.083 |
| Dissolved Aluminum (µg/L) | 48.6 | 135.0 | 47.0 |
| Dissolved Arsenic (µg/L) | 0.55 | 0.61 | 0.54 |
| Dissolved Cadmium (µg/L) | 0.026 | 0.041 | 0.015 |
| Dissolved Chromium (µg/L) | 1.0 | 1.0 | 1.0 |
| Dissolved Copper (µg/L) | 2.9 | 3.5 | 2.8 |
| Dissolved Iron (µg/L) | 334 | 403 | 358 |
| Dissolved Lead (µg/L) | 0.20 | 0.20 | 0.20 |
| Dissolved Molybdenum (µg/L) | 1.0 | 1.0 | 1.0 |
| Dissolved Nickel (µg/L) | 1.6 | 1.8 | 1.6 |
| Dissolved Selenium (µg/L) | 0.17 | 0.20 | 0.16 |
| Dissolved Silver (µg/L) | 0.020 | 0.020 | 0.020 |
| Dissolved Zinc (µg/L) | 5.0 | 5.2 | 5.0 |

**Table 2-11: Specific Indicators, Performance Thresholds and Responses for Surface Water Quality in McGinty Creek**

| Specific Indicators | Specific Performance Thresholds | Specific Responses |
|---|---|---|
| Aqueous Concentrations at Station MN-4.5 for parameters with Water Quality Objectives.<br><br>(See Table 2-10 above for Water Quality Objective and threshold values.) | **Specific Threshold 1**<br><br>• Exceedance of ST1 value in two consecutive samples **(scheduled or re-sample)** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Compare with MN-1.5 results<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• If comparison with other results suggests that Minto North loading may be responsible for exceedance and validation confirms original result, then:<br>o Evaluate causes for load contributions, and<br>o If trend analysis suggests WQO exceedance within one year, then initiate actions for threshold 2. |
| | **Specific Threshold 2**<br><br>• Exceedance of the IDPE-WQO (grab vs. IDPE, or 12-month moving average vs. CTE) | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Measures from ST1, and<br>• Engage a qualified professional to evaluate potential effects to aquatic resources<br>• A trend analysis will be conducted by Minto's senior level environmental personnel.<br>**Action**<br>• If comparison with results suggests that Minto North loadings are responsible for exceedance and validation confirms original result, then:<br>o Re-sample MN-1.5 and MN-4.5 within **two weeks** of original sample result review; and<br>o Evaluate causes for load contributions<br>o Develop a mitigation strategy with recommendations based on the findings of the potential effects to aquatic resources evaluation<br>• Actions will continue until performance thresholds are no longer exceeded. |
| | **Specific Threshold 3**<br><br>• Exceedance of the IDPE-WQO (as defined above) in **2 consecutive samples (scheduled or re-sample)** where evaluation confirmed mine loading responsible for first exceedance | **Notification**<br>• Notify management, SFN and YG<br>• include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>**Evaluation**<br>• Measures from ST2<br>**Action**<br>• If comparison with results (evaluation, above) suggests that Minto North loadings are STILL responsible for exceedance; and validation confirms original result, then:<br>o If not already implemented, increase monitoring frequency.<br>o Implement recommendations from mitigation strategy (threshold 2 response). This could include batch water treatment in the Minto North pit if determined feasible and appropriate.<br>o Actions will continue until performance thresholds are no longer exceeded. |

## 2.2 Groundwater Quality

### 2.2.1 Minto Creek Watershed

#### *2.2.1.1 Description*

Groundwater quality has the potential to be important in terms of contributions to surface water quality. Groundwater contributes to streamflow as baseflow, which is typically most important during the autumn/winter low flow season when surface water flows are minimal.

All mine workings and waste facilities within in the Minto Creek catchment are located upgradient (and west) of the Water Storage Pond (WSP). During final closure the WSP will be decommissioned and a passive treatment system (wetlands) established within its footprint.

The groundwater monitoring supporting the Closure AMP framework is defined and described in the Monitoring and Maintenance program, which is included in Section 7.11 of the RCP. The monitoring requirements build on those of the Groundwater Monitoring Program of the Environmental Monitoring, Surveillance and Reporting Plan (EMSRP) (Minto Explorations Ltd., 2018b) implemented in the mine operations phase. The purpose of the operational groundwater monitoring program is to provide information to better understand the potential for off-site migration of contamination and to better understand and define source terms and conditions of waste emplacement, for comparison to source terms used in the predictive Water Balance and Water Quality model. An additional objective of the operational groundwater monitoring plan is to provide for the development of baseline hydrogeological conditions in areas where future mine components are being planned.

Groundwater monitoring is carried out both upgradient and downgradient of the WSP, via multi-level monitoring wells at MW12-06, MW12-05 and MW17-12 (MW12-05 is located downgradient of the new MW17-12. Both wells will be monitored until comparison by a qualified professional determines that the use of MW12-05 should be discontinued).

As described in the 2018 Minto Groundwater Characterization Hydrogeologic Conceptual Model Update Report (SRK 2018), groundwater coming from the mine area (the western and highest elevation portion of the Minto Creek catchment) is expected to discharge to surface water in the vicinity of the WSP. Minimal groundwater from the mine area is expected to discharge to Minto Creek down gradient of the WSP. Surface water downgradient of the WSP is monitored at several stations including station W2 located near the Yukon River. W2 is 6 km downstream of the Minto lease boundary and water reporting to W2 is subject to influences from groundwater and surface water outside the mine area.

The Closure AMP framework below complements the RCP water management plan for the mine site with a decision-based structure for ensuring that negative impacts to lower Minto Creek from mining and closure activities are avoided.

#### *2.2.1.2 Risk Narrative*

Flux of geochemical load from a mine component via groundwater pathways causes surface water quality objectives to be in exceeded in Minto Creek at station W2.

#### *2.2.1.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to groundwater quality in Minto Creek watershed are provided in Table 2-12. Specific Performance Thresholds (SPTs) are defined for each of the Effluent Standards (ES) parameters identified in Clause 9 (a), Table 1 of Water Use Licence QZ14-031, with the exception of pH, oil and grease, iron and nitrite (as discussed later in this section). Additionally, although it is not specified in Clause 9(a), sulphate has been included in the SPTs. Table 2-13 compiles the concentration of background groundwater for each Specific Indicator and the Specific Performance Threshold values.

The concentrations of the background groundwater are based on the respective median parameter concentrations at monitoring well MW09-03 (including all monitoring ports). At present (February 2018), the MW09-03 monitoring record is still considered to be the most representative indicator of the baseline groundwater conditions for the entire project site. MW09-03 was installed in 2009 and monitored to collect baseline data downgradient of the Minto North ore body- this well is located near the southern limit of the McGinty Creek catchment close to the surface water divide with Minto Creek. Pre-mining groundwater concentrations for certain parameters such as cadmium and iron were relatively high, likely due to the adjacent highly mineralized zone. Mining of this ore body began in Q3 2015 and as such the monitoring record prior for the 2009-2015 period reflects baseline conditions. MW17-08 was installed in late 2017 to allow groundwater quality monitoring within the Minto Creek catchment upgradient of any mine disturbances. Once an adequate record of the groundwater quality from MW17-08 is developed, the groundwater quality at MW09-03 and MW17-08 will be compared by a qualified professional to verify and assess if background groundwater concentrations used in the current operational AMP remain appropriate. Minto expects that an adequate record will be available after 3 years of monitoring. In addition, as reported in SRK (2018) elevated sulphate at MW12-05 is believed to not be a result of mine impacts, but represents elevated background concentrations. Sulphate will continue to be reviewed to improve confidence in this finding, and other parameter will be reviewed within this context. Other new wells installed in 2017 will be monitored in accordance with Minto's EMSRP, but will not be included in the AMP.

Iron and nitrite have been excluded from the Specific Indicators for groundwater quality because of the magnitude of the natural variability observed in groundwater at Minto. In addition, pH as also been excluded as a Specific Indicator for groundwater quality because it is not as useful an early warning indicator as sulphate and metal/ metalloid concentrations, and Oil & Grease has been excluded because it is not relevant as a specific indicator for groundwater. Although iron, nitrite and pH are excluded from the Specific Indicator list, these three constituents are monitored and would be included in the review of groundwater quality if an SPT was exceeded.

Three SPTs have been defined for the Minto Creek watershed. Rationale for development of the SPTs is as follows:

- SPT-1 corresponds to a trend-based assessment designed to flag a potential rapid increase in groundwater loadings that has not yet exceeded concentration-based thresholds. The assessment is structured to determine if an indicator has increased significantly compared to the last sampling event. The assessment will be performed as followed:

  $$((C_n - C_{n-1})/( C_{SPT-2} – C_n) > 0.2$$

  Where:

  - $C_n$ = the parameter concentration of groundwater from the latest sampling event;
  - $C_{n-1}$ = the parameter concentration of groundwater from the last sampling event ;

- $C_{SPT-2}$ = the parameter concentration for the SPT-2;

The SPT-1 provides a conservative threshold considering that it is weighted against the concentration for the SPT-2. The SPT-1 will be increasingly sensitive to change in concentrations between two sampling events as groundwater approaches the SPT-2, since the size of the denominator decreases as the SPT-2 value is approached.

- SPT-2 generally corresponds to the EQS concentrations defined in Clause 9 (a), Table 1 of Water Use License QZ14-031 (with four exceptions (Cr-D, Cu-D, Ni-D and sulphate) as indicated in the notes to Table 2-13). The EQS are defined for surface water discharge, and the mine is not permitted to discharge water that exceeds any EQS guidelines to surface water. As SPT-2 applies to groundwater (not surface water) concentrations in single zone, this is a highly conservative threshold.
- SPT-3 generally corresponds to the estimated concentrations in groundwater that would be necessary to cause exceedance of the Water Quality Objectives in lower Minto Creek, at W2, under long term steady state conditions (exceptions are listed in the notes to Table 2-13). These concentrations were determined by conducting a mass loading calculation to determine the groundwater concentrations that would be necessary to cause exceedance of WQOs in lower Minto Creek during low flow periods where all streamflow is derived from groundwater discharge. The mass loading calculation was structured to represent a low-flow period when all surface flows in lower Minto Creek originate from groundwater discharge to the creek. The calculation was done using the following formula:

$$C_{gw\text{-}mine\_max} = ((Q_{W2} \times C_{W2\text{-}WQO}) - (Q_{gw\text{-}bgrnd} \times C_{gw\text{-}bgrnd}))/Q_{gw\text{-}mine}$$

Where:

- $C_{gw\text{-}mine\_max}$ = the indicator parameter concentration of all groundwater upgradient of MW12-05 that reports to Minto Creek that would be required to cause surface water to exceed the WQO at station W2.
- $Q_{W2}$ = the combined groundwater flow discharging to Minto Creek (total groundwater discharge to Minto Creek from the 2015 groundwater model update) during low flow periods
- $C_{W2\text{-}WQO}$ = the WQO parameter concentration for surface water at W2
- $Q_{gw\text{-}bgrnd}$ = background groundwater flow discharging to Minto Creek (groundwater discharge down gradient of the Water Storage Pond from the 2015 groundwater model update) during low flow periods
- $C_{gw\text{-}bgrnd}$ = background groundwater concentration (based on median concentrations from the 2009-2015 baseline monitoring period in MW09-03)
- $Q_{gw\text{-}mine}$ = the estimated groundwater flow from the mine at the Water Storage Pond (from the 2015 groundwater model update)

If groundwater concentration of one indicator reached the SPT-3 in an individual port, the quality of the lower Minto Creek at W2 would not yet exceed the Water Quality Objective due to the contribution of groundwater from un-impacted areas of the Minto Creek watershed and the fact that groundwater concentrations at a specific monitoring well port represents only a portion of the flow and not the whole groundwater flow field. The SPT-3

provides therefore a conservative threshold for action before any significant effect would be observed in surface water.

The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Groundwater Monitoring Program of the EMSRP (Minto Explorations Ltd., 2018b). The monitoring data will be compared to the specific performance thresholds quarterly.

Examples of actions that may arise from recommendations include:

- Continuation of monitoring;
- Continuation monitoring with an increase in monitoring frequency;
- Development of additional monitoring points and monitoring of those newly-established monitoring locations;
- Completion of appropriate risk assessment;
- Development and execution of a focused study to better understand the cause of exceedance.

**Table 2-12: Specific Indicators, Performance Thresholds and Responses for Groundwater Quality in Minto Creek**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| Aqueous concentrations in samples collected from multi-level groundwater monitoring wells MW12-05 or MW12-06 for the following parameters with water quality objectives:<br>• Dissolved Aluminum<br>• Dissolved Arsenic<br>• Dissolved Cadmium<br>• Dissolved Chromium<br>• Dissolved Copper<br>• Dissolved Iron<br>• Dissolved Lead<br>• Dissolved Molybdenum<br>• Dissolved Nickel<br>• Dissolved Silver<br>• Dissolved Selenium<br>• Dissolved Zinc<br>• $NH_4$-N<br>• $NO_3$-N<br>• Sulphate | **SPT-1**<br>• Exceedance of SPT-1 for any sample collected during routine monitoring from multilevel groundwater monitoring wells MW12-05 or MW12-06. | **All Stages** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (trend analysis included) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>• Include the trend analysis in scheduled reporting<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator |
| | **SPT-2**<br>• Exceedance of SPT-2 concentrations in 2 consecutive samples (scheduled or re-sampled) collected during routine monitoring from multilevel groundwater monitoring wells MW12-05 or MW12-06. | **All Stages** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (including trend analysis) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>o Timing: initiate within 1 week of QA/QC review validating original results<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator |

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | **SPT-3**<br>• Exceedance of SPT-3 in 2 consecutive samples (Scheduled or re-sampled) collected during routine monitoring from multilevel groundwater monitoring wells MW12-05 or MW12-06. | **All Stages** | **Notification**<br>• Minto Management<br>• Include in scheduled Water Use Licence monthly reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original result, or re-run sample if a laboratory error is indicated<br>o Timing: initiate within 1 week of triggering SPT<br>**Evaluation**<br>• Review of groundwater monitoring data (including a trend analysis) to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>o Timing: initiate within 1 week of QA/QC review validating original results<br>• Submit recommendations to regulator for review and approval<br>o Timing: submit within 1 week of receipt of recommendations<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>o Timing: initiate implementation of recommendations within 1 month of receipt of approval from regulator<br>• Increase monitoring frequency to monthly sampling of all monitored zones in the affected multi-level well for a period to be defined by qualified professional. |

**Table 2-13: Background concentrations and SPTs for the groundwater monitoring in the Minto Creek watershed**

| **Minto Creek** | ***Concentrations (mg/L)*** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ag-D | Al-D | As-D | Cd-D | Cr-D | Cu-D | Pb-D | Mo-D | Ni-D | Se-D | Zn-D | N-NO3 | Ammonia | Sulphate[2] |
| SPT-3 [1] | 0.00046 | 0.48 | 0.025 | 0.0060 | 0.0030 | 0.060 | 0.020 | 0.34 | 0.33 | 0.0093 | 0.13 | 45 | 1.0 | 4951 |
| SPT-2 | 0.00030 | 0.30 | 0.015 | 0.0030 | 0.0015[4] | 0.030 [4] | 0.012 | 0.22 | 0.165[4] | 0.0060 | 0.090 | 27 | 0.75 | 1000 |
| Background Groundwater[3] | 0.00001 | 0.0045 | 0.0001 | 0.00002 | 0.00050 | 0.0014 | 0.0001 | 0.006 | 0.001 | 0.0002 | 0.006 | 0.07 | 0.051 | 12 |

Notes:

1: For most Specific Indicators, SPT-3 is the calculated concentration that all groundwater from the mine catchment must attain to reach the Operational Water Quality Objectives at W2. Model flows were based on 2015 Groundwater Model Update. 15 L/s is the total groundwater discharging to Minto Creek. 3 L/s is the estimated groundwater flow from the Minto Creek catchment up gradient of the Water Storage Pond. The exceptions are dissolved chromium, dissolved copper and dissolved nickel, for which SPT-3 is equal to the Effluent Quality Standard value that applies to surface water discharge from the mine site.

2: There is no Effluent Quality Standard for sulphate. For the SPT-2, the guideline for Aquatic Life from the Contaminated Site Regulation Schedule 3 was used as a replacement.

3: The background concentration in groundwater is calculated as the median of concentrations observed at groundwater monitoring well MW09-03.

4: SPT-2 for dissolved copper, dissolved chromium and dissolved nickel set at one-half (50%) of Effluent Quality Standard (SPT-2 for all remaining parameters (other than sulphate) is equal to (100% of) the Effluent Quality Standard).

### 2.2.2 McGinty Creek Watershed

#### *2.2.2.1 Description*

The mine workings in the McGinty Creek catchment are limited to the Minto North Pit. The catchment area of the Minto North Pit is roughly 15 ha and the catchment area of the McGinty Creek watershed is roughly 3400 ha (SRK 2013); in other words, the Minto North Pit catchment is roughly 0.4% of the total McGinty Creek catchment area. While a groundwater model encompassing the full extent of the McGinty Creek catchment has not been developed, it is clear that only a very small proportion of the groundwater in the McGinty Creek watershed can be affected by the Minto North Pit.

The monitoring supporting the closure AMP framework is defined and described in the Post-Closure Monitoring Plan of the RCP. The monitoring requirements build on those of the operational Groundwater Monitoring Plan (part of the EMSRP ( (Minto Explorations Ltd., 2018b)). Groundwater in the McGinty Creek catchment downgradient of the Minto North Pit is currently monitored at multi-level monitoring well MW09-03. MW09-03 was installed in 2009 and monitored to collect baseline at the Minto North ore body. Mining of this ore body began in Q3 2015 and as such the monitoring record prior for the 2009-2015 period reflects baseline conditions. An additional multi-level groundwater well MW17-11 was installed downgradient of the Minto North Pit in late 2017 to fulfill WUL requirements.

#### *2.2.2.2 Risk Narrative*

Flux of geochemical load from the Minto North Pit via groundwater pathways causes surface water quality objectives to be in exceeded in McGinty Creek at station MN4.5.

#### *2.2.2.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to groundwater quality in McGinty Creek watershed are provided below in Table 2-14. SPTs are defined for each of the Effluent Standards (ES) parameters identified in Clause 9 (a), Table 1 of Water Use License QZ14-031, with the exception of pH, Oil & Grease, iron and nitrite (for reasons described in the Minto Creek groundwater section (Section 2.2.1). Additionally, although it is not specified in Clause 9(a), sulphate has been included in the SPTs. The concentration of background groundwater and the Specific Performance Threshold values for each Specific Indicator and each zone (i.e. individual well port) of MW09-03 are compiled in Table 2-15. The monitoring record for MW09-03 for the 2009-2015 period reflects baseline conditions (prior to the development of the open pit). Pre-mining groundwater concentrations for certain parameters such as cadmium and iron have been relatively high, likely due to the adjacent highly mineralized zone.

Two Specific Performance Thresholds have been defined for McGinty Creek watershed groundwater- both are conservative given the application of the thresholds at individual ports, the small proportion of catchment groundwater that will be influenced by the mine workings and the expected slow rates of groundwater movement. Rationale for development of the two specific performance thresholds is as follows:

- SPT-1: Three consecutive exceedances of the 75$^{th}$ percentile background level in a single monitoring port.
    - The specification of three consecutive exceedances is intended to avoid triggering the AMP unnecessarily, but to ensure that any sustained increase from baseline conditions receives appropriate scrutiny.
- SPT-2: Three consecutive exceedances of the 95$^{th}$ percentile background level in a single monitoring port.

- The specification of three consecutive exceedances is intended to avoid triggering the AMP unnecessarily, but to ensure that any sustained increase from baseline conditions receives appropriate scrutiny.

The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the operational Groundwater Monitoring Program of the EMSRP (Minto Explorations Ltd., 2018b) and the Post-Closure Monitoring Plan of the RCP.

**Table 2-14: Specific Indicators, Performance Thresholds and Responses for Groundwater Quality in McGinty Creek**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| Aqueous concentrations in samples collected from multi-level groundwater monitoring well MW09-03 for the following parameters:<br>• Dissolved Aluminum<br>• Dissolved Arsenic<br>• Dissolved Cadmium<br>• Dissolved Chromium<br>• Dissolved Copper<br>• Dissolved Lead<br>• Dissolved Molybdenum<br>• Dissolved Nickel<br>• Dissolved Silver<br>• Dissolved Selenium<br>• Dissolved Zinc<br>• $NH_4$-N<br>• $NO_3$-N<br>• Sulphate | **Specific Threshold 1**<br>• Three consecutive exceedances of the 75$^{th}$ percentile value* from the baseline period (2009-2015) in routine monitoring results from a single monitoring port in MW09-03.<br><br>*values provided in Table 2-13 | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original results, or re-run samples if a laboratory error is indicated<br>**Evaluation**<br>• Review of groundwater monitoring data to be undertaken by qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional. |
| | **Specific Threshold 2**<br>• Three consecutive exceedances of the 95$^{th}$ percentile value* from the baseline period (2009-2015) in routine monitoring results from a single monitoring port in MW09-03.<br><br>*values provided in Table 2-13 | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Include in scheduled Water Use Licence reporting<br>**Review**<br>• Follow QA/QC investigative protocol:<br>o Review laboratory QA/QC report<br>o Validate original results, or re-run samples if a laboratory error is indicated<br>**Evaluation**<br>• Review of groundwater monitoring data to be undertaken by a qualified professional, and appropriate recommendations to be developed<br>o Review must consider the risk narrative (i.e. exceedance of surface water quality objectives as a result of groundwater flux)<br>**Action**<br>• Follow recommendations arising from review undertaken by qualified professional.<br>• Increase monitoring frequency of all monitored zones in the affected multi-level well for a period to be defined by qualified professional. |

**Table 2-15: Background Concentrations and SPTs for the Groundwater Monitoring in the McGinty Creek Watershed**

| Minto Creek | | *Concentrations (mg/L)*[1] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ag-D[3] | Al-D | As-D | Cd-D | Cr-D[3] | Cu-D | Pb-D[3] | Mo-D | Ni-D | Se-D | Zn-D | N-NO3 | $NH_4$-N | Sulphate |
| MW09-03-01 | 95th Percentile | 0.000016 | 0.0101 | 0.00081 | 0.000272 | 0.000575 | 0.00625 | 0.0003 | 0.026 | 0.0060 | 0.0015 | 0.022 | 0.28 | 0.133 | 38 |
| | 75th Percentile | 0.000010 | 0.0065 | 0.00011 | 0.000075 | 0.000500 | 0.00155 | 0.0001 | 0.005 | 0.0021 | 0.0001 | 0.013 | 0.13 | 0.067 | 24 |
| | Median[2] | 0.000010 | 0.0045 | 0.00005 | 0.000022 | 0.000500 | 0.00031 | 0.0001 | 0.004 | 0.0015 | 0.0001 | 0.006 | 0.07 | 0.045 | 22 |
| MW09-03-02 | 95th Percentile | 0.000034 | 0.0095 | 0.00092 | 0.000272 | 0.000796 | 0.01080 | 0.0002 | 0.062 | 0.0026 | 0.0040 | 0.015 | 0.07 | 0.282 | 67 |
| | 75th Percentile | 0.000018 | 0.0073 | 0.00074 | 0.000031 | 0.000500 | 0.00263 | 0.0001 | 0.018 | 0.0009 | 0.0005 | 0.010 | 0.03 | 0.230 | 7 |
| | Median[2] | 0.000010 | 0.0062 | 0.00067 | 0.000026 | 0.000500 | 0.00122 | 0.0001 | 0.017 | 0.0005 | 0.0002 | 0.008 | 0.01 | 0.210 | 1 |
| MW09-03-03 | 95th Percentile | 0.000010 | 0.0075 | 0.00014 | 0.000069 | 0.000500 | 0.00500 | 0.0003 | 0.018 | 0.0011 | 0.0004 | 0.011 | 0.54 | 0.058 | 13 |
| | 75th Percentile | 0.000010 | 0.0047 | 0.00005 | 0.000023 | 0.000500 | 0.00247 | 0.0001 | 0.006 | 0.0005 | 0.0004 | 0.008 | 0.50 | 0.020 | 12 |
| | Median[2] | 0.000010 | 0.0025 | 0.00005 | 0.000015 | 0.000500 | 0.00174 | 0.0001 | 0.005 | 0.0005 | 0.0003 | 0.003 | 0.48 | 0.012 | 11 |

Notes:

1: For monitoring results where concentrations were below the analytical detection limits, a concentration of half the detection limit was adopted for calculation purposes.

2: For AMP purposes, the background concentration in groundwater at MW09-03 is defined as the median concentration observed in each port over the 2009-2015 baseline monitoring period.

3: For Ag-D, Cr-D and Pb-D, most 2009-2015 concentrations were at the limit of analytical detection, and as such the calculated 75th and 95th percentile values are skewed low.

## 2.3 Water Management Infrastructure

### 2.3.1 Description

The closure water conveyance infrastructure is a network of channels, erosion protection features, and energy dissipation structures that convey surface water from the mine surface to Minto Creek. The network of channels is designed to collect, intercept, and convey water through the mine in its closed state. In addition to the conveyance system, three reservoirs will be present into active closure and post closure phases. Two of the reservoirs, the Main Pit Lake and the Area 2 Pit Lake will remain in perpetuity, while the third one, the WSP, will be decommissioned and the dam deconstructed. The Water Storage Dam has been excluded from the closure AMP as the facility is to be managed according to its Operation, Maintenance and Surveillance (OMS) Manual (Tetra Tech EBA, 2014) until it is decommissioned. A Constructed Wetland Treatment System (CWTS) is to be constructed within the footprint currently occupied by the WSP as part of mine closure works at Minto Mine.

Conveyance and collection structures and reservoirs are used to convey drainage from the major waste infrastructure to treatment systems prior to release. As discussed in the Section 7.7.1 of the RCP the water treatment plant used during operations will remain in operational until WUL criteria can be achieved consistently without its utilization.

The design criteria for the water conveyance system is described in the Section 3 of the Minto Mine – Closure Water Conveyance System Design Update Report (Appendix G2, Minto Mine RCP). Design details specific to each of the five conveyance channels are provided in Section 5 of the design report.

The water management system is able to deal with most foreseeable conditions that may be encountered though the mine closure. However, certain unforeseen conditions may require an adaptive response as described below.

For clarity, this AMP component applies to the following water management infrastructure:

- Water Storage Pond and WSP Dam;
- Tailings Diversion Ditch;
- All primary and secondary conveyance ditches and pit inflow/outflow structures;
- CWTS head ponds;
- CWTS High Flow Bypass Ditch;

### 2.3.2 CWTS treatment cells and outflow channel.Risk Narrative

A mass failure of one of the conveyance and collection facilities has the potential to endanger the health and safety of site employees or visitors, or lead to an increase in contaminant loadings from the mine and subsequent adverse effects to aquatic resources in the receiving environment (lower Minto Creek).

### 2.3.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to water management are provided below in Table 2-16. The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Post-Closure Monitoring Program.

**Table 2-16: Specific Indicators, Performance Thresholds and Responses for Water Management Infrastructure**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| • Failure or blockage of conveyance structures resulting in changed flow paths and/or overtopping of drainage ditches<br>• Failure of upstream diversions leads to excessive infiltration into upgradient base of DSTF, resulting in increased flows and/or metal loads and unacceptable water quality conditions downstream.<br>• Occurrence of a major precipitation event<br>• Increased sediment load in ditch flow and or downstream (increased TSS)<br>• Pit wall failure | **Specific Threshold 1**<br>• Observation of unusual occurrence including:<br>  • Partial blockage;<br>  • Physical damage;<br>  • Turbulent flow where laminar flow is expected or is normal;<br>  • Cracks, settlement of sloughing;<br>  • Downstream movement of channel bedding material (rip rap or liner);<br>  • Erosion channels or flowing water outside of the designed structures;<br>  • Abnormal seepage;<br>  • Rainfall event that exceeds the design criteria;<br>  • Increase turbidity of flow. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, survey data and precipitation records<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of the need for design modifications<br>**Action**<br>• Inspect area to determine source of blockage and potential for repeated occurrence<br>• Develop plan to address the need for repairs or modifications.<br>• Increase frequency of monitoring as recommended by a qualified professional |
| | **Specific Threshold 2**<br>• Observation of unusual occurrence including:<br>  • Complete blockage;<br>  • Substantial physical damage;<br>  • overtopping of drainage ditches;<br>  • Downstream water quality exceeds TSS criteria. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, survey data and precipitation records.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of the need for design modifications<br>**Action**<br>• Inspect area to determine source of blockage and potential for repeated occurrence<br>• Immediately develop and implement a plan to address the need for repairs or modifications<br>• Increase frequency of monitoring as recommended by a qualified professional |

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | **Specific Threshold 3**<br>• Complete compromise of functionality. | **All Stages** | **Notification**<br>• Mine/Project Manager, SFN and YG<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, survey data and precipitation records.<br>**Evaluation**<br>• Engage a qualified professional to evaluate potential effects to aquatic resources.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area accommodate modifications/repairs.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for modifications to the conveyance and retention structures and the need for an increased frequency of monitoring. |

## 2.4 Physical Stability of Waste Rock, Overburden and Tailings Storage Facilities

### 2.4.1 Description

The physical stability of the site, during Post Closure I and II periods, will be monitored according to the Monitoring and Maintenance section (7.11) of the Minto Mine RCP. During active closure the physical stability of the waste rock, overburden dumps, tailings and water storage facilities are will be monitored according to the Physical Monitoring Plan, which forms part of the Environmental Monitoring, Surveillance and Reporting Plan (Minto Explorations Ltd., 2016). These monitoring plans describe the inspection and instrumentation data collection frequencies, instrument locations, installation details, as well as the data collection procedures.

The purpose of the monitoring program is to identify physical changes to the conditions of the facilities which may lead to future instability and to allow Minto to mitigate these conditions prior to any occurrence of instability. The facilities have been separated into two sets of geotechnical thresholds and response criteria (Table 2-17). Soil cover performance and stability is addressed under Section 2.5 General Reclamation Measures of this plan.

**Table 2-17: Physical Stability Categories**

| Category | Facility |
|---|---|
| 1 | • Dry Stack Tailings Storage Facility and Mill Valley Fill Extension (Stage 1 and 2)<br>• Southwest Waste Dump<br>• South Wall Buttress of the Main Pit Dump |
| 2 | • Main Waste Dump and Main Waste Dump Extension<br>• Reclamation Overburden Dump<br>• Ice-Rich Overburden Dump<br>• Main Pit Dump (except the South Wall Buttress)<br>• Area 118 Backfill Dump |

Category 1 facilities are founded in areas of ice-rich periglacial foundations that have previously experienced deep seated foundation movement. The Mill Valley Fill Extension (MVFE) and South Wall Buttress (SWB) are designed to mitigate movements in the Dry Stack Tailings Storage Facility (DSTSF) and Main Pit South Wall areas, respectively, and the Main Pit Dump provides further stabilization to the Main Pit South Wall area. Additional monitoring inspection and response requirements for the DSTSF are detailed in the Operations, Maintenance, and Surveillance Manual (OMS) for the facility (Minto Explorations Ltd., 2014).

Category 2 facilities consist of all the remaining waste rock dumps. These waste dumps are located in areas with good foundation conditions that avoid areas underlain by ice-rich overburden.

### 2.4.2 Risk Narrative

A mass failure of one of the waste facilities has the potential to endanger the health and safety of site employees or visitors, or lead to an increase in contaminant loadings from the mine and subsequent adverse effects to aquatic resources in the receiving environment (lower Minto Creek).

### 2.4.3 Specific Indicators, Performance Thresholds and Responses

Indicators, performance thresholds and responses specific to Category 1 and Category 2 Facilities are provided in Table 2-18 and Table 2-19, respectively. The responses are dependent on the phase of closure as indicated in the tables. The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Physical Monitoring Program of the EMSRP (Minto Explorations Ltd., 2016) and the Monitoring and Maintenance section (7.11) of the Minto RCP.

**Table 2-18: Specific Indicators, Performance Thresholds and Responses for Category 1 Facilities**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| • Mass movement indicated by monitoring of geotechnical instrumentation<br>• Visual observations of physical damage<br>• Visual observations of evidence that could suggest mass movement<br>• Occurrence of seismic events | **Specific Threshold 1**<br>• Observation of unusual occurrence including:<br>  • tension cracks, settlement, or sloughing;<br>  • a seismic event that exceeds the 1:475 return period event[2];<br>  • abnormal seepage from any area of the slopes;<br>  • increased turbidity from seepage;<br>  • physical damage. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Follow any recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>  o An increase in the frequency of routine inspections and monitoring.<br>  o Additional inspection, instrumentation, monitoring, or analyses<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 2**<br>• One survey hub or inclinometer reading indicating acceleration of movement greater than the long-term trend and outside range of instrumentation error | **All Stages** | **Notification**<br>• Geotechnical Engineer<br>**Review**<br>• Review existing instrumentation data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results.<br>**Action**<br>• Retake reading.<br>• If the reading was accurate, increase the survey hub or inclinometer frequency.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 3**<br>• For DSTSF and MVFE piezometers 13-DSP-05a, 13-DSP-06, 15-DSP-07, and 15-DSP-08, an increase in pore water pressures such that Ru[3] exceeds 0.4[4].<br>• For MVFE2 piezometer 15-DSP-10, an increase in pore water pressures such that the water elevation is 1 m above the original ground surface.<br>Or<br>• Temperature greater than zero at a depth of 2 m below original ground *(all SWD ground temperature cables, and DSTSF ground temperature cables DST-10, DST-11, and DST-14 only)* | **Active**<br>**Closure** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• If pore water pressure threshold exceeded, increase frequency as directed by the Engineer until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | | **Post Closure I,**<br>**Post Closure II** | **Notification**<br>• Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting |

[2] This size of a seismic event would be felt by most people on site. It would shake buildings, and rattle or break dishes, hanging objects, etc. Earthquake information may also be found online at: http://www.earthquakescanada.nrcan.gc.ca/index-eng.php

[3] Ru is the pore water pressure coefficient which is the ratio of pore water pressure to the overburden pressure. A pore water pressure ratio of 0.5 would be similar to the effect of a groundwater table at surface.

[4] Piezometer 13-DSP-5b exceeded this trigger on April 2015. A review of the data and stability analysis was completed and documented in the 2015 annual geotechnical inspection report (SRK 2015a) and found no stability issue and recommended continued monthly monitoring.

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | | | **Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• If pore water pressure threshold exceeded, increase frequency as directed by the Engineer until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 4**<br>• For DSTSF and MVFE piezometers 13-DSP-05, 13-DSP-06, 15-DSP-07, and 15-DSP-08, an increase in pore water pressures such that Ru exceeds 0.6.<br>• For MVFE2 piezometer 15-DSP-10, an increase in pore water pressures such that the water elevation is 3 m above the original ground surface. | **Active Closure** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Increase pore water pressure monitoring and data review frequency as directed by the Engineer until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses.<br>o Modifications to the waste placement/construction practices.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | | **Post Closure I, Post Closure II** | **Notification**<br>• Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Increase pore water pressure monitoring and data review frequency as directed by the Engineer until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses.<br>o Modifications to the waste placement/construction practices.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 5**<br>• Three consecutive survey hub or inclinometer readings indicating acceleration of movement greater than the long-term trend.<br>Or<br>• Three consecutive survey hub readings indicating a change in horizontal direction of movement greater than 15 degrees from the long term trend. | **Active Closure** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to monitor any future displacement.<br>• Increase monitoring and data review frequency as directed by the Engineer until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring. |

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | | | o Additional inspection, instrumentation, monitoring, or analyses<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | | **Post Closure I, Post Closure II** | **Notification**<br>• Project Manager<br>• Geotechnical Engineer<br>• In Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to monitor any future displacement.<br>• Increase monitoring and data review frequency as directed by the Engineer until determined unnecessary.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately |

**Table 2-19: Specific Indicators, Performance Thresholds and Responses for Category 2 Facilities**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| • Mass movement indicated by monitoring of geotechnical instrumentation<br>• Visual observations of physical damage<br>• Visual observations of evidence that could suggest mass movement<br>• Occurrence of seismic events | **Specific Threshold 1**<br>• Observation of unusual occurrence including:<br>• tension cracks, settlement, or sloughing;<br>• a seismic event that exceeds the 1:475 return period event;<br>• abnormal seepage from any area of the slopes;<br>• increased turbidity from seepage;<br>• physical damage. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Follow any recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 2**<br>• Survey hub cumulative displacements between 150 mm and 500 mm;<br>Or<br>• Increase in pore water pressures such that Ru exceeds 0.2. | **Active Closure** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action** |

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | | | • Inspect the area for any signs of instability.<br>• Immediately Increase monitoring and data review frequency until determined unnecessary:<br>o If survey hub threshold exceeded, increase frequency as directed by the Engineer.<br>o If pore water pressure threshold exceeded, increase frequency as directed by the Engineer.<br>• Follow any additional recommendations of the Geotechnical Engineer.<br>• If the results of the analysis indicates there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | | **Post Closure I, Post Closure II** | **Notification**<br>• Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any signs of instability.<br>• Increase monitoring and data review frequency until determined unnecessary:<br>o If survey hub threshold exceeded, increase frequency as directed by the Engineer.<br>o If pore water pressure threshold exceeded, increase frequency as directed by the Engineer.<br>• Follow any additional recommendations of the Geotechnical Engineer.<br>• If the results of the analysis indicates there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 3**<br>• Survey hub cumulative displacements greater than 500 mm.<br>Or<br>• Increase in pore water pressures such that Ru exceeds 0.4. | **Active Closure** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to allow for a stability assessment to be completed (if required by the Engineer), and to monitor any future displacement.<br>• Increase monitoring and data review frequency until determined unnecessary:<br>o If survey hub threshold exceeded, increase frequency as directed by the Engineer.<br>o If pore water pressure threshold exceeded, increase frequency as directed by the Engineer.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | | **Post Closure I, Post Closure II** | **Notification**<br>• Project Manager<br>• Geotechnical Engineer<br>• Include in annual report<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Complete a ground survey of the area of interest to allow for a stability assessment to be completed (if required by the Engineer), and to monitor any future displacement.<br>• Increase monitoring and data review frequency until determined unnecessary: |

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| | | | o If survey hub threshold exceeded, increase frequency as directed by the Engineer.<br>o If pore water pressure threshold exceeded, increase frequency as directed by the Engineer.<br>• Follow any additional recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of routine inspections and monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses<br>o Modifications to the waste placement/construction practices, including discontinuation of loading.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |

## 2.5 General Reclamation Measures

### 2.5.1 Soil Cover Performance

#### *2.5.1.1 Description*

Soil covers are to be placed over the dry stacked tailings storage facility (DSTSF) and the waste rock storage facilities. 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 High Grade Waste (HGW), the Area 118 Dump, and the Mill Valley Fill (MVF). An infiltration reduction soil cover is to be placed on these features either as part of the progressive reclamation program or during final closure activities. The cover on the HGW is to include a very low infiltration cover system incorporating a geosynthetic membrane. The primary cover functions are to:

- Minimize 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.

The design criteria for the site is described in the Section 2.2 of the preliminary cover design report (SRK 2016). Design details specific to the DSTSF and each of the waste rock storage facilities are provided in Sections 5 thru 10 of the design report.

#### *2.5.1.2 Risk Narrative*

- Covers do not perform as designed resulting in unacceptable water quality conditions downstream of the site.
- Cover on a steeper slope becomes over saturated and slumps.

#### *2.5.1.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to water management are provided below in Table 2-20. The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Post-Closure Geotechnical Monitoring Program.

**Table 2-20: Specific Indicators, Performance Thresholds and Responses for Cover Performance**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| • Visual observations of physical damage<br>• Visual observation of ponding water<br>• Visual observation of surface erosion | **Specific Threshold 1**<br>• Observation of unusual occurrence including:<br>  • settlement, or sloughing;<br>  • abnormal seepage from any area of the slopes;<br>  • increased turbidity from seepage;<br>  • isolated pockets of vegetation stress;<br>  • physical damage. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any other signs of instability.<br>• Repair the cover to adhere to design specifications.<br>• Follow any recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>  o An increase in the frequency of routine inspections and monitoring.<br>  o Additional inspection, instrumentation, monitoring, or analyses.<br>• If the results of the analysis indicates there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |
| | **Specific Threshold 2**<br>• Erosion of cover;<br>• Large scale vegetation stress | **All Stages** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports, existing instrumentation including piezometer, temperature, inclinometer, and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability.<br>**Action**<br>• Inspect the area for any signs of instability.<br>• Immediately increase monitoring and data review frequency as directed by the Engineer until determined unnecessary.<br>• Follow recommendations of the Geotechnical Engineer to repair the cover.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |

### 2.5.2 Minto North Pit Water Level

#### *2.5.2.1 Description*

At closure, the Minto North Pit will be allowed to flood. Groundwater observations and preliminary water balance monitoring under most scenarios indicate the pit is not likely to fill to the point where it would spill. Monitoring of pit water levels have been included in the post-closure monitoring Program, in Section 7.11, Table 7-1. The water balance model will be reviewed and updated annually during the post closure, and should the water level in the pit be projected to overflow, an engineered spillway may be required to control outflow from the pit and mitigate erosion.

#### *2.5.2.2 Risk Narrative*

- Water levels rise higher than predicted by the site water balance model and overtop the pit resulting in erosion of surficial materials at the spill location and unacceptable water quality conditions downstream of the site.

#### *2.5.2.3 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to water management are provided below in Table 2-21. The monitoring results that are evaluated and utilized for this component of the AMP are included in Section 7.11 of the RCP.

**Table 2-21: Specific Indicators, Performance Thresholds and Responses for Minto North Pit Water Level**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| Updated water balance model indicates pit will overtop | **Specific Threshold 1**<br>• Updated water balance model indicates Minto North Pit overtop within 10 years. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review water balance inputs and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of the need for spillway design considerations.<br>**Action**<br>• Develop spillway design.<br>• Follow any recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses. |
| | **Specific Threshold 2**<br>• Updated water balance model indicates Minto North Pit overtop within 3 years. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Geotechnical Engineer<br>• SFN and YG<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review water balance inputs and survey data.<br>**Evaluation**<br>• Geotechnical Engineer to compare recent monitoring results against older results for additional evidence of instability for subsequent design modifications.<br>**Action**<br>• Develop spillway design (if not already completed).<br>• Construct the spillway within the three-year period (or implement plan to manage water to prevent uncontrolled release from the pit).<br>• Follow any recommendations of the Geotechnical Engineer. At a minimum, the Engineer will consider the need for:<br>o An increase in the frequency of monitoring.<br>o Additional inspection, instrumentation, monitoring, or analyses. |

### 2.5.3 Revegetation

The primary objective is the minimization of erosion (and corresponding sediment delivery) from sloped cover areas. Revegetation treatments at Minto are designed to achieve restoration and land-use objectives, while achieving the protection objective of maintaining surficial substrate stability and erosion control where necessary.

#### *2.5.3.1 Risk Narrative*

- Vegetation does not establish fast enough to prevent rill erosions on covers
- Deep rooted vegetation not established before a forest fire.

#### *2.5.3.2 Specific Indicators, Performance Thresholds and Responses*

Indicators, performance thresholds and responses specific to water management are provided below in Table 2-22. The monitoring results that are evaluated and utilized for this component of the AMP are a requirement of the Monitoring and Maintenance program of this RCP.

**Table 2-22: Specific Indicators, Performance Thresholds and Responses for Vegetation Performance**

| Specific Indicators | Specific Performance Thresholds | Stage | Specific Responses |
|---|---|---|---|
| • Visual observations of failure of vegetation to establish<br>• Visual observation of failure of native species to establish.<br>• Visual observation of stressed vegetation. | **Specific Threshold 1**<br>• Observation of isolated pockets of stressed vegetation. | **All Stages** | **Notification**<br>• Mine/Project Manager<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports.<br>**Evaluation**<br>• Compare recent monitoring results against older results for additional evidence of vegetation stress.<br>• Evaluate cover integrity.<br>**Action**<br>• Follow any recommendations of a qualified professional to determine if a reapplication of seeds and fertilizer is required.<br>• Repair covers as recommended by a Geotechnical Engineer |
| | **Specific Threshold 2**<br>• Large scale stressed vegetation.<br>• Failure of vegetation to establish in erosion-control areas. | **All Stages** | **Notification**<br>• Mine Manager<br>• Geotechnical Engineer<br>• Include in scheduled WUL reporting<br>**Review**<br>• Review previous inspection reports and precipitation data.<br>**Evaluation**<br>• Compare recent monitoring results against older results for additional evidence of vegetation stress.<br>• Evaluate cover integrity<br>**Action**<br>• Inspect the area for any signs of a source of contamination.<br>• Immediately increase monitoring and data review frequency as directed by a qualified professional until determined unnecessary.<br>• Follow recommendations of a qualified professional to restore vegetation to the area.<br>• Repair covers as recommended by a Geotechnical Engineer.<br>• If the results of the analysis indicate there is a stability concern, the mine inspector and Selkirk First Nation will be notified immediately. |

# 3 Reporting and Review

Reporting and review represent an essential part of the Adaptive Management Framework, as described in section 1.3.2, and reporting on adaptive management is included in the notification component of all specific responses described in section 2.

## 3.1 Monthly and Annual Reporting

Monthly reports are required to be submitted to the Yukon Water Board under Water Licence QZ14-031, and annual reports are required for submission under both the Water Licence and the Quartz Mining License. Both licenses require reporting on adaptive management.

Monthly reporting includes all activities carried out under the Adaptive Management Plan and will be continued throughout active closure but will reduce frequency to annually for PCI and PCII.

Annual reporting will include summaries of all activities carried out under the Closure Adaptive Management Plan, including monitoring results compared to thresholds and any actions taken.

## 3.2 Annual Review

The AMP may be modified when unexpected circumstances are encountered and the protocol is implemented or when additional understanding becomes available. An annual review of the AMP will take place prior to annual reporting, and Annual Reports will include a summary of proposed updates and revisions to the Adaptive Management Plan and include a revised Adaptive Management Plan, if warranted.

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# Minto Mine Closure Cost Estimate – RCP Revision 2018-01

**Prepared for**

Minto Explorations Ltd.



**Prepared by**

SRK Consulting (Canada) Inc.
1CM002.045
February 2018

# Minto Mine Closure Cost Estimate – RCP Revision 2018-01

February 2018


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# Appendices

Appendix A – Basis and Validation of Labour and Equipment Rates
Appendix B – Cost Estimate Worksheets

# 1 Introduction

## 1.1 General

This document presents the estimates for reclamation and closure liability based on the Minto Mine Reclamation Closure Plan, revision 2018-01. The estimates have been prepared in accordance with the costing guidance from YG EMR in the document Reclamation and Closure Planning for Quartz Mining Projects: Plan Requirements and Closure Costing Guidance (YG, 2013).

The report describes the basis of the estimate and the major costing assumptions. This document should be read in conjunction with the entire RCP, which provides details on the level of engineering for each cost component, as well as the cost estimate spreadsheet provided in Appendix B, which provides a complete costing details and assumptions.

## 1.2 Scope of Estimate

YG (2013) guidance document requires liability estimates for three separate conditions:

- Current status (i.e. Year 0);
- Peak Liability within the two-year period for this the RCP approval will apply; and,
- End-of-mine (EOM) Life.

For the Minto Mine, the peak liability is expected to occur in 2019 following mining of the Ridgetop North and Ridgetop South Open Pits. The Year 0 liability estimate assumes that mining at the Area 2 Stage 3 Pit is complete, and that mining of the Ridgetop North and South has yet to begin. The end-of-mine life closure liability occurs following completion of all open pit and underground mining, as well as the milling of all ore stockpiles by the end of 2021.

Closure implementation is estimated to take 3 years for each liability estimate with construction occurring between April and September. The site is estimated to be accessed by air during the spring, and by barge following spring break-up. Two years of interim care and maintenance is assumed to be required after mining ceases and prior to implementation of the final closure plan for the Year 0 and Peak liability estimates. These costs are not included in the EOM estimate as the closure plan would be finalized at the end-of-mining.

As noted in Section 8 of the RCP, the Post-Closure I and Post-Closure II periods have durations of 5 years and 10 years, respectively. During Post-Closure I, site access is maintained by air during the spring, and by barge following spring break-up. During Post-Closure II, site maintenance is assumed to be required every 5 years with the site accessed by barge and work completed in one month. Site access for monitoring events and geotechnical inspections when no barge is in place are assumed to be completed by helicopter. During Post-Closure II, the geotechnical inspection completed by helicopter will also be used to determine the maintenance requirements to be completed during the next summer.

Costs have also been allocated for on-going site maintenance past the Post-Closure II period into perpetuity. Routine site inspections and maintenance were assumed to be completed every 10 years, with access to the site established by barge. During these 10 year maintenance events, costs were allocated for passive treatment maintenance, site grading, as well as maintenance of the access road (including Big Creek Bridge).

# 2 Unit Rates

## 2.1 Equipment Rates

The equipment rates used in the Minto cost estimate are based on 2017-18 BC Blue Book equipment rates[1]. The BC Blue Book rates are determined by the BC Ministry of Transportation based on recommendations from the BC Road Builders and Heavy Construction Association, and is validated from its own research and calculations. The BC Blue book publishes 'all-found rates' with includes all ownership and operating costs that consist of the following:

- Ownership: financing costs and depreciation
- Maintenance: repair, lube, wear items, and tire costs
- Operator costs: wages including benefits and overhead
- Equipment overhead and profit.

The BC Blue Book also publishes 'all-found less operator' rates that exclude operator costs.

As many of the above items are site-specific and are included in other portions of the cost estimate (labour, overhead, profit, fuel), these costs are removed from the "all-found" rate to obtain the base ownership and maintenance (O&M) hourly rates to avoid double-accounting of costs. The BC Rates were selected for use as a basis in the cost estimate as the methodology to obtain the base O&M rate from the published 'all-found' hourly rates is known, and use of the O&M rates in the cost estimate allows for site-specific mark-ups to be applied in a clear and transparent way. The details of the calculation details and mark-ups applied are provided in Section 3.2.

Use of the O&M rates in the cost estimate is a robust methodology to develop the overall project costs as the cost of ownership and maintenance is not expected to vary significantly between project locations, and allows for the site-specific project mark-ups to be costed based on the expected execution of the actual project.

The BC Blue Book 'all-found less operator' unit rates were broken down to obtain the base ownership and maintenance costs for each piece of equipment as follows:

- 20% profit and overhead was removed. This percentage mark-up was obtained from communications with the BC Road Builders and Heavy Construction Association.

[1] B.C. Road Builders and Heavy Construction Association.

- Fuel was removed based on a $0.94/L and based on fuel consumption rates obtained from the Caterpillar Performance Handbook. The fuel rate to remove was obtained from the BC Ministry of Transportation website.

A site-specific fuel operating cost was then added back to the equipment rates based on a delivered diesel fuel cost of $0.96/L was assumed based on the average on-site cost. The equipment costs are further marked-up in the project indirect costs where contractor profit (10%), contract administration (5%), bonding (3%), insurance (1.5%) are applied, resulting in a further mark-up of 19.5%.

Appendix A provides a comparison of the BC Blue Book rates to rates listed in the Yukon Government Equipment Rental Rates Guidebook. This comparison and review of equipment rates was completed in 2017 as a result of review comments of the 2016 Minto Mine Closure Cost Estimate (RCP 2016-01) received from the Yukon Government Department of Energy, Mines and Resources. The results of the comparison recommended that the equipment rate basis presented in this section continue to be used as there is a valid basis to the derived 'ownership and maintenance' equipment costs, and the site-specific build-up of the fuel and indirect costs results in an overall project cost that is representative to the execution of the Reclamation and Closure Plan.

## 2.2 Labour Rates

Labour rates for a third-party contractor were built up from base hourly rates presented in the Yukon Government Fair Wage Schedule effective April 1, 2017. The resulting rates were compared and validated with actual on-site base wages, and wages published by InfoMine (2017) for another mine site in the Yukon Territory. Details of the comparison are provided in Appendix A.

Workers were assumed to work a '3 weeks in, 2 weeks out' schedule, working 12 hour days while on site. The base wages were adjusted to account for: travel, overtime, vacation, statutory holidays, and other benefits as follows:

- **Travel Time:** Workers were compensated for travel time at the start and end of each rotation. Staff were assumed to originate either from Pelly Crossing or Whitehorse, and were compensated either 2.5 or 4 hours, respectively, for each trip between home origin and the site.
- **Overtime:** Each hour worked in addition to a standard 40 hour work week was compensated at a rate 1.5 times the base hourly wage.
- **Vacation**: Workers were compensated a pro-rated amount of 80 hours of pay over each year worked.
- **Statutory Holidays**: Workers were compensated a pro-rated amount of 88 hours of pay over each year worked.

- **Employment Insurance (EI)**: EI was added at a rate of 1.6% of base earnings up to the maximum insurable earning of $51,300 as per Canadian Revenue Agency guidance.[2]
- **Canada Pension Plan (CPP):** CPP contributions were added at a rate of 4.95% of base earnings up to the CPP salary limit of $55,300.[3]
- **Worker's compensation**: Added for all workers at a rate prescribed by the Yukon Workers' Compensation Health and Safety Board (YWC) that varied depending on the worker's group assessment rate as determined by YWC. Rates varied from 1.42% for camp support staff to 4.79% for equipment operators.[4]
- A small tool allowance was added at $250 per year for trades workers based on InfoMine (2017) for a British Columbian mine site.

The labour rates do not include costs of camp accommodation or flights that are included elsewhere in the cost estimate indirect costs. In addition, labour rates do not include MSP, as the Yukon Territory has no employer or employee premiums or payroll taxes for health care.

Including all benefits paid by the third-party contractor, the 'loaded' labour rates are generally 45 to 60% higher than the base hourly wage depending on the labour category.

## 2.3 Material Rates

Primary material rates used in the estimate consisted of: revegetation materials, fuel, and geosynthetic materials. The revegetation, fuel, and geotextile costs were provided by supplier quotes. The remaining material costs were obtained using RSMeans Online – a cost database service that provides up-to-date construction cost data. Material costs used were factored by RSMeans to be based in Whitehorse, and were further adjusted by 15% to account for shipping to Minto.

# 3 Basis of Estimate – Closure

## 3.1 Direct Costs

Direct costs were estimated based on the construction fleet and productivities assigned to each task. Determination of the construction fleet and productivities were obtained based on first principals, from experience on similar projects, or from the RS Means Online cost database. Earthmoving unit rates were based on calculated productivities that followed standard methods, as used by earthwork contractors. The calculations make use of equipment specifications obtained from manufacturer's data, in this case the Caterpillar Handbook.

Table 1 provides a summary of the major direct cost quantity sources and assumptions. Further details are provided in the cost estimate worksheets provided in Appendix B.

[2] http://www.cra-arc.gc.ca/tx/bsnss/tpcs/pyrll/clcltng/ei/cnt-chrt-pf-eng.html
[3] http://www.cra-arc.gc.ca/tx/bsnss/tpcs/pyrll/clcltng/cpp-rpc/cnt-chrt-pf-eng.html
[4] http://www.wcb.yk.ca/QuestionResults/Assessments/Rates/Q0269.aspx

**Table 1: Direct Cost Inputs and Costing Assumptions**

| Area | Inputs and Assumptions |
|---|---|
| Waste Dumps | • Waste rock dump and ore stockpile dimensions were obtained from AutoCAD drawings of the September 2017 site topography with dimensions for waste dump facilities currently under construction estimated based on design drawings.<br>• The dump slopes were assumed to be regraded to be flatter than 3H:1V and flat areas were assumed to be regraded to form tertiary drainage catchments with a minimum 2% grade.<br>• The SWD high grade waste stockpile was assumed to be relocated to the Main Pit and placed below the expected long-term water elevation of 786 m. The remaining stockpile volume was provided by Minto on December 31, 2017.<br>• The waste rock covers were assumed to be entirely sourced from the Reclamation Overburden Dump. |
| Overburden Dumps | • Dump dimensions were obtained from AutoCAD drawings of the September 2017 site topography.<br>• The dump slopes were assumed to be regraded to be flatter than 3H:1V and flat areas were assumed to be regraded to form tertiary drainage catchments with a minimum 2% grade. |
| Ore Stockpiles | • The remaining stockpile volumes near the mill and the Main Waste Dump were provided by Minto on December 31, 2017. They are assumed to be relocated into the Main Pit, along with the upper two meters of the ore pads.<br>• Stockpile pad dimensions were obtained from AutoCAD drawings of the September 2017 site topography. |
| Open Pits | • Earthen safety berms are assumed to be placed around the pit high walls, with large boulders placed near pit access points and warning signs placed at key locations around the perimeter.<br>• Perimeter lengths were obtained from the latest site topography for completed pits, or design drawings for pits currently under construction, or yet to be mined. |
| Underground Openings | • A backfill plug is assumed to placed at all portals with backfill material sourced from near-by waste rock. The areas near the portal is assumed to be backfilled and recontoured.<br>• All vent raises are assumed to be sealed with a reinforced concrete cap with a vent raise pipe, and covered with fill. |
| External Tailings Facilities | • Dimensions of the DSTSF were obtained from AutoCAD drawings of the September 2017 site topography. |
| Roads | • Road dimensions were obtained from the 2017 site topography and aerial photos. Roads no longer required following closure are assumed to be scarified and revegetated.<br>• The main site access road is assumed to be maintained for long-term site access. |

| Area | Inputs and Assumptions |
|---|---|
| Demolition | • Building dimensions were obtained from site drawings for all major structures, and were estimated based on site photos for minor structures where drawings were not available.<br>• All equipment was assumed to be dismantled and removed from site. Equipment lists were provided by Minto in 'Issued-for-Construction' Drawings, or based on the Hatch 2006 feasibility study equipment list.<br>• Demolition debris was assumed to be disposed in the on-site landfill located near the airstrip, with all hazardous material, recyclables, and re-useable equipment removed an appropriate off-site facility. |
| Site infrastructure | • Pipeline and power line lengths and details were provided by Minto in AutoCAD format.<br>• The pipelines were assumed to be disposed on-site, with the power lines and power poles disposed off-site once no longer needed. |
| Water Detention Structures | • The water storage dam volumes were obtained from dam as-built drawings. The dam material is assumed to be partially utilized as construction material for the wetland system upstream of the dam. |
| Yards | • Yard areas were obtained from AutoCAD drawings and aerial photography. The yard boundaries are provided in Figure 9-1. |
| Waste Disposal | • Hydrocarbon contaminated soils were assumed to be hauled to the on-site landfill located at the airstrip, with the landfarm operated for a period of three years.<br>• Areas of hydrocarbon contaminated soils were assumed to be present near fuelling storage and mechanic working areas, with an average contamination depth of 1.0 m. |
| Surface water conveyance | • Excavation volumes, channel lengths, alignments, and other quantities for the primary catchment channels were obtained from AutoCAD drawings.<br>• The secondary catchment quantities were calculated based on the typical section provided in Section 7 of the RCP, with an allowance of 40 m of secondary channel lengths per hectare of dump. |
| Water Treatment | • Fill used to construct the wetland cells was assumed to be sourced from the Water Storage Pond Dam.<br>• The wetland cells are assumed to be lined with HDPE with organics assumed to be produced using a power mulcher form vegetation cleared from the water storage pond footprint.<br>• The passive treatment system is assumed to be constructed in Year 3 of closure with the first year of operation in Year 1 of post-closure.<br>• The active treatment system is assumed to be decommissioned and removed from site at the end of Post-Closure 2. |

## 3.2 Indirect Costs

Indirect costs during the closure implementation include costs for mobilization-demobilization, site transport costs, site and road maintenance, construction support, project management, and quality assurance. A summary of the major indirect assumptions is provided in Table 2. Further

details regarding assumptions and cost sources are provided in the cost estimate worksheets in Appendix B.

**Table 2: Indirect Cost Inputs and Costing Assumptions**

| Area | Inputs and Assumptions |
|---|---|
| Mobilization | • The assumed closure equipment fleet is listed in Worksheet 24 in Appendix B. Each piece of equipment is likely not required throughout the entire closure period, however, for the purposes of the estimate, the entire fleet was assumed to be mobilized in Year 1 of closure, with most equipment demobilized from site at the end of Year 3.<br>• A small site maintenance fleet was assumed to remain on site to allow for earthwork repairs and passive treatment maintenance during the post-closure period. The storage location of the equipment has yet to be finalized, but is expected to consist of an existing site warehouse.<br>• All equipment was assumed to be mobilized from Whitehorse. |
| Site Transport | • Site transport costs include barge and bus operations, as well as air transport and airstrip operations during periods where the barge is not in service. |
| Road and Site Maintenance | • A water truck and grader were both assumed to be required 150 hours per month.<br>• An allowance of 7 km of silt fencing and 1 ha of erosion control matting was assumed for erosion protection prior to vegetation begin established. |
| Construction Support | • Field support staff, vehicles, and support equipment were estimated based on past project experience on projects of similar size.<br>• The existing camp and office facilities are assumed to be used by the closure contractor.<br>• Camp cost man-days were estimate based on a sum of the calculated man-hours required for closure implementation.<br>• Camp costs including power and heat were provided by Minto. |
| QA, Project Management | • Project management and QA during implementation includes costs for staffing to provide on-site management of the contractor to ensure the project is implemented as per the closure plan. |
| Indirect Percentage Add-on Costs | • Additional indirect add-ons included the following:<br>o Contingency = 12%<br>o Worker's Compensation = 0% (included in labour rates)<br>o Insurance = 2% of labour costs (equipment insurance included in equipment rates).<br>o Bonding = 3% of project implementation and care and maintenance costs.<br>o Contractor profit = 10%<br>o Contract administration = 5% |

## 3.3 Contingency

As noted in Table 2, contingency is added to all costs at a rate of 12%. In Worksheet 1 (Cost Summary), the implementation cost contingency is applied to the direct costs (A01 through A14), interim monitoring and care and maintenance, and Indirect Costs (B1 through B5). The closure cost contingency is applied to the direct cost items 1 to 7 in Worksheet 1. Contingency is also

distributed in the cost schedules and subjected to inflation and net present value calculations as detailed in Section 6.

The contingency value was selected based on a review of the site uncertainty and available published reclamation guidance. The contingency value was lowered from 15% to 12% in the 2016 version of the RCP because of advancement in the engineering design (i.e. landform design, wetland treatment, and conveyance channels) and reduction in the performance uncertainty related to the DSTSF and Mill Valley Fill Extension Stage 2. RECLAIM guidance recommends a contingency of 10% for definitive or construction level drawings, and 15% for preliminary or budget level drawings (GNWT 2017). The level of engineering for the Minto closure is believed to be between these two values. 12% was selected because the engineering design has already adopted generally conservative assumptions where uncertainty remains.

# 4 Basis of Estimate – Post Closure and C&M Costs

The following section describes the costs allocated for care and maintenance of the site for all phases of closure. Further details of the costs for each closure phase are provided in Worksheets 3, 8 and 13 for the Year 0, Peak, and EOM liability estimates, respectively, in Appendix B.

## 4.1 Water Treatment

Active treatment operational costs are based on on-site costs for 2015. Based on a review of water treatment costs from 2013 through 2016, 2015 was found to best represent typical conditions in terms of days operating per year and operating costs. The 2015 costs were updated to 2018 dollars based on an inflation factor of 1.03 obtained from the Bank of Canada inflation calculator. The active treatment system is assumed to be operated through Active Closure and Post-Closure I. Costs for capital replacement and maintenance of the active treatment system are included through to the end of the Post-Closure II period, after which the system is assumed to be dismantled and removed from site.

The passive treatment wetlands are assumed to start operations in Year 1 of post-closure. Allocated costs for operation and maintenance of the system includes costs for staffing and oversight of the system, an allowance for replacement of the organic media, as well as for carbon source injections.

## 4.2 Reclamation and Site Maintenance

Reclamation and site maintenance costs include allowances for equipment maintenance, road maintenance, repair of earthworks including site grading, cover and revegetation repair.

## 4.3 Site Management

Costs are included for the management of the site and care and maintenance activities, as well as camp operation.

## 4.4 Transport Costs

Transport costs include staffing transport between site and Whitehorse, as well as barge operations and mobilization-demobilization. Barge costs are based on Minto's operational site costs and assumed to be operated 20 hrs per week.

## 4.5 Post-Closure Indirect Costs

Post-closure indirect costs include the same percentage add-on costs as used during closure. These costs include: contingency (12%), insurance, bonding, contractor profit, and contract administration.

# 5 Closure Planning, Engineering, Permitting, and Monitoring

Planning, permitting and engineering cost details are provided in Worksheets 6, 11, and 16 for the Year 0, Peak, and EOM liability estimates, respectably.

Planning and permitting costs are included for the Year 0 and Peak liability estimates, and are assumed to be included during operations in the End-of-Mine Scenario. Planning and permitting costs include: reclamation research and planning, and allowance for additional technical studies, monitoring and management plans, and permitting staffing and meetings.

Engineering, Design, and Construction plans are calculated as 5% of the direct implementation costs. Costs for engineering oversight during construction is included in the indirect costs during implementation (i.e. on Worksheets 4, 9, and 14).

Monitoring of the site was costed according to the monitoring schedule presented in Section 7 of the RCP. Monitoring costing details are provided in Worksheet 25 in Appendix B.

# 6 Inflation and Net Present Value Analysis

Inflation and net present value (NPV) calculations are presented in Worksheets 2, 7, and 12 of Appendix B for the Year 0, Peak, and EOM liability estimates respectively. The tables include the cost schedule and undiscounted cash flow starting in 2018 through post-closure year 105 (100 years after Post-Closure 1). As required by YG (2013a), inflation has been applied to the period of active implementation, while NPV discount rates were applied to post-closure monitoring and maintenance costs. The NPV calculations include annual cash flows to perpetuity (modeled as 105 years after decommissioning and reclamation).

Inflation has been applied at a rate of 1.6%, which corresponds to the average annual rate of inflation for the past ten years.

As per Yukon Mine Site Reclamation and Closure Policy Financial Guidelines (YG 2013b), the discount rate used in NPV calculation are to be the most recent Government of Canada benchmark bond yields as published by the Bank of Canada, with the bond term selected to be

the longest term published that does not exceed the expected duration of the post-closure reclamation, monitoring and maintenance program. For the Minto site, this corresponds to a bond term of ten years, which as of February 2018, this corresponds to a bond yield of 2.35%. Given the historically low yield, a variable discount rate has been selected for the NPV calculations. The NPV calculations apply a discount rate of 2.35% for the first two years, 2.5% for the next 3 years, and 2.8% thereafter. The 2.8% corresponds to the average yield since 2005.

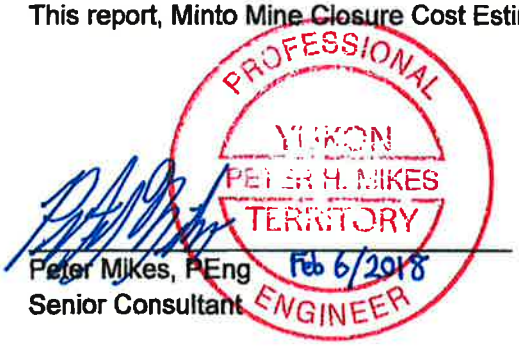
# 7 Cost Summary

Table 3 summarizes the reclamation and closure liability for the Year 0, Peak, and End-of-Mine scenarios. The costs are presented in 2018 Canadian Dollars.

**Table 3: Reclamation and Closure Liability Cost Summary**

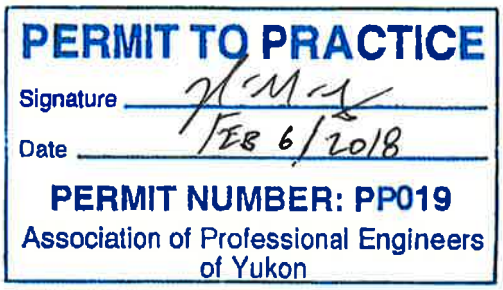
| Description of Cost | Year 0 | Peak | EOM |
|---|---|---|---|
| Closure Implementation | | | |
| Direct Costs | $17,044,478 | $19,431,701 | $16,987,765 |
| Care & Maintenance Costs to the end of implementation | $10,152,363 | $10,271,725 | $3,910,414 |
| Indirect Costs | $18,869,092 | $20,172,562 | $17,445,555 |
| *Cost Inflation* | *$2,352,313* | *$3,724,678* | *$3,997,740* |
| Sub-total - Implementation Costs | $48,418,245 | $53,600,666 | $42,341,475 |
| Post-Closure NPV | $13,777,523 | $13,096,047 | $12,621,082 |
| **TOTAL FINANCIAL SECURITY** | **$62,195,768** | **$66,696,713** | **$62,701,817** |

This report, Minto Mine Closure Cost Estimate – RCP Revision 2018-01, was prepared by




Peter Mikes, PEng
Senior Consultant

Feb 6/2018




and reviewed by

Dylan MacGregor, 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.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

# 8 References

B.C. Road Builders and Heavy Construction Association, 2017. 2017-18 Equipment Rental Rate Guide. Published July.

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InfoMine Inc. (2017). CostMine Mining Cost Service, October.

[YG] Government of Yukon, Energy Mines and Resources, 2013a. Reclamation and Closure Planning for Quartz Mining Projects: Plan Requirements and Closure Costing Guidance. August.

[YG] Government of Yukon, Energy Mines and Resources, 2013b. Yukon Mine Site and Reclamation Closure Policy, Financial and Technical Guidelines September.

[YG] Government of Yukon, Department of Community Services, 2017. Fair Wage Schedule, effective April 1, 2017. Accessed at http://www.community.gov.yk.ca/fairwage.html on January 27, 2018.

# Appendix A – Basis and Validation of Labour and Equipment Rates

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**F: +1.604.687.5532**
vancouver@srk.com
www.srk.com

# Memo

| | | | |
|---|---|---|---|
| **To:** | Ryan Herbert | **Client:** | Minto Explorations Ltd. |
| **From:** | Peter Mikes, PEng. | **Project No:** | 1CM002.045 |
| **Cc:** | Dylan MacGregor, SRK | **Date:** | January 27, 2018 |
| **Subject:** | Basis and Validation of Labour and Equipment Unit Rates used in the Minto Mine Closure Cost Model | | |

# 1 Introduction

Minto Mine's Reclamation and Closure Plan (RCP) Revision 2016-01 and closure cost estimate was submitted to the Yukon Water Board (YWB) in August 2016. Following a review of the RCP Revision 2016-01 closure cost estimate and memorandum by SteveJan Consultants Inc. (SJCI) on behalf of the Yukon Government Department of Energy, Mines and Resources, additional details on the basis and calculation of the labour and equipment rates were requested.

Additional basis for the rates and calculation details have been provided within the main body of this report. This memorandum provides a validation of the labour and equipment rates used in the 2016 cost estimate that have continued to be basis for the estimate for Revision 2018-01 of the RCP.

# 2 Labour Rates

## 2.1 Basis and Validation

Labour rates for a third-party contractor were built up from base hourly rates presented in the Yukon Government Fair Wage Schedule effective April 1, 2016. The Fair Wage Schedule was compared and validated with two sources: actual contractor base wages paid at site[1], and from a mine wage benefit survey published by InfoMine (2016)[2] for a "Tungsten mine located in the Yukon Territory"[3]. All three sources resulted in similar base hourly wages. As an example for the two published sources: InfoMine (2016) lists hourly base wages of $19.20 and $22.15 for entry-level and semi-skilled labourers, and $28.20 for a heavy equipment operators. The Yukon Fair Wage Schedule lists slightly higher hourly base wages of $23.19 for labourers, and $28.81 for heavy equipment operators. The Yukon Fair Wage Schedule was therefore deemed to be appropriate for use in the closure cost estimate.

[1] Personal Communication with Minto Mine Manager on May 23, 2017.
[2] InfoMine (2016), CostMine Mining Cost Service, Section LA Labour – Canada 2016.
[3] As there are no Tungsten Mines in YT, it is likely that the InfoMine reference is the Cantung Mine in NWT.

# 3 Equipment Rates

## 3.1 Basis

The equipment rates used in the Minto cost estimate are based on BC Blue Book equipment rates[4]. The BC Blue Book rates are determined by the BC Ministry of Transportation based on recommendations from the BC Road Builders and Heavy Construction Association, and is validated from its own research and calculations. The BC Blue book publishes 'all-found rates' with includes all ownership and operating costs that consists of the following:

- Ownership: financing costs and depreciation
- Maintenance: repair, lube, wear items, and tire costs
- Operator costs: wages including benefits and overhead
- Equipment overhead and profit.

The BC Blue Book also publishes 'all-found less operator' rates that exclude operator costs.

As many of the above items are site-specific and are included in other portions of the cost estimate (labour, overhead, profit, fuel), these costs are removed from the "all-found" rate to obtain the base ownership and maintenance (O&M) hourly rates to avoid double-accounting of costs. The BC Rates were selected for use as a basis in the cost estimate as the methodology to obtain the base O&M rate from the published 'all-found' hourly rates is known, and use of the O&M rates in the cost estimate allows for site-specific mark-ups to be applied in a clear and transparent way. The details of the calculation details and mark-ups applied are provided in Section 3.2.

Use of the O&M rates in the cost estimate is a more robust methodology to develop the overall project costs as the cost of ownership and maintenance would not be expected to vary significantly between project locations, and it allows for the site-specific project mark-ups to be costed based on the expected execution of the project.

## 3.2 Comparison with Yukon Guidebook Rates

Table 1 provides a comparison of the 'wet' (all-found) rates from the Yukon Guidebook compared to BC Blue Book rates for common equipment used in the closure cost estimate. For each type of equipment, Table 1 includes the number of unique pieces of equipment available in the Yukon Guidebook

Rates in Yukon Guidebook are highly variable and the basis for the rates are unknown. The Yukon Guidebook is prepared by the YG Department of Highways and Public Works and is understood to be compiled through a voluntary survey of contractors throughout the Territory. The Yukon Guidebook is understood to generally be used for smaller highways projects that are

[4] B.C. Road Builders and Heavy Construction Association.

not procured through a competitive public bidding process. In addition, there is no validation of the rates to determine the 'fair rate value' as is completed for the BC Blue Book rates.

Due to the variability in the costs, the Yukon Guidebook is not considered to be a valid source to determine the true O&M costs as the basis for the profit, overhead, and operator costs are unknown. The rates provided through the survey could be substantially different than what would be provided through a competitive bid process, or through any sort of negotiation. In addition, there are no listings for many of the larger pieces of equipment.

**Table 1: Comparison between BC Blue Book and YG Equipment Rental Rates Guidebook Rates**

| | BC Blue Book 2015-16 | YG Equipment Rental Rates 2016 | | | | Percentage difference between average YG and BC Rate |
|---|---|---|---|---|---|---|
| Equipment | All Found Rate ($/hr) | # of Listings | Minimum | Average | Maximum | |
| Dozer - CAT D8 | $261.00 | 13 | $200.00 | $325.00 | $455.00 | 25% |
| Dozer - CAT D10 | $382.00 | 0 | | | | |
| Excavator CAT 330 | $200.00 | 5 | $280.00 | $295.00 | $330.00 | 48% |
| Excavator CAT 385 | $355.85 | 0 | | | | |
| Grader - 16M | $173.00 | 4 | $165.00 | $206.00 | $310.00 | 19% |
| Truck - CAT 735 | $180.00 | 1 | $250.00 | $250.00 | | 39% |
| Truck - CAT 777 | $331.00 | 0 | | | | |
| Loader - CAT 950 | $151.00 | 6 | $160.00 | $180.00 | $215.00 | 19% |
| | | | | | **Average difference:** | **30%** |

The average rate listed in the Yukon Guidebook is approximately 30% higher than rates listed in the BC Bluebook and the average of the minimum rates listed in the Yukon Guidebook is approximately 10% higher than the BC Bluebook. However, this comparison does not consider the additional indirect costs included in the Minto cost estimate that would typically be factored into equipment rates on a typical large earthworks project. Examples of these indirect costs include:

- Road maintenance that consists of a grader and a water truck
- Field support staff including a foreman, mechanic, surveyor, medic/H&S supervisor
- Field support vehicles, including pick-up trucks, fuel truck, mechanic service vehicle ETV, and a passenger bus for transporting workers to and from their work locations at the start and end of each shift
- Field support equipment including: lighting towers, management plans, office overhead (supplies, communications, office administration, office power and heat).
- Insurance (1.5%)

- Bonding (3%)
- Contractor Profit (10%)
- Contract Administration (5%)

If these indirect costs were to be factored into the equipment rates, the resulting equipment rates used in the Minto cost estimate would be higher than those listed in the Yukon Guidebook.

On completion of this review and comparison to the Yukon Guidebook equipment rates, we recommend that Minto maintain the approach to costing of equipment rates as there is a valid basis to the derived 'ownership and maintenance' equipment costs, and the site-specific build-up of the fuel and indirect costs results in an overall project cost that is representative to the execution of the Reclamation and Closure Plan.

# Appendix B – Cost Estimate Worksheets

# Table of Contents

Project: Minto Mine Closure Cost Estimate - RCP 2018-01
Project No.: 1CM002.045
Client: Minto Explorations Ltd.
Date: February 6, 2018
File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

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| Worksheet # | Title | Worksheet Name |
|---|---|---|
| 1 | Cost Summary | 01-Summary |
| 2 | Year 0 Estimate - Cashflow Calculations | 02-Yr0NPV |
| 3 | Year 0 Estimate - Annual C&M costs | 03-Yr0CCM |
| 4 | Year 0 Estimate - Implementation Costs | 04-Yr0Active |
| 5 | Year 0 Estimate - Schedule Details | 05-Yr0Sched |
| 6 | Year 0 Estimate - Planning and Permitting | 06-Yr0Planning |
| 7 | Peak Liability Estimate - Cashflow Calculations | 07-PeakNPV |
| 8 | Peak Liability Estimate - Annual C&M costs | 08-PeakCCM |
| 9 | Peak Liability Estimate - Implementation Costs | 09-PeakActive |
| 10 | Peak Liability Estimate - Schedule Details | 10-PeakSched |
| 11 | Peak Liability Estimate - Planning and Permitting | 11-PeakPlanning |
| 12 | End-of-Mine Liability Estimate - Cashflow Calculations | 12-EOMNPV |
| 13 | End-of-Mine Liability Estimate - Annual C&M costs | 08-EOMCCM |
| 14 | End-of-Mine Liability Estimate - Implementation Costs | 14-EOMActive |
| 15 | End-of-Mine Liability Estimate - Schedule Details | 15-EOMSched |
| 16 | End-of-Mine Liability Estimate - Planning and Permitting | 16-EOMPlanning |
| 17 | Labour Rate Calculations | 17-LaborRate |
| 18 | Equipment Rate Calculations | 18-EquipRate |
| 19 | Material Rates and Indirect Cost Inputs | 19-MatRate |
| 20 | Task Unit Rate Calculations | 20-TASK UNIT RATE |
| 21 | Relocation Unit Rates | 21-UNIT RELOCATION |
| 22 | Area Calculations for Covers and Revegetation | 22-Areas |
| 23 | Demolition | 23-Demolition |
| 24 | Mobilization-Demobilization Calculations | 24-MobDemob |
| 25 | Monitoring Costs | 25-Monitoring |
| 26 | Ore Stockpiles and Misc. Volume Calculations | 26-Ore-MiscVol |
| 27 | Open Pit Calculations | 27-Pits |
| 28 | Resloping Quantity Calculations | 28-Regrade |
| 29 | Revegetation Perscriptions | 29-Reveg |
| 30 | Road Calculations | 30-Roads |
| 31 | Surface Infrastructure Calculations | 31-SurfInfra |
| 32 | Underground | 32-UG |
| 33 | Waste Disposal | 33-Waste Disposal |
| 34 | WaterStructures | 34-Water |
| 35 | Water Treatment | 35-Water Treatment |

# Worksheet 1 - Cost Summary

Project: Minto Mine Closure Cost Estimate - RCP 2018-01
Project No.: 1CM002.045
Client: Minto Explorations Ltd.
Date: February 6, 2018
File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## COST SUMMARY - YEAR 0 (Dec. 31, 2017)

| WBS | Description of Cost | Proposed Cost |
|---|---|---|
| **Closure Implementation** | | |
| **Direct Costs** | | |
| A01 | Waste Dump | $6,847,702 |
| A02 | Overburden Dumps | $370,112 |
| A03 | Ore Stockpiles | $1,419,486 |
| A04 | Open Pits | $177,927 |
| A05 | Underground Openings | $81,637 |
| A06 | External Tailings Facilities | $202,656 |
| A07 | Roads | $136,050 |
| A08 | Demolition | $1,976,253 |
| A09 | Surface Infrastructure | $169,527 |
| A10 | Water Detention Structures | $786,952 |
| A11 | Yards/Laydown Areas | $758,907 |
| A12 | Waste Disposal | $452,923 |
| A13 | Surface Water Conveyance | $3,181,261 |
| A14 | Water Treatment | $483,085 |
| **Subtotal - Direct Implementation** | | **$17,044,478** |
| **Monitoring and C&M** | | |
| P | Planning, Permitting, Monitoring | $2,325,691 |
| CM | Care and Maintenance | $7,826,673 |
| **Subtotal - Monitoring and C&M** | | **$10,152,363** |
| **Indirect Costs** | | |
| B1 | Mobilization/Demobilization | $324,077 |
| B2 | Transport Costs | $405,599 |
| B3 | Site/Road Maintenance | $757,001 |
| B4 | Construction Support | $5,054,174 |
| B5 | QA and Project Management | $1,668,691 |
| - | Other Indirects | $6,428,205 |
| - | Contingency (12%) | $4,231,344 |
| **Subtotal - Indirect Costs** | | **$18,869,092** |
| *Cost Inflation* | | *$2,352,313* |
| **SUB-TOTAL IMPLEMENTATION COSTS** | | **$48,418,245** |
| **Post-Closure Costs (Undiscounted)** | | |
| **Direct Costs** | | |
| 1 | Monitoring | $1,761,326 |
| 2 | Water Treatment - Active Treatment | $4,446,180 |
| 3 | Passive Treatment | $560,239 |
| 4 | Reclamation Maintenance | $1,834,053 |
| 5 | Site Maintenance | $1,670,177 |
| 6 | Site Management | $4,798,081 |
| 7 | Transportation Costs | $994,297 |
| **Subtotal Direct Costs** | | **$16,064,353** |
| **Indirect Costs** | | |
| 1 | Indirects | $2,934,273 |
| 2 | Contingency (12%) | $1,945,144 |
| **Subtotal - Indirects** | | **$4,879,417** |
| *SUB-TOTAL - POST-CLOSURE COSTS* | | *$20,943,770* |
| **POST-CLOSURE NPV** | | **$13,777,523** |
| **TOTAL FINANCIAL SECURITY** | | **$62,195,768** |

## COST SUMMARY - Peak Liability (2019)

| WBS | Description of Cost | Proposed Cost |
|---|---|---|
| **Closure Implementation** | | |
| **Direct Costs** | | |
| A01 | Waste Dump | $6,893,723 |
| A02 | Overburden Dumps | $395,276 |
| A03 | Ore Stockpiles | $3,331,999 |
| A04 | Open Pits | $620,582 |
| A05 | Underground Openings | $81,637 |
| A06 | External Tailings Facilities | $57,291 |
| A07 | Roads | $136,050 |
| A08 | Demolition | $1,976,253 |
| A09 | Surface Infrastructure | $169,527 |
| A10 | Water Detention Structures | $786,952 |
| A11 | Yards/Laydown Areas | $758,907 |
| A12 | Waste Disposal | $452,923 |
| A13 | Surface Water Conveyance | $3,287,496 |
| A14 | Water Treatment | $483,085 |
| **Subtotal - Direct Implementation** | | **$19,431,701** |
| **Monitoring and C&M** | | |
| P | Planning, Permitting, Monitoring | $2,445,052 |
| CM | Care and Maintenance | $7,826,673 |
| **Subtotal - Monitoring and C&M** | | **$10,271,725** |
| **Indirect Costs** | | |
| B1 | Mobilization/Demobilization | $324,077 |
| B2 | Transport Costs | $419,142 |
| B3 | Site/Road Maintenance | $791,662 |
| B4 | Construction Support | $5,344,480 |
| B5 | QA and Project Management | $1,752,126 |
| - | Other Indirects | $6,958,307 |
| - | Contingency (12%) | $4,582,768 |
| **Subtotal - Indirect Costs** | | **$20,172,562** |
| *Cost Inflation* | | *$3,724,678* |
| **SUB-TOTAL IMPLEMENTATION COSTS** | | **$53,600,666** |
| **Post-Closure Costs (Undiscounted)** | | |
| **Direct Costs** | | |
| 1 | Monitoring | $1,761,326 |
| 2 | Water Treatment - Active Treatment | $4,446,180 |
| 3 | Passive Treatment | $560,239 |
| 4 | Reclamation Maintenance | $1,834,053 |
| 5 | Site Maintenance | $1,670,177 |
| 6 | Site Management | $4,798,081 |
| 7 | Transportation Costs | $994,297 |
| **Subtotal Direct Costs** | | **$16,064,353** |
| **Indirect Costs** | | |
| 1 | Indirects | $2,931,730 |
| 2 | Contingency (12%) | $1,945,144 |
| **Subtotal - Indirects** | | **$4,876,874** |
| *SUB-TOTAL - POST-CLOSURE COSTS* | | *$20,941,227* |
| **POST-CLOSURE NPV** | | **$13,096,047** |
| **TOTAL FINANCIAL SECURITY** | | **$66,696,713** |

## COST SUMMARY - End-of-Mine Liability (Closure Yr 1 202

| WBS | Description of Cost | Proposed Cost |
|---|---|---|
| **Closure Implementation** | | |
| **Direct Costs** | | |
| A01 | Waste Dump | $6,987,586 |
| A02 | Overburden Dumps | $395,276 |
| A03 | Ore Stockpiles | $794,200 |
| A04 | Open Pits | $620,582 |
| A05 | Underground Openings | $81,637 |
| A06 | External Tailings Facilities | $57,291 |
| A07 | Roads | $136,050 |
| A08 | Demolition | $1,976,253 |
| A09 | Surface Infrastructure | $169,527 |
| A10 | Water Detention Structures | $786,952 |
| A11 | Yards/Laydown Areas | $758,907 |
| A12 | Waste Disposal | $452,923 |
| A13 | Surface Water Conveyance | $3,287,496 |
| A14 | Water Treatment | $483,085 |
| **Subtotal - Direct Implementation** | | **$16,987,765** |
| **Monitoring and C&M** | | |
| P | Planning, Permitting, Monitoring | $769,108 |
| CM | Care and Maintenance | $3,141,306 |
| **Subtotal - Monitoring and C&M** | | **$3,910,414** |
| **Indirect Costs** | | |
| B1 | Mobilization/Demobilization | $324,077 |
| B2 | Transport Costs | $419,142 |
| B3 | Site/Road Maintenance | $791,662 |
| B4 | Construction Support | $5,263,751 |
| B5 | QA and Project Management | $1,752,126 |
| - | Other Indirects | $5,378,346 |
| - | Contingency (12%) | $3,516,451 |
| **Subtotal - Indirect Costs** | | **$17,445,555** |
| *Cost Inflation* | | *$3,997,740* |
| **SUB-TOTAL IMPLEMENTATION COSTS** | | **$42,341,475** |
| **Post-Closure Costs (Undiscounted)** | | |
| **Direct Costs** | | |
| 1 | Monitoring | $1,761,326 |
| 2 | Water Treatment - Active Treatment | $4,446,180 |
| 3 | Passive Treatment | $560,239 |
| 4 | Reclamation Maintenance | $1,386,205 |
| 5 | Site Maintenance | $1,670,177 |
| 6 | Site Management | $4,798,081 |
| 7 | Transportation Costs | $994,297 |
| **Subtotal Direct Costs** | | **$15,616,504** |
| **Indirect Costs** | | |
| 1 | Indirects | $2,852,436 |
| 2 | Contingency (12%) | $1,891,402 |
| **Subtotal - Indirects** | | **$4,743,838** |
| *SUB-TOTAL - POST-CLOSURE COSTS* | | *$20,360,342* |
| **POST-CLOSURE NPV** | | **$12,621,082** |
| **TOTAL FINANCIAL SECURITY** | | **$62,701,817** |

# Worksheet 2 - Year 0 Estimate - Cashflow Calculations

Project: Minto Mine Closure Cost Estimate - RCP 2018-01
Project No.: 1CM002.045
Client: Minto Explorations Ltd.
Date: February 6, 2018
File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## NPV CALCULATION INPUTS

**NOTE: Columns between Years 2052 and 2126 are hidden for printing purposes.**

**Short-Term Interest Rate (Interim Care/Implementation Costs)**

| ## | Inflation Rate | Years in effect | Start Year | End Year |
|---|---|---|---|---|
| 1 | 2.0% | 100 | 2018 | 2118 |

**Input Parameters**

Scenario: Year 0 Closure
Current Year: 2018 Year that the estimate is costed
Closure Year 1: 2020
Closure Period: 3 yrs
Post-Closure Year 1: 2023

**Long-Term Monitoring/Maintenance NPV Discount Rates**

| ## | Discount Rate | Years in effect | Start Year | End Year |
|---|---|---|---|---|
| 1 | 2.35% | 2 | 2018 | 2020 |
| 2 | 2.5% | 3 | 2021 | 2024 |
| 3 | 2.8% | - | 2025 | |

## SCHEDULE

### Implementation Schedule

| | Area | Closure Year: | INTERIM CARE Year -2 | Year -1 | CLOSURE Year 1 | Year 2 | Year 3 | POST CLOSURE Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 | Year 31 | Year 32 | Year 33 | Year 107 | Year 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
| Direct Costs | Waste Dumps | 100% | | | 60% | 40% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Overburden Dumps | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ore Stockpiles | 100% | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Open Pits | 100% | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Underground Openings | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | External Tailings Facilities | 100% | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Roads | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Demolition | 100% | | | 10% | 75% | 15% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Surface Infrastructure | 100% | | | 25% | 50% | 25% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water Detention Structures | 100% | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Yards/Laydown Areas | 100% | | | 25% | 25% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Waste Disposal | 100% | | | | 12% | 75% | 2% | 2% | 2% | 6% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Surface Water Conveyance | 100% | | | 20% | 30% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water Treatment | 100% | | | | | 86% | | | | | 14% | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Indirect | Mobilization-Demobilization | 100% | | | 50% | | 45% | | | | | 5% | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Transport Costs | 100% | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Road Maintenance | 100% | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Construction Support | 100% | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | QA and Pro. Mgmt. | 100% | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

### Monitoring Schedule

| | | Set Monitoring/C&M Stage: | 1 - Interim | 1 - Interim | 2 - Active | 2 - Active | 2 - Active | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | | | | | | | | | 5 - Perpetual | | | | | | | 5 - Perpetual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Post-Closure Year: | Year -5 | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 | Year 104 | Year 105 |
| | | Sum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Planning and permitting | Reclamation Research and Planning | 100% | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Technical Studies and Investigations | 100% | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Engineering, Design, and Construction Plans | 100% | 30% | 40% | 10% | 10% | 10% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Monitoring and Management Plans | 100% | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Permitting | 100% | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monitoring | Water Quality Monitoring (surface and groundwater) | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | 1 | | | | | | | 1 |
| | Sediment Monitoring | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | | | | | | | 1 |
| | Biological Monitoring | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | | | | | | | 1 |
| | Geotechnical Monitoring | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | | | | | | | 1 |
| | Revegetation Monitoring | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | | | | | | | 1 |
| | Annual Inspection Reporting | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | | | | | | | 1 |

### Care and Maintenance Schedule

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Treatment/Management | Active System | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | | | | | | | | x | | | | | | | x |
| | Passive System | | | | | | | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | x | | | | | | | x |
| Reclamation Maintenance | Revegetation, cover repair, etc. | | | | | | | x | x | x | x | x | | | | | | | | | | | | | | | | | | | x | | | | | | | x |
| Site Maintenance | | | x | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | x | | | | | | | x |
| On-site Management | | | x | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | x | | | | | | | x |
| Transportation Costs | | | x | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | x | | | | | | | x |

## UNDISCOUNTED CASH FLOW (TO 100 YEARS POST CLOSURE)

### Implementation Costs

| | Area | Total | % of Total | Check Sum | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 | Year 31 | Year 32 | Year 33 | Year 107 | Year 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
| Direct Costs | Waste Dumps | $6,847,702 | 27% | $6,847,702 | $0 | $0 | $4,108,621 | $2,739,081 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Overburden Dumps | $370,112 | 1% | $370,112 | $0 | $0 | $0 | $0 | $370,112 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Ore Stockpiles | $1,419,486 | 6% | $1,419,486 | $0 | $0 | $1,419,486 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Open Pits | $177,927 | 1% | $177,927 | $0 | $0 | $0 | $88,964 | $88,964 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Underground Openings | $81,637 | 0% | $81,637 | $0 | $0 | $0 | $0 | $81,637 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | External Tailings Facilities | $202,656 | 1% | $202,656 | $0 | $0 | $202,656 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Roads | $136,050 | 1% | $136,050 | $0 | $0 | $0 | $0 | $136,050 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Demolition | $1,976,253 | 8% | $1,976,253 | $0 | $0 | $197,625 | $1,482,189 | $296,438 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Infrastructure | $169,527 | 1% | $169,527 | $0 | $0 | $42,382 | $84,763 | $42,382 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Detention Structures | $786,952 | 3% | $786,952 | $0 | $0 | $0 | $393,476 | $393,476 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Yards/Laydown Areas | $758,907 | 3% | $758,907 | $0 | $0 | $189,727 | $189,727 | $379,454 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Waste Disposal | $452,923 | 2% | $452,923 | $0 | $0 | $0 | $54,828 | $339,692 | $11,145 | $11,145 | $11,145 | $24,967 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Water Conveyance | $3,181,261 | 13% | $3,181,261 | $0 | $0 | $636,252 | $954,378 | $1,590,630 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Treatment | $483,085 | 2% | $483,085 | $0 | $0 | $0 | $0 | $413,938 | $0 | $0 | $0 | $0 | $69,147 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect | Mobilization-Demobilization | $324,077 | 1% | $324,077 | $0 | $0 | $162,039 | $0 | $144,406 | $0 | $0 | $0 | $0 | $17,633 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Transport Costs | $405,599 | 2% | $405,599 | $0 | $0 | $137,904 | $133,848 | $133,848 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Site/Road Maintenance | $757,001 | 3% | $757,001 | $0 | $0 | $257,380 | $249,810 | $249,810 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Construction Support | $5,054,174 | 20% | $5,054,174 | $0 | $0 | $1,718,419 | $1,667,877 | $1,667,877 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | QA and Pro. Mgmt. | $1,668,691 | 7% | $1,668,691 | $0 | $0 | $567,355 | $550,668 | $550,668 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Subtotal - Closure Implementation Costs** | | **$25,254,020** | | $25,254,020 | **$0** | **$0** | **$9,639,846** | **$8,589,610** | **$6,879,381** | **$11,145** | **$11,145** | **$11,145** | **$24,967** | **$86,780** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Monitoring Costs

| | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Planning and | Reclamation Research and Planning | $400,000 | 10% | $400,000 | $200,000 | $200,000 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | Permitting | Technical Studies and Investigations | $58,500 | 1% | $58,500 | $29,250 | $29,250 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Engineering, Design, and Construction Plans | $852,224 | 21% | $852,224 | $255,667 | $340,890 | $85,222 | $85,222 | $85,222 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Monitoring and Management Plans | $209,158 | 5% | $209,158 | $104,579 | $104,579 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Permitting | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 1 | Monitoring | Water Quality Monitoring | $1,403,014 | 34% | $1,403,014 | $115,295 | $115,295 | $130,437 | $130,437 | $130,437 | $51,987 | $51,987 | $51,987 | $51,987 | $51,987 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $27,664 | $0 | $0 | $0 | $0 | $0 | $27,664 |
| 2 | | Sediment Monitoring | $64,372 | 2% | $64,372 | $3,388 | $3,388 | $3,388 | $3,388 | $3,388 | $0 | $3,388 | $0 | $3,388 | $0 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $0 | $0 | $3,388 |
| 3 | | Biological Monitoring | $233,587 | 6% | $233,587 | $12,294 | $12,294 | $12,294 | $12,294 | $12,294 | $0 | $12,294 | $0 | $12,294 | $0 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $0 | $0 | $12,294 |
| 4 | | Geotechnical Monitoring | $379,471 | 9% | $379,471 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $0 | $0 | $23,216 |
| 5 | | Revegetation Monitoring | $200,071 | 5% | $200,071 | $0 | $0 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $0 | $0 | $10,530 |
| 6 | | Annual Inspection Reporting | $286,620 | 7% | $286,620 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $0 | $0 | $0 | $23,900 | $0 | $0 | $0 | $0 | $23,900 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,900 | $0 | $0 | $0 | $0 | $0 | $23,900 |
| **Post Closure Costs Subtotal** | | | **$4,087,017** | | $4,087,017 | **$735,255** | **$820,477** | **$256,653** | **$256,653** | **$256,653** | **$92,981** | **$77,299** | **$92,981** | **$77,299** | **$92,981** | **$27,220** | **$27,220** | **$27,220** | **$27,220** | **$100,548** | **$27,220** | **$27,220** | **$27,220** | **$27,220** | **$100,548** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$100,993** | **$0** | **$0** | **$0** | **$0** | **$0** | **$100,993** |

### Care and Maintenance Costs

| | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $7,981,012 | 36% | $7,981,012 | $706,966.58 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $560,239 | 3% | $560,239 | $0 | $0 | $0 | $0 | $0 | $35,015 | $35,015 | $35,015 | $35,015 | $35,015 | $0 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $0 | $0 | $0 | $35,015 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $1,834,053 | 8% | $1,834,053 | $0 | $0 | $0 | $0 | $0 | $0 | $366,811 | $366,811 | $366,811 | $366,811 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $2,478,551 | 11% | $2,478,551 | $359,187 | $359,187 | $30,000 | $30,000 | $30,000 | $99,414 | $99,414 | $99,414 | $99,414 | $99,414 | $0 | $0 | $0 | $0 | $99,414 | $0 | $0 | $0 | $0 | $99,414 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $108,253 | $0 | $0 | $0 | $0 | $0 | $108,253 |
| 5 | On-site Management | | $7,978,119 | 36% | $7,978,119 | $1,124,816 | $1,124,816 | $310,135 | $310,135 | $310,135 | $606,140 | $606,140 | $606,140 | $606,140 | $606,140 | $0 | $0 | $0 | $0 | $79,830 | $0 | $0 | $0 | $0 | $79,830 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $178,636 | $0 | $0 | $0 | $0 | $0 | $178,636 |
| 6 | Transportation Costs | | $1,297,725 | 6% | $1,297,725 | $151,714 | $151,714 | $0 | $0 | $0 | $64,628 | $64,628 | $64,628 | $64,628 | $64,628 | $0 | $0 | $0 | $0 | $20,832 | $0 | $0 | $0 | $0 | $20,832 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $69,943 | $0 | $0 | $0 | $0 | $0 | $69,943 |
| **Post Closure Costs Subtotal** | | | **$22,129,700** | | $22,129,700 | **$2,342,683** | **$2,342,683** | **$1,047,102** | **$1,047,102** | **$1,047,102** | **$1,878,975** | **$1,878,975** | **$1,878,975** | **$1,878,975** | **$1,878,975** | **$91,135** | **$91,135** | **$91,135** | **$91,135** | **$326,226** | **$91,135** | **$91,135** | **$91,135** | **$91,135** | **$326,226** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$391,847** | **$0** | **$0** | **$0** | **$0** | **$0** | **$391,847** |

### Other Add-on Costs

| | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $6,176,488 | | $6,176,488 | $369,353 | $379,579 | $1,313,232 | $1,187,204 | $981,976 | $237,972 | $236,090 | $237,972 | $237,749 | $247,048 | $14,203 | $14,203 | $14,203 | $14,203 | $51,213 | $14,203 | $14,203 | $14,203 | $14,203 | $51,213 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $59,141 | $0 | $0 | $0 | $0 | $0 | $59,141 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 1.5% % of above labour costs | $220,355.80 | | $220,356 | $13,177 | $13,542 | $46,852 | $42,355 | $35,034 | $8,490 | $8,423 | $8,490 | $8,482 | $8,814 | $507 | $507 | $507 | $507 | $1,827 | $507 | $507 | $507 | $507 | $1,827 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $2,110 | $0 | $0 | $0 | $0 | $0 | $2,110 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $1,421,511.59 | | $1,421,512 | $70,280.50 | $70,280 | $320,608 | $289,101 | $237,794 | $56,704 | $56,704 | $56,704 | $57,118 | $58,973 | $2,734 | $2,734 | $2,734 | $2,734 | $9,787 | $2,734 | $2,734 | $2,734 | $2,734 | $9,787 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $11,755 | $0 | $0 | $0 | $0 | $0 | $11,755 |
| 5 | Contractor Profit | 10% % of above costs | $5,147,074 | | $5,147,074 | $307,794 | $316,316 | $1,094,360 | $989,337 | $818,314 | $198,310 | $196,742 | $198,310 | $198,124 | $205,874 | $11,835 | $11,835 | $11,835 | $11,835 | $42,677 | $11,835 | $11,835 | $11,835 | $11,835 | $42,677 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $49,284 | $0 | $0 | $0 | $0 | $0 | $49,284 |
| 6 | Contract Administration | 5% % of above costs | $2,573,537 | | $2,573,537 | $153,897 | $158,158 | $547,180 | $494,668 | $409,157 | $99,155 | $98,371 | $99,155 | $99,062 | $102,937 | $5,918 | $5,918 | $5,918 | $5,918 | $21,339 | $5,918 | $5,918 | $5,918 | $5,918 | $21,339 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $24,642 | $0 | $0 | $0 | $0 | $0 | $24,642 |
| **Other Add-On Costs Subtotal** | | | **$15,538,966** | | $15,538,966 | **$914,501** | **$937,876** | **$3,322,232** | **$3,002,665** | **$2,482,275** | **$600,631** | **$596,330** | **$600,631** | **$600,535** | **$623,645** | **$35,196** | **$35,196** | **$35,196** | **$35,196** | **$126,843** | **$35,196** | **$35,196** | **$35,196** | **$35,196** | **$126,843** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$146,932** | **$0** | **$0** | **$0** | **$0** | **$0** | **$146,932** |
| **TOTAL** | | **$67,009,703** | | $67,009,703 | $3,992,439 | $4,101,036 | $14,265,834 | $12,896,030 | $10,665,411 | $2,583,731 | $2,563,748 | $2,583,731 | $2,581,775 | $2,682,381 | $153,551 | $153,551 | $153,551 | $153,551 | $553,617 | $153,551 | $153,551 | $153,551 | $153,551 | $553,617 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $639,772 | $0 | $0 | $0 | $0 | $0 | $639,772 |

## INFLATION FACTORED INTERIM CARE AND CLOSURE IMPLEMENTATION COSTS

| | Area | Present Value | % of Total | Future Value | Year -2 2018 | Year -1 2019 | Year 1 2020 | Year 2 2021 | Year 3 2022 | Year 4 2023 | Year 5 2024 | Year 6 2025 | Year 7 2026 | Year 8 2027 | Year 9 2028 | Year 10 2029 | Year 11 2030 | Year 12 2031 | Year 13 2032 | Year 14 2033 | Year 15 2034 | Year 16 2035 | Year 17 2036 | Year 18 2037 | Year 19 2038 | Year 20 2039 | Year 21 2040 | Year 22 2041 | Year 23 2042 | Year 24 2043 | Year 25 2044 | Year 26 2045 | Year 27 2046 | Year 28 2047 | Year 29 2048 | Year 30 2049 | Year 31 2050 | Year 32 2051 | Year 33 2052 | Year 107 2126 | Year 108 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direct Costs | Waste Dumps | $6,847,702 | 27% | $7,181,344 | $0 | $0 | $4,274,610 | $2,906,735 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Overburden Dumps | $370,112 | 1% | $400,621 | $0 | $0 | $0 | $0 | $400,621 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Ore Stockpiles | $1,419,486 | 6% | $1,476,833 | $0 | $0 | $1,476,833 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Open Pits | $177,927 | 1% | $190,706 | $0 | $0 | $0 | $94,409 | $96,297 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Underground Openings | $81,637 | 0% | $88,367 | $0 | $0 | $0 | $0 | $88,367 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | External Tailings Facilities | $202,656 | 1% | $210,844 | $0 | $0 | $210,844 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Roads | $136,050 | 1% | $147,265 | $0 | $0 | $0 | $0 | $147,265 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Demolition | $1,976,253 | 8% | $2,099,395 | $0 | $0 | $205,609 | $1,572,911 | $320,874 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Infrastructure | $169,527 | 1% | $179,921 | $0 | $0 | $44,094 | $89,952 | $45,875 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Detention Structures | $786,952 | 3% | $843,470 | $0 | $0 | $0 | $417,560 | $425,911 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Yards/Laydown Areas | $758,907 | 3% | $809,464 | $0 | $0 | $197,392 | $201,340 | $410,733 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Waste Disposal | $452,923 | 2% | $492,790 | $0 | $0 | $0 | $58,184 | $367,694 | $12,305 | $12,551 | $12,802 | $29,253 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Water Conveyance | $3,181,261 | 13% | $3,396,500 | $0 | $0 | $661,957 | $1,012,794 | $1,721,750 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Treatment | $483,085 | 2% | $530,697 | $0 | $0 | $0 | $0 | $448,060 | $0 | $0 | $0 | $0 | $82,637 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect | Mobilization-Demobilization | $324,077 | 1% | $345,967 | $0 | $0 | $168,585 | $0 | $156,309 | $0 | $0 | $0 | $0 | $21,073 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Transport Costs | $405,599 | 2% | $430,396 | $0 | $0 | $143,475 | $142,040 | $144,881 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Road Maintenance | $757,001 | 3% | $803,282 | $0 | $0 | $267,779 | $265,101 | $270,403 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Construction Support | $5,054,174 | 20% | $5,363,172 | $0 | $0 | $1,787,843 | $1,769,965 | $1,805,364 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | QA and Pro. Mgmt. | $1,668,691 | 7% | $1,770,711 | $0 | $0 | $590,276 | $584,373 | $596,061 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Subtotal - Closure Implementation Costs** | | **$25,254,020** | | **$26,761,744** | **$0** | **$0** | **$10,029,296** | **$9,115,363** | **$7,446,463** | **$12,305** | **$12,551** | **$12,802** | **$29,253** | **$103,710** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Monitoring Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Planning and permitting | Reclamation Research and Planning | $400,000 | 10% | $404,000 | $200,000 | $204,000 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Technical Studies and Investigations | $58,500 | 1% | $59,085 | $29,250 | $29,835 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Engineering, Design, and Construction Plans | $852,224 | 21% | $874,726 | $255,667 | $347,707 | $88,665 | $90,439 | $92,247 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Monitoring and Management Plans | $209,158 | 5% | $211,250 | $104,579 | $106,671 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Permitting | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 1 | Monitoring | Water Quality Monitoring | $621,903 | 15% | $648,215 | $115,295 | $117,601 | $135,707 | $138,421 | $141,190 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Sediment Monitoring | $16,940 | 0% | $17,631 | $3,388 | $3,456 | $3,525 | $3,595 | $3,667 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Biological Monitoring | $61,470 | 2% | $63,979 | $12,294 | $12,540 | $12,791 | $13,047 | $13,307 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Geotechnical Monitoring | $62,045 | 2% | $64,577 | $12,409 | $12,657 | $12,910 | $13,169 | $13,432 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Revegetation Monitoring | $31,590 | 1% | $33,528 | $0 | $0 | $10,955 | $11,175 | $11,398 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | | Annual Inspection Reporting | $11,860 | 0% | $12,344 | $2,372 | $2,419 | $2,468 | $2,517 | $2,568 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Post Closure Costs Subtotal** | | | **$2,325,691** | | **$2,389,335** | **$735,255** | **$836,887** | **$267,022** | **$272,362** | **$277,809** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Care and Maintenance Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $3,534,833 | 16% | $3,679,082 | $706,967 | $721,106 | $735,528 | $750,239 | $765,243 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $808,374 | 4% | $821,079 | $359,187 | $366,371 | $31,212 | $31,836 | $32,473 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | On-site Management | | $3,180,037 | 14% | $3,259,611 | $1,124,816 | $1,147,312 | $322,665 | $329,118 | $335,701 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | Transportation Costs | | $303,428 | 1% | $306,462 | $151,714 | $154,748 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Post Closure Costs Subtotal** | | | **$7,826,673** | | $8,066,235 | **$2,342,683** | **$2,389,537** | **$1,089,405** | **$1,111,193** | **$1,133,417** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Other Add-on Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $4,231,344 | | $4,445,603 | $369,353 | $387,171 | $1,366,287 | $1,259,870 | $1,062,923 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 2% % of above labour costs | $150,960 | | $158,604 | $13,177 | $13,813 | $48,744 | $44,948 | $37,921 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $988,065 | | $1,039,721 | $70,280 | $71,686 | $333,561 | $306,797 | $257,396 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | Contractor Profit | 10% % of above costs | $3,526,120 | | $3,704,669 | $307,794 | $322,642 | $1,138,572 | $1,049,892 | $885,769 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | Contract Administration | 5% % of above costs | $1,763,060 | | $1,852,335 | $153,897 | $161,321 | $569,286 | $524,946 | $442,884 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Other Add-On Costs Subtotal** | | | **$10,659,549** | | $11,200,931 | **$914,501** | **$956,633** | **$3,456,451** | **$3,186,452** | **$2,686,894** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** | | | **$46,065,933** | | **$48,418,245** | **$3,992,439** | **$4,183,057** | **$14,842,173** | **$13,685,371** | **$11,544,584** | **$12,305** | **$12,551** | **$12,802** | **$29,253** | **$103,710** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

## NET PRESENT VALUE CALCULATIONS - LONG TERM MONITORING AND MAINTENANCE

### Monitoring Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Monitoring | Water Quality Monitoring | $781,111 | 19% | $463,795 | | | | | | $46,084 | $46,084 | $44,829 | $43,608 | $42,420 | $21,605 | $21,017 | $20,444 | $19,888 | $19,346 | $18,819 | $18,306 | $17,808 | $17,323 | $16,851 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $12,994 | $0 | $0 | $0 | $0 | $0 | $0 | $1,427 |
| 2 | | Sediment Monitoring | $47,432 | 1% | $19,240 | | | | | | $3,003 | $0 | $2,921 | $0 | $2,765 | $0 | $0 | $0 | $0 | $2,408 | $0 | $0 | $0 | $0 | $2,097 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,591 | $0 | $0 | $0 | $0 | $0 | $0 | $175 |
| 3 | | Biological Monitoring | $172,117 | 4% | $69,816 | | | | | | $10,898 | $0 | $10,601 | $0 | $10,032 | $0 | $0 | $0 | $0 | $8,738 | $0 | $0 | $0 | $0 | $7,611 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $5,774 | $0 | $0 | $0 | $0 | $0 | $0 | $634 |
| 4 | | Geotechnical Monitoring | $317,426 | 8% | $125,534 | | | | | | $11,000 | $11,000 | $10,700 | $10,409 | $10,125 | $0 | $0 | $0 | $0 | $16,501 | $0 | $0 | $0 | $0 | $14,373 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,905 | $0 | $0 | $0 | $0 | $0 | $0 | $1,197 |
| 5 | | Revegetation Monitoring | $168,481 | 4% | $77,966 | | | | | | $9,334 | $9,334 | $9,080 | $8,833 | $8,592 | $0 | $0 | $0 | $0 | $7,484 | $0 | $0 | $0 | $0 | $6,519 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $4,946 | $0 | $0 | $0 | $0 | $0 | $0 | $543 |
| 6 | | Annual Inspection Reporting | $274,760 | 7% | $84,604 | | | | | | $2,103 | $2,103 | $2,045 | $1,990 | $1,935 | $0 | $0 | $0 | $0 | $16,987 | $0 | $0 | $0 | $0 | $14,796 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $11,226 | $0 | $0 | $0 | $0 | $0 | $0 | $1,232 |
| **Post Closure Costs Subtotal** | | | **$1,761,326** | | **$840,955** | **$0** | **$0** | **$0** | **$0** | **$0** | **$82,422** | **$68,521** | **$80,177** | **$64,839** | **$75,869** | **$21,605** | **$21,017** | **$20,444** | **$19,888** | **$71,463** | **$18,819** | **$18,306** | **$17,808** | **$17,323** | **$62,247** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$47,435** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$5,208** |

### Care and Maintenance Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $4,446,180 | 20% | $3,673,728 | | | | | | $626,688 | $626,688 | $609,619 | $593,015 | $576,862 | $72,338 | $70,367 | $68,451 | $66,586 | $64,773 | $63,008 | $61,292 | $59,623 | $57,999 | $56,419 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $560,239 | 3% | $259,255 | | | | | | $31,039 | $31,039 | $30,193 | $29,371 | $28,571 | $0 | $0 | $0 | $0 | $24,886 | $0 | $0 | $0 | $0 | $21,677 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $16,446 | $0 | $0 | $0 | $0 | $0 | $0 | $1,806 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $1,834,053 | 8% | $1,573,611 | | | | | | $325,158 | $325,158 | $316,302 | $307,687 | $299,306 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $1,670,177 | 8% | $751,847 | | | | | | $88,125 | $88,125 | $85,725 | $83,390 | $81,119 | $0 | $0 | $0 | $0 | $70,657 | $0 | $0 | $0 | $0 | $61,545 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $50,845 | $0 | $0 | $0 | $0 | $0 | $0 | $5,582 |
| 5 | On-site Management | | $4,798,081 | 22% | $3,025,236 | | | | | | $537,311 | $537,311 | $522,676 | $508,440 | $494,591 | $0 | $0 | $0 | $0 | $56,738 | $0 | $0 | $0 | $0 | $49,420 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $83,903 | $0 | $0 | $0 | $0 | $0 | $0 | $9,211 |
| 6 | Transportation Costs | | $994,297 | 4% | $429,761 | | | | | | $57,290 | $57,290 | $55,729 | $54,211 | $52,735 | $0 | $0 | $0 | $0 | $14,806 | $0 | $0 | $0 | $0 | $12,897 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $32,852 | $0 | $0 | $0 | $0 | $0 | $0 | $3,607 |
| **Post Closure Costs Subtotal** | | | **$14,303,027** | | $9,713,438 | **$0** | **$0** | **$0** | **$0** | **$0** | **$1,665,611** | **$1,665,611** | **$1,620,245** | **$1,576,113** | **$1,533,184** | **$72,338** | **$70,367** | **$68,451** | **$66,586** | **$231,860** | **$63,008** | **$61,292** | **$59,623** | **$57,999** | **$201,958** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$184,047** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$20,206** |

### Other Add-on Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2126 | 2127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $1,945,144 | | $1,281,062 | | | | | | $210,950 | $209,281 | $205,204 | $199,427 | $201,584 | $11,273 | $10,966 | $10,667 | $10,377 | $36,399 | $9,819 | $9,552 | $9,292 | $9,039 | $31,705 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $27,778 | $0 | $0 | $0 | $0 | $0 | $0 | $3,050 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | | | | | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 2% % of above labour costs | $69,396 | | $45,704 | | | | | | $7,526 | $7,466 | $7,321 | $7,115 | $7,192 | $402 | $391 | $381 | $370 | $1,299 | $350 | $341 | $331 | $322 | $1,131 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $991 | $0 | $0 | $0 | $0 | $0 | $0 | $109 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $433,446 | | $295,037 | | | | | | $50,265 | $50,265 | $48,896 | $47,912 | $48,120 | $2,170 | $2,111 | $2,054 | $1,998 | $6,956 | $1,890 | $1,839 | $1,789 | $1,740 | $6,059 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $5,521 | $0 | $0 | $0 | $0 | $0 | $0 | $606 |
| 5 | Contractor Profit | 10% % of above costs | $1,620,954 | | $1,067,552 | | | | | | $175,791 | $174,401 | $171,003 | $166,190 | $167,986 | $9,394 | $9,138 | $8,890 | $8,647 | $30,332 | $8,183 | $7,960 | $7,743 | $7,532 | $26,420 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,148 | $0 | $0 | $0 | $0 | $0 | $0 | $2,541 |
| 6 | Contract Administration | 5% % of above costs | $810,477 | | $533,776 | | | | | | $87,896 | $87,201 | $85,502 | $83,095 | $83,993 | $4,697 | $4,569 | $4,445 | $4,324 | $15,166 | $4,091 | $3,980 | $3,872 | $3,766 | $13,210 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $11,574 | $0 | $0 | $0 | $0 | $0 | $0 | $1,271 |
| **Other Add-On Costs Subtotal** | | | **$4,879,417** | | $3,223,130 | **$0** | **$0** | **$0** | **$0** | **$0** | **$532,427** | **$528,614** | **$517,925** | **$503,738** | **$508,875** | **$27,937** | **$27,176** | **$26,436** | **$25,716** | **$90,152** | **$24,334** | **$23,671** | **$23,026** | **$22,399** | **$78,525** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$69,012** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$7,577** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** | | | **$20,943,770** | | **$13,777,523** | **$0** | **$0** | **$0** | **$0** | **$0** | **$2,280,461** | **$2,262,747** | **$2,218,347** | **$2,144,691** | **$2,117,928** | **$121,880** | **$118,560** | **$115,331** | **$112,190** | **$393,475** | **$106,161** | **$103,270

# Worksheet 3 - Year 0 Estimate - Annual C&M Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## Summary of Annual Care and Maintenance Costs

| | | Annual Cost Per Phase | | | | | | | Number of Years | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual | n/a | Total Cost | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual |
| 1 | Active Water Treatment System | $706,967 | $706,967 | $706,967 | $91,135 | $0 | $0 | $7,981,012 | 2 | 3 | 5 | 10 | 0 |
| 2 | Passive Treatment System | $0 | $0 | $35,015 | $35,015 | $35,015 | $0 | $560,239 | 2 | 3 | 5 | 2 | 9 |
| 3 | Reclamation Maintenance | $0 | $0 | $366,811 | $0 | $0 | $0 | $1,834,053 | 2 | 3 | 5 | 2 | 9 |
| 4 | Site Maintenance | $359,187 | $30,000 | $99,414 | $99,414 | $108,253 | $0 | $2,478,551 | 2 | 3 | 5 | 2 | 9 |
| 5 | On-site Management | $1,124,816 | $310,135 | $606,140 | $79,830 | $178,636 | $0 | $7,978,119 | 2 | 3 | 5 | 2 | 9 |
| 6 | Transportation Costs | $151,714 | $0 | $64,628 | $20,832 | $69,943 | $0 | $1,297,725 | 2 | 3 | 5 | 2 | 9 |

**NOTES:**
1. This table is used as a check to the NPV calculation spreadsheet.

## Phase 1 - Annual Care & Maintenance Costs - Prior to Closure

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S1.1 | **Water Treatment** | | | | | | | | | | | | | | | **$706,967** | |
| S1.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S1.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S1.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S1.2 | **Onsite Management** | | | | | | | | | | | | | | | **$1,124,816** | |
| S1.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $761,189 | | |
| S1.2.1.1 | | Mine Manager | | 4 | months | 360 | site working hours per month | | | $23,408 | | | | $81,930 | | | (Notes: staffing costs include cross-shifts) |
| S1.2.1.2 | | Office/Camp manager | | 6 | months | 360 | site working hours per month | | | $22,267 | | | | $133,604 | | | |
| S1.2.1.3 | | Administrative Assistants/HR/Accounting | | 4 | months | 360 | site working hours per month | | | $16,600 | | | | $58,098 | | | |
| S1.2.1.4 | | Water Treatment Staff Operator | | 5 | months | 360 | site working hours per month | | | $18,912 | | | | $94,560 | | | |
| S1.2.1.5 | | Environmental/Safety Manager | | 4 | months | 360 | site working hours per month | | | $22,267 | | | | $89,069 | | | |
| S1.2.1.6 | | Environmental Technicians | | 7 | months | 360 | site working hours per month | | | $16,046 | | | | $104,301 | | | |
| S1.2.1.7 | | Mechanic | | 2 | months | 360 | site working hours per month | | | $17,769 | | | | $35,538 | | | |
| S1.2.1.8 | | Tradesmen | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $42,552 | | | |
| S1.2.1.9 | | General Labour/helpers | | 10 | months | 360 | site working hours per month | | | $12,793 | | | | $121,536 | | | |
| S1.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $131,186 | | |
| S1.2.2.1 | | Pick-up trucks (3 required) | | 12 | months | | | | | $4,446 | | | | $53,350 | | | |
| S1.2.2.2 | | Mechanic service vehicle | | 2 | months | | | | | $11,803 | | | | $23,607 | | | |
| S1.2.2.3 | | Emergency transport vehicle | | 12 | months | | | | | $4,519 | | | | $54,229 | | | |
| S1.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $232,440 | | |
| S1.2.3.1 | | Office supplies | | 12 | months | | | | | $1,000 | | | | $12,000 | | | |
| S1.2.3.2 | | Communications | | 12 | months | | | | | $1,000 | | | | $12,000 | | | |
| S1.2.3.3 | | Misc. supplies | | 12 | months | | | | | $500 | | | | $6,000 | | | |
| S1.2.3 | | Camp Operation | | 1,995 | man-days | | | | | $80 | | | | $159,600 | | | |
| S1.2.3 | | Power, heat, fuel | | 12 | months | | | | | $3,570 | | | | $42,840 | | | |
| S1.3 | **Site Maintenance** | | | | | | | | | | | | | | $359,187 | **$359,187** | |
| S1.3.1 | | Equipment Maintenance | | 1 | ls | | $20,000 | | | | | | | $20,000 | | | Labour included in field support staff |
| S1.3.2 | | Road Maintenance | Grader (assume 80 hrs/month) | 1 | ls | 960 | | $44 | $106 | $150 | $0 | $42,612 | $101,443 | $144,056 | | | Operator cost included in Field support staff |
| S1.3.3 | | Earthwork Repair allowance (assume 40 hrs per month) | | 1 | ls | 480 | $0 | $132 | $344 | $344 | | | $165,132 | $165,132 | | | Task Code C.2.14 |
| S1.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $30,000 | | | | $30,000 | | | Allowance for pump maintenance/fuel etc. |
| S1.4 | **Transportation Costs** | | | | | | | | | | | | | | $151,714 | **$151,714** | |
| S1.4.1 | | Barge Operations | | 5 | months | | | | | $10,832 | | | | $54,162 | | | |
| S1.4.2 | | Staffing Bus trips during barge operation period | | 20 | ea | | | | | $678 | | | | $13,552 | | | One per week |
| S1.4.3 | | Air transport and airstrip operations | | 8 | flights | | | | | $3,000 | | | | $24,000 | | | One flight per week |
| S1.4.4 | | Helicopter transport | | 20 | flights | | | | | $3,000 | | | | $60,000 | | | One flight per week |
| **TOTAL** | | | | | | | | | | | | | | **$2,342,683** | **$2,342,683** | **$2,342,683** | |

## Phase 2 - Annual Care & Maintenance Costs During Active Closure

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S2.1 | **Water Treatment** | | | | | | | | | | | | | | | **$706,967** | |
| S2.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S2.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S2.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S2.2 | **Onsite Management** | | | | | | | | | | | | | | | **$310,135** | |
| S2.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $247,815 | | |
| S2.2.1.1 | | Water Treatment Staff Operator | | 5 | months | 360 | site working hours per month | | | $18,912 | | | | $94,560 | | | |
| S2.2.1.2 | | Environmental/Safety Manager | | 4 | months | 360 | site working hours per month | | | $22,267 | | | | $89,069 | | | |
| S2.2.1.3 | | Environmental Technicians | | 4 | months | 360 | site working hours per month | | | $16,046 | | | | $64,185 | | | |
| S2.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $31,121 | | |
| S2.2.2.1 | | Pick-up trucks (1 required) | | 7 | months | | | | | $4,446 | | | | $31,121 | | | |
| S2.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $31,200 | | |
| S2.2.3.1 | | Camp Operation | | 390 | man-days | | | | | $80 | | | | $31,200 | | | |
| S2.3 | **Site Maintenance** | | | | | | | | | | | | | | $30,000 | **$30,000** | |
| S2.3.1 | | Pumping equipment/consumables allowance | | 1 | ls | | | | | $30,000 | | | | $30,000 | | | Allowance for pump maintenance/fuel etc. |
| S2.4 | **Transportation Costs** | | | | | | | | | | | | | | $0 | **$0** | |
| S2.4.1 | | Barge Operations | | 0 | months | | | | | $10,832 | | | | $0 | | | Included in construction indirect costs |
| **TOTAL** | | | | | | | | | | | | | | **$1,047,102** | **$1,047,102** | **$1,047,102** | |

## Phase 3 - Annual Care & Maintenance Costs - Post Closure I

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S3.1 | **Water Treatment** | | | | | | | | | | | | | | | **$741,982** | |
| S3.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S3.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S3.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S3.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S3.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S3.2 | **Onsite Management** | | | | | | | | | | | | | | | **$606,140** | |
| S3.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $377,100 | | |
| S3.2.1.1 | | Mine Manager | | 3 | months | 360 | site working hours per month | | | $23,408 | | | | $58,521 | | | (Notes: staffing costs include cross-shifts) |
| S3.2.1.2 | | Office/Camp manager | | 3 | months | 360 | site working hours per month | | | $22,267 | | | | $66,802 | | | |
| S3.2.1.3 | | Administrative Assistants/HR/Accounting | | 1 | months | 360 | site working hours per month | | | $16,600 | | | | $20,749 | | | |
| S3.2.1.4 | | Water Treatment Staff Operator | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $33,096 | | | |
| S3.2.1.5 | | Environmental/Safety Manager | | 3 | months | 360 | site working hours per month | | | $22,267 | | | | $55,668 | | | |
| S3.2.1.6 | | Environmental Technicians | | 3 | months | 360 | site working hours per month | | | $16,046 | | | | $40,116 | | | |
| S3.2.1.7 | | Mechanic | | 2 | months | 360 | site working hours per month | | | $17,769 | | | | $35,538 | | | |
| S3.2.1.8 | | Tradesmen | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $37,824 | | | |
| S3.2.1.9 | | General Labour/helpers | | 2 | months | 360 | site working hours per month | | | $12,793 | | | | $28,785 | | | |
| S3.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $112,890 | | |
| S3.2.2.1 | | Pick-up trucks (3 required) | | 15 | months | | | | | $4,446 | | | | $66,688 | | | |
| S3.2.2.2 | | Mechanic service vehicle | | 2 | months | | | | | $11,803 | | | | $23,607 | | | |
| S3.2.2.3 | | Emergency transport vehicle | | 5 | months | | | | | $4,519 | | | | $22,596 | | | |
| S3.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $116,150 | | |
| S3.2.3.1 | | Office supplies | | 5 | months | | | | | $1,000 | | | | $5,000 | | | |
| S3.2.3.2 | | Communications | | 5 | months | | | | | $1,000 | | | | $5,000 | | | |
| S3.2.3.3 | | Misc. supplies | | 5 | months | | | | | $500 | | | | $2,500 | | | |
| S3.2.3 | | Camp Operation | | 1,073 | man-days | | | | | $80 | | | | $85,800 | | | |
| S3.2.3 | | Power, heat, fuel | | 5 | months | | | | | $3,570 | | | | $17,850 | | | |
| S3.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$366,811** | |
| S3.3.1 | *Cover repairs* | | | | | | | | | | | | | | $320,441 | | |
| S3.3.1.1 | | Cover Repair allowance | Load, haul, dump, spread (spoil lo | 2% | of total | 1,336,364 | m3 of cover required replacement at: | | | $5.31 | /m3 | | | $142,044 | | | Assumes 10% of area reseeded over 5 yr PC1 perio |
| S3.3.1.2 | | | Seed/Fertilize: broadcast seeding | 67 | ha | | | | | $2,669.89 | /ha | | | $178,397 | | | |
| S3.3.2.1 | *Revegetation* | | | | | | | | | | | | | | $46,370 | | |
| S3.3.2.2 | | Reseeding allowance | Seed/Fertilize: broadcast seeding | 5% | of total | 347 | ha requires reseeding at | | | $2,669.89 | /ha | | | $46,370 | | | Assumes 25% of area reseeded over 5 yr PC1 perio |
| S3.3 | **Site Maintenance** | | | | | | | | | | | | | | $99,414 | **$99,414** | |
| S3.3.1 | | Equipment Maintenance | | 1 | ls | | $20,000 | | | | | | | $20,000 | | | Labour included in field support staff |
| S3.3.2 | | Road Maintenance | Grader (assume 40 hrs/month) | 1 | ls | 200 | | $44 | $106 | $150 | $0 | $8,878 | $21,134 | $30,012 | | | Operator cost included in Field support staff |
| S3.3.3 | | Earthwork Repair allowance (assume 20 hrs per month) | | 1 | ls | 100 | $0 | $132 | $344 | $344 | | | $34,402 | $34,402 | | | Task Code C.2.14 |
| S3.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $15,000 | | | | $15,000 | | | Allowance for pump maintenance/fuel etc. |
| S3.4 | **Transportation Costs** | | | | | | | | | | | | | | $64,628 | **$64,628** | |
| S3.4.1 | | Barge Operations | | 3 | months | | | | | $10,832 | | | | $32,497 | | | |
| S3.4.2 | | Staffing Bus trips during barge operation period | | 12 | ea | | | | | $678 | | | | $8,131 | | | One per week |
| S3.4.3 | | Air transport and airstrip operations | | 8 | flights | | | | | $3,000 | | | | $24,000 | | | One flights per week |
| **TOTAL** | | | | | | | | | | | | | | **$1,878,975** | **$1,878,975** | **$1,878,975** | |

## Phase 4 - Annual Care & Maintenance Costs - Post Closure II

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S4.1 | **Water Treatment** | | | | | | | | | | | | | | | **$126,150** | |
| S4.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $91,135 | | |
| S4.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S4.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S4.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S4.2 | **Onsite Management** | | | | | | | | | | | | | | | **$79,830** | |
| S4.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $44,847 | | |
| S4.2.1.1 | | Project Manager | | 0.5 | months | 360 | site working hours per month | | | $23,408 | | | | $11,704 | | | (Notes: staffing costs include cross-shifts) |
| S4.2.1.2 | | Passive Treatment specialist | | 0.5 | months | 360 | site working hours per month | | | $42,120 | | | | $21,060 | | | |
| S4.2.1.3 | | Mechanic | | 0.5 | months | 360 | site working hours per month | | | $17,769 | | | | $8,885 | | | |
| S4.2.1.4 | | General Labour/helpers | | 0.3 | months | 360 | site working hours per month | | | $12,793 | | | | $3,198 | | | |
| S4.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $19,313 | | |
| S4.2.2.1 | | Pick-up trucks (2 required) | | 2.0 | months | | | | | $4,446 | | | | $8,892 | | | |
| S4.2.2.2 | | Mechanic service vehicle | | 0.5 | months | | | | | $11,803 | | | | $5,902 | | | |
| S4.2.2.3 | | Emergency transport vehicle | | 1.0 | months | | | | | $4,519 | | | | $4,519 | | | |
| S4.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $15,670 | | |
| S4.2.3.1 | | Office supplies | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S4.2.3.2 | | Communications | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S4.2.3.3 | | Misc. supplies | | 1 | months | | | | | $500 | | | | $500 | | | |
| S4.2.3 | | Camp Operation | | 120 | man-days | | | | | $80 | | | | $9,600 | | | |
| S4.2.3 | | Power, heat, fuel | | 1 | months | | | | | $3,570 | | | | $3,570 | | | |
| S4.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$0** | |
| S4.3.1 | *Cover repairs* | | | | | | | | | | | | | | $0 | | |
| S4.3.2 | *Revegetation* | | | | | | | | | | | | | | $0 | | |
| S4.3 | **Site Maintenance** | | | | | | | | | | | | | | $29,882 | **$29,882** | |
| S4.3.1 | | Equipment Maintenance (parts, supplies) | | 1 | ls | | $10,000 | | | | | | | $10,000 | | | Labour included in field support staff |
| S4.3.2 | | Road Maintenance | Grader (assume 20 hrs/month) | 1 | ls | 20 | | $44 | $106 | $150 | $0 | $888 | $2,113 | $3,001 | | | Operator cost included in Field support staff |
| S4.3.3 | | Earthwork Repair allowance (assume 20 hrs per month) | | 1 | ls | 20 | $0 | $132 | $344 | $344 | | | $6,880 | $6,880 | | | Task Code C.2.14 |
| S4.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | Allowance for pump maintenance/fuel etc. |
| S4.4 | **Transportation Costs** | | | | | | | | | | | | | | $20,832 | **$20,832** | |
| S4.4.1 | | Barge Operations | | 1 | months | | | | | $10,832 | | | | $10,832 | | | |
| S4.4.2 | | Staffing Bus trips during barge operation period | | 0 | ea | | | | | $678 | | | | $0 | | | Pick-up trucks used (time included in labour rate) |
| S4.4.3 | | Barge mob/demob | | 1 | LS | | | | | $10,000 | | | | $10,000 | | | |
| **TOTAL** | | | | | | | | | | | | | | **$256,693** | **$256,693** | **$256,693** | |

## Phase 5 - Perpetual Care & Maintenance Event Year Annual Costs

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S5.1 | **Water Treatment** | | | | | | | | | | | | | | | **$35,015** | |
| S5.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S5.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S5.2 | **Onsite Management** | | | | | | | | | | | | | | | **$178,636** | |
| S5.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $129,326 | | |
| S5.2.1.1 | | Project Manager | | 1.0 | months | 360 | site working hours per month | | | $23,408 | | | | $23,408 | | | (Notes: staffing costs include cross-shifts) |
| S5.2.1.2 | | Passive Treatment specialist | | 1.0 | months | 360 | site working hours per month | | | $42,120 | | | | $42,120 | | | |
| S5.2.1.3 | | Site Engineer | | 1.0 | months | 360 | site working hours per month | | | $42,120 | | | | $42,120 | | | |
| S5.2.1.4 | | HD mechanic | | 0.5 | months | 360 | site working hours per month | | | $17,769 | | | | $8,885 | | | |
| S5.2.1.5 | | General Labour/helpers | | 1.0 | months | 360 | site working hours per month | | | $12,793 | | | | $12,793 | | | |
| S5.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $19,239 | | |
| S5.2.2.1 | | Pick-up trucks (3 required) | | 3 | months | | | | | $4,446 | | | | $13,338 | | | |
| S5.2.2.2 | | Mechanic service vehicle | | 1 | months | | | | | $11,803 | | | | $5,902 | | | |
| S5.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $30,070 | | |
| S5.2.3.1 | | Office supplies | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S5.2.3.2 | | Communications | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S5.2.3.3 | | Misc. supplies | | 1 | months | | | | | $500 | | | | $500 | | | |
| S5.2.3.4 | | Camp Operation | | 300 | man-days | | | | | $80 | | | | $24,000 | | | |
| S5.2.3.5 | | Power, heat, fuel | | 1 | months | | | | | $3,570 | | | | $3,570 | | | |
| S5.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$0** | |
| S5.4 | **Site Maintenance** | | | | | | | | | | | | | | $108,253 | **$108,253** | |
| S5.4.1 | | Grader Maintenance | Grader (assume 2 weeks, 10hrs/d | 1 | ls | 140 | | $44 | $106 | $150 | $0 | $6,214 | $14,794 | $21,008 | | | Operator cost included in Field support staff |
| S5.4.2 | | Earthwork Repair allowance (assume 3 weeks, 10hrs/day) | | 1 | ls | 210 | $0 | $132 | $344 | $344 | | | $72,245 | $72,245 | | | Task Code C.2.14 |
| S5.4.3 | | Big Creek Bridge - Capital replacement allowance | | 1 | ls | | | | | $15,000 | | | | $15,000 | | | Allowance for supplies, pumping, etc. |
| S5.4.4 | | Sundry allowance | | 1 | ls | | | | | $2,500 | | | | $2,500 | | | Allowance for supplies, pumping, etc. |
| S5.5 | **Transportation Costs** | | | | | | | | | | | | | | $69,943 | **$69,943** | |
| S5.5.1 | | Barge Operations | | 1 | months | | | | | $10,832 | | | | $10,832 | | | |
| S5.5.2 | | Barge mobilization/demob and set up | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | assumed |
| S5.5.3 | | Camp Mob/demob | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | assumed |
| S5.5.4 | | Equipment mobilization and demobilization | | 2 | ls | | | | | $19,555 | | | | $39,110.91 | | | See details on 'mob-demob 'worksheet |
| **TOTAL** | | | | | | | | | | | | | | **$394,347** | **$391,847** | **$391,847** | |

# Worksheet 4 - Year 0 Estimate - Implementation Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| **DIRECT COSTS** | | | | | | | | | | | | | | | | | | | | | |
| A1 | **Waste Dumps** | | | | | | | | | | | | | | | | | | | **$6,847,702** | |
| A1.1 | *Main Waste Dump (inc. MWDE)* | | | | | | | | | | | | | | | | | | $776,082 | | Does not include MWD Wrap |
| A1.1.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 187 | hrs | C.2.13 | 187 | $44.39 | $8,303 | $194.68 | $36,415 | $67.01 | 13,056 | $12,534 | $0.00 | $0 | $306.07 | $57,252 | | | |
| A1.1.1.2 | | | Slopes: Re-grade to 3H:1V | 336 | hrs | C.2.13 | 336 | $44.39 | $14,916 | $194.68 | $65,421 | $67.01 | 23,456 | $22,518 | $0.00 | $0 | $306.07 | $102,855 | | | |
| A1.1.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 22,513 | Cm3 | R.050 | 420.0 | $0.82 | $18,498 | $2.67 | $60,112 | $0.88 | 20,606 | $19,782 | $0.00 | $0 | $4.37 | $98,392 | | | |
| A1.1.2.2 | | | Slope area cover material: Load, haul, dump along crest | 59,101 | Cm3 | R.051 | 964.8 | $0.72 | $42,444 | $2.37 | $140,125 | $0.80 | 49,031 | $47,070 | $0.00 | $0 | $3.89 | $229,639 | | | |
| A1.1.2.3 | | | Slope area cover material: Spread down slope | 179 | hrs | C.2.13 | 178.9 | $44.39 | $7,941 | $194.68 | $34,828 | $67.01 | 12,487 | $11,988 | $0.00 | $0 | $306.07 | $54,757 | | | |
| A1.1.3.1 | | Revegetate | Seed/Fertilize: tractor application | 42 | ha | C.6.01 | 1,379.7 | $1,029.50 | $42,879 | $401.72 | $16,732 | $232.94 | 10,107 | $9,702 | $1,005.72 | $41,889 | $2,670 | $111,202 | | | |
| A1.1.3.2 | | | Tree seedling application (1,000 stems/ha) | 52 | ha | C.6.06 | 2,668.2 | $1,832.33 | $95,397 | $25.98 | $1,353 | $15.00 | 813 | $781 | $469.71 | $24,455 | $2,343 | $121,985 | | | |
| A1.2 | *Southwest Dump (excluding high grade waste area)* | | | | | | | | | | | | | | | | | | $907,790 | | |
| A1.2.1 | | Re-grade | Slopes: Re-grade remaining to 3H:1V | 12 | hrs | C.2.13 | 12.1 | $44.39 | $536.44 | $194.68 | $2,353 | $67.01 | 844 | $809.81 | $0.00 | $0.00 | $306.07 | $3,699 | | | |
| A1.2.2 | | Cover | Load, haul, dump spread | 156,905 | m3 | R.059 | 2,731.6 | $0.77 | $120,388.52 | $2.49 | $391,345 | $0.82 | 133,341 | $128,007.23 | $0.00 | $0.00 | $4.08 | $639,741 | | | |
| A1.2.3.1 | | Revegetate | Seed/Fertilize: tractor application | 43.93 | ha | C.6.01 | 1,455.4 | $1,029.50 | $45,229.58 | $401.72 | $17,649 | $232.94 | 10,660 | $10,234.04 | $1,005.72 | $44,184.74 | $2,669.89 | $117,297 | | | |
| A1.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 62.76 | ha | C.6.06 | 3,216.6 | $1,832.33 | $115,000.98 | $25.98 | $1,631 | $15.00 | 981 | $941.43 | $469.71 | $29,479.97 | $2,343.03 | $147,053 | | | |
| A1.3 | *Southwest Dump High-Grade Waste* | | | | | | | | | | | | | | | | | | $249,632 | | |
| A1.3.1.1 | | Relocate High-grade waste | Load, haul, dump, spread in pit (below long-term water elevation) | 45,711 | Bm3 | R.069 | 688.0 | $0.66 | $30,283.89 | $2.19 | $100,276 | $0.73 | 34,965 | $33,566.76 | $0.00 | $0.00 | $3.59 | $164,127 | | | |
| A1.3.2.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 31 | hrs | C.2.13 | 31.1 | $44.39 | $1,378.38 | $194.68 | $6,045 | $67.01 | 2,168 | $2,080.81 | $0.00 | $0.00 | $306.07 | $9,505 | | | |
| A1.3.3.1 | | Cover | Flat area cover material: Load, haul, dump spread | 15,583 | Cm3 | R.060 | 257.8 | $0.73 | $11,362.15 | $2.37 | $36,935 | $0.78 | 12,585 | $12,081.20 | $0.00 | $0.00 | $3.87 | $60,378 | | | |
| A1.3.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.12 | ha | C.6.01 | 103.2 | $1,029.50 | $3,208.44 | $401.72 | $1,252 | $232.94 | 756 | $725.97 | $1,005.72 | $3,134.33 | $2,669.89 | $8,321 | | | |
| A1.3.4.2 | | | Tree seedling application (1,000 stems/ha) | 3.12 | ha | C.6.06 | 159.7 | $1,832.33 | $5,710.47 | $25.98 | $81 | $15.00 | 49 | $46.75 | $469.71 | $1,463.85 | $2,343.03 | $7,302 | | | |
| A1.4 | *Main Pit SAT* | | | | | | | | | | | | | | | | | | $4,103,230 | | |
| A1.4.1.1 | | Relocate SAT below water | Load, haul, dump, spread in pit | 1,040,000 | Cm3 | R.012 | 17,781.5 | $0.75 | $785,076.51 | $1.86 | $1,935,773 | $0.51 | 555,290 | $533,078.26 | $0.00 | $0.00 | $3.13 | $3,253,928 | | | |
| A1.4.1.2 | | | Allowance for additional SAT material from SAT Dump | 30,000 | Cm3 | R.012 | 512.9 | $0.75 | $22,646.44 | $1.86 | $55,840 | $0.51 | 16,018 | $15,377.26 | $0.00 | $0.00 | $3.13 | $93,863 | | | |
| A1.4.2.1 | | Backfill SAT Excavation | Load, haul, dump WR to form buttress below MPD | 245,000 | Cm3 | R.013 | 3,226.9 | $0.58 | $142,343.39 | $1.89 | $462,905 | $0.61 | 156,449 | $150,191.13 | $0.00 | $0.00 | $3.08 | $755,439 | | | Cover and revegetation of backfill included in MPD (A1.5) |
| A1.5 | *Main Pit Dump (Incl. SWB, In-Pit Dumps)* | | | | | | | | | | | | | | | | | | $686,521 | | |
| A1.5.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 65 | hrs | C.2.13 | 65.1 | $44.39 | $2,891.84 | $194.68 | $12,683 | $67.01 | 4,547 | $4,365.54 | $0.00 | $0.00 | $306.07 | $19,941 | | | Assumes MPD is fully constructed |
| A1.5.1.2 | | | Slopes: Re-grade to 3H:1V | 207 | hrs | C.2.13 | 206.7 | $44.39 | $9,174.86 | $194.68 | $40,240 | $67.01 | 14,428 | $13,850.42 | $0.00 | $0.00 | $306.07 | $63,265 | | | |
| A1.5.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 45,270 | m3 | R.053 | 732.0 | $0.71 | $32,263.18 | $2.32 | $104,877 | $0.76 | 35,734 | $34,304.93 | $0.00 | $0.00 | $3.79 | $171,445 | | | |
| A1.5.2.2 | | | Slope area cover material: Load, haul, dump along crest | 84,053 | m3 | R.054 | 1,165.0 | $0.61 | $51,284.32 | $2.02 | $169,813 | $0.68 | 59,212 | $56,843.70 | $0.00 | $0.00 | $3.31 | $277,941 | | | |
| A1.5.2.3 | | | Slope area cover material: Spread down slope | 79 | hrs | C.2.13 | 79.3 | $44.39 | $3,520.01 | $194.68 | $15,438 | $67.01 | 5,535 | $5,313.82 | $0.00 | $0.00 | $306.07 | $24,272 | | | |
| A1.5.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 25.9 | ha | C.6.01 | 856.8 | $1,029.50 | $26,627.72 | $401.72 | $10,390 | $232.94 | 6,276 | $6,025.02 | $1,005.72 | $26,012.60 | $2,669.89 | $69,056 | | | |
| A1.5.3.2 | | | Tree seedling application (1,000 stems/ha) | 25.9 | ha | C.6.06 | 1,325.6 | $1,832.33 | $47,392.66 | $25.98 | $672 | $15.00 | 404 | $387.97 | $469.71 | $12,148.89 | $2,343.03 | $60,602 | | | |
| A1.6.0.0 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $124,446 | | |
| A1.6.1.1 | | Complete Fill Placement | Waste Rock fill: Load, haul, dump spread | 0 | m3 | R.041 | 0.0 | $0.97 | $0.00 | $3.15 | $0 | $1.04 | 0 | $0.00 | $0.00 | $0.00 | $5.15 | $0 | | | Quantitiies updated in late 2017 to reflect progressive |
| A1.6.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 81 | hrs | C.2.13 | 81.2 | $44.39 | $3,605.65 | $194.68 | $15,814 | $67.01 | 5,670 | $5,443.12 | $0.00 | $0.00 | $306.07 | $24,863 | | | reclamation completed at the facility. |
| A1.6.2.2 | | | Slopes: Re-grade to 3H:1V | 4 | hrs | C.2.13 | 4.3 | $44.39 | $189.50 | $194.68 | $831 | $67.01 | 298 | $286.07 | $0.00 | $0.00 | $306.07 | $1,307 | | | |
| A1.6.3.1 | | Cover | Flat area cover material: Load, haul, dump spread | 5,743 | m3 | R.056 | 116.9 | $0.90 | $5,150.07 | $2.91 | $16,736 | $0.96 | 5,737 | $5,507.52 | $0.00 | $0.00 | $4.77 | $27,394 | | | |
| A1.6.3.2 | | | Slope area cover material: Load, haul, dump along crest | 1,496 | m3 | R.057 | 26.7 | $0.78 | $1,172.86 | $2.59 | $3,872 | $0.87 | 1,355 | $1,300.68 | $0.00 | $0.00 | $4.24 | $6,346 | | | |
| A1.6.3.3 | | | Slope area cover material: Spread down slope | 1 | hrs | C.2.13 | 0.9 | $44.39 | $40.75 | $194.68 | $179 | $67.01 | 64 | $61.52 | $0.00 | $0.00 | $306.07 | $281 | | | |
| A1.6.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 8.74 | ha | C.6.01 | 289.4 | $1,029.50 | $8,992.98 | $401.72 | $3,509 | $232.94 | 2,120 | $2,034.83 | $1,005.72 | $8,785.24 | $2,669.89 | $23,322 | | | |
| A1.6.4.2 | | | Tree seedling application (1,000 stems/ha) | 17.47 | ha | C.6.06 | 895.4 | $1,832.33 | $32,011.85 | $25.98 | $454 | $15.00 | 273 | $262.06 | $469.71 | $8,206.09 | $2,343.03 | $40,934 | | | |
| A2 | **Overburden Dumps** | | | | | | | | | | | | | | | | | | | **$370,112** | |
| A2.1 | *Area 118 Pit Backfill Dump* | | | | | | | | | | | | | | | | | | $25,293 | | |
| A2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 14 | hrs | C.2.13 | 14.0 | $44.39 | $621.99 | $194.68 | $2,728 | $67.01 | 978 | $938.96 | $0.00 | $0.00 | $306.07 | $4,289 | | | |
| A2.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 4 | ha | C.6.01 | 138.8 | $1,029.50 | $4,313.51 | $401.72 | $1,683 | $232.94 | 1,017 | $976.01 | $1,005.72 | $4,213.87 | $2,669.89 | $11,187 | | | |
| A2.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 4 | ha | C.6.06 | 214.7 | $1,832.33 | $7,677.29 | $25.98 | $109 | $15.00 | 65 | $62.85 | $469.71 | $1,968.04 | $2,343.03 | $9,817 | | | |
| A2.2 | *Ice-rich Overburden Dump* | | | | | | | | | | | | | | | | | | $13,827 | | |
| A2.2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.2.1.2 | | | Berm: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | WR Berm area included in Southwest Dump |
| A2.2.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.76 | ha | C.6.01 | 91.4 | $1,029.50 | $2,839.68 | $401.72 | $1,108 | $232.94 | 669 | $642.53 | $1,005.72 | $2,774.08 | $2,669.89 | $7,364 | | | |
| A2.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 2.76 | ha | C.6.06 | 141.4 | $1,832.33 | $5,054.12 | $25.98 | $72 | $15.00 | 43 | $41.37 | $469.71 | $1,295.60 | $2,343.03 | $6,463 | | | |
| A2.3 | *Reclamation Overburden Dump* | | | | | | | | | | | | | | | | | | $330,992 | | |
| A2.3.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 594 | hrs | C.2.13 | 593.6 | $44.39 | $26,347.50 | $194.68 | $115,557 | $67.01 | 41,432 | $39,774.35 | $0.00 | $0.00 | $306.07 | $181,679 | | | |
| A2.3.1.2 | | | Slopes: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | Assumes borrow removed in such a manner that significant resloping is not required. |
| A2.3.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 29.79 | ha | C.6.01 | 986.7 | $1,029.50 | $30,664.45 | $401.72 | $11,966 | $232.94 | 7,228 | $6,938.40 | $1,005.72 | $29,956.07 | $2,669.89 | $79,525 | | | |
| A2.3.2.2 | | | Tree seedling application (1,000 stems/ha) | 29.79 | ha | C.6.06 | 1,526.5 | $1,832.33 | $54,577.32 | $25.98 | $774 | $15.00 | 465 | $446.79 | $469.71 | $13,990.64 | $2,343.03 | $69,789 | | | |
| A2.4 | *Ridgetop South Backfill Dump* | | | | | | | | | | | | | | | | | | $0 | | |
| **A3** | **Ore Stockpiles** | | | | | | | | | | | | | | | | | | | **$1,419,486** | |
| A3.1 | *High and Medium Grade Sulphide Ore Stockpile (South of Mill)* | | | | | | | | | | | | | | | | | | $1,264,472 | | (North, West, East, and South Stockpiles) |
| A3.1.1.1 | | Relocate to Pit | Ore: Load, haul, dump, spread into Main Pit | 205,490 | m3 | R.044 | 2,417.3 | $0.52 | $106,498.23 | $1.72 | $354,091 | $0.57 | 122,871 | $117,956.06 | $0.00 | $0.00 | $2.82 | $578,546 | | | |
| A3.1.1.2 | | | Ore Pads (over-excavate): Load, haul, dump spread into Main Pit | 71,007 | m3 | R.044 | 835.3 | $0.52 | $36,800.28 | $1.72 | $122,356 | $0.57 | 42,458 | $40,759.51 | $0.00 | $0.00 | $2.82 | $199,915 | | | |
| A3.1.1.3 | | | Complete confirmation testing | 1,421 | ea | C.3.02 | 236.8 | $7.43 | $10,556.37 | $1.33 | $1,883 | $0.00 | 0 | $0.00 | $13.26 | $18,842.46 | $22.01 | $31,282 | | | |
| A3.1.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 289 | hrs | C.2.13 | 289.4 | $44.39 | $12,843.71 | $194.68 | $56,331 | $67.01 | 20,197 | $19,388.95 | $0.00 | $0.00 | $306.07 | $88,564 | | | |
| A3.1.3.1 | | Cover | Cover material: Load, haul, dump spread (0.5m) | 69,653 | m3 | R.055 | 1,264.9 | $0.80 | $55,711.18 | $2.60 | $181,043 | $0.86 | 62,060 | $59,577.97 | $0.00 | $0.00 | $4.25 | $296,332 | | | |
| A3.1.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 13.93 | ha | C.6.01 | 461.5 | $1,029.50 | $14,341.67 | $401.72 | $5,596 | $232.94 | 3,380 | $3,245.07 | $1,005.72 | $14,010.36 | $2,669.89 | $37,193 | | | |
| A3.1.4.2 | | | Tree seedling application (1,000 stems/ha) | 13.93 | ha | C.6.06 | 713.9 | $1,832.33 | $25,525.64 | $25.98 | $362 | $15.00 | 218 | $208.96 | $469.71 | $6,543.38 | $2,343.03 | $32,640 | | | |
| A3.2 | *Low Grade Sulphide Ore Stockpile (Main Dump Area)* | | | | | | | | | | | | | | | | | | $155,014 | | |
| A3.2.1.1 | | Relocate to Pit | Ore: Load, haul, dump, spread into Main Pit | 15,490 | m3 | R.036 | 195.9 | $0.56 | $8,624.35 | $1.84 | $28,557 | $0.62 | 9,958 | $9,559.25 | $0.00 | $0.00 | $3.02 | $46,741 | | | |
| A3.2.1.2 | | | Ore Pad (over-excavate): Load, haul, dump spread into Main Pit | 31,316 | m3 | R.036 | 396.1 | $0.56 | $17,435.36 | $1.84 | $57,732 | $0.62 | 20,131 | $19,325.41 | $0.00 | $0.00 | $3.02 | $94,493 | | | |
| A3.2.1.3 | | | Complete confirmation testing | 626 | ea | C.3.02 | 104.3 | $7.43 | $4,650.45 | $1.33 | $829 | $0.00 | 0 | $0.00 | $13.26 | $8,300.76 | $22.01 | $13,781 | | | |
| A3.2.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.3.1 | | Cover | Cover material: Load, haul, dump spread | 0 | m3 | R.050 | 0.0 | $0.82 | $0.00 | $2.67 | $0 | $0.88 | 0 | $0.00 | $0.00 | $0.00 | $4.37 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.4.2 | | | Tree seedling application (1,000 stems/ha) | 0 | ha | C.6.06 | 0.0 | $1,832.33 | $0.00 | $25.98 | $0 | $15.00 | 0 | $0.00 | $469.71 | $0.00 | $2,343.03 | $0 | | | Included in Main Waste Dump Closure |
| **A4** | **Open Pits** | | | | | | | | | | | | | | | | | | | **$177,927** | |
| A4.1 | *Main Pit* | | | | | | | | | | | | | | | | | | $150,984 | | |
| A4.1.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 7,500 | m2 | C.2.03 | 28.5 | $0.17 | $1,265.55 | $0.49 | $3,658 | $0.13 | 1,048 | $1,005.87 | $0.00 | $0.00 | $0.79 | $5,930 | | | |
| A4.1.1.2 | | | Safety Berm: Construct around highwall perimeter | 4,860 | m3 | C.2.02 | 45.8 | $0.42 | $2,035.14 | $0.89 | $4,333 | $0.25 | 1,267 | $1,215.92 | $0.00 | $0.00 | $1.56 | $7,584 | | | |
| A4.1.1.3 | | | Place large boulders across any pit access points | 52 | m3 | R.001 | 1.6 | $1.39 | $72.20 | $3.03 | $157 | $0.90 | 49 | $46.76 | $0.00 | $0.00 | $5.31 | $276 | | | |
| A4.1.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.1.2.1 | | Exposed tailings cover | Trafficability Layer: Load, haul, dump spread | 17,750 | m3 | R.014 | 554.4 | $1.38 | $24,425.58 | $2.86 | $50,708 | $0.82 | 15,091 | $14,487.41 | $0.00 | $0.00 | $5.05 | $89,621 | | | |
| A4.1.2.2 | | | Overburden Layer: Load, haul, dump spread | 8,875 | m3 | R.052 | 158.4 | $0.79 | $6,976.73 | $2.55 | $22,672 | $0.84 | 7,772 | $7,460.97 | $0.00 | $0.00 | $4.18 | $37,110 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A4.1.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2 | ha | C.6.01 | 58.8 | $1,029.50 | $1,827.37 | $401.72 | $713 | $232.94 | 431 | $413.48 | $1,005.72 | $1,785.15 | $2,669.89 | $4,739 | | | |
| A4.1.3.2 | | | Tree seedling application (1,000 stems/ha) | 2 | ha | C.6.06 | 91.0 | $1,832.33 | $3,252.39 | $25.98 | $46 | $15.00 | 28 | $26.63 | $469.71 | $833.74 | $2,343.03 | $4,159 | | | |
| A4.2 | *Area 2 Pit* | | | | | | | | | | | | | | | | | | $10,001 | | |
| A4.2.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | |
| A4.2.1.2 | | | Safety Berm: Construct around highwall perimeter | 5,317 | m3 | C.2.02 | 50.2 | $0.42 | $2,226.54 | $0.89 | $4,740 | $0.25 | 1,386 | $1,330.27 | $0.00 | $0.00 | $1.56 | $8,297 | | | |
| A4.2.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.2.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.3 | *Area 118 Pit* | | | | | | | | | | | | | | | | | | $5,461 | | |
| A4.3.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 2,580 | m2 | C.2.03 | 9.8 | $0.17 | $435.35 | $0.49 | $1,258 | $0.13 | 360 | $346.02 | $0.00 | $0.00 | $0.79 | $2,040 | | | |
| A4.3.1.2 | | | Safety Berm: Construct around highwall perimeter | 1,435 | m3 | C.2.02 | 13.5 | $0.42 | $600.85 | $0.89 | $1,279 | $0.25 | 374 | $358.99 | $0.00 | $0.00 | $1.56 | $2,239 | | | |
| A4.3.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.3.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 4 | ea | C.5.13 | 3.7 | $40.27 | $161.09 | $15.90 | $64 | $5.57 | 23 | $22.26 | $199.26 | $797.04 | $261.00 | $1,044 | | | |
| A4.4 | *Minto North Pit* | | | | | | | | | | | | | | | | | | $11,481 | | |
| A4.4.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 5,900 | m2 | C.2.03 | 22.4 | $0.17 | $995.56 | $0.49 | $2,878 | $0.13 | 824 | $791.29 | $0.00 | $0.00 | $0.79 | $4,665 | | | |
| A4.4.1.2 | | | Safety Berm: Construct around highwall perimeter | 3,610 | m | C.2.02 | 34.1 | $0.42 | $1,511.81 | $0.89 | $3,219 | $0.25 | 941 | $903.25 | $0.00 | $0.00 | $1.56 | $5,634 | | | |
| A4.4.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.4.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 4 | ea | C.5.13 | 3.7 | $40.27 | $161.09 | $15.90 | $64 | $5.57 | 23 | $22.26 | $199.26 | $797.04 | $261.00 | $1,044 | | | |
| **A5** | **Underground Openings** | | | | | | | | | | | | | | | | | | | **$81,637** | |
| A5.1 | *Minto North Portal* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.1.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.1.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.2 | *Minto North Portal Egress* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.2.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.2.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.3 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.3.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.3.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.3.2.1 | | Revegetate | Included in Yards (WBS No. A11-10) | | | | | | | | | | | | | | | | | | |
| A5.4 | *Area 118 Vent Raise* | | | | | | | | | | | | | | | | | | $10,691 | | |
| A5.4.1.1 | | Site Preparation | Removal of Heater/Fan included in Demolition | | | | | | | | | | | | | | | | | | |
| A5.4.1.2 | | | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.4.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.4.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.4.2.3 | | | Ringwall Rebar: supply and install | 32 | m | C.8.05 | 0.8 | $1.27 | $40.74 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $107.82 | $4.64 | $149 | | | |
| A5.4.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.4.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.4.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| A5.5 | *Minto East Vent Raise* | | | | | | | | | | | | | | | | | | $10,610 | | |
| A5.5.1.2 | | Preparation | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.5.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.5.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.5.2.3 | | | Ringwall Rebar: supply and install | 14 | m | C.8.05 | 0.3 | $1.27 | $18.33 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $48.52 | $4.64 | $67 | | | |
| A5.5.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.5.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.5.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| A5.6 | *Minto East 2 Vent Raise* | | | | | | | | | | | | | | | | | | $10,617 | | |
| A5.6.1.1 | | Site Preparation | Removal of Heater/Fan included in Demolition | | | | | | | | | | | | | | | | | | |
| A5.6.1.2 | | | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.6.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.6.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.6.2.3 | | | Ringwall Rebar: supply and install | 16 | m | C.8.05 | 0.4 | $1.27 | $20.37 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $53.91 | $4.64 | $74 | | | |
| A5.6.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.6.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.6.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| **A6** | **External Tailings Facilities** | | | | | | | | | | | | | | | | | | | **$202,656** | |
| A6.1 | *Dry Stack Tailings Storage Facility* | | | | | | | | | | | | | | | | | | $202,656 | | |
| A6.1.1.1 | | Waste Rock Shell | Regrade WR shell slopes to 4H:1V | 3 | hrs | C.2.13 | 2.6 | $44.39 | $117.60 | $194.68 | $516 | $67.01 | 185 | $177.52 | $0.00 | $0.00 | $306.07 | $811 | | | |
| A6.1.1.2 | | | Cover material: Load, haul, dump spread (0.5m) | 5,296 | m3 | R.048 | 102.8 | $0.86 | $4,529.70 | $2.78 | $14,720 | $0.91 | 5,046 | $4,844.09 | $0.00 | $0.00 | $4.55 | $24,094 | | | |
| A6.1.1.3 | | | Scarify surface | 0 | m2 | C.2.16 | 0.0 | $0.03 | $0.00 | $0.07 | $0 | $0.02 | 0 | $0.00 | $0.00 | $0.00 | $0.12 | $0 | | | |
| A6.1.1.4 | | | Seed/Fertilize: broadcast seeding | 1.06 | ha | C.6.01 | 35.1 | $1,029.50 | $1,090.39 | $401.72 | $425 | $232.94 | 257 | $246.72 | $1,005.72 | $1,065.20 | $2,669.89 | $2,828 | | | |
| A6.1.1.5 | | | Tree seedling application (1,000 stems/ha) | 5.30 | ha | C.6.06 | 271.4 | $1,832.33 | $9,703.52 | $25.98 | $138 | $15.00 | 83 | $79.44 | $469.71 | $2,487.45 | $2,343.03 | $12,408 | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| A6.1.2.1 | | Fill Area at south end of DS | Load, haul, dump, spread | 9,090 | Cm3 | R.001 | 286.5 | $1.39 | $12,620.67 | $3.03 | $27,515 | $0.90 | 8,514 | $8,173.14 | $0.00 | $0.00 | $5.31 | $48,309 | | | Fill from TDD road and/or unsuitable DSTSF cover material |
| A6.1.3.1 | | Tailings surface | Regrade tailings area south of the tailings | 2 | hrs | C.2.13 | 1.6 | $44.39 | $71.53 | $194.68 | $314 | $67.01 | 112 | $107.98 | $0.00 | $0.00 | $306.07 | $493 | | | |
| A6.1.3.2 | | | Regrade surface to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A6.1.3.3 | | | Cover: Excavate unsuitable temporary cover material | 0 | m3 | R.003 | 0.0 | $0.51 | $0.00 | $1.70 | $0 | $0.57 | 0 | $0.00 | $0.00 | $0.00 | $2.78 | $0 | | | |
| A6.1.3.4 | | | Cover material: Load, haul, dump spread (0.5m) | 3,887 | m3 | R.048 | 75.5 | $0.86 | $3,324.91 | $2.78 | $10,805 | $0.91 | 3,704 | $3,555.68 | $0.00 | $0.00 | $4.55 | $17,685 | | | |
| A6.1.3.5 | | | Seed/Fertilize: broadcast seeding | 19.16 | ha | C.6.01 | 634.6 | $1,029.50 | $19,721.25 | $401.72 | $7,695 | $232.94 | 4,648 | $4,462.30 | $1,005.72 | $19,265.67 | $2,669.89 | $51,145 | | | |
| A6.1.3.6 | | | Tree seedling application (1,000 stems/ha) | 19.16 | ha | C.6.06 | 981.8 | $1,832.33 | $35,100.35 | $25.98 | $498 | $15.00 | 299 | $287.34 | $469.71 | $8,997.81 | $2,343.03 | $44,883 | | | |
| **A7** | **Roads** | | | | | | | | | | | | | | | | | | | **$136,050** | |
| A7.1 | *Exploration Roads* | | | | | | | | | | | | | | | | | | $33,589 | | |
| A7.1.1.1 | | Regrade/Scarify | Scarify road surface | 54,285 | m2 | C.2.16 | 0.0 | $0.03 | $1,886.30 | $0.07 | $3,564 | $0.02 | 965 | $926.07 | $0.00 | $0.00 | $0.12 | $6,377 | | | |
| A7.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.43 | ha | C.6.01 | 179.8 | $1,029.50 | $5,588.65 | $401.72 | $2,181 | $232.94 | 1,317 | $1,264.54 | $1,005.72 | $5,459.55 | $2,669.89 | $14,494 | | | |
| A7.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 5.43 | ha | C.6.06 | 278.2 | $1,832.33 | $9,946.82 | $25.98 | $141 | $15.00 | 85 | $81.43 | $469.71 | $2,549.82 | $2,343.03 | $12,719 | | | |
| A7.2 | *Access Roads (excl. Main Site Access Road)* | | | | | | | | | | | | | | | | | | $9,082 | | |
| A7.2.1.1 | | Regrade/Scarify | Regrade side slopes | 9 | hrs | C.2.13 | 9.5 | $44.39 | $419.85 | $194.68 | $1,841 | $67.01 | 660 | $633.81 | $0.00 | $0.00 | $306.07 | $2,895 | | | |
| A7.2.1.2 | | | Scarify road surface | 52,636 | m2 | C.2.16 | 0.0 | $0.03 | $1,829.00 | $0.07 | $3,456 | $0.02 | 935 | $897.94 | $0.00 | $0.00 | $0.12 | $6,183 | | | |
| A7.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.77 | $401.72 | $0 | $232.94 | 0 | $0.17 | $1,005.72 | $0.75 | $2,669.89 | $2 | | | |
| A7.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 0.00 | ha | C.6.06 | 0.0 | $1,832.33 | $1.36 | $25.98 | $0 | $15.00 | 0 | $0.01 | $469.71 | $0.35 | $2,343.03 | $2 | | | |
| A7.3 | *Main Site Access Road* | | | | | | | | | | | | | | | | | | $1,343 | | |
| A7.3.1.1 | | New Access over MVFE | Regrade new access through MVFE | 0 | m3 | | | | | | | | | | | | | | | | |
| A7.3.2.1 | | Signage | Install large sign on east and west side of barge landing on Yukon River | 2 | ea. | C.5.14 | 1.9 | $40.27 | $80.54 | $15.90 | $32 | $5.57 | 12 | $11.13 | $609.74 | $1,219.48 | $671.48 | $1,343 | | | |
| A7.4 | *Haul Roads* | | | | | | | | | | | | | | | | | | $72,436 | | |
| A7.4.1.1 | | Regrade/Scarify | Regrade side slopes | 21 | hrs | C.2.13 | 20.5 | $44.39 | $910.71 | $194.68 | $3,994 | $67.01 | 1,432 | $1,374.82 | $0.00 | $0.00 | $306.07 | $6,280 | | | |
| A7.4.1.2 | | | Scarify road surface | 91,084 | m2 | C.2.16 | 0.0 | $0.03 | $3,164.99 | $0.07 | $5,981 | $0.02 | 1,619 | $1,553.84 | $0.00 | $0.00 | $0.12 | $10,700 | | | |
| A7.4.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 11.06 | ha | C.6.01 | 366.5 | $1,029.50 | $11,389.06 | $401.72 | $4,444 | $232.94 | 2,684 | $2,576.99 | $1,005.72 | $11,125.97 | $2,669.89 | $29,536 | | | |
| A7.4.2.2 | | | Tree seedling application (1,000 stems/ha) | 11.06 | ha | C.6.06 | 567.0 | $1,832.33 | $20,270.53 | $25.98 | $287 | $15.00 | 173 | $165.94 | $469.71 | $5,196.25 | $2,343.03 | $25,920 | | | |
| A7.5 | *Culvert Removal* | | | | | | | | | | | | | | | | | | $19,600 | | |
| A7.5.1.1 | | Excavate culverts | Mobilization allowance for excavation fleet to various sites | 6 | hrs | C.7.01 | 12.0 | $88.22 | $529.34 | $118.29 | $710 | $44.16 | 276 | $264.96 | $0.00 | $0.00 | $250.67 | $1,504 | | | |
| A7.5.1.2 | | | Load, haul, dump, spread (spoil locally) | 18,020 | m3 | R.901 | 59.1 | $0.15 | $2,622.79 | $0.58 | $10,499 | $0.20 | 3,841 | $3,687.10 | $0.00 | $0.00 | $0.93 | $16,809 | | | |
| A7.5.1.2 | | Waste disposal | On-site disposal (demolition debris, etc.) | 190 | Lm3 | R.037 | 8.1 | $1.87 | $356.36 | $3.75 | $713 | $1.14 | 227 | $217.54 | $0.00 | $0.00 | $6.77 | $1,287 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| **A8** | **Demolition** | | | | | | | | | | | | | | | | | | | **$1,976,253** | |
| A8.1 | *Airstrip Area* | | | | | | | | | | | | | | | | | | $21,059 | | |
| A8.1.1.1 | | Remove tanks/equipment | Dismantle and prep for transport | 7 | hrs | C.1.13 | 28.0 | $168.00 | $1,175.97 | $86.19 | $603 | $14.53 | 106 | $101.70 | $0.00 | $0.00 | $268.71 | $1,881 | | | |
| A8.1.2.1 | | Waste Oil Tanker Secondar | Bedding Material: Load, haul dump bedding material to landfarm | 47 | Cm3 | R.001 | 1.5 | $1.39 | $65.73 | $3.03 | $143 | $0.90 | 44 | $42.57 | $0.00 | $0.00 | $5.31 | $252 | | | |
| A8.1.2.2 | | | Cut and fold liner | 219 | m2 | C.1.15 | 2.5 | $0.43 | $94.83 | $0.19 | $43 | $0.07 | 16 | $15.13 | $0.00 | $0.00 | $0.70 | $152 | | | |
| A8.1.2.3 | | | Regrade area to promote positive drainage | 192 | m2 | C.2.11 | 1.9 | $0.44 | $85.22 | $1.28 | $246 | $0.35 | 71 | $67.74 | $0.00 | $0.00 | $2.08 | $399 | | | |
| A8.1.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 10 | hrs | C.1.22 | 40.0 | $159.30 | $1,592.98 | $95.83 | $958 | $26.93 | 281 | $269.28 | $0.00 | $0.00 | $282.05 | $2,821 | | | |
| A8.1.3.2 | | | Disconnect services | 4 | hrs | C.1.09 | 12.0 | $88.07 | $352.28 | $7.55 | $30 | $4.80 | 20 | $19.20 | $0.00 | $0.00 | $100.42 | $402 | | | |
| A8.1.4.1 | | Demolition | Structural building demolition: wooden buildings/tents | 1,149 | m3 | C.1.08 | 87.7 | $2.88 | $3,310.74 | $1.60 | $1,834 | $0.57 | 680 | $652.51 | $0.00 | $0.00 | $5.05 | $5,797 | | | |
| A8.1.4.2 | | | Other demolition: covered storage, debris, etc. | 530 | m3 | C.1.07 | 52.5 | $3.74 | $1,980.53 | $2.07 | $1,097 | $0.74 | 407 | $390.34 | $0.00 | $0.00 | $6.55 | $3,468 | | | |
| A8.1.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 379 | m3 | R.006 | 12.8 | $1.48 | $562.06 | $2.95 | $1,117 | $0.92 | 361 | $346.89 | $0.00 | $0.00 | $5.35 | $2,026 | | | |
| A8.1.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 4 | m3 | C.7.07 | 34.6 | $355.10 | $1,536.93 | $423.68 | $1,834 | $113.33 | 511 | $490.50 | $0.00 | $0.00 | $892.11 | $3,861 | | | |
| A8.2 | *Airport Laydown Area* | | | | | | | | | | | | | | | | | | $33,408 | | |
| A8.2.1.1 | | Remove tanks/equipment | Dismantle and prep for transport | 2 | hrs | C.1.13 | 8.0 | $168.00 | $335.99 | $86.19 | $172 | $14.53 | 30 | $29.06 | $0.00 | $0.00 | $268.71 | $537 | | | |
| A8.2.2.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.2.2.2 | | | Disconnect services | 4 | hrs | C.1.09 | 12.0 | $88.07 | $352.28 | $7.55 | $30 | $4.80 | 20 | $19.20 | $0.00 | $0.00 | $100.42 | $402 | | | |
| A8.2.3.1 | | Demolition | Structural building demolition: steel structures | 96 | tonnes | C.1.05 | 191.3 | $69.36 | $6,633.00 | $139.08 | $13,301 | $33.84 | 3,371 | $3,236.25 | $0.00 | $0.00 | $242.28 | $23,170 | | | |
| A8.2.3.2 | | | Other demolition: covered storage etc. | 560 | m3 | C.1.07 | 55.5 | $3.74 | $2,093.92 | $2.07 | $1,160 | $0.74 | 430 | $412.69 | $0.00 | $0.00 | $6.55 | $3,667 | | | |
| A8.2.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 393 | Lm3 | R.005 | 15.8 | $1.76 | $693.24 | $3.53 | $1,387 | $1.08 | 441 | $423.19 | $0.00 | $0.00 | $6.37 | $2,504 | | | |
| A8.2.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 3 | trips | C.7.07 | 23.0 | $355.10 | $1,020.92 | $423.68 | $1,218 | $113.33 | 339 | $325.82 | $0.00 | $0.00 | $892.11 | $2,565 | | | |
| A8.3 | *Camp Area* | | | | | | | | | | | | | | | | | | $375,774 | | |
| A8.3.1.1 | | Equipment Removal | Remove salvageable equipment | 48 | hrs | C.1.13 | 192.0 | $168.00 | $8,063.76 | $86.19 | $4,137 | $14.53 | 726 | $697.34 | $0.00 | $0.00 | $268.71 | $12,898 | | | |
| A8.3.2.1 | | Remove modular buildings | Dismantle and prep for transport | 92 | ea. | C.1.20 | 1,794.0 | $850.98 | $78,290.06 | $730.60 | $67,215 | $166.46 | 15,953 | $15,314.69 | $0.00 | $0.00 | $1,748.04 | $160,820 | | | |
| A8.3.2.2 | | | Transport structures off-site (Whitehorse) | 92 | ea. | C.7.04 | 736.0 | $351.24 | $32,314.23 | $303.64 | $27,935 | $113.33 | 10,861 | $10,426.18 | $0.00 | $0.00 | $768.21 | $70,675 | | | |
| A8.3.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 1 | hrs | C.1.22 | 4.0 | $159.30 | $159.30 | $95.83 | $96 | $26.93 | 28 | $26.93 | $0.00 | $0.00 | $282.05 | $282 | | | |
| A8.3.3.2 | | | Disconnect services | 8 | hrs | C.1.09 | 24.0 | $88.07 | $704.56 | $7.55 | $60 | $4.80 | 40 | $38.40 | $0.00 | $0.00 | $100.42 | $803 | | | |
| A8.3.4.1 | | Demolition | Structural building demolition: Steel | 175 | tonnes | C.1.05 | 350.7 | $69.36 | $12,160.50 | $139.08 | $24,385 | $33.84 | 6,180 | $5,933.13 | $0.00 | $0.00 | $242.28 | $42,479 | | | |
| A8.3.4.2 | | | Structural building demolition: Wood/misc. structures | 10,959 | m3 | C.1.08 | 836.7 | $2.88 | $31,584.20 | $1.60 | $17,497 | $0.57 | 6,484 | $6,224.86 | $0.00 | $0.00 | $5.05 | $55,306 | | | |
| A8.3.4.4 | | | Other demolition: Utilidors, etc. | 466 | m3 | C.1.07 | 46.1 | $3.74 | $1,742.09 | $2.07 | $965 | $0.74 | 358 | $343.34 | $0.00 | $0.00 | $6.55 | $3,051 | | | |
| A8.3.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 3,867 | m3 | R.007 | 175.3 | $1.99 | $7,708.84 | $3.99 | $15,425 | $1.22 | 4,902 | $4,705.86 | $0.00 | $0.00 | $7.20 | $27,839 | | | |
| A8.3.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 1 | trips | C.7.07 | 8.0 | $355.10 | $355.10 | $423.68 | $424 | $113.33 | 118 | $113.33 | $0.00 | $0.00 | $892.11 | $892 | | | |
| A8.3.6.1 | | Demolish foundations | Break in place concrete foundations | 51 | m3 | C.1.01 | 4.1 | $2.39 | $122.15 | $9.37 | $479 | $2.48 | 132 | $126.81 | $0.00 | $0.00 | $14.24 | $728 | | | |
| A8.4 | *Explosives Plant and Storage Areas* | | | | | | | | | | | | | | | | | | $30,611 | | |
| A8.4.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 37 | hrs | C.1.13 | 149.3 | $168.00 | $6,271.81 | $86.19 | $3,218 | $14.53 | 565 | $542.38 | $0.00 | $0.00 | $268.71 | $10,032 | | | |
| A8.4.2.1 | | Remove modular buildings | Dismantle and prep for transport | 1 | ea. | C.1.20 | 19.5 | $850.98 | $850.98 | $730.60 | $731 | $166.46 | 173 | $166.46 | $0.00 | $0.00 | $1,748.04 | $1,748 | | | |
| A8.4.2.2 | | | Transport structures off-site (Whitehorse) | 1 | ea. | C.7.04 | 8.0 | $351.24 | $351.24 | $303.64 | $304 | $113.33 | 118 | $113.33 | $0.00 | $0.00 | $768.21 | $768 | | | |
| A8.4.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 4 | hrs | C.1.22 | 16.0 | $159.30 | $637.19 | $95.83 | $383 | $26.93 | 112 | $107.71 | $0.00 | $0.00 | $282.05 | $1,128 | | | |
| A8.4.3.2 | | | Disconnect services | 2 | hrs | C.1.09 | 6.0 | $88.07 | $176.14 | $7.55 | $15 | $4.80 | 10 | $9.60 | $0.00 | $0.00 | $100.42 | $201 | | | |
| A8.4.4.1 | | Demolition | Structural building demolition: Steel | 47 | tonnes | C.1.05 | 94.2 | $69.36 | $3,266.25 | $139.08 | $6,550 | $33.84 | 1,660 | $1,593.61 | $0.00 | $0.00 | $242.28 | $11,410 | | | |
| A8.4.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 103 | m3 | R.008 | 5.4 | $2.32 | $239.23 | $4.65 | $479 | $1.42 | 152 | $146.04 | $0.00 | $0.00 | $8.39 | $864 | | | |
| A8.4.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 5 | trips | C.7.07 | 40.0 | $355.10 | $1,775.51 | $423.68 | $2,118 | $113.33 | 590 | $566.64 | $0.00 | $0.00 | $892.11 | $4,461 | | | |
| A8.5 | *Fuel Storage Area* | | | | | | | | | | | | | | | | | | $114,842 | | |
| A8.5.1.1 | | Remove equipment/dismant | Small equipment: dismantle and prep for transport | 24 | hrs | C.1.13 | 96.0 | $168.00 | $4,031.88 | $86.19 | $2,069 | $14.53 | 363 | $348.67 | $0.00 | $0.00 | $268.71 | $6,449 | | | |
| A8.5.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 192 | hrs | C.1.14 | 1,153.4 | $269.89 | $51,883.26 | $167.56 | $32,213 | $20.53 | 4,111 | $3,946.31 | $0.00 | $0.00 | $457.98 | $88,042 | | | |
| A8.5.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.5.2.2 | | | Disconnect services | 8 | hrs | C.1.09 | 24.0 | $88.07 | $704.56 | $7.55 | $60 | $4.80 | 40 | $38.40 | $0.00 | $0.00 | $100.42 | $803 | | | |
| A8.5.2.3 | | | Clean out tanks, pressure wash, remove sludge | 10 | hrs | C.1.04 | 10.3 | $35.54 | $365.13 | $15.75 | $162 | $2.00 | 21 | $20.55 | $0.00 | $0.00 | $53.29 | $548 | | | |
| A8.5.3.1 | | Demolish structures | Misc. debris/scraps (tanks included in dismantling above) | 75 | m3 | C.1.08 | 5.7 | $2.88 | $216.15 | $1.60 | $120 | $0.57 | 44 | $42.60 | $0.00 | $0.00 | $5.05 | $378 | | | |
| A8.5.4.1 | | Remove secondary containr | Bedding Material: Load, haul dump bedding material to landfarm | 623 | Cm3 | R.009 | 32.8 | $2.32 | $1,442.73 | $4.64 | $2,887 | $1.41 | 917 | $880.71 | $0.00 | $0.00 | $8.37 | $5,210 | | | |
| A8.5.4.2 | | | Cut and fold liner | 1,747 | m2 | C.1.15 | 20.3 | $0.43 | $758.23 | $0.19 | $340 | $0.07 | 126 | $120.97 | $0.00 | $0.00 | $0.70 | $1,219 | | | |
| A8.5.4.3 | | | Regrade area to promote positive drainage | 1,666 | m2 | C.2.11 | 16.7 | $0.44 | $739.50 | $1.28 | $2,138 | $0.35 | 612 | $587.76 | $0.00 | $0.00 | $2.08 | $3,465 | | | |
| A8.5.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 229 | m3 | R.009 | 12.1 | $2.32 | $531.18 | $4.64 | $1,063 | $1.41 | 338 | $324.26 | $0.00 | $0.00 | $8.37 | $1,918 | | | |
| A8.5.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 7 | trips | C.7.07 | 56.0 | $355.10 | $2,485.71 | $423.68 | $2,966 | $113.33 | 826 | $793.30 | $0.00 | $0.00 | $892.11 | $6,245 | | | |
| A8.6 | *Mill Area* | | | | | | | | | | | | | | | | | | $1,265,173 | | Excludes WTP |
| A8.6.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 379 | hrs | C.1.13 | 1,515.0 | $168.00 | $63,626.87 | $86.19 | $32,644 | $14.53 | 5,732 | $5,502.37 | $0.00 | $0.00 | $268.71 | $101,773 | | | |
| A8.6.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 466 | hrs | C.1.14 | 2,796.5 | $269.89 | $125,789.65 | $167.56 | $78,099 | $20.53 | 9,966 | $9,567.74 | $0.00 | $0.00 | $457.98 | $213,456 | | | |
| A8.6.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 65 | hrs | C.1.22 | 260.0 | $159.30 | $10,354.37 | $95.83 | $6,229 | $26.93 | 1,823 | $1,750.32 | $0.00 | $0.00 | $282.05 | $18,333 | | | Off-site disposal included in 'Waste Disposal' |
| A8.6.2.6 | | | Reagents: Disposal and tipping fees | 1.0 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A8.6.2.7 | | | Decontaminate buildings: wash equipment/structures, etc. | 38 | hrs | C.1.04 | 37.8 | $35.54 | $1,342.93 | $15.75 | $595 | $2.00 | 79 | $75.58 | $0.00 | $0.00 | $53.29 | $2,014 | | | |
| A8.6.2.8 | | | Decontaminate buildings: Wash floors etc. | 4,732 | m2 | C.1.03 | 40.8 | $0.31 | $1,448.16 | $0.14 | $642 | $0.02 | 85 | $81.50 | $0.00 | $0.00 | $0.46 | $2,171 | | | |
| A8.6.3.1 | | Demolition | Structural building demolition: Steel | 2,660 | tonnes | C.1.05 | 5,319.1 | $69.36 | $184,463.18 | $139.08 | $369,899 | $33.84 | 93,750 | $89,999.96 | $0.00 | $0.00 | $242.28 | $644,363 | | | |
| A8.6.3.2 | | | Structural building demolition: Wood/misc. structures | 960 | m3 | C.1.08 | 73.3 | $2.88 | $2,766.75 | $1.60 | $1,533 | $0.57 | 568 | $545.29 | $0.00 | $0.00 | $5.05 | $4,845 | | | |
| A8.6.3.3 | | | Other demolition: Steel | 526 | tonnes | C.1.05 | 1,052.7 | $69.36 | $36,505.48 | $139.08 | $73,204 | $33.84 | 18,553 | $17,811.10 | $0.00 | $0.00 | $242.28 | $127,520 | | | |
| A8.6.3.4 | | | Other demolition: concrete | 602 | m3 | C.1.06 | 323.7 | $15.92 | $9,579.30 | $62.48 | $37,592 | $16.53 | 10,359 | $9,944.51 | $0.00 | $0.00 | $94.92 | $57,116 | | | |
| A8.6.3.5 | | | Other demolition: miscellaneous | 244 | m3 | C.1.07 | 24.1 | $3.74 | $910.78 | $2.07 | $505 | $0.74 | 187 | $179.50 | $0.00 | $0.00 | $6.55 | $1,595 | | | |
| A8.6.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 5,985 | m3 | R.037 | 255.1 | $1.87 | $11,217.23 | $3.75 | $22,445 | $1.14 | 7,133 | $6,847.56 | $0.00 | $0.00 | $6.77 | $40,510 | | | |
| A8.6.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 33 | trips | C.7.07 | 266.0 | $355.10 | $11,806.23 | $423.68 | $14,086 | $113.33 | 3,925 | $3,767.87 | $0.00 | $0.00 | $892 | $29,660 | | | |
| A8.6.5.1 | | Demolish foundations | Break in place concrete foundations | 1,532 | m3 | C.1.01 | 123.7 | $2.39 | $3,659.05 | $9.37 | $14,359 | $2.48 | 3,957 | $3,798.55 | $0.00 | $0.00 | $14.24 | $21,817 | | | |
| A8.7 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $28,525 | | |
| A8.7.1.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 8 | hrs | C.1.22 | 30.0 | $159.30 | $1,194.73 | $95.83 | $719 | $26.93 | 210 | $201.96 | $0.00 | $0.00 | $282.05 | $2,115 | | | |
| A8.7.1.2 | | | Reagents: Disposal and tipping fees | 1 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A8.7.2.1 | | Demolish buildings | Structural building demolition: Wood/misc. structures (Reagent tent) | 1,800 | m3 | C.1.08 | 137.4 | $2.88 | $5,187.66 | $1.60 | $2,874 | $0.57 | 1,065 | $1,022.42 | $0.00 | $0.00 | $5.05 | $9,084 | | | |
| A8.7.3.1 | | Haul waste to landfill | Demolition debris | 594 | m3 | R.037 | 25.3 | $1.87 | $1,113.25 | $3.75 | $2,228 | $1.14 | 708 | $679.58 | $0.00 | $0.00 | $6.77 | $4,020 | | | |
| A8.7.3.2 | | | Remove tires off-site for disposal | 10 | trips | C.7.07 | 78.8 | $355.10 | $3,495.53 | $423.68 | $4,171 | $113.33 | 1,162 | $1,115.57 | $0.00 | $0.00 | $892.11 | $8,782 | | | |
| A8.7.3.3 | | | Misc. debris/scraps | 652 | m3 | R.037 | 27.8 | $1.87 | $1,221.95 | $3.75 | $2,445 | $1.14 | 777 | $745.94 | $0.00 | $0.00 | $6.77 | $4,413 | | | |
| A8.7.4.1 | | Demolish foundations | Break and bury concrete foundations | 8 | m3 | C.1.01 | 0.6 | $2.39 | $18.48 | $9.37 | $73 | $2.48 | 20 | $19.19 | $0.00 | $0.00 | $14.24 | $110 | | | |
| A8.8 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $8,516 | | |
| A8.8.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 6 | hrs | C.1.13 | 24.0 | $168.00 | $1,007.97 | $86.19 | $517 | $14.53 | 91 | $87.17 | $0.00 | $0.00 | $268.71 | $1,612 | | | |
| A8.8.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.8.3.1 | | Demolition | Other demolition: miscellaneous | 462 | m3 | C.1.07 | 45.7 | $3.74 | $1,727.03 | $2.07 | $957 | $0.74 | 355 | $340.38 | $0.00 | $0.00 | $6.55 | $3,024 | | | |
| A8.8.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 462 | m3 | R.043 | 20.9 | $1.99 | $918.18 | $3.98 | $1,837 | $1.21 | 584 | $560.51 | $0.00 | $0.00 | $7.18 | $3,316 | | | |
| A8.9 | *Minto North Portal* | | | | | | | | | | | | | | | | | | $8,981 | | Qntys assumed to be same as Minto South Portal |
| A8.9.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 6 | hrs | C.1.13 | 24.0 | $168.00 | $1,007.97 | $86.19 | $517 | $14.53 | 91 | $87.17 | $0.00 | $0.00 | $268.71 | $1,612 | | | |
| A8.9.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.9.3.1 | | Demolition | Other demolition: miscellaneous | 462 | m3 | C.1.07 | 45.7 | $3.74 | $1,727.03 | $2.07 | $957 | $0.74 | 355 | $340.38 | $0.00 | $0.00 | $6.55 | $3,024 | | | |
| A8.9.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 462 | m3 | R.042 | 23.8 | $2.27 | $1,046.71 | $4.53 | $2,094 | $1.38 | 666 | $638.96 | $0.00 | $0.00 | $8.18 | $3,780 | | | |
| A8.10 | *Pelly Laydown (Includes propane tanks by W15 Sump)* | | | | | | | | | | | | | | | | | | $83,981 | | |
| A8.10.1.1 | | Remove modular buildings/t | Dismantle and prep for transport | 7 | ea. | C.1.20 | 136.5 | $850.98 | $5,956.85 | $730.60 | $5,114 | $166.46 | 1,214 | $1,165.25 | $0.00 | $0.00 | $1,748.04 | $12,236 | | | |
| A8.10.1.2 | | | Transport structures off-site (Whitehorse) | 7 | ea. | C.7.04 | 56.0 | $351.24 | $2,458.69 | $303.64 | $2,125 | $113.33 | 826 | $793.30 | $0.00 | $0.00 | $768.21 | $5,377 | | | |
| A8.10.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.10.3.1 | | Demolish buildings | Structural building demolition: Steel | 80 | tonnes | C.1.05 | 159.4 | $69.36 | $5,527.50 | $139.08 | $11,084 | $33.84 | 2,809 | $2,696.88 | $0.00 | $0.00 | $242.28 | $19,309 | | | |
| A8.10.3.2 | | | Structural building demolition: Wood/misc. structures | 5,672 | m3 | C.1.08 | 433.1 | $2.88 | $16,347.99 | $1.60 | $9,057 | $0.57 | 3,356 | $3,221.99 | $0.00 | $0.00 | $5.05 | $28,627 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A8.10.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 2,165 | m3 | R.045 | 100.0 | $2.03 | $4,395.81 | $4.06 | $8,796 | $1.24 | 2,795 | $2,683.42 | $0.00 | $0.00 | $7.33 | $15,875 | | | |
| A8.10.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 2 | trips | C.7.07 | 15.0 | $355.10 | $665.82 | $423.68 | $794 | $113.33 | 221 | $212.49 | $0.00 | $0.00 | $892.11 | $1,673 | | | |
| A8.10.5.1 | | Demolish foundations | Break and bury concrete foundations | 23 | m3 | C.1.01 | 1.8 | $2.39 | $53.73 | $9.37 | $211 | $2.48 | 58 | $55.78 | $0.00 | $0.00 | $14.24 | $320 | | | |
| A8.11 | *Vent Raise - Area 118* | | | | | | | | | | | | | | | | | | $5,381 | | |
| A8.11.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 20 | hrs | C.1.13 | 80.0 | $168.00 | $3,359.90 | $86.19 | $1,724 | $14.53 | 303 | $290.56 | $0.00 | $0.00 | $268.71 | $5,374 | | | |
| A8.11.2.1 | | Waste disposal | Off-site disposal (re-usable equipment, etc.) | 1 | trips | R.043 | 0.0 | $1.99 | $1.99 | $3.98 | $4 | $1.21 | 1 | $1.21 | $0.00 | $0.00 | $7.18 | $7 | | | |
| **A9** | **Surface Infrastructure** | | | | | | | | | | | | | | | | | | | **$169,527** | |
| A9.1 | *Tailings and Water Conveyance Pipelines* | | | | | | | | | | | | | | | | | | $91,886 | | |
| A9.1.1.1 | | Dismantle piping systems | Flush and clean tailings pipeline systems | 8 | ls | C.1.21 | 32.0 | $203.78 | $1,630.27 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $203.78 | $1,630 | | | |
| A9.1.1.2 | | | Cut pipelines and prep for transport (6 to 8" HDPE pipes) | 6,800 | m | C.1.17 | 1,070.9 | $7.21 | $49,056.06 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $7.21 | $49,056 | | | |
| A9.1.1.3 | | | Cut pipelines and prep for transport (10 to 18" HDPE pipes) | 1,740 | m | C.1.18 | 456.7 | $12.02 | $20,920.96 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $12.02 | $20,921 | | | |
| A9.1.1.4 | | | Cut pipelines and prep for transport (20 to 36" HDPE pipes) | 885 | m | C.1.19 | 348.4 | $18.04 | $15,961.25 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $18.04 | $15,961 | | | |
| A9.2.2.1 | | Waste disposal | Haul pipes lines and debris to landfill | 638 | m3 | R.037 | 27.2 | $1.87 | $1,195.62 | $3.75 | $2,392 | $1.14 | 760 | $729.86 | $0.00 | $0.00 | $6.77 | $4,318 | | | |
| A9.2 | *Conveyance Pipeline Equipment* | | | | | | | | | | | | | | | | | | $12,462 | | |
| A9.2.1.1 | | Dismantle piping systems | Remove pumps and prep for transport | 15 | ea. | C.1.24 | 198.0 | $602.98 | $9,044.72 | $24.94 | $374 | $14.40 | 225 | $216.00 | $0.00 | $0.00 | $642.33 | $9,635 | | | |
| A9.2.1.2 | | | Remove barges/Support Equipment prep for transport | 2 | ea. | C.1.23 | 52.8 | $1,205.96 | $2,411.93 | $49.89 | $100 | $28.80 | 60 | $57.60 | $0.00 | $0.00 | $1,284.65 | $2,569 | | | |
| A9.2.2.1 | | Waste disposal | Transport pumps, barge and support equip. offsite (Whitehorse) | 6.7 | tonnes | C.7.02 | 2.7 | $17.56 | $117.67 | $15.18 | $102 | $5.67 | 40 | $37.96 | $0.00 | $0.00 | $38.41 | $257 | | | |
| A9.3 | *Powerlines* | | | | | | | | | | | | | | | | | | $65,179 | | |
| A9.3.1.1 | | Dismantle | Dismantle and collect powerlines | 3.2 | km | C.1.10 | 217.9 | $2,639.96 | $8,342.27 | $940.09 | $2,971 | $251.90 | 829 | $795.99 | $0.00 | $0.00 | $3,831.94 | $12,109 | | | |
| A9.3.1.2 | | | Remove power poles and load for transport off-site | 60 | ea. | C.1.11 | 548.6 | $423.67 | $25,420.14 | $88.51 | $5,311 | $18.29 | 1,143 | $1,097.14 | $0.00 | $0.00 | $530.46 | $31,828 | | | |
| A9.3.1.3 | | | Disconnect transformers and load for transport | 4 | ea. | C.1.12 | 93.3 | $892.89 | $3,571.55 | $317.96 | $1,272 | $85.20 | 355 | $340.78 | $0.00 | $0.00 | $1,296.04 | $5,184 | | | |
| A9.3.2.1 | | Waste disposal | Transport powerlines, poles and transformers off-site | 18 | trips | C.7.07 | 144.0 | $355.10 | $6,391.83 | $423.68 | $7,626 | $113.33 | 2,125 | $2,039.90 | $0.00 | $0.00 | $892.11 | $16,058 | | | |
| **A10** | **Water Detention Structures** | | | | | | | | | | | | | | | | | | | **$786,952** | |
| A10.1 | *W15 Sump* | | | | | | | | | | | | | | | | | | $1,049 | | |
| A10.1.1.1 | | Remove secondary containr | Cut and fold liner | 1,310 | m2 | C.1.15 | 15.2 | $0.43 | $568.50 | $0.19 | $255 | $0.07 | 94 | $90.70 | $0.00 | $0.00 | $0.70 | $914 | | | |
| A10.1.1.2 | | | Haul liner to landfill | 20 | Lm3 | R.070 | 0.8 | $1.90 | $37.35 | $3.80 | $75 | $1.16 | 24 | $22.80 | $0.00 | $0.00 | $6.86 | $135 | | | |
| A10.2 | *Sewage Lagoon (near IROD)* | | | | | | | | | | | | | | | | | | $23,852 | | |
| A10.2.1 | | Remove pond | Backfill pond | 4,488 | m3 | R.001 | 141.4 | $1.39 | $6,231.19 | $3.03 | $13,585 | $0.90 | 4,203 | $4,035.32 | $0.00 | $0.00 | $5.31 | $23,852 | | | |
| A10.3 | *Water Storage Pond Dam* | | | | | | | | | | | | | | | | | | $762,051 | | |
| A10.3.1.1 | | Water Management | Install pump and pump around system | 4 | hrs | C.4.14 | 16.0 | $120.43 | $481.73 | $20.53 | $82 | $6.80 | 28 | $27.20 | $0.00 | $0.00 | $147.76 | $591 | | | |
| A10.3.1.2 | | | Pump pond water to discharge | 400,000 | m3 | C.4.12 | 146.8 | $0.01 | $5,216.05 | $0.05 | $19,052 | $0.01 | 3,058 | $2,935.56 | $0.00 | $0.00 | $0.07 | $27,203 | | | |
| A10.3.1.3 | | | Maintain pump around system during WSP closure activities | 103 | days | C.4.13 | 10.3 | $3.55 | $364.31 | $12.98 | $1,331 | $2.00 | 214 | $205.03 | $0.00 | $0.00 | $18.53 | $1,900 | | | Duration calculated as sum of associated tasks plus 20% contingency |
| A10.3.2.1 | | Breach dam | Granular zones/gen. fill: Load, haul, dump, spread in upstream North ab | 62,301 | m3 | R.001 | 1,963.4 | $1.39 | $86,500.02 | $3.03 | $188,587 | $0.90 | 58,351 | $56,017.38 | $0.00 | $0.00 | $5.31 | $331,104 | | | |
| A10.3.2.2 | | | Dam Core: Load, haul, dump in temporary stockpile | 23,617 | m3 | R.001 | 744.3 | $1.39 | $32,789.73 | $3.03 | $71,488 | $0.90 | 22,119 | $21,234.62 | $0.00 | $0.00 | $5.31 | $125,512 | | | |
| A10.3.2.3 | | | Rip-rap: Sort and stockpile durable rip-rap for reuse | 19,285 | m3 | R.001 | 607.8 | $1.39 | $26,776.14 | $3.03 | $58,377 | $0.90 | 18,063 | $17,340.22 | $0.00 | $0.00 | $5.31 | $102,494 | | | |
| A10.3.2.4 | | | Rip-rap: Load haul, dump unsuitable rip-rap in upstream North abutmen | 19,285 | m3 | R.001 | 607.8 | $1.39 | $26,776.14 | $3.03 | $58,377 | $0.90 | 18,063 | $17,340.22 | $0.00 | $0.00 | $5.31 | $102,494 | | | |
| A10.3.3.1 | | Channel restoration | Excavate stream channel | 5,584 | m3 | R.902 | 97.1 | $0.77 | $4,308.58 | $1.64 | $9,173 | $0.46 | 2,681 | $2,574.22 | $0.00 | $0.00 | $2.88 | $16,056 | | | |
| A10.3.3.2 | | | Bedding layer: Load haul, dump, place granular bedding layer along cha | 726 | m3 | R.001 | 22.9 | $1.39 | $1,008.60 | $3.03 | $2,199 | $0.90 | 680 | $653.17 | $0.00 | $0.00 | $5.31 | $3,861 | | | |
| A10.3.3.3 | | | Rip-rap: Load, haul dump from temporary stockpile | 964 | m3 | R.001 | 30.4 | $1.39 | $1,337.77 | $3.03 | $2,917 | $0.90 | 902 | $866.34 | $0.00 | $0.00 | $5.31 | $5,121 | | | |
| A10.3.3.4 | | | Rip-rap: place and secure | 964 | m3 | R.904 | 10.5 | $0.48 | $465.10 | $0.91 | $877 | $0.32 | 325 | $311.83 | $0.00 | $0.00 | $1.72 | $1,653 | | | |
| A10.3.4.1 | | Cover | Cover material: Load, haul, dump spread (1m) | 6,975 | m3 | R.001 | 219.8 | $1.39 | $9,684.17 | $3.03 | $21,113 | $0.90 | 6,533 | $6,271.47 | $0.00 | $0.00 | $5.31 | $37,069 | | | Cover sourced from dam core material |
| A10.3.5.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 1.4 | ha | C.6.01 | 46.2 | $1,029.50 | $1,436.16 | $401.72 | $560 | $232.94 | 338 | $324.96 | $1,005.72 | $1,402.98 | $2,669.89 | $3,724 | | | |
| A10.3.5.2 | | | Tree seedling application (1,000 stems/ha) | 1.4 | ha | C.6.06 | 71.5 | $1,832.33 | $2,556.10 | $25.98 | $36 | $15.00 | 22 | $20.93 | $469.71 | $655.25 | $2,343.03 | $3,269 | | | |
| **A11** | **Yards/Laydown Areas** | | | | | | | | | | | | | | | | | | | **$758,907** | |
| A11.1 | *Airstrip Area* | | | | | | | | | | | | | | | | | | $39,834 | | |
| A11.1.1.1 | | Re-grade | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.1.1.2 | | | Scarify surface | 64,378 | m2 | C.2.16 | 0.0 | $0.03 | $2,236.99 | $0.07 | $4,227 | $0.02 | 1,144 | $1,098.24 | $0.00 | $0.00 | $0.12 | $7,562 | | | |
| A11.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 6.4 | ha | C.6.01 | 213.3 | $1,029.50 | $6,627.68 | $401.72 | $2,586 | $232.94 | 1,562 | $1,499.64 | $1,005.72 | $6,474.57 | $2,669.89 | $17,188 | | | |
| A11.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 6.4 | ha | C.6.06 | 329.9 | $1,832.33 | $11,796.10 | $25.98 | $167 | $15.00 | 101 | $96.57 | $469.71 | $3,023.88 | $2,343.03 | $15,084 | | | |
| A11.2 | *Airport Laydown Area* | | | | | | | | | | | | | | | | | | $13,165 | | |
| A11.2.1.1 | | Re-grade | Scarify surface | 21,277 | m2 | C.2.16 | 0.0 | $0.03 | $739.33 | $0.07 | $1,397 | $0.02 | 378 | $362.97 | $0.00 | $0.00 | $0.12 | $2,499 | | | |
| A11.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.1 | ha | C.6.01 | 70.5 | $1,029.50 | $2,190.47 | $401.72 | $855 | $232.94 | 516 | $495.64 | $1,005.72 | $2,139.87 | $2,669.89 | $5,681 | | | |
| A11.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 2.1 | ha | C.6.06 | 109.0 | $1,832.33 | $3,898.65 | $25.98 | $55 | $15.00 | 33 | $31.92 | $469.71 | $999.40 | $2,343.03 | $4,985 | | | |
| A11.3 | *Camp Area* | | | | | | | | | | | | | | | | | | $118,708 | | |
| A11.3.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 7 | hrs | C.2.13 | 6.9 | $44.39 | $306.20 | $194.68 | $1,343 | $67.01 | 481 | $462.24 | $0.00 | $0.00 | $306.07 | $2,111 | | | |
| A11.3.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 24 | hrs | C.2.13 | 24.5 | $44.39 | $1,086.58 | $194.68 | $4,766 | $67.01 | 1,709 | $1,640.31 | $0.00 | $0.00 | $306.07 | $7,493 | | | Slope between camp and main access road |
| A11.3.1.3 | | | Scarify surfaces | 20,626 | m2 | C.2.16 | 0.0 | $0.03 | $716.72 | $0.07 | $1,354 | $0.02 | 367 | $351.87 | $0.00 | $0.00 | $0.12 | $2,423 | | | |
| A11.3.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 10,313 | Cm3 | R.046 | 198.2 | $0.85 | $8,729.48 | $2.75 | $28,368 | $0.91 | 9,724 | $9,335.37 | $0.00 | $0.00 | $4.50 | $46,433 | | | |
| A11.3.2.2 | | | Slope area cover material: Load, haul, dump along crest | 9,349 | Cm3 | R.047 | 157.2 | $0.74 | $6,916.70 | $2.44 | $22,835 | $0.82 | 7,990 | $7,670.53 | $0.00 | $0.00 | $4.00 | $37,422 | | | |
| A11.3.2.3 | | | Slope area cover material: Spread down slope | 10 | hrs | C.2.13 | 10.2 | $44.39 | $451.46 | $194.68 | $1,980 | $67.01 | 710 | $681.52 | $0.00 | $0.00 | $306.07 | $3,113 | | | |
| A11.3.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.93 | ha | C.6.01 | 130.3 | $1,029.50 | $4,048.49 | $401.72 | $1,580 | $232.94 | 954 | $916.05 | $1,005.72 | $3,954.97 | $2,669.89 | $10,499 | | | |
| A11.3.3.2 | | | Tree seedling application (1,000 stems/ha) | 3.93 | ha | C.6.06 | 201.5 | $1,832.33 | $7,205.60 | $25.98 | $102 | $15.00 | 61 | $58.99 | $469.71 | $1,847.12 | $2,343.03 | $9,214 | | | |
| A11.4 | *Crusher Area* | | | | | | | | | | | | | | | | | | $73,635 | | |
| A11.2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 9 | hrs | C.2.13 | 9.0 | $44.39 | $400.28 | $194.68 | $1,756 | $67.01 | 629 | $604.27 | $0.00 | $0.00 | $306.07 | $2,760 | | | |
| A11.2.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 13,482 | m3 | R.055 | 244.8 | $0.80 | $10,783.37 | $2.60 | $35,042 | $0.86 | 12,012 | $11,531.82 | $0.00 | $0.00 | $4.25 | $57,358 | | | |
| A11.2.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.70 | ha | C.6.01 | 89.3 | $1,029.50 | $2,775.95 | $401.72 | $1,083 | $232.94 | 654 | $628.11 | $1,005.72 | $2,711.82 | $2,669.89 | $7,199 | | | |
| A11.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 3 | ha | C.6.06 | 138.2 | $1,832.33 | $4,940.70 | $25.98 | $70 | $15.00 | 42 | $40.45 | $469.71 | $1,266.53 | $2,343.03 | $6,318 | | | |
| A11.5 | *Exploration Disturbances* | | | | | | | | | | | | | | | | | | $21,519 | | |
| A11.5.1.1 | | Ridgetop Area | Scarify surfaces | 34,778 | m2 | C.2.16 | 0.0 | $0.03 | $1,208.47 | $0.07 | $2,284 | $0.02 | 618 | $593.29 | $0.00 | $0.00 | $0.12 | $4,085 | | | |
| A11.5.1.2 | | | Seed/Fertilize: broadcast seeding | 3 | ha | C.6.01 | 115.2 | $1,029.50 | $3,580.40 | $401.72 | $1,397 | $232.94 | 844 | $810.13 | $1,005.72 | $3,497.69 | $2,669.89 | $9,285 | | | |
| A11.5.1.3 | | | Tree seedling application (1,000 stems/ha) | 3 | ha | C.6.06 | 178.2 | $1,832.33 | $6,372.49 | $25.98 | $90 | $15.00 | 54 | $52.17 | $469.71 | $1,633.56 | $2,343.03 | $8,149 | | | |
| A11.6 | *Explosives Plant and Storage Areas* | | | | | | | | | | | | | | | | | | $43,165 | | |
| A11.6.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 30 | hrs | C.2.13 | 29.6 | $44.39 | $1,314.39 | $194.68 | $5,765 | $67.01 | 2,067 | $1,984.22 | $0.00 | $0.00 | $306.07 | $9,063 | | | |
| A11.6.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.6.1.3 | | | Scarify surfaces | 55,113 | m2 | C.2.16 | 0.0 | $0.03 | $1,915.08 | $0.07 | $3,619 | $0.02 | 979 | $940.20 | $0.00 | $0.00 | $0.12 | $6,474 | | | |
| A11.6.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.5 | ha | C.6.01 | 182.6 | $1,029.50 | $5,673.94 | $401.72 | $2,214 | $232.94 | 1,337 | $1,283.83 | $1,005.72 | $5,542.86 | $2,669.89 | $14,715 | | | |
| A11.6.2.2 | | | Tree seedling application (1,000 stems/ha) | 5.5 | ha | C.6.06 | 282.5 | $1,832.33 | $10,098.61 | $25.98 | $143 | $15.00 | 86 | $82.67 | $469.71 | $2,588.73 | $2,343.03 | $12,913 | | | |
| A11.7 | *Fuel Storage Areas* | | | | | | | | | | | | | | | | | | $24,758 | | |
| A11.7.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 5 | hrs | C.2.13 | 4.5 | $44.39 | $200.33 | $194.68 | $879 | $67.01 | 315 | $302.42 | $0.00 | $0.00 | $306.07 | $1,381 | | | |
| A11.7.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 4,200 | m3 | R.049 | 81.8 | $0.86 | $3,603.19 | $2.79 | $11,709 | $0.92 | 4,014 | $3,853.28 | $0.00 | $0.00 | $4.56 | $19,166 | | | |
| A11.7.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.84 | ha | C.6.01 | 27.8 | $1,029.50 | $864.78 | $401.72 | $337 | $232.94 | 204 | $195.67 | $1,005.72 | $844.80 | $2,669.89 | $2,243 | | | |
| A11.7.3.2 | | | Tree seedling application (1,000 stems/ha) | 1 | ha | C.6.06 | 43.1 | $1,832.33 | $1,539.16 | $25.98 | $22 | $15.00 | 13 | $12.60 | $469.71 | $394.56 | $2,343.03 | $1,968 | | | |
| A11.8 | *IROD Laydown Area* | | | | | | | | | | | | | | | | | | $18,300 | | |
| A11.8.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 15 | hrs | C.2.13 | 14.8 | $44.39 | $654.96 | $194.68 | $2,873 | $67.01 | 1,030 | $988.72 | $0.00 | $0.00 | $306.07 | $4,516 | | | |
| A11.8.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.8.1.3 | | | Scarify surface | 18,106 | m2 | C.2.16 | 0.0 | $0.03 | $629.15 | $0.07 | $1,189 | $0.02 | 322 | $308.88 | $0.00 | $0.00 | $0.12 | $2,127 | | | |
| A11.8.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.33 | ha | C.6.01 | 77.0 | $1,029.50 | $2,393.91 | $401.72 | $934 | $232.94 | 564 | $541.67 | $1,005.72 | $2,338.60 | $2,669.89 | $6,208 | | | |
| A11.8.2.2 | | | Tree seedling application (1,000 stems/ha) | 2.33 | ha | C.6.06 | 119.2 | $1,832.33 | $4,260.73 | $25.98 | $60 | $15.00 | 36 | $34.88 | $469.71 | $1,092.22 | $2,343.03 | $5,448 | | | |
| A11.9 | *Mill Area* | | | | | | | | | | | | | | | | | | $134,673 | | |
| A11.9.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 60 | hrs | C.2.13 | 59.9 | $44.39 | $2,659.96 | $194.68 | $11,666 | $67.01 | 4,183 | $4,015.50 | $0.00 | $0.00 | $306.07 | $18,342 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A11.9.1.2 | | | Scarify surface | 42,365 | m2 | C.2.16 | 0.0 | $0.03 | $1,472.09 | $0.07 | $2,782 | $0.02 | 753 | $722.72 | $0.00 | $0.00 | $0.12 | $4,977 | | | |
| A11.9.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 21,182 | m3 | R.055 | 384.7 | $0.80 | $16,942.37 | $2.60 | $55,057 | $0.86 | 18,873 | $18,118.30 | $0.00 | $0.00 | $4.25 | $90,118 | | | |
| A11.9.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 4.24 | ha | C.6.01 | 140.3 | $1,029.50 | $4,361.46 | $401.72 | $1,702 | $232.94 | 1,028 | $986.86 | $1,005.72 | $4,260.70 | $2,669.89 | $11,311 | | | |
| A11.9.3.2 | | | Tree seedling application (1,000 stems/ha) | 4.24 | ha | C.6.06 | 217.1 | $1,832.33 | $7,762.62 | $25.98 | $110 | $15.00 | 66 | $63.55 | $469.71 | $1,989.91 | $2,343.03 | $9,926 | | | |
| A11.10 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $0 | | |
| A11.10.1 | | Costs included in Waste Rock Dump Section (WBS#: A1.5) | | 0 | hrs | | | | | | | | | | | | | | | | |
| A11.11 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $87,165 | | |
| A11.11.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 51 | hrs | C.2.13 | 51.5 | $44.39 | $2,284.70 | $194.68 | $10,020 | $67.01 | 3,593 | $3,449.00 | $0.00 | $0.00 | $306.07 | $15,754 | | | |
| A11.11.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 28 | hrs | C.2.13 | 28.0 | $44.39 | $1,244.58 | $194.68 | $5,459 | $67.01 | 1,957 | $1,878.82 | $0.00 | $0.00 | $306.07 | $8,582 | | | |
| A11.11.1.3 | | | Scarify surface | 62,765 | m2 | C.2.16 | 0.0 | $0.03 | $2,180.95 | $0.07 | $4,121 | $0.02 | 1,115 | $1,070.73 | $0.00 | $0.00 | $0.12 | $7,373 | | | |
| A11.11.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 11.1 | ha | C.6.01 | 366.5 | $1,029.50 | $11,389.08 | $401.72 | $4,444 | $232.94 | 2,684 | $2,576.99 | $1,005.72 | $11,125.98 | $2,669.89 | $29,536 | | | |
| A11.11.2.2 | | | Tree seedling application (1,000 stems/ha) | 11.1 | ha | C.6.06 | 567.0 | $1,832.33 | $20,270.56 | $25.98 | $287 | $15.00 | 173 | $165.94 | $469.71 | $5,196.26 | $2,343.03 | $25,920 | | | |
| A11.12 | *Pelly Laydown Area* | | | | | | | | | | | | | | | | | | $147,962 | | |
| A11.12.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 107 | hrs | C.2.13 | 107.4 | $44.39 | $4,767.52 | $194.68 | $20,910 | $67.01 | 7,497 | $7,197.08 | $0.00 | $0.00 | $306.07 | $32,874 | | | |
| A11.12.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 25,855 | m3 | R.058 | 380.7 | $0.65 | $16,779.44 | $2.11 | $54,545 | $0.69 | 18,585 | $17,841.31 | $0.00 | $0.00 | $3.45 | $89,165 | | | |
| A11.12.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.17 | ha | C.6.01 | 171.3 | $1,029.50 | $5,323.56 | $401.72 | $2,077 | $232.94 | 1,255 | $1,204.55 | $1,005.72 | $5,200.58 | $2,669.89 | $13,806 | | | |
| A11.12.3.2 | | | Tree seedling application (1,000 stems/ha) | 5.17 | ha | C.6.06 | 265.0 | $1,832.33 | $9,474.99 | $25.98 | $134 | $15.00 | 81 | $77.57 | $469.71 | $2,428.87 | $2,343.03 | $12,116 | | | |
| A11.13 | *W15 Sump Area Laydown* | | | | | | | | | | | | | | | | | | $36,022 | | |
| A11.13.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 9 | hrs | C.2.13 | 8.8 | $44.39 | $390.13 | $194.68 | $1,711 | $67.01 | 613 | $588.94 | $0.00 | $0.00 | $306.07 | $2,690 | | | |
| A11.13.1.2 | | | Slopes: Re-grade to 3H:1V | 1 | hrs | C.2.13 | 1.2 | $44.39 | $55.15 | $194.68 | $242 | $67.01 | 87 | $83.26 | $0.00 | $0.00 | $306.07 | $380 | | | |
| A11.13.1.3 | | | Scarify surface | 9,484 | m2 | C.2.16 | 0.0 | $0.03 | $329.54 | $0.07 | $623 | $0.02 | 169 | $161.79 | $0.00 | $0.00 | $0.12 | $1,114 | | | |
| A11.13.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 6,974 | m3 | R.065 | 106.1 | $0.67 | $4,675.54 | $2.18 | $15,199 | $0.71 | 5,179 | $4,971.43 | $0.00 | $0.00 | $3.56 | $24,846 | | | |
| A11.13.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 1.39 | ha | C.6.01 | 46.2 | $1,029.50 | $1,435.97 | $401.72 | $560 | $232.94 | 338 | $324.92 | $1,005.72 | $1,402.80 | $2,669.89 | $3,724 | | | |
| A11.13.3.2 | | | Tree seedling application (1,000 stems/ha) | 1.39 | ha | C.6.06 | 71.5 | $1,832.33 | $2,555.78 | $25.98 | $36 | $15.00 | 22 | $20.92 | $469.71 | $655.16 | $2,343.03 | $3,268 | | | |
| **A12** | **Waste Disposal** | | | | | | | | | | | | | | | | | | | **$452,923** | |
| A12.1 | *Hydrocarbon contaminated soils* | | | | | | | | | | | | | | | | | | $66,551 | | |
| A12.1.1.1 | | Excavate HC contaminated | Complete testing for contaminated soils | 48 | test pits | C.3.03 | 24.0 | $22.24 | $1,067.53 | $2.89 | $139 | $2.92 | 146 | $139.97 | $204.00 | $9,792.00 | $232.05 | $11,138 | | | |
| A12.1.1.2 | | | Excavate and haul contaminated soils to on-site landfarm facility | 726 | m3 | R.038 | 26.0 | $1.58 | $1,144.07 | $3.17 | $2,298 | $0.96 | 723 | $693.78 | $0.00 | $0.00 | $5.70 | $4,136 | | | |
| A12.1.2.1 | | Construct landfarm | Existing Facility assumed to have sufficient capacity | 0 | m3 | | | | | | | | | | | | | | | | |
| A12.1.3.1 | | Operate landfarm | Aerate contaminated soils (mix) | 12 | event | C.3.04 | 270.0 | $999.20 | $11,990.37 | $923.10 | $11,077 | $333.60 | 4,170 | $4,003.20 | $0.00 | $0.00 | $2,255.90 | $27,071 | | | |
| A12.1.3.2 | | | Annual confirmation sampling | 3 | years | C.3.05 | 48.0 | $711.69 | $2,135.06 | $92.63 | $278 | $93.31 | 292 | $279.94 | $1,224.00 | $3,672.00 | $2,121.63 | $6,365 | | | |
| A12.1.4.1 | | Close landfarm | Remove soils and collect liner | 726 | m3 | R.001 | 22.9 | $1.39 | $1,007.57 | $3.03 | $2,197 | $0.90 | 680 | $652.50 | $0.00 | $0.00 | $5.31 | $3,857 | | | |
| A12.1.4.2 | | | Cut/fold liner and place into waste disposal container | 4,265 | m2 | C.1.15 | 49.6 | $0.43 | $1,850.89 | $0.19 | $830 | $0.07 | 308 | $295.29 | $0.00 | $0.00 | $0.70 | $2,976 | | | |
| A12.1.4.3 | | | Regrade area | 4,265 | m2 | C.2.11 | 42.7 | $0.44 | $1,893.14 | $1.28 | $5,472 | $0.35 | 1,567 | $1,504.69 | $0.00 | $0.00 | $2.08 | $8,870 | | | |
| A12.1.4.4 | | | Revegetation: Seed/Fertilizer: broadcast seeding | 0.43 | ha | C.6.01 | 14.1 | $1,029.50 | $439.08 | $401.72 | $171 | $232.94 | 103 | $99.35 | $1,005.72 | $428.94 | $2,669.89 | $1,139 | | | |
| A12.1.4.5 | | | Tree seedling application (1,000 stems/ha) | 0.43 | ha | C.6.06 | 21.9 | $1,832.33 | $781.49 | $25.98 | $11 | $15.00 | 7 | $6.40 | $469.71 | $200.33 | $2,343.03 | $999 | | | |
| | *Metal Contaminated soils* | | | | | | | | | | | | | | | | | | $159,118 | | |
| A12.2.1.1 | | Crusher area | Delineate contaminated soil areas | 197 | test pits | C.3.01 | 98.5 | $22.24 | $4,381.32 | $2.89 | $570 | $2.92 | 598 | $574.45 | $265.20 | $52,244.40 | $293.25 | $57,770 | | | |
| A12.2.1.2 | | | Load, haul, dump contaminated soils to underground | 2,949 | m3 | R.039 | 102.1 | $1.53 | $4,499.64 | $3.33 | $9,810 | $0.99 | 3,035 | $2,913.97 | $0.00 | $0.00 | $5.84 | $17,224 | | | |
| A12.2.1.3 | | | Complete confirmation testing | 197 | ea | C.3.02 | 32.8 | $7.43 | $1,463.48 | $1.33 | $261 | $0.00 | 0 | $0.00 | $13.26 | $2,612.22 | $22.01 | $4,337 | | | |
| A12.2.2.1 | | Mill Area | Delineate contaminated soil areas | 198 | test pits | C.3.01 | 99.0 | $22.24 | $4,403.56 | $2.89 | $573 | $2.92 | 601 | $577.37 | $265.20 | $52,509.60 | $293.25 | $58,064 | | | |
| A12.2.2.2 | | | Load, haul, dump contaminated soils to underground | 2,973 | m3 | R.039 | 103.0 | $1.53 | $4,536.49 | $3.33 | $9,890 | $0.99 | 3,060 | $2,937.83 | $0.00 | $0.00 | $5.84 | $17,365 | | | |
| A12.2.2.3 | | | Complete confirmation testing | 198 | ea | C.3.02 | 33.0 | $7.43 | $1,470.91 | $1.33 | $262 | $0.00 | 0 | $0.00 | $13.26 | $2,625.48 | $22.01 | $4,359 | | | |
| A12.3 | *Solid Waste Landfill* | | | | | | | | | | | | | | | | | | $217,134 | | |
| A12.3.1.1 | | Construction landfill | Place waste from site facilities | 12,920 | LCM | C.2.07 | 550.6 | $1.89 | $24,440.80 | $8.30 | $107,194 | $2.86 | 38,433 | $36,895.99 | $0.00 | $0.00 | $13.04 | $168,531 | | | |
| A12.3.1.2 | | | Place fill to minimize voids in the debris | 3,371 | m3 | R.001 | 106.2 | $1.39 | $4,679.67 | $3.03 | $10,203 | $0.90 | 3,157 | $3,030.55 | $0.00 | $0.00 | $5.31 | $17,913 | | | |
| A12.3.2.1 | | Close landfill | Soil Cover: Load haul, dump spread, compact (0.6m) | 5,024 | m3 | R.002 | 190.0 | $1.61 | $8,100.50 | $3.21 | $16,144 | $0.99 | 5,196 | $4,988.33 | $0.00 | $0.00 | $5.82 | $29,233 | | | |
| A12.3.2.2 | | | Revegetation: Seed/Fertilizer: broadcast seeding | 0.55 | ha | C.6.01 | 18.1 | $1,029.50 | $562.06 | $401.72 | $219 | $232.94 | 132 | $127.18 | $1,005.72 | $549.07 | $2,669.89 | $1,458 | | | |
| A12.4 | *Hazardous Material Off-Site Disposal* | | | | | | | | | | | | | | | | | | $10,120 | | |
| A12.4.1.1 | | Hazardous Waste | From Building Demo: Transport off-site for disposal | 2 | trip | C.7.04 | 14.5 | $351.24 | $634.94 | $303.64 | $549 | $113.33 | 213 | $204.86 | $0.00 | $0.00 | $768.21 | $1,389 | | | |
| A12.4.3.3 | | | Hazardous materials: Disposal and Tipping fees. | 1 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0 | $0 | | | |
| A12.4.2.1 | | Reagents | Reagents: Transport to Whitehorse | 25 | hrs | C.1.22 | 99.3 | $159.30 | $3,955.90 | $95.83 | $2,380 | $26.93 | 697 | $668.71 | $0.00 | $0.00 | $282.05 | $7,004 | | | |
| A12.4.2.2 | | | Reagents: Disposal and tipping fees | 2.2 | trips | C.7.04 | 18.0 | $351.24 | $789.50 | $303.64 | $682 | $113.33 | 265 | $254.73 | $0.00 | $0.00 | $768.21 | $1,727 | | | |
| **A13** | **Surface Water Conveyance** | | | | | | | | | | | | | | | | | | | **$3,181,261** | |
| A13.1 | *Channel A - W-15 to Main Pit* | | | | | | | | | | | | | | | | | | $207,036 | | |
| A13.1.1.1 | | Excavate channel | Load, haul, dump locally | 40,300 | m3 | R.902 | 700.5 | $0.77 | $31,093.04 | $1.64 | $66,199 | $0.46 | 19,351 | $18,576.93 | $0.00 | $0.00 | $2.88 | $115,869 | | | |
| A13.1.2.1 | | Place channel materials | Geotextile: Supply and place | 7,785 | m3 | C.5.08 | 221.4 | $1.09 | $8,520.21 | $0.11 | $854 | $0.11 | 897 | $860.72 | $2.16 | $16,802.77 | $3.47 | $27,038 | | | |
| A13.1.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 3,855 | m3 | C.2.15 | 0.0 | $2.54 | $9,777.29 | $6.06 | $23,344 | $1.86 | 7,462 | $7,163.19 | $0.00 | $0.00 | $10.45 | $40,285 | | | |
| A13.1.2.3 | | | Rip-rap: Load, haul, dump | 3,855 | m3 | R.018 | 102.2 | $1.17 | $4,501.31 | $2.55 | $9,814 | $0.76 | 3,037 | $2,915.04 | $0.00 | $0.00 | $4.47 | $17,230 | | | |
| A13.1.2.4 | | | Rip-rap: Place and secure | 3,855 | m3 | R.904 | 41.9 | $0.48 | $1,860.68 | $0.91 | $3,507 | $0.32 | 1,299 | $1,247.51 | $0.00 | $0.00 | $1.72 | $6,615 | | | |
| A13.2 | *Channel B - W-35 to Area 2 Pit* | | | | | | | | | | | | | | | | | | $198,304 | | |
| A13.2.1.1 | | Excavate channel | Load, haul, dump locally | 48,038 | m3 | R.902 | 835.0 | $0.77 | $37,063.29 | $1.64 | $78,910 | $0.46 | 23,067 | $22,143.92 | $0.00 | $0.00 | $2.88 | $138,117 | | | |
| A13.2.2.1 | | Place channel materials | Geotextile: Supply and place | 4,682 | m2 | C.5.08 | 133.1 | $1.09 | $5,124.06 | $0.11 | $514 | $0.11 | 539 | $517.64 | $2.16 | $10,105.20 | $3.47 | $16,261 | | | |
| A13.2.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,554 | m3 | C.2.15 | 0.0 | $2.54 | $6,477.46 | $6.06 | $15,465 | $1.86 | 4,943 | $4,745.61 | $0.00 | $0.00 | $10.45 | $26,689 | | | |
| A13.2.2.3 | | | Rip-rap: Load, haul, dump | 2,554 | m3 | R.020 | 76.2 | $1.32 | $3,358.44 | $2.87 | $7,322 | $0.85 | 2,266 | $2,174.93 | $0.00 | $0.00 | $5.03 | $12,855 | | | |
| A13.2.2.4 | | | Rip-rap: Place and secure | 2,554 | m3 | R.904 | 27.8 | $0.48 | $1,232.70 | $0.91 | $2,323 | $0.32 | 861 | $826.47 | $0.00 | $0.00 | $1.72 | $4,382 | | | |
| A13.3 | *Channel C - Main Pit to Main Access Road* | | | | | | | | | | | | | | | | | | $125,034 | | |
| A13.3.2.1 | | Excavate channel | Load, haul, dump locally | 8,656 | m3 | R.902 | 150.5 | $0.77 | $6,678.68 | $1.64 | $14,219 | $0.46 | 4,157 | $3,990.26 | $0.00 | $0.00 | $2.88 | $24,888 | | | |
| A13.3.3.1 | | Intake structure | Excavate soils to competent foundation materials | 2,450 | Bm3 | R.902 | 42.6 | $0.77 | $1,890.07 | $1.64 | $4,024 | $0.46 | 1,176 | $1,129.25 | $0.00 | $0.00 | $2.88 | $7,043 | | | |
| A13.3.3.2 | | | Supply an install precast-concrete intake wingwall intake structure | 1 | ls | C.5.12 | 140.0 | $5,946 | $5,945.57 | $3,583 | $3,583 | $643.84 | 671 | $643.84 | $37,000 | $37,000.00 | $47,172 | $47,172 | | | |
| A13.3.3.6 | | | Backfill and compact around structure | 2,450 | Cm3 | C.2.04 | 237.3 | $2.58 | $6,323.25 | $3.01 | $7,367 | $1.03 | 2,638 | $2,532.57 | $0.00 | $0.00 | $6.62 | $16,223 | | | |
| A13.3.4.1 | | Place channel materials | Geotextile: Supply and place | 3,171 | m2 | C.5.08 | 90.2 | $1.09 | $3,470.31 | $0.11 | $348 | $0.11 | 365 | $350.57 | $2.16 | $6,843.83 | $3.47 | $11,013 | | | |
| A13.3.4.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 1,037 | m3 | C.2.15 | 0.0 | $2.54 | $2,631.28 | $6.06 | $6,282 | $1.86 | 2,008 | $1,927.76 | $0.00 | $0.00 | $10.45 | $10,841 | | | |
| A13.3.4.3 | | | Rip-rap: Load, haul, dump | 1,037 | m3 | R.022 | 36.4 | $1.54 | $1,600.27 | $3.33 | $3,452 | $0.98 | 1,064 | $1,021.09 | $0.00 | $0.00 | $5.85 | $6,073 | | | |
| A13.3.4.4 | | | Rip-rap: Place and secure | 1,037 | m3 | R.904 | 11.3 | $0.48 | $500.75 | $0.91 | $944 | $0.32 | 350 | $335.73 | $0.00 | $0.00 | $1.72 | $1,780 | | | |
| A13.4 | *Channel D - Area 2 Pit to Channel E* | | | | | | | | | | | | | | | | | | $195,636 | | |
| A13.4.1.1 | | Excavate channel | Load, haul, dump locally | 17,840 | m3 | R.902 | 310.1 | $0.77 | $13,763.89 | $1.64 | $29,304 | $0.46 | 8,566 | $8,223.41 | $0.00 | $0.00 | $2.88 | $51,291 | | | |
| A13.4.2.1 | | Intake structure | Excavate soils to competent foundation materials | 4,453 | Bm3 | R.902 | 77.4 | $0.77 | $3,435.48 | $1.64 | $7,314 | $0.46 | 2,138 | $2,052.57 | $0.00 | $0.00 | $2.88 | $12,802 | | | |
| A13.4.2.2 | | | Supply an install precast-concrete intake wingwall intake structure | 1 | ls | C.5.12 | 140.0 | $5,946 | $5,945.57 | $3,583 | $3,583 | $643.84 | 671 | $643.84 | $37,000 | $37,000.00 | $47,172 | $47,172 | | | |
| A13.4.2.6 | | | Backfill and compact around structure | 4,453 | Cm3 | C.2.04 | 431.4 | $2.58 | $11,493.42 | $3.01 | $13,390 | $1.03 | 4,795 | $4,603.31 | $0.00 | $0.00 | $6.62 | $29,487 | | | |
| A13.4.3.1 | | Place channel materials | Geotextile: Supply and place | 4,910 | m2 | C.5.08 | 139.6 | $1.09 | $5,373.23 | $0.11 | $539 | $0.11 | 565 | $542.81 | $2.16 | $10,596.59 | $3.47 | $17,051 | | | |
| A13.4.3.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,199 | m3 | C.2.15 | 0.0 | $2.54 | $5,578.78 | $6.06 | $13,320 | $1.86 | 4,258 | $4,087.21 | $0.00 | $0.00 | $10.45 | $22,986 | | | |
| A13.4.3.3 | | | Rip-rap: Load, haul, dump | 2,199 | m3 | R.020 | 65.7 | $1.32 | $2,892.50 | $2.87 | $6,306 | $0.85 | 1,951 | $1,873.18 | $0.00 | $0.00 | $5.03 | $11,072 | | | |
| A13.4.3.4 | | | Rip-rap: Place and secure | 2,199 | m3 | R.904 | 23.9 | $0.48 | $1,061.68 | $0.91 | $2,001 | $0.32 | 741 | $711.81 | $0.00 | $0.00 | $1.72 | $3,774 | | | |
| A13.5 | *Channel E - Main Access Road to toe of MVFE* | | | | | | | | | | | | | | | | | | $739,690 | | |
| A13.5.1.1 | | Construct channel | Bulk fill to grade: Load, haul, dump, spread | 29,750 | m3 | | | | | | | | | | | | | | | | Vol. from AutoCAD3D; Vol. placed as part of excavation of ren |
| A13.5.1.2 | | | Excavate/form Channel: Load, haul, dump locally | 46,386 | m3 | R.001 | 1,461.8 | $1.39 | $64,402.28 | $3.03 | $140,409 | $0.90 | 43,445 | $41,706.89 | $0.00 | $0.00 | $5.31 | $246,519 | | | |
| A13.5.2.1 | | Place channel materials | Geotextile: Supply and place | 27,307 | m2 | C.5.08 | 776.5 | $1.09 | $29,885.47 | $0.11 | $2,997 | $0.11 | 3,145 | $3,019.05 | $2.16 | $58,937.36 | $3.47 | $94,839 | | | |
| A13.5.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 20,558 | m3 | C.2.15 | 0.0 | $2.54 | $52,143.07 | $6.06 | $124,496 | $1.86 | 39,794 | $38,201.83 | $0.00 | $0.00 | $10.45 | $214,841 | | | |
| A13.5.2.3 | | | Rip-rap: Load, haul, dump | 20,558 | m3 | R.025 | 845.7 | $1.81 | $37,226.38 | $3.91 | $80,296 | $1.16 | 24,743 | $23,753.12 | $0.00 | $0.00 | $6.87 | $141,275 | | | |
| A13.5.2.4 | | | Rip-rap: Place and secure | 20,558 | m3 | R.904 | 223.6 | $0.48 | $9,923.17 | $0.91 | $18,701 | $0.32 | 6,930 | $6,653.05 | $0.00 | $0.00 | $1.72 | $35,277 | | | |
| A13.5.3.1 | | Stilling Basin/Energy Dissip | Excavate basin (spoil locally) | 645 | m3 | R.902 | 11.2 | $0.77 | $497.87 | $1.64 | $1,060 | $0.46 | 310 | $297.46 | $0.00 | $0.00 | $2.88 | $1,855 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A13.5.3.2 | | | Geotextile: Supply and place | 540 | m2 | C.5.08 | 15.4 | $1.09 | $591.07 | $0.11 | $59 | $0.11 | 62 | $59.71 | $2.16 | $1,165.65 | $3.47 | $1,876 | | | |
| A13.5.3.3 | | | Bedding layer: Screen and stockpile | 131 | m3 | C.2.01 | 2.7 | $0.96 | $125.01 | $2.11 | $276 | $0.44 | 60 | $57.55 | $0.00 | $0.00 | $3.51 | $459 | | | |
| A13.5.3.4 | | | Bedding layer: Load, haul, dump and place | 131 | m3 | R.028 | 7.7 | $2.59 | $337.69 | $5.78 | $755 | $1.69 | 229 | $220.12 | $0.00 | $0.00 | $10.05 | $1,312 | | | |
| A13.5.3.5 | | | Rip-rap (at inlet and outlet): Screen and stockpile | 75 | m3 | C.2.15 | 0.0 | $2.54 | $190.23 | $6.06 | $454 | $1.86 | 145 | $139.37 | $0.00 | $0.00 | $10.45 | $784 | | | |
| A13.5.3.6 | | | Rip-rap (at inlet and outlet): Load, haul, dump | 75 | m3 | R.027 | 3.2 | $1.86 | $139.15 | $3.97 | $298 | $1.17 | 91 | $87.84 | $0.00 | $0.00 | $7.00 | $525 | | | |
| A13.5.3.7 | | | Rip-rap (at inlet and outlet): Place and secure | 75 | m3 | R.904 | 0.8 | $0.48 | $36.20 | $0.91 | $68 | $0.32 | 25 | $24.27 | $0.00 | $0.00 | $1.72 | $129 | | | |
| A13.6 | *Minto Creek Wetland By-Pass Channel* | | | | | | | | | | | | | | | | | | $231,721 | | |
| A13.6.1.1 | | Excavate channel | Load, haul, dump locally | 29,668 | m3 | R.902 | 515.7 | $0.77 | $22,889.69 | $1.64 | $48,733 | $0.46 | 14,246 | $13,675.73 | $0.00 | $0.00 | $2.88 | $85,299 | | | |
| A13.6.2.1 | | Place channel materials | Geotextile: Supply and place | 12,212 | m2 | C.5.08 | 347.3 | $1.09 | $13,364.91 | $0.11 | $1,340 | $0.11 | 1,406 | $1,350.13 | $2.16 | $26,357.04 | $3.47 | $42,412 | | | |
| A13.6.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 5,950 | m3 | C.2.15 | 0.0 | $2.54 | $15,091.24 | $6.06 | $36,032 | $1.86 | 11,517 | $11,056.37 | $0.00 | $0.00 | $10.45 | $62,179 | | | |
| A13.6.2.3 | | | Rip-rap: Load, haul, dump | 5,950 | m3 | R.001 | 187.5 | $1.39 | $8,260.73 | $3.03 | $18,010 | $0.90 | 5,573 | $5,349.64 | $0.00 | $0.00 | $5.31 | $31,620 | | | Assumes WSP rip-rap can be re-used |
| A13.6.2.4 | | | Rip-rap: Place and secure | 5,950 | m3 | R.904 | 64.7 | $0.48 | $2,871.96 | $0.91 | $5,412 | $0.32 | 2,006 | $1,925.52 | $0.00 | $0.00 | $1.72 | $10,210 | | | |
| A13.7 | *Allowance: Minto North Spillway* | | | | | | | | | | | | | | | | | | $83,528 | | |
| A13.7.1.1 | | Excavate channel | Load, haul, dump locally | 13,035 | m3 | R.902 | 226.6 | $0.77 | $10,056.98 | $1.64 | $21,412 | $0.46 | 6,259 | $6,008.67 | $0.00 | $0.00 | $2.88 | $37,477 | | | |
| A13.7.2.1 | | Place channel materials | Geotextile: Supply and place | 4,136 | m2 | C.5.08 | 117.6 | $1.09 | $4,526.14 | $0.11 | $454 | $0.11 | 476 | $457.23 | $2.16 | $8,926.04 | $3.47 | $14,363 | | | |
| A13.7.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 1,943 | m3 | C.2.15 | 0.0 | $2.54 | $4,929.10 | $6.06 | $11,769 | $1.86 | 3,762 | $3,611.23 | $0.00 | $0.00 | $10.45 | $20,309 | | | |
| A13.7.2.3 | | | Rip-rap: Load, haul, dump | 1,943 | m3 | R.024 | 47.7 | $1.08 | $2,101.36 | $2.36 | $4,581 | $0.70 | 1,418 | $1,360.84 | $0.00 | $0.00 | $4.14 | $8,044 | | | Assumes WSP rip-rap can be re-used |
| A13.7.2.4 | | | Rip-rap: Place and secure | 1,943 | m3 | R.904 | 21.1 | $0.48 | $938.04 | $0.91 | $1,768 | $0.32 | 655 | $628.91 | $0.00 | $0.00 | $1.72 | $3,335 | | | |
| A13.8 | *Secondary Catchment Channels* | | | | | | | | | | | | | | | | | | $775,342 | | |
| A13.8.1.1 | | Southwest Dump | Excavate mild-graded channels (good access), spoil locally | 10,787 | Bm3 | R.902 | 187.5 | $0.77 | $8,322.78 | $1.64 | $17,720 | $0.46 | 5,180 | $4,972.55 | $0.00 | $0.00 | $2.88 | $31,015 | | | |
| A13.8.1.2 | | | Excavate steep-graded channels (poor access), spoil locally | 6,640 | Bm3 | R.903 | 131.0 | $0.88 | $5,815.42 | $1.86 | $12,381 | $0.52 | 3,619 | $3,474.49 | $0.00 | $0.00 | $3.26 | $21,671 | | | |
| A13.8.1.3 | | | Geotextile: Supply and place | 25,206 | m2 | C.5.08 | 716.7 | $1.09 | $27,585.63 | $0.11 | $2,766 | $0.11 | 2,903 | $2,786.72 | $2.16 | $54,401.82 | $3.47 | $87,541 | | | |
| A13.8.1.4 | | | Bedding layer: Screen and stockpile | 2,054 | Cm3 | C.2.01 | 41.8 | $0.96 | $1,967.27 | $2.11 | $4,343 | $0.44 | 943 | $905.70 | $0.00 | $0.00 | $3.51 | $7,216 | | | |
| A13.8.1.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 2,054 | Cm3 | R.032 | 72.2 | $1.55 | $3,176.63 | $3.34 | $6,852 | $0.99 | 2,111 | $2,026.92 | $0.00 | $0.00 | $5.87 | $12,055 | | | |
| A13.8.1.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 6,806 | Cm3 | C.2.15 | 0.0 | $2.54 | $17,263.99 | $6.06 | $41,219 | $1.86 | 13,175 | $12,648.20 | $0.00 | $0.00 | $10.45 | $71,131 | | | |
| A13.8.1.7 | | | Rip-rap: Load, haul, dump | 6,806 | m3 | R.031 | 223.5 | $1.45 | $9,846.77 | $3.15 | $21,468 | $0.94 | 6,642 | $6,376.76 | $0.00 | $0.00 | $5.54 | $37,691 | | | |
| A13.8.1.8 | | | Rip-rap: Place in mild-graded channels (good access) | 3,787 | m3 | R.904 | 41.2 | $0.48 | $1,828.10 | $0.91 | $3,445 | $0.32 | 1,277 | $1,225.66 | $0.00 | $0.00 | $1.72 | $6,499 | | | |
| A13.8.1.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 3,019 | m3 | R.905 | 74.5 | $1.10 | $3,308.57 | $2.33 | $7,044 | $0.65 | 2,059 | $1,976.75 | $0.00 | $0.00 | $4.08 | $12,329 | | | |
| A13.8.2.1 | | Main Waste Dump | Excavate mild-graded channels (good access), spoil locally | 6,477 | Bm3 | R.902 | 112.6 | $0.77 | $4,997.00 | $1.64 | $10,639 | $0.46 | 3,110 | $2,985.52 | $0.00 | $0.00 | $2.88 | $18,621 | | | |
| A13.8.2.2 | | | Excavate steep-graded channels (poor access), spoil locally | 3,986 | Bm3 | R.903 | 78.6 | $0.88 | $3,490.67 | $1.86 | $7,432 | $0.52 | 2,172 | $2,085.55 | $0.00 | $0.00 | $3.26 | $13,008 | | | |
| A13.8.2.3 | | | Geotextile: Supply and place | 15,132 | m2 | C.5.08 | 430.3 | $1.09 | $16,560.93 | $0.11 | $1,661 | $0.11 | 1,743 | $1,672.99 | $2.16 | $32,659.93 | $3.47 | $52,555 | | | |
| A13.8.2.4 | | | Bedding layer: Screen and stockpile | 1,233 | Cm3 | C.2.01 | 25.1 | $0.96 | $1,180.84 | $2.11 | $2,607 | $0.44 | 566 | $543.64 | $0.00 | $0.00 | $3.51 | $4,331 | | | |
| A13.8.2.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 1,233 | Cm3 | R.030 | 34.8 | $1.25 | $1,535.65 | $2.76 | $3,401 | $0.82 | 1,059 | $1,016.39 | $0.00 | $0.00 | $4.83 | $5,953 | | | |
| A13.8.2.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 4,086 | Cm3 | C.2.15 | 0.0 | $2.54 | $10,364.11 | $6.06 | $24,745 | $1.86 | 7,909 | $7,593.11 | $0.00 | $0.00 | $10.45 | $42,702 | | | |
| A13.8.2.7 | | | Rip-rap: Load, haul, dump | 4,086 | m3 | R.029 | 101.4 | $1.09 | $4,473.09 | $2.42 | $9,908 | $0.72 | 3,084 | $2,960.56 | $0.00 | $0.00 | $4.24 | $17,341 | | | |
| A13.8.2.8 | | | Rip-rap: Place in mild-graded channels (good access) | 2,274 | m3 | R.904 | 24.7 | $0.48 | $1,097.59 | $0.91 | $2,068 | $0.32 | 767 | $735.89 | $0.00 | $0.00 | $1.72 | $3,902 | | | |
| A13.8.2.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 1,812 | m3 | R.905 | 44.7 | $1.10 | $1,985.96 | $2.33 | $4,228 | $0.65 | 1,236 | $1,186.53 | $0.00 | $0.00 | $4.08 | $7,401 | | | |
| A13.8.3.1 | | Reclamation Overburden D | Excavate mild-graded channels (good access), spoil locally | 4,886 | Bm3 | R.902 | 84.9 | $0.77 | $3,769.89 | $1.64 | $8,026 | $0.46 | 2,346 | $2,252.36 | $0.00 | $0.00 | $2.88 | $14,049 | | | |
| A13.8.3.2 | | | Excavate steep-graded channels (poor access), spoil locally | 3,007 | Bm3 | R.903 | 59.3 | $0.88 | $2,633.47 | $1.86 | $5,607 | $0.52 | 1,639 | $1,573.40 | $0.00 | $0.00 | $3.26 | $9,814 | | | |
| A13.8.3.3 | | | Geotextile: Supply and place | 11,416 | m2 | C.5.08 | 324.6 | $1.09 | $12,494.07 | $0.11 | $1,253 | $0.11 | 1,315 | $1,262.16 | $2.16 | $24,639.65 | $3.47 | $39,649 | | | |
| A13.8.3.4 | | | Bedding layer: Screen and stockpile | 930 | Cm3 | C.2.01 | 18.9 | $0.96 | $890.86 | $2.11 | $1,967 | $0.44 | 427 | $410.14 | $0.00 | $0.00 | $3.51 | $3,268 | | | |
| A13.8.3.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 930 | Cm3 | R.034 | 34.7 | $1.64 | $1,527.43 | $3.58 | $3,330 | $1.06 | 1,030 | $989.17 | $0.00 | $0.00 | $6.29 | $5,847 | | | |
| A13.8.3.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 3,083 | Cm3 | C.2.15 | 0.0 | $2.54 | $7,819.00 | $6.06 | $18,669 | $1.86 | 5,967 | $5,728.47 | $0.00 | $0.00 | $10.45 | $32,216 | | | |
| A13.8.3.7 | | | Rip-rap: Load, haul, dump | 3,083 | m3 | R.033 | 97.0 | $1.39 | $4,271.96 | $3.02 | $9,314 | $0.90 | 2,882 | $2,766.52 | $0.00 | $0.00 | $5.30 | $16,352 | | | |
| A13.8.3.8 | | | Rip-rap: Place in mild-graded channels (good access) | 1,715 | m3 | R.904 | 18.7 | $0.48 | $828.06 | $0.91 | $1,561 | $0.32 | 578 | $555.18 | $0.00 | $0.00 | $1.72 | $2,944 | | | |
| A13.8.3.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 1,367 | m3 | R.905 | 33.8 | $1.10 | $1,498.27 | $2.33 | $3,190 | $0.65 | 932 | $895.16 | $0.00 | $0.00 | $4.08 | $5,583 | | | |
| A13.8.4.1 | | DSTSF & MVFE | Excavate mild-graded channels (good access), spoil locally | 7,378 | Bm3 | R.902 | 128.3 | $0.77 | $5,692.78 | $1.64 | $12,120 | $0.46 | 3,543 | $3,401.22 | $0.00 | $0.00 | $2.88 | $21,214 | | | |
| A13.8.4.2 | | | Excavate steep-graded channels (poor access), spoil locally | 4,541 | Bm3 | R.903 | 89.6 | $0.88 | $3,976.72 | $1.86 | $8,467 | $0.52 | 2,475 | $2,375.94 | $0.00 | $0.00 | $3.26 | $14,819 | | | |
| A13.8.4.3 | | | Geotextile: Supply and place | 17,239 | m2 | C.5.08 | 490.2 | $1.09 | $18,866.88 | $0.11 | $1,892 | $0.11 | 1,985 | $1,905.94 | $2.16 | $37,207.52 | $3.47 | $59,872 | | | |
| A13.8.4.4 | | | Bedding layer: Screen and stockpile | 1,405 | Cm3 | C.2.01 | 28.6 | $0.96 | $1,345.27 | $2.11 | $2,970 | $0.44 | 645 | $619.34 | $0.00 | $0.00 | $3.51 | $4,935 | | | |
| A13.8.4.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 1,405 | Cm3 | R.028 | 82.5 | $2.59 | $3,633.88 | $5.78 | $8,121 | $1.69 | 2,467 | $2,368.79 | $0.00 | $0.00 | $10.05 | $14,124 | | | |
| A13.8.4.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 4,655 | Cm3 | C.2.15 | 0.0 | $2.54 | $11,807.22 | $6.06 | $28,191 | $1.86 | 9,011 | $8,650.38 | $0.00 | $0.00 | $10.45 | $48,648 | | | |
| A13.8.4.7 | | | Rip-rap: Load, haul, dump | 4,655 | m3 | C.5.08 | 132.4 | $1.09 | $5,094.58 | $0.11 | $511 | $0.11 | 536 | $514.66 | $2.16 | $10,047.05 | $3.47 | $16,167 | | | |
| A13.8.4.8 | | | Rip-rap: Place in mild-graded channels (good access) | 2,590 | m3 | R.904 | 28.2 | $0.48 | $1,250.42 | $0.91 | $2,356 | $0.32 | 873 | $838.35 | $0.00 | $0.00 | $1.72 | $4,445 | | | |
| A13.8.4.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 2,065 | m3 | R.905 | 51.0 | $1.10 | $2,262.48 | $2.33 | $4,817 | $0.65 | 1,408 | $1,351.75 | $0.00 | $0.00 | $4.08 | $8,431 | | | |
| A13.8 | *Tailings Diversion Ditch* | | | | | | | | | | | | | | | | | | $624,970 | | |
| A13.8.1.2 | | Regrade | Slopes: Re-grade to 3H:1V | 28 | hrs | C.2.13 | 28 | $44.39 | $1,226 | $194.68 | $5,376 | $67.01 | 1,928 | $1,850 | $0.00 | $0 | $306.07 | $8,452 | | | |
| A13.8.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 25,182 | Cm3 | R.066 | 562.3 | $0.98 | $24,763 | $3.20 | $80,473 | $1.05 | 27,585 | $26,482 | $0.00 | $0 | $5.23 | $131,718 | | | |
| A13.8.2.2 | | | Slope area cover material: Load, haul, dump along crest | 18,049 | Cm3 | R.067 | 352.6 | $0.86 | $15,513 | $2.84 | $51,216 | $0.95 | 17,921 | $17,204 | $0.00 | $0 | $4.65 | $83,933 | | | |
| A13.8.2.3 | | | Slope area cover material: Spread down slope | 14 | hrs | C.2.13 | 14.0 | $44.39 | $621 | $194.68 | $2,724 | $67.01 | 977 | $937 | $0.00 | $0 | $306.07 | $4,282 | | | |
| A13.8.3.1 | | Revegetate | Seed/Fertilize: tractor application | 9 | ha | C.6.01 | 286.4 | $1,029.50 | $8,901 | $401.72 | $3,473 | $232.94 | 2,098 | $2,014 | $1,005.72 | $8,696 | $2,670 | $23,085 | | | |
| A13.8.3.2 | | | Tree seedling application (1,000 stems/ha) | 9 | ha | C.6.06 | 443.1 | $1,832.33 | $15,843 | $25.98 | $225 | $15.00 | 135 | $130 | $469.71 | $4,061 | $2,343 | $20,258 | | | |
| A13.8.4.1 | | Extend Channel to WSP | Clear and grub footprint | 13,889 | m2 | C.2.03 | 52.8 | $0.17 | $2,344 | $0.49 | $6,774 | $0.13 | 1,940 | $1,863 | $0.00 | $0 | $0.79 | $10,981 | | | |
| A13.8.4.2 | | | Geotextile: Supply and place | 13,889 | m2 | C.5.08 | 394.9 | $1.09 | $15,200 | $0.11 | $1,524 | $0.11 | 1,600 | $1,536 | $2.16 | $29,976 | $3.47 | $48,236 | | | |
| A13.8.4.3 | | | Rip-rap (angular, high quality): Screen and stockpile | 13,169 | m3 | C.2.15 | 0.0 | $2.54 | $33,403 | $6.06 | $79,753 | $1.86 | 25,492 | $24,472 | $0.00 | $0 | $10.45 | $137,629 | | | |
| A13.8.4.4 | | | Rip-rap: Load, haul, dump | 13,169 | m3 | R.035 | 618.4 | $2.07 | $27,207 | $4.42 | $58,233 | $1.30 | 17,890 | $17,175 | $0.00 | $0 | $7.79 | $102,615 | | | |
| A13.8.4.5 | | | Rip-rap: Place in steep-graded channels (poor access) | 13,169 | m3 | R.905 | 325.1 | $1.10 | $14,432 | $2.33 | $30,726 | $0.65 | 8,982 | $8,622 | $0.00 | $0 | $4.08 | $53,780 | | | |
| **A14** | **Water Treatment** | | | | | | | | | | | | | | | | | | | **$483,085** | |
| A14.1 | *Passive Treatment System - Minto Creek Valley* | | | | | | | | | | | | | | | | | | $397,994 | | |
| A14.1.1.1 | | Water Management | Install pump and pump around system | 8 | hrs | C.4.14 | 32.0 | $120.43 | $963.46 | $20.53 | $164 | $6.80 | 57 | $54.40 | $0.00 | $0.00 | $147.76 | $1,182 | | | Assumed |
| A14.1.1.2 | | | Maintain pump around system during wetland construction activities | 1,440 | hrs | C.4.13 | 144.0 | $3.55 | $5,117.32 | $12.98 | $18,691 | $2.00 | 3,000 | $2,880.00 | $0.00 | $0.00 | $18.53 | $26,689 | | | Assumes wetlands constructed over 2 months |
| A14.1.2.1 | | Valley Fill placement | Load, haul, dump material from the WSP excavation | 85,918 | m3 | n/a - coste | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.1.2.1 | | | Load, haul dump valley fill material | 0 | m3 | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | Fill from WSP excavation exceeds the required amount. |
| A14.1.3.1 | | Construct wetlands | Excavate cells: Load, haul dump, spoil locally | 14,459 | m3 | R.902 | 251.3 | $0.77 | $11,155.61 | $1.64 | $23,751 | $0.46 | 6,943 | $6,665.06 | $0.00 | $0.00 | $2.88 | $41,572 | | | |
| A14.1.3.2 | | | Subgrade preparation: remove sharp objects, place fill as required | 9,273 | m2 | C.2.18 | 317.0 | $1.31 | $12,142.93 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $1.31 | $12,143 | | | |
| A14.1.3.3 | | | Geotextile: Supply and install | 10,201 | m2 | C.5.08 | 290.1 | $1.09 | $11,163.84 | $0.11 | $1,120 | $0.11 | 1,175 | $1,127.78 | $2.16 | $22,016.30 | $3.47 | $35,428 | | | |
| A14.1.3.4 | | | HDPE liner: Supply and install | 10,201 | m2 | C.5.11 | 1,187.0 | $4.74 | $48,319.12 | $0.27 | $2,749 | $0.27 | 2,884 | $2,769.07 | $9.38 | $95,723.03 | $14.66 | $149,560 | | | |
| A14.1.3.5 | | | Organics: Mulch organics, produce and stockpile | 5,122 | Cm3 | C.2.10 | 577.1 | $4.50 | $23,023.50 | $4.87 | $24,922 | $1.82 | 9,720 | $9,331.25 | $0.00 | $0.00 | $11.18 | $57,277 | | | |
| A14.1.3.6 | | | Organics: Load, haul, dump, place in cell | 5,122 | Cm3 | R.001 | 161.4 | $1.39 | $7,111.43 | $3.03 | $15,504 | $0.90 | 4,797 | $4,605.36 | $0.00 | $0.00 | $5.31 | $27,221 | | | |
| A14.1.3.7 | | | Plant wetland vegetation | 0.9 | ha | C.6.05 | 40.6 | $1,443.27 | $1,338.39 | $307.03 | $285 | $180.00 | 174 | $166.92 | $1,159.23 | $1,074.99 | $3,089.53 | $2,865 | | | |
| A14.1.4.1 | | Conveyance channels | Excavate channels: Load, haul, dump locally | 1,402 | m3 | R.902 | 24.4 | $0.77 | $1,081.90 | $1.64 | $2,303 | $0.46 | 673 | $646.39 | $0.00 | $0.00 | $2.88 | $4,032 | | | |
| A14.1.4.2 | | | Surface preparation: remove sharp objects, place fill as required | 1,858 | m2 | C.2.18 | 63.5 | $1.31 | $2,432.63 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $1.31 | $2,433 | | | |
| A14.1.4.3 | | | Geotextile: Supply and place | 1,858 | m2 | C.5.08 | 52.8 | $1.09 | $2,033.17 | $0.11 | $204 | $0.11 | 214 | $205.39 | $2.16 | $4,009.63 | $3.47 | $6,452 | | | |
| A14.1.4.4 | | | HDPE Liner: Supply and install | 1,858 | m2 | C.5.11 | 216.2 | $4.74 | $8,799.92 | $0.27 | $501 | $0.27 | 525 | $504.31 | $9.38 | $17,433.16 | $14.66 | $27,238 | | | |
| A14.1.4.5 | | | Bedding/Protection layer: Screen and stockpile | 442 | m3 | C.2.01 | 9.0 | $0.96 | $423.54 | $2.11 | $935 | $0.44 | 203 | $194.99 | $0.00 | $0.00 | $3.51 | $1,554 | | | |
| A14.1.4.6 | | | Bedding/Protection layer: Load, haul, dump and place | 442 | m3 | R.001 | 13.9 | $1.39 | $614.04 | $3.03 | $1,339 | $0.90 | 414 | $397.65 | $0.00 | $0.00 | $5.31 | $2,350 | | | Assumes WSP fill can be re-used |
| A14.1.5.1 | | Operation and maintenance | System to be started Yr. 1 post-closure | 0 | yr | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.2 | *Southwest Wetlands* | | | | | | | | | | | | | | | | | | $15,944 | | |
| A14.2.1 | | Berm construction | Construct 3 berms across valley | 3,000 | m3 | R.001 | 94.5 | $1.39 | $4,165.24 | $3.03 | $9,081 | $0.90 | 2,810 | $2,697.41 | $0.00 | $0.00 | $5.31 | $15,944 | | | Assumed |
| A14.2.2 | | Outlet structures | Excavate outlet channels through berms | 1 | ls | | | | | | | | | | | | | | | | Allowance |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A14.3 | *Decommission/demolish Water Treatment System* | | | | | | | | | | | | | | | | | | $69,147 | | |
| A14.3.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 17 | hrs | C.1.13 | 67.1 | $168.00 | $2,819.22 | $86.19 | $1,446 | $14.53 | 254 | $243.80 | $0.00 | $0.00 | $268.71 | $4,509 | | | |
| A14.3.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 29 | hrs | C.1.14 | 175.7 | $269.89 | $7,903.93 | $167.56 | $4,907 | $20.53 | 626 | $601.18 | $0.00 | $0.00 | $457.98 | $13,412 | | | |
| A14.3.2.1 | | Prepare for demolition | Reagents: Load for transport | 25 | hrs | C.1.22 | 99.3 | $159.30 | $3,955.90 | $95.83 | $2,380 | $26.93 | 697 | $668.71 | $0.00 | $0.00 | $282.05 | $7,004 | | | |
| A14.3.2.2 | | | Reagents: Transport to Whitehorse | 2.2 | trips | C.7.04 | 18.0 | $351.24 | $789.50 | $303.64 | $682 | $113.33 | 265 | $254.73 | $0.00 | $0.00 | $768.21 | $1,727 | | | |
| A14.3.2.3 | | | Reagents: Disposal and tipping fees | 1.0 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.3.3.1 | | Demolition | Structural building demolition | 163 | tonnes | C.1.05 | 325.0 | $69.36 | $11,272.12 | $139.08 | $22,604 | $33.84 | 5,729 | $5,499.69 | $0.00 | $0.00 | $242.28 | $39,376 | | | |
| A14.3.3.2 | | | Other demolition: miscellaneous | 15 | m3 | C.1.07 | 1.5 | $3.74 | $56.09 | $2.07 | $31 | $0.74 | 12 | $11.05 | $0.00 | $0.00 | $6.55 | $98 | | | |
| A14.3.4.1 | | Waste disposal | Off-site disposal (re-usable equipment, etc.) | 3 | trips | C.7.07 | 27.1 | $355.10 | $1,202.32 | $423.68 | $1,435 | $113.33 | 400 | $383.71 | $0.00 | $0.00 | $892 | $3,021 | | | |
| **Subtotal Direct Costs - Active Closure** | | | | | | | **114,724** | | **$4,864,705** | | **$8,474,076** | | | **$2,573,011** | | **$1,132,685** | | | | **$17,044,478** | |
| **INDIRECT COSTS** | | | | | | | | | | | | | | | | | | | | | |
| **B1** | **Mobilization-Demobilization** | | | | | | | | | | | | | | | | | | | **$324,077** | |
| B1.1 | | Mobilization | Year 0 | 1 | LS | | | | | | | | | | | | $162,039 | $162,038.53 | | | |
| B1.2 | | Demobilization | Year 3 (end of Active Closure) | 1 | LS | | | | | | | | | | | | $144,406 | $144,405.50 | | | |
| B1.4 | | Demobilization | End of Passive closure | 1 | LS | | | | | | | | | | | | $17,633 | $17,633.03 | | | |
| **B2** | **Transportation Costs** | | | | | | | | | | | | | | | | | | | **$405,599** | |
| B2.1.1 | | Barge Operations | | 14 | month | | | | | | | | | | | | $10,832 | $151,654 | | | |
| | | Staffing Bus trips during barge operation period | | 56 | ea (one per week) | | | | | | | | | | | | $678 | $37,946 | | | Turnaround labour costs included in labour build-up |
| B2.2.2 | | Air transport and airstrip operations | | 72 | flights | | | | | | | | | | | | $3,000 | $216,000 | | | Three flights per week |
| **B3** | **Site/Road Maintenance** | | | | | | | | | | | | | | | | | | | **$757,001** | |
| B3.1 | *Road Maintenance* | | | | | | | | | | | | | | | | | | $693,226 | | |
| B3.1.1 | | Water Truck | Assume needed 150 hrs per month | 20 | month | | | | | | | | | | | | $12,153 | $243,052 | | | |
| B3.1.2 | | Grader | Assume needed 150 hrs per month (16H + Operator) | 20 | month | | | | | | | | | | | | $22,509 | $450,173 | | | Includes Main Access Road throughout closure period. |
| B3.2 | *Soil Erosion* | | | | | | | | | | | | | | | | | | $63,775 | | |
| B3.2.1 | | Erosion control allowance | Silt fencing: supply, install remove at strategic locations | 7023.7 | m | C.2.17 | 283.5 | $3.23 | $22,661.96 | $1.93 | $13,533 | $0.68 | 4,941 | $4,743.08 | $0.92 | $6,485.58 | $6.75 | $47,424 | | | |
| B3.2.2 | | | Supply and install erosion control matting | 10000 | m2 | C.2.09 | 175.4 | $0.66 | $6,622.75 | $0.09 | $912 | $0.05 | 548 | $526.32 | $0.83 | $8,290.76 | $1.64 | $16,352 | | | |
| **B4** | **Construction Support** | | | | | | | | | | | | | | | | | | | **$5,054,174** | |
| B4.1 | *Field Support Staff* | | | | | | | | | | | | | | | | | | $3,081,160 | | Turnaround labour costs included in labour build-up |
| B4.1.1 | | Mine Manager | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $23,408 | $468,170 | | | |
| B4.1.2 | | Office/Camp manager | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $22,267 | $445,347 | | | |
| B4.1.3 | | Security/Administrative Assistant | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $16,600 | $331,991 | | | |
| B4.1.4 | | Foreman | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $355,383 | | | |
| B4.1.5 | | Mechanic | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $355,383 | | | |
| B4.1.6 | | Surveyor | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $355,383 | | | |
| B4.1.7 | | Engineering technician | Material & QA/QC testing | 10 | month | | | ( 360 ) site working hours per month | | | | | | | | | $42,120 | $421,200 | | | Assumed needed 1/2 of time |
| B4.1.8 | | Medic/H&S supervisor | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,415 | $348,303 | | | |
| B4.2 | *Field support Vehicles* | | | | | | | | | | | | | | | | | | $821,700 | | |
| B4.2.1 | | Pick-up trucks (4 required) | | 80 | month | | | | | | | | | | | | $4,446 | $355,668 | | | |
| B4.2.2 | | Fuel truck | | 20 | month | | | | | | | | | | | | $4,720 | $94,403 | | | |
| B4.2.3 | | Mechanic service vehicle | | 20 | month | | | | | | | | | | | | $11,803 | $236,069 | | | |
| B4.2.4 | | Emergency transport vehicle | | 20 | month | | | | | | | | | | | | $4,519 | $90,382 | | | |
| B4.2.5 | | Passenger bus | | 20 | month | | | | | | | | | | | | $2,259 | $45,177 | | | |
| B4.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | | | | | $1,151,314 | | |
| B4.3.1 | | Light Towers | | 20 | month | | | 2 # of Units | | | | | | | | | $3,356 | $67,120 | | | |
| B4.3.2 | | Material/Laboratory testing allowance | | 20 | month | | | | | | | | | | | | $1,000 | $20,000 | | | |
| B4.4 | | Construction, Environmental, and H&S Management Plans | | 1 | LS | | | | | | | | | | | | $25,000 | $25,000 | | | |
| B4.5 | | Office supplies | | 20 | month | | | | | | | | | | | | $1,000 | $20,000 | | | |
| B4.6 | | Communications | | 20 | month | | | | | | | | | | | | $1,000 | $20,000 | | | |
| B4.7 | | Misc. supplies | | 20 | month | | | | | | | | | | | | $500 | $10,000 | | | |
| B4.8 | | Camp costs | Includes catering and housekeeping | 11,472 | man-day | | | | | | | | | | | | $80 | $917,793 | | | |
| B4.9 | | Power and heat | | 20 | month | | | | | | | | | | | | $3,570 | $71,400 | | | |
| **B5** | **QA and Project Management** | | | | | | | | | | | | | | | | | | | **$1,668,691** | |
| B5.1 | | Project Manager | | 20 | month | | | ( 160 ) site working hours per month | | | | | | | | | $9,897 | $197,932 | | | |
| B5.2 | | Design Engineer | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $48,600 | $972,000 | | | |
| B5.3 | | Environmental Monitor | | 20 | month | | | ( 360 ) site working hours per month | | | | | | | | | $16,046 | $320,926 | | | |
| B5.4 | | Engineering , Design, and Construction plans (included in Planning and Permitting Costs) | | | | | | | | | | | | | | | $0.00 | $0 | | | |
| B5.5 | | Field support vehicles (2 vehicles) | | 40 | month | | | | | | | | | | | | $4,446 | $177,834 | | | |
| **Subtotal Indirect Costs - Active Closure** | | | | | | | | | | | | | | | | | | | | **$8,209,543** | |
| **CLOSURE IMPLEMENTATION COSTS - TOTAL** | | | | | | | | | | | | | | | | | | | | **$25,254,020** | |

# Worksheet 5 - Year 0 Estimate - Schedule Details

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## A: Year 0 Site Access Schedule

| Stage | Flight Months | Helicopter Months | Barge Months | Total Months | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interim Care | 2 | 5 | 5 | 12 | H | H | H | F | F | B | B | B | B | B | H | H | |
| **SUB-TOTAL INTERIM CARE** | **2** | **5** | **5** | **12** | | | | | | | | | | | | | |
| Active Closure 1 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| Active Closure 2 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| Active Closure 3 | 2 | 0 | 4 | 6 | | | | F | F | B | B | B | B | | | | |
| **SUB-TOTAL ACTIVE CLOSURE** | **6** | **0** | **14** | **20** | | | | | | | | | | | | | |
| Post-Closure 1 | 2 | 0 | 3 | 5 | | | | F | F | B | B | B | | | | | |
| **SUB-TOTAL POST-CLOSURE 1** | **2** | **0** | **3** | **5** | | | | | | | | | | | | | |
| Post-Closure 2 | 0 | 0 | 1 | 1 | | | | | | B | | | | | | | |
| **SUB-TOTAL POST-CLOSURE 2** | **0** | **0** | **1** | **1** | | | | | | | | | | | | | |

## B: Annual C&M Staffing Schedule - Interim Operations

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **12** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 4 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 2 | Office/Camp Mgr | | 6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 3 | Payroll/Accounting/HR | | 4 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Warehouse/Water Treatment Operator | | 5 | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | | | |
| 2 | Environmental Manager | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 3 | Environmental Technician | | 7 | 0.5 | 0.5 | 0.5 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 10 | | | | | | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | | | |
| 5 | Equipment operators | | 13 | | | | 2.0 | 3.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | | | |
| 6 | HD Mechanic | | 2 | | | | 0.5 | 0.3 | 0.3 | 0.3 | 0.25 | 0.25 | 0.25 | | | |
| 7 | Tradesmen | | 2 | | | | 0.5 | 0.3 | 0.3 | 0.3 | 0.25 | 0.25 | 0.5 | | | |
| 8 | Labour/Helpers | | 10 | 1 | 1 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | 1.0 | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 2 | | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.0 | | |
| **TOTAL** | | | **66.5** | **2.0** | **2.0** | **2.0** | **8.8** | **8.3** | **8.3** | **8.3** | **8.3** | **7.3** | **7.5** | **2.0** | **2.0** | |
| | | **Annual man-days:** | **1,995** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## C: Annual C&M Staffing Schedule - During Active Phase

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **7** | | | | **1** | **1** | **1** | **1** | **1** | **1** | **1** | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Warehouse/Water Treatment Operator | | 5 | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | | | |
| 2 | Environmental Manager | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 3 | Environmental Technician | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| **TOTAL** | | | **13** | **0** | **0** | **0** | **3** | **2** | **2** | **2** | **2** | **1** | **1** | **0** | **0** | |
| | | **Annual man-days:** | **390** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)

## D: Annual C&M Staffing Schedule - Post Closure 1

| # | Role | | Months Required | Month | | | | | | | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| **Months Active at Site** | | | **5** | | | | **1** | **1** | **1** | **1** | **1** | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 2 | Office/Camp Mgr | | 3 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 3 | Payroll/Accounting/HR | | 1 | | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Operator | | 2 | | | | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | | | | | |
| 2 | Environmental Manager | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 3 | Environmental Technician | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 6 | | | | | | 2.0 | 2.0 | 2.0 | | | | | |
| 5 | Equipment operators | | 10 | | | | 2.0 | 3.0 | 1.5 | 1.5 | 1.5 | | | | | |
| 6 | HD Mechanic | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| 7 | Tradesmen | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| 8 | Labour/Helpers | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.5 | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 1 | | | | 0.25 | | | | 0.25 | | | | | |
| **TOTAL** | | | **36** | **0** | **0** | **0** | **9** | **7** | **7** | **7** | **7** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **1,073** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## E: Annual C&M Staffing Schedule - Post Closure 2

| # | Role | | Months Required | Month | | | | | | | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| **Months Active at Site** | | | **1** | | | | | | **1** | | | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 1 | | | | | | 0.5 | | | | | | | |
| 2 | Office/Camp Mgr | | 0 | | | | | | 0.0 | | | | | | | |
| 3 | Payroll/Accounting/HR | | 0 | | | | | | 0.00 | | | | | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Passive Treatment Scientist | | 1 | | | | | | 0.5 | | | | | | | |
| 2 | Environmental Manager | | 0 | | | | | | | | | | | | | |
| 3 | Environmental Technician | | 0 | | | | | | | | | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 1 | | | | | | 1.0 | | | | | | | |
| 5 | Equipment operators | | 1 | | | | | | 1.0 | | | | | | | |
| 6 | HD Mechanic | | 1 | | | | | | 0.50 | | | | | | | |
| 7 | Tradesmen | | 0 | | | | | | | | | | | | | |
| 8 | Labour/Helpers | | 0 | | | | | | 0.25 | | | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | | | 0.0 | | | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 0 | | | | | | 0.25 | | | | | | | |
| **TOTAL** | | | **4** | **0** | **0** | **0** | **0** | **0** | **4** | **0** | **0** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **120** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## E: Annual C&M Staffing Schedule - Long-term perpetual maintenance year

| # | Role | | Months Required | Month | | | | | | | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| **Months Active at Site** | | | **1** | | | | | | | **1** | | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Project Manager/Foreman | | 1 | | | | | | | 1.0 | | | | | | |
| **Water Treatment/Engineering Staffing** | | | | | | | | | | | | | | | | |
| 1 | Passive Treatment Scientist | | 1 | | | | | | | 1.0 | | | | | | |
| 2 | Site Engineer | | 1 | | | | | | | 1.0 | | | | | | |
| 3 | Environmental Technician | | 0 | | | | | | | | | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 1 | | | | | | | 1.0 | | | | | | Assumed required 1/2 the time (near mob and demob) |
| 5 | Equipment operators | | 4 | | | | | | | 4.0 | | | | | | |
| 6 | HD Mechanic | | 1 | | | | | | | 0.50 | | | | | | |
| 7 | Tradesmen | | 0 | | | | | | | | | | | | | |
| 8 | Labour/Helpers | | 1 | | | | | | | 1.00 | | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | | | | | | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 1 | | | | | | | 0.50 | | | | | | |
| **TOTAL** | | | **10** | **0** | **0** | **0** | **0** | **0** | **0** | **10** | **0** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **300** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

# Worksheet 6- Year 0 Estimate - Planning and Permitting Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## Planning And Permitting

| WBS | Facility/Area | Task | Activity | Qnty | Unit | Total Unit Rate ($/unit) | Activity Total | Subtotal | Source / Comments |
|---|---|---|---|---|---|---|---|---|---|
| M1 | **Planning and Permitting** | | | | | | | | |
| M1.1 | *Reclamation Research/Planning* | | | | | | | $400,000 | |
| M1.1.1 | | Complete reclamation closure and research plan | | 2 | yr | $200,000 | $400,000 | | |
| M1.2 | *Technical studies and investigations* | | | | | | | $58,500 | |
| M1.2.1 | | Allowance for additional technical studies | | 1 | ls | $58,500 | $58,500 | | |
| M1.3 | *Monitoring and Management Plans* | | | | | | | $209,158 | |
| M1.3.1 | | Adaptive Mgmt Plans | Physcial, water quality, etc | 1 | ls | $15,000 | $15,000 | | |
| M1.3.2 | | Revegetation plan | | 1 | ls | $30,000 | $30,000 | | |
| M1.3.3 | | Waste Management Plan | Water treatment, sludge, landfarm, etc. | 1 | ls | $50,000 | $50,000 | | |
| M1.3.4 | | MMER Final Monitoring Study | | 1 | ls | $114,158 | $114,158 | | |
| M1.4 | *Engineering, Design, and Construction Plans* | | | | | | | $852,224 | |
| M1.4.1 | | Percentage of direct implementation costs | | 5% | of | $17,044,478 | $852,224 | | |
| M1.5 | *Permitting* | | | | | | | $0 | |
| M1.5.1.1 | | Permit Staffing | Permitting Manager | 0 | ls | $0 | $0 | | Staffing costs included in tasks above |
| M1.5.1.2 | | | Environmental Manager | 0 | ls | $0 | $0 | | |
| M1.5.1.3 | | | Technical Consultants | 0 | ls | $0 | $0 | | |
| **TOTAL** | | | | | | | | **$1,519,882** | |

# Worksheet 7 - Peak Liability Estimate - Cashflow Calculations

Project: Minto Mine Closure Cost Estimate - RCP 2018-01
Project No.: 1CM002.045
Client: Minto Explorations Ltd.
Date: February 6, 2018
File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## NPV CALCULATION INPUTS

**NOTE: Columns between Years 2047 and 2128 are hidden for printing purposes.**

**Short-Term Interest Rate (Interim Care/Implementation Costs)**

| ## | Inflation Rate | Years in effect | Start Year | End Year |
|---|---|---|---|---|
| 1 | 1.6% | 100 | 2018 | 2118 |

**Input Parameters**

Scenario: Peak Liability - Mid 2019 - Interim Care starts 2020
Current Year: 2018 Year that the estimate is costed
Closure Year 1: 2022
Closure Period: 3 yrs
Post-Closure Year 1: 2025

**Long-Term Monitoring/Maintenance NPV Discount Rates**

| ## | Discount Rate | Years in effect | Start Year | End Year |
|---|---|---|---|---|
| 1 | 2.35% | 2 | 2018 | 2020 |
| 2 | 2.5% | 3 | 2021 | 2024 |
| 3 | 2.8% | - | 2025 | |

## SCHEDULE

### Implementation Schedule

| | | | OPERATIONS | | INTERIM CARE | | CLOSURE | | | POST CLOSURE | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Closure Year: | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 107 | Year 108 |
| | Area | Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
| Direct Costs | Waste Dumps | 100% | | | | | 40% | 60% | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Overburden Dumps | 100% | | | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ore Stockpiles | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Open Pits | 100% | | | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Underground Openings | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | External Tailings Facilities | 100% | | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Roads | 100% | | | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Demolition | 100% | | | | | 10% | 75% | 15% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Surface Infrastructure | 100% | | | | | 25% | 50% | 25% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water Detention Structures | 100% | | | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Yards/Laydown Areas | 100% | | | | | 25% | 25% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Waste Disposal | 100% | | | | | | 12% | 75% | 2% | 2% | 2% | 6% | | | | | | | | | | | | | | | | | | | | | |
| | Surface Water Conveyance | 100% | | | | | 20% | 30% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water Treatment | 100% | | | | | | | 86% | | | | | 14% | | | | | | | | | | | | | | | | | | | | |
| Indirect | Mobilization-Demobilization | 100% | | | | | 50% | | 45% | | | | | 5% | | | | | | | | | | | | | | | | | | | | |
| | Transport Costs | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Road Maintenance | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Construction Support | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | QA and Pro. Mgmt. | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | |

### Monitoring Schedule

| | | | | | 1 - Interim | 1 - Interim | 2 - Active | 2 - Active | 2 - Active | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | | | | | | | | | | 5 - Perpetual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Post-Closure Year: | Year -7 | Year -6 | Year -5 | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 104 | Year 105 |
| | | Sum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Planning and permitting | Reclamation Research and Planning | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Technical Studies and Investigations | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Engineering, Design, and Construction Plans | 100% | | | 30% | 40% | 10% | 10% | 10% | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Monitoring and Management Plans | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Permitting | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monitoring | Water Quality Monitoring (surface and groundwater) | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | 1 | |
| | Sediment Monitoring | | | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | |
| | Biological Monitoring | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | |
| | Geotechnical Monitoring | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | |
| | Revegetation Monitoring | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | |
| | Annual Inspection Reporting | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | 1 | |

### Care and Maintenance Schedule

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Treatment/Management | Active System | | | | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | x | x | x | x | x | | | | | | | | | | |
| | Passive System | | | | | | | | | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | |
| Reclamation Maintenance | Revegetation, cover repair, etc. | | | | | | | | | x | x | x | x | x | | | | | | | | | | | | | | | | | | | | x | |
| Site Maintenance | | | | | x | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | |
| On-site Management | | | | | x | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | |
| Transportation Costs | | | | | x | x | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | |

## UNDISCOUNTED CASH FLOW (TO 100 YEARS POST CLOSURE)

### Implementation Costs

| | | | Total | % of Total | Check Sum | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 107 | Year 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | | | | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
| Direct Costs | Waste Dumps | | $6,893,723 | 25% | $6,893,723 | $0 | $0 | $0 | $0 | $2,757,489 | $4,136,234 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Overburden Dumps | | $395,276 | 1% | $395,276 | $0 | $0 | $0 | $0 | $0 | $0 | $395,276 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Ore Stockpiles | | $3,331,999 | 12% | $3,331,999 | $0 | $0 | $0 | $0 | $3,331,999 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Open Pits | | $620,582 | 2% | $620,582 | $0 | $0 | $0 | $0 | $0 | $310,291 | $310,291 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Underground Openings | | $81,637 | 0% | $81,637 | $0 | $0 | $0 | $0 | $81,637 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | External Tailings Facilities | | $57,291 | 0% | $57,291 | $0 | $0 | $0 | $0 | $28,646 | $28,646 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Roads | | $136,050 | 0% | $136,050 | $0 | $0 | $0 | $0 | $0 | $0 | $136,050 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Demolition | | $1,976,253 | 7% | $1,976,253 | $0 | $0 | $0 | $0 | $197,625 | $1,482,189 | $296,438 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Infrastructure | | $169,527 | 1% | $169,527 | $0 | $0 | $0 | $0 | $42,382 | $84,763 | $42,382 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Detention Structures | | $786,952 | 3% | $786,952 | $0 | $0 | $0 | $0 | $0 | $393,476 | $393,476 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Yards/Laydown Areas | | $758,907 | 3% | $758,907 | $0 | $0 | $0 | $0 | $189,727 | $189,727 | $379,454 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Waste Disposal | | $452,923 | 2% | $452,923 | $0 | $0 | $0 | $0 | $0 | $54,828 | $339,692 | $11,145 | $11,145 | $11,145 | $24,967 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Water Conveyance | | $3,287,496 | 12% | $3,287,496 | $0 | $0 | $0 | $0 | $657,499 | $986,249 | $1,643,748 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Treatment | | $483,085 | 2% | $483,085 | $0 | $0 | $0 | $0 | $0 | $0 | $413,938 | $0 | $0 | $0 | $0 | $69,147 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect | Mobilization-Demobilization | | $324,077 | 1% | $324,077 | $0 | $0 | $0 | $0 | $162,039 | $0 | $144,406 | $0 | $0 | $0 | $0 | $17,633 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Transport Costs | | $419,142 | 1% | $419,142 | $0 | $0 | $0 | $0 | $142,508 | $138,317 | $138,317 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Site/Road Maintenance | | $791,662 | 3% | $791,662 | $0 | $0 | $0 | $0 | $269,165 | $261,249 | $261,249 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Construction Support | | $5,344,480 | 19% | $5,344,480 | $0 | $0 | $0 | $0 | $1,817,123 | $1,763,678 | $1,763,678 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | QA and Pro. Mgmt. | | $1,752,126 | 6% | $1,752,126 | $0 | $0 | $0 | $0 | $595,723 | $578,202 | $578,202 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Subtotal - Closure Implementation Costs** | | | **$28,063,189** | | $28,063,189 | **$0** | **$0** | **$0** | **$0** | **$10,273,563** | **$10,407,849** | **$7,236,595** | **$11,145** | **$11,145** | **$11,145** | **$24,967** | **$86,780** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Monitoring Costs

| | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Planning and | Reclamation Research and Planning | $400,000 | 10% | $400,000 | $0 | $0 | $200,000 | $200,000 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | Permitting | Technical Studies and Investigations | $58,500 | 1% | $58,500 | $0 | $0 | $29,250 | $29,250 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Engineering, Design, and Construction Plans | $971,585 | 23% | $971,585 | $0 | $0 | $291,476 | $388,634 | $97,159 | $97,159 | $97,159 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Monitoring and Management Plans | $209,158 | 5% | $209,158 | $0 | $0 | $104,579 | $104,579 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Permitting | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 1 | Monitoring | Water Quality Monitoring | $1,403,014 | 33% | $1,403,014 | $0 | $0 | $115,295 | $115,295 | $130,437 | $130,437 | $130,437 | $51,987 | $51,987 | $51,987 | $51,987 | $51,987 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $27,664 |
| 2 | | Sediment Monitoring | $64,372 | 2% | $64,372 | $0 | $0 | $3,388 | $3,388 | $3,388 | $3,388 | $3,388 | $0 | $3,388 | $0 | $3,388 | $0 | $0 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $3,388 |
| 3 | | Biological Monitoring | $233,587 | 6% | $233,587 | $0 | $0 | $12,294 | $12,294 | $12,294 | $12,294 | $12,294 | $12,294 | $0 | $12,294 | $0 | $12,294 | $0 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $12,294 |
| 4 | | Geotechnical Monitoring | $379,471 | 9% | $379,471 | $0 | $0 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $0 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,216 |
| 5 | | Revegetation Monitoring | $200,071 | 5% | $200,071 | $0 | $0 | $0 | $0 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $0 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,530 |
| 6 | | Annual Inspection Reporting | $286,620 | 7% | $286,620 | $0 | $0 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $23,900 | $0 | $0 | $0 | $23,900 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,900 |
| **Post Closure Costs Subtotal** | | | **$4,206,378** | | $4,206,378 | **$0** | **$0** | **$771,063** | **$868,221** | **$268,589** | **$268,589** | **$268,589** | **$92,981** | **$77,299** | **$92,981** | **$77,299** | **$92,981** | **$27,220** | **$27,220** | **$27,220** | **$27,220** | **$100,548** | **$27,220** | **$27,220** | **$27,220** | **$27,220** | **$100,548** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$100,993** |

### Care and Maintenance Costs

| | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $7,981,012 | 36% | $7,981,012 | $0.00 | $0 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $560,239 | 3% | $560,239 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $35,015 | $35,015 | $35,015 | $35,015 | $35,015 | $0 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $35,015 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $1,834,053 | 8% | $1,834,053 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $366,811 | $366,811 | $366,811 | $366,811 | $366,811 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $2,478,551 | 11% | $2,478,551 | $0 | $0 | $359,187 | $359,187 | $30,000 | $30,000 | $30,000 | $99,414 | $99,414 | $99,414 | $99,414 | $99,414 | $0 | $0 | $0 | $0 | $99,414 | $0 | $0 | $0 | $0 | $99,414 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $108,253 |
| 5 | On-site Management | | $7,978,119 | 36% | $7,978,119 | $0 | $0 | $1,124,816 | $1,124,816 | $310,135 | $310,135 | $310,135 | $606,140 | $606,140 | $606,140 | $606,140 | $606,140 | $0 | $0 | $0 | $0 | $79,830 | $0 | $0 | $0 | $0 | $79,830 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $178,636 |
| 6 | Transportation Costs | | $1,297,725 | 6% | $1,297,725 | $0 | $0 | $151,714 | $151,714 | $0 | $0 | $0 | $64,628 | $64,628 | $64,628 | $64,628 | $64,628 | $0 | $0 | $0 | $0 | $20,832 | $0 | $0 | $0 | $0 | $20,832 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $69,943 |
| **Post Closure Costs Subtotal** | | | **$22,129,700** | | $22,129,700 | **$0** | **$0** | **$2,342,683** | **$2,342,683** | **$1,047,102** | **$1,047,102** | **$1,047,102** | **$1,878,975** | **$1,878,975** | **$1,878,975** | **$1,878,975** | **$1,878,975** | **$91,135** | **$91,135** | **$91,135** | **$91,135** | **$326,226** | **$91,135** | **$91,135** | **$91,135** | **$91,135** | **$326,226** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$391,847** |

### Other Add-on Costs

| | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $6,527,912 | | $6,527,912 | $0 | $0 | $373,650 | $385,309 | $1,390,710 | $1,406,825 | $1,026,274 | $237,972 | $236,090 | $237,972 | $237,749 | $247,048 | $14,203 | $14,203 | $14,203 | $14,203 | $51,213 | $14,203 | $14,203 | $14,203 | $14,203 | $51,213 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $59,141 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 1.5% % of above labour costs | $224,359.88 | | $224,360 | $0 | $0 | $12,842 | $13,243 | $47,798 | $48,352 | $35,272 | $8,179 | $8,114 | $8,179 | $8,171 | $8,491 | $488 | $488 | $488 | $488 | $1,760 | $488 | $488 | $488 | $488 | $1,760 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $2,033 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $1,505,786.67 | | $1,505,787 | $0.00 | $0 | $70,280 | $70,280 | $339,620 | $343,649 | $248,511 | $56,704 | $56,704 | $56,704 | $57,118 | $58,973 | $2,734 | $2,734 | $2,734 | $2,734 | $9,787 | $2,734 | $2,734 | $2,734 | $2,734 | $9,787 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $11,755 |
| 5 | Contractor Profit | 10% % of above costs | $5,439,927 | | $5,439,927 | $0 | $0 | $311,375 | $321,090 | $1,158,925 | $1,172,354 | $855,229 | $198,310 | $196,742 | $198,310 | $198,124 | $205,874 | $11,835 | $11,835 | $11,835 | $11,835 | $42,677 | $11,835 | $11,835 | $11,835 | $11,835 | $42,677 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $49,284 |
| 6 | Contract Administration | 5% % of above costs | $2,719,963 | | $2,719,963 | $0 | $0 | $155,687 | $160,545 | $579,463 | $586,177 | $427,614 | $99,155 | $98,371 | $99,155 | $99,062 | $102,937 | $5,918 | $5,918 | $5,918 | $5,918 | $21,339 | $5,918 | $5,918 | $5,918 | $5,918 | $21,339 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $24,642 |
| **Other Add-On Costs Subtotal** | | | **$16,417,949** | | $16,417,949 | **$0** | **$0** | **$923,834** | **$950,468** | **$3,516,516** | **$3,557,356** | **$2,592,901** | **$600,320** | **$596,021** | **$600,320** | **$600,224** | **$623,322** | **$35,178** | **$35,178** | **$35,178** | **$35,178** | **$126,776** | **$35,178** | **$35,178** | **$35,178** | **$35,178** | **$126,776** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$146,855** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** | | | **$70,817,215** | | $70,817,215 | **$0** | **$0** | **$4,037,580** | **$4,161,372** | **$15,105,770** | **$15,280,896** | **$11,145,187** | **$2,583,420** | **$2,563,440** | **$2,583,420** | **$2,581,465** | **$2,682,058** | **$153,532** | **$153,532** | **$153,532** | **$153,532** | **$553,550** | **$153,532** | **$153,532** | **$153,532** | **$153,532** | **$553,550** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$639,695** |

## INFLATION FACTORED INTERIM CARE AND CLOSURE IMPLEMENTATION COSTS

| | Area | Present Value | % of Total | Future Value | Year -4 2018 | Year -3 2019 | Year -2 2020 | Year -1 2021 | Year 1 2022 | Year 2 2023 | Year 3 2024 | Year 4 2025 | Year 5 2026 | Year 6 2027 | Year 7 2028 | Year 8 2029 | Year 9 2030 | Year 10 2031 | Year 11 2032 | Year 12 2033 | Year 13 2034 | Year 14 2035 | Year 15 2036 | Year 16 2037 | Year 17 2038 | Year 18 2039 | Year 19 2040 | Year 20 2041 | Year 21 2042 | Year 22 2043 | Year 23 2044 | Year 24 2045 | Year 25 2046 | Year 26 2047 | Year 107 2128 | Year 108 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direct Costs | Waste Dumps | $6,893,723 | 25% | $7,416,141 | $0 | $0 | $0 | $0 | $2,938,249 | $4,477,892 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Overburden Dumps | $395,276 | 1% | $434,773 | $0 | $0 | $0 | $0 | $0 | $0 | $434,773 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Ore Stockpiles | $3,331,999 | 12% | $3,550,420 | $0 | $0 | $0 | $0 | $3,550,420 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Open Pits | $620,582 | 2% | $677,218 | $0 | $0 | $0 | $0 | $0 | $335,922 | $341,296 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Underground Openings | $81,637 | 0% | $86,989 | $0 | $0 | $0 | $0 | $86,989 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | External Tailings Facilities | $57,291 | 0% | $61,535 | $0 | $0 | $0 | $0 | $30,523 | $31,012 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Roads | $136,050 | 0% | $149,644 | $0 | $0 | $0 | $0 | $0 | $0 | $149,644 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Demolition | $1,976,253 | 7% | $2,141,259 | $0 | $0 | $0 | $0 | $210,580 | $1,604,620 | $326,059 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Infrastructure | $169,527 | 1% | $183,542 | $0 | $0 | $0 | $0 | $45,160 | $91,765 | $46,617 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Detention Structures | $786,952 | 3% | $858,770 | $0 | $0 | $0 | $0 | $0 | $425,977 | $432,793 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Yards/Laydown Areas | $758,907 | 3% | $824,932 | $0 | $0 | $0 | $0 | $202,164 | $205,398 | $417,370 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Waste Disposal | $452,923 | 2% | $500,221 | $0 | $0 | $0 | $0 | $0 | $59,357 | $373,635 | $12,455 | $12,654 | $12,857 | $29,262 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Water Conveyance | $3,287,496 | 12% | $3,576,310 | $0 | $0 | $0 | $0 | $700,600 | $1,067,714 | $1,807,996 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Treatment | $483,085 | 2% | $537,639 | $0 | $0 | $0 | $0 | $0 | $0 | $455,300 | $0 | $0 | $0 | $0 | $82,339 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect | Mobilization-Demobilization | $324,077 | 1% | $352,492 | $0 | $0 | $0 | $0 | $172,661 | $0 | $158,835 | $0 | $0 | $0 | $0 | $20,997 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Transport Costs | $419,142 | 1% | $453,730 | $0 | $0 | $0 | $0 | $151,850 | $149,742 | $152,138 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Road Maintenance | $791,662 | 3% | $856,991 | $0 | $0 | $0 | $0 | $286,810 | $282,828 | $287,353 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Construction Support | $5,344,480 | 19% | $5,785,511 | $0 | $0 | $0 | $0 | $1,936,240 | $1,909,361 | $1,939,910 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | QA and Pro. Mgmt. | $1,752,126 | 6% | $1,896,713 | $0 | $0 | $0 | $0 | $634,774 | $625,962 | $635,977 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Subtotal - Closure Implementation Costs** | | **$28,063,189** | | **$30,344,831** | **$0** | **$0** | **$0** | **$0** | **$10,947,020** | **$11,267,550** | **$7,959,697** | **$12,455** | **$12,654** | **$12,857** | **$29,262** | **$103,336** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Monitoring Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Planning and permitting | Reclamation Research and Planning | $400,000 | 10% | $416,206 | $0 | $0 | $206,451 | $209,754 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Technical Studies and Investigations | $58,500 | 1% | $60,870 | $0 | $0 | $30,193 | $30,677 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Engineering, Design, and Construction Plans | $971,585 | 23% | $1,024,044 | $0 | $0 | $300,877 | $407,589 | $103,527 | $105,184 | $106,867 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Monitoring and Management Plans | $209,158 | 5% | $217,632 | $0 | $0 | $107,952 | $109,680 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Permitting | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 1 | Monitoring | Water Quality Monitoring | $621,903 | 15% | $663,604 | $0 | $0 | $119,014 | $120,919 | $138,988 | $141,212 | $143,471 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Sediment Monitoring | $16,940 | 0% | $18,055 | $0 | $0 | $3,497 | $3,553 | $3,610 | $3,668 | $3,727 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Biological Monitoring | $61,470 | 1% | $65,516 | $0 | $0 | $12,691 | $12,894 | $13,100 | $13,310 | $13,523 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Geotechnical Monitoring | $62,045 | 1% | $66,129 | $0 | $0 | $12,809 | $13,014 | $13,222 | $13,434 | $13,649 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Revegetation Monitoring | $31,590 | 1% | $34,202 | $0 | $0 | $0 | $0 | $11,220 | $11,400 | $11,582 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | | Annual Inspection Reporting | $11,860 | 0% | $12,641 | $0 | $0 | $2,449 | $2,488 | $2,527 | $2,568 | $2,609 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Post Closure Costs Subtotal** | | | **$2,445,052** | | **$2,578,899** | **$0** | **$0** | **$795,934** | **$910,566** | **$286,196** | **$290,775** | **$295,427** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Care and Maintenance Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $3,534,833 | 16% | $3,767,499 | $0 | $0 | $729,770 | $741,447 | $753,310 | $765,363 | $777,609 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $808,374 | 4% | $844,921 | $0 | $0 | $370,773 | $376,706 | $31,967 | $32,478 | $32,998 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | On-site Management | | $3,180,037 | 14% | $3,348,116 | $0 | $0 | $1,161,098 | $1,179,675 | $330,466 | $335,753 | $341,125 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | Transportation Costs | | $303,428 | 1% | $315,721 | $0 | $0 | $156,608 | $159,113 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Post Closure Costs Subtotal** | | | **$7,826,673** | | **$8,276,257** | **$0** | **$0** | **$2,418,249** | **$2,456,941** | **$1,115,742** | **$1,133,594** | **$1,151,732** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Other Add-on Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $4,582,768 | | $4,923,531 | $0 | $0 | $385,702 | $404,101 | $1,481,875 | $1,523,030 | $1,128,823 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 2% % of above labour costs | $157,507 | | $169,218 | $0 | $0 | $13,256 | $13,889 | $50,931 | $52,346 | $38,797 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $1,072,340 | | $1,153,516 | $0 | $0 | $72,547 | $73,708 | $361,883 | $372,034 | $273,343 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | Contractor Profit | 10% % of above costs | $3,818,973 | | $4,102,942 | $0 | $0 | $321,418 | $336,751 | $1,234,896 | $1,269,192 | $940,686 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | Contract Administration | 5% % of above costs | $1,909,487 | | $2,051,471 | $0 | $0 | $160,709 | $168,375 | $617,448 | $634,596 | $470,343 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Other Add-On Costs Subtotal** | | | **$11,541,074** | | $12,400,678 | **$0** | **$0** | **$953,633** | **$996,824** | **$3,747,032** | **$3,851,198** | **$2,851,991** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |
| **TOTAL** | | | **$49,875,988** | | **$53,600,666** | **$0** | **$0** | **$4,167,817** | **$4,364,331** | **$16,095,990** | **$16,543,117** | **$12,258,847** | **$12,455** | **$12,654** | **$12,857** | **$29,262** | **$103,336** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

## NET PRESENT VALUE CALCULATIONS - LONG TERM MONITORING AND MAINTENANCE

### Monitoring Costs

| | | | Undiscounted | % of Total | NPV - 2018 | Year -4 2018 | Year -3 2019 | Year -2 2020 | Year -1 2021 | Year 1 2022 | Year 2 2023 | Year 3 2024 | Year 4 2025 | Year 5 2026 | Year 6 2027 | Year 7 2028 | Year 8 2029 | Year 9 2030 | Year 10 2031 | Year 11 2032 | Year 12 2033 | Year 13 2034 | Year 14 2035 | Year 15 2036 | Year 16 2037 | Year 17 2038 | Year 18 2039 | Year 19 2040 | Year 20 2041 | Year 21 2042 | Year 22 2043 | Year 23 2044 | Year 24 2045 | Year 25 2046 | Year 26 2047 | Year 107 2128 | Year 108 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Monitoring | Water Quality Monitoring | $781,111 | 19% | $440,095 | | | | | | | | $44,829 | $43,608 | $42,420 | $41,265 | $40,141 | $20,444 | $19,888 | $19,346 | $18,819 | $18,306 | $17,808 | $17,323 | $16,851 | $16,392 | $15,945 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,350 |
| 2 | | Sediment Monitoring | $47,432 | 1% | $18,286 | | | | | | | | $2,921 | $0 | $2,765 | $0 | $2,616 | $0 | $0 | $0 | $0 | $2,279 | $0 | $0 | $0 | $0 | $1,985 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $165 |
| 3 | | Biological Monitoring | $172,117 | 4% | $66,354 | | | | | | | | $10,601 | $0 | $10,032 | $0 | $9,493 | $0 | $0 | $0 | $0 | $8,268 | $0 | $0 | $0 | $0 | $7,202 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $600 |
| 4 | | Geotechnical Monitoring | $317,426 | 8% | $119,080 | | | | | | | | $10,700 | $10,409 | $10,125 | $9,850 | $9,581 | $0 | $0 | $0 | $0 | $15,614 | $0 | $0 | $0 | $0 | $13,600 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,133 |
| 5 | | Revegetation Monitoring | $168,481 | 4% | $74,024 | | | | | | | | $9,080 | $8,833 | $8,592 | $8,358 | $8,131 | $0 | $0 | $0 | $0 | $7,082 | $0 | $0 | $0 | $0 | $6,169 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $514 |
| 6 | | Annual Inspection Reporting | $274,760 | 7% | $80,114 | | | | | | | | $2,045 | $1,990 | $1,935 | $1,883 | $1,831 | $0 | $0 | $0 | $0 | $16,074 | $0 | $0 | $0 | $0 | $14,001 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,166 |
| **Post Closure Costs Subtotal** | | | **$1,761,326** | | **$797,952** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$80,177** | **$64,839** | **$75,869** | **$61,355** | **$71,793** | **$20,444** | **$19,888** | **$19,346** | **$18,819** | **$67,623** | **$17,808** | **$17,323** | **$16,851** | **$16,392** | **$58,902** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$4,928** |

### Care and Maintenance Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $4,446,180 | 20% | $3,492,933 | | | | | | | | $609,619 | $593,015 | $576,862 | $561,150 | $545,866 | $68,451 | $66,586 | $64,773 | $63,008 | $61,292 | $59,623 | $57,999 | $56,419 | $54,882 | $53,388 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $560,239 | 3% | $246,147 | | | | | | | | $30,193 | $29,371 | $28,571 | $27,793 | $27,036 | $0 | $0 | $0 | $0 | $23,549 | $0 | $0 | $0 | $0 | $20,512 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,709 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $1,834,053 | 8% | $1,497,671 | | | | | | | | $316,302 | $307,687 | $299,306 | $291,154 | $283,223 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $1,670,177 | 8% | $713,783 | | | | | | | | $85,725 | $83,390 | $81,119 | $78,909 | $76,760 | $0 | $0 | $0 | $0 | $66,860 | $0 | $0 | $0 | $0 | $58,238 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $5,282 |
| 5 | On-site Management | | $4,798,081 | 22% | $2,876,918 | | | | | | | | $522,676 | $508,440 | $494,591 | $481,120 | $468,016 | $0 | $0 | $0 | $0 | $53,689 | $0 | $0 | $0 | $0 | $46,765 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $8,717 |
| 6 | Transportation Costs | | $994,297 | 4% | $408,186 | | | | | | | | $55,729 | $54,211 | $52,735 | $51,298 | $49,901 | $0 | $0 | $0 | $0 | $14,011 | $0 | $0 | $0 | $0 | $12,204 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $3,413 |
| **Post Closure Costs Subtotal** | | | **$14,303,027** | | $9,235,638 | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$1,620,245** | **$1,576,113** | **$1,533,184** | **$1,491,424** | **$1,450,802** | **$68,451** | **$66,586** | **$64,773** | **$63,008** | **$219,402** | **$59,623** | **$57,999** | **$56,419** | **$54,882** | **$191,106** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$19,120** |

### Other Add-on Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $1,945,144 | | $1,217,816 | | | | | | | | $205,204 | $198,036 | $194,178 | $188,712 | $190,752 | $10,667 | $10,377 | $10,094 | $9,819 | $34,443 | $9,292 | $9,039 | $8,792 | $8,553 | $30,001 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $2,886 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 2% % of above labour costs | $66,853 | | $41,856 | | | | | | | | $7,053 | $6,806 | $6,674 | $6,486 | $6,556 | $367 | $357 | $347 | $337 | $1,184 | $319 | $311 | $302 | $294 | $1,031 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $99 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $433,446 | | $280,515 | | | | | | | | $48,896 | $47,564 | $46,268 | $45,337 | $45,534 | $2,054 | $1,998 | $1,943 | $1,890 | $6,582 | $1,789 | $1,740 | $1,693 | $1,646 | $5,733 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $574 |
| 5 | Contractor Profit | 10% % of above costs | $1,620,954 | | $1,014,847 | | | | | | | | $171,003 | $165,030 | $161,815 | $157,260 | $158,960 | $8,890 | $8,647 | $8,412 | $8,183 | $28,702 | $7,743 | $7,532 | $7,327 | $7,127 | $25,001 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $2,405 |
| 6 | Contract Administration | 5% % of above costs | $810,477 | | $507,423 | | | | | | | | $85,502 | $82,515 | $80,907 | $78,630 | $79,480 | $4,445 | $4,324 | $4,206 | $4,091 | $14,351 | $3,872 | $3,766 | $3,663 | $3,564 | $12,500 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,202 |
| **Other Add-On Costs Subtotal** | | | **$4,876,874** | | $3,062,457 | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$517,657** | **$499,952** | **$489,842** | **$476,424** | **$481,282** | **$26,422** | **$25,702** | **$25,002** | **$24,321** | **$85,263** | **$23,014** | **$22,387** | **$21,778** | **$21,184** | **$74,266** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$7,166** |
| **TOTAL** | | | **$20,941,227** | | **$13,096,047** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$2,218,079** | **$2,140,904** | **$2,098,895** | **$2,029,204** | **$2,003,876** | **$115,317** | **$112,176** | **$109,121** | **$106,148** | **$372,287** | **$100,445** | **$97,709** | **$95,048** | **$92,459** | **$324,274** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$31,214** |
| **GRAND-TOTAL** | | | | | **$66,696,713** | **$0** | **$0** | **$4,167,817** | **$4,364,331** | **$16,095,990** | **$16,543,117** | **$12,258,847** | **$2,230,534** | **$2,153,558** | **$2,111,752** | **$2,058,466** | **$2,107,212** | **$115,317** | **$112,176** | **$109,121** | **$106,148** | **$372,287** | **$100,445** | **$97,709** | **$95,048** | **$92,459** | **$324,274** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$31,214** |

# Worksheet 8 - Peak Liability Estimate - Annual C&M Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## Summary of Annual Care and Maintenance Costs

| | | Annual Cost Per Phase | | | | | | | Number of Years | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual | n/a | Total Cost | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual |
| 1 | Active Water Treatment System | $706,967 | $706,967 | $706,967 | $91,135 | $0 | $0 | $7,981,012 | 2 | 3 | 5 | 10 | 0 |
| 2 | Passive Treatment System | $0 | $0 | $35,015 | $35,015 | $35,015 | $0 | $560,239 | 2 | 3 | 5 | 2 | 9 |
| 3 | Reclamation Maintenance | $0 | $0 | $366,811 | $0 | $0 | $0 | $1,834,053 | 2 | 3 | 5 | 2 | 9 |
| 4 | Site Maintenance | $359,187 | $30,000 | $99,414 | $99,414 | $108,253 | $0 | $2,478,551 | 2 | 3 | 5 | 2 | 9 |
| 5 | On-site Management | $1,124,816 | $310,135 | $606,140 | $79,830 | $178,636 | $0 | $7,978,119 | 2 | 3 | 5 | 2 | 9 |
| 6 | Transportation Costs | $151,714 | $0 | $64,628 | $20,832 | $69,943 | $0 | $1,297,725 | 2 | 3 | 5 | 2 | 9 |

**NOTES:**
1. This table is used as a check to the NPV calculation spreadsheet.

## Phase 1 - Annual Care & Maintenance Costs - Prior to Closure

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S1.1 | **Water Treatment** | | | | | | | | | | | | | | | **$706,967** | |
| S1.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S1.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S1.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S1.2 | **Onsite Management** | | | | | | | | | | | | | | | **$1,124,816** | |
| S1.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $761,189 | | |
| S1.2.1.1 | | Mine Manager | | 4 | months | 360 | site working hours per month | | | $23,408 | | | | $81,930 | | | (Notes: staffing costs include cross-shifts) |
| S1.2.1.2 | | Office/Camp manager | | 6 | months | 360 | site working hours per month | | | $22,267 | | | | $133,604 | | | |
| S1.2.1.3 | | Administrative Assistants/HR/Accounting | | 4 | months | 360 | site working hours per month | | | $16,600 | | | | $58,098 | | | |
| S1.2.1.4 | | Water Treatment Staff Operator | | 5 | months | 360 | site working hours per month | | | $18,912 | | | | $94,560 | | | |
| S1.2.1.5 | | Environmental/Safety Manager | | 4 | months | 360 | site working hours per month | | | $22,267 | | | | $89,069 | | | |
| S1.2.1.6 | | Environmental Technicians | | 7 | months | 360 | site working hours per month | | | $16,046 | | | | $104,301 | | | |
| S1.2.1.7 | | Mechanic | | 2 | months | 360 | site working hours per month | | | $17,769 | | | | $35,538 | | | |
| S1.2.1.8 | | Tradesmen | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $42,552 | | | |
| S1.2.1.9 | | General Labour/helpers | | 10 | months | 360 | site working hours per month | | | $12,793 | | | | $121,536 | | | |
| S1.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $131,186 | | |
| S1.2.2.1 | | Pick-up trucks (3 required) | | 12 | months | | | | | $4,446 | | | | $53,350 | | | |
| S1.2.2.2 | | Mechanic service vehicle | | 2 | months | | | | | $11,803 | | | | $23,607 | | | |
| S1.2.2.3 | | Emergency transport vehicle | | 12 | months | | | | | $4,519 | | | | $54,229 | | | |
| S1.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $232,440 | | |
| S1.2.3.1 | | Office supplies | | 12 | months | | | | | $1,000 | | | | $12,000 | | | |
| S1.2.3.2 | | Communications | | 12 | months | | | | | $1,000 | | | | $12,000 | | | |
| S1.2.3.3 | | Misc. supplies | | 12 | months | | | | | $500 | | | | $6,000 | | | |
| S1.2.3 | | Camp Operation | | 1,995 | man-days | | | | | $80 | | | | $159,600 | | | |
| S1.2.3 | | Power, heat, fuel | | 12 | months | | | | | $3,570 | | | | $42,840 | | | |
| S1.3 | **Site Maintenance** | | | | | | | | | | | | | | $359,187 | **$359,187** | |
| S1.3.1 | | Equipment Maintenance | | 1 | ls | | $20,000 | | | | | | | $20,000 | | | Labour included in field support staff |
| S1.3.2 | | Road Maintenance | Grader (assume 80 hrs/month) | 1 | ls | 960 | | $44 | $106 | $150 | $0 | $42,612 | $101,443 | $144,056 | | | Operator cost included in Field support staff |
| S1.3.3 | | Earthwork Repair allowance (assume 40 hrs per month) | | 1 | ls | 480 | $0 | $132 | $344 | $344 | | | $165,132 | $165,132 | | | Task Code C.2.14 |
| S1.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $30,000 | | | | $30,000 | | | Allowance for pump maintenance/fuel etc. |
| S1.4 | **Transportation Costs** | | | | | | | | | | | | | | $151,714 | **$151,714** | |
| S1.4.1 | | Barge Operations | | 5 | months | | | | | $10,832 | | | | $54,162 | | | |
| S1.4.2 | | Staffing Bus trips during barge operation period | | 20 | ea | | | | | $678 | | | | $13,552 | | | One per week |
| S1.4.3 | | Air transport and airstrip operations | | 8 | flights | | | | | $3,000 | | | | $24,000 | | | One flight per week |
| S1.4.4 | | Helicopter transport | | 20 | flights | | | | | $3,000 | | | | $60,000 | | | One flight per week |
| **TOTAL** | | | | | | | | | | | | | | **$2,342,683** | **$2,342,683** | **$2,342,683** | |

## Phase 2 - Annual Care & Maintenance Costs During Active Closure

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S2.1 | **Water Treatment** | | | | | | | | | | | | | | | **$706,967** | |
| S2.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S2.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S2.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S2.2 | **Onsite Management** | | | | | | | | | | | | | | | **$310,135** | |
| S2.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $247,815 | | |
| S2.2.1.1 | | Water Treatment Staff Operator | | 5 | months | 360 | site working hours per month | | | $18,912 | | | | $94,560 | | | |
| S2.2.1.2 | | Environmental/Safety Manager | | 4 | months | 360 | site working hours per month | | | $22,267 | | | | $89,069 | | | |
| S2.2.1.3 | | Environmental Technicians | | 4 | months | 360 | site working hours per month | | | $16,046 | | | | $64,185 | | | |
| S2.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $31,121 | | |
| S2.2.2.1 | | Pick-up trucks (1 required) | | 7 | months | | | | | $4,446 | | | | $31,121 | | | |
| S2.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $31,200 | | |
| S2.2.3.1 | | Camp Operation | | 390 | man-days | | | | | $80 | | | | $31,200 | | | |
| S2.3 | **Site Maintenance** | | | | | | | | | | | | | | $30,000 | **$30,000** | |
| S2.3.1 | | Pumping equipment/consumables allowance | | 1 | ls | | | | | $30,000 | | | | $30,000 | | | Allowance for pump maintenance/fuel etc. |
| S2.4 | **Transportation Costs** | | | | | | | | | | | | | | $0 | **$0** | |
| S2.4.1 | | Barge Operations | | 0 | months | | | | | $10,832 | | | | $0 | | | Included in construction indirect costs |
| **TOTAL** | | | | | | | | | | | | | | **$1,047,102** | **$1,047,102** | **$1,047,102** | |

## Phase 3 - Annual Care & Maintenance Costs - Post Closure I

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S3.1 | **Water Treatment** | | | | | | | | | | | | | | | **$741,982** | |
| S3.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S3.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S3.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S3.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S3.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S3.2 | **Onsite Management** | | | | | | | | | | | | | | | **$606,140** | |
| S3.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $377,100 | | |
| S3.2.1.1 | | Mine Manager | | 3 | months | 360 | site working hours per month | | | $23,408 | | | | $58,521 | | | (Notes: staffing costs include cross-shifts) |
| S3.2.1.2 | | Office/Camp manager | | 3 | months | 360 | site working hours per month | | | $22,267 | | | | $66,802 | | | |
| S3.2.1.3 | | Administrative Assistants/HR/Accounting | | 1 | months | 360 | site working hours per month | | | $16,600 | | | | $20,749 | | | |
| S3.2.1.4 | | Water Treatment Staff Operator | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $33,096 | | | |
| S3.2.1.5 | | Environmental/Safety Manager | | 3 | months | 360 | site working hours per month | | | $22,267 | | | | $55,668 | | | |
| S3.2.1.6 | | Environmental Technicians | | 3 | months | 360 | site working hours per month | | | $16,046 | | | | $40,116 | | | |
| S3.2.1.7 | | Mechanic | | 2 | months | 360 | site working hours per month | | | $17,769 | | | | $35,538 | | | |
| S3.2.1.8 | | Tradesmen | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $37,824 | | | |
| S3.2.1.9 | | General Labour/helpers | | 2 | months | 360 | site working hours per month | | | $12,793 | | | | $28,785 | | | |
| S3.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $112,890 | | |
| S3.2.2.1 | | Pick-up trucks (3 required) | | 15 | months | | | | | $4,446 | | | | $66,688 | | | |
| S3.2.2.2 | | Mechanic service vehicle | | 2 | months | | | | | $11,803 | | | | $23,607 | | | |
| S3.2.2.3 | | Emergency transport vehicle | | 5 | months | | | | | $4,519 | | | | $22,596 | | | |
| S3.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $116,150 | | |
| S3.2.3.1 | | Office supplies | | 5 | months | | | | | $1,000 | | | | $5,000 | | | |
| S3.2.3.2 | | Communications | | 5 | months | | | | | $1,000 | | | | $5,000 | | | |
| S3.2.3.3 | | Misc. supplies | | 5 | months | | | | | $500 | | | | $2,500 | | | |
| S3.2.3 | | Camp Operation | | 1,073 | man-days | | | | | $80 | | | | $85,800 | | | |
| S3.2.3 | | Power, heat, fuel | | 5 | months | | | | | $3,570 | | | | $17,850 | | | |
| S3.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$366,811** | |
| S3.3.1 | *Cover repairs* | | | | | | | | | | | | | | $320,441 | | |
| S3.3.1.1 | | Cover Repair allowance | Load, haul, dump, spread (spoil lo | 2% | of total | 1,336,364 | m3 of cover required replacement at: | | | $5.31 | /m3 | | | $142,044 | | | Assumes 10% of area reseeded over 5 yr PC1 perio |
| S3.3.1.2 | | | Seed/Fertilize: broadcast seeding | 67 | ha | | | | | $2,669.89 | /ha | | | $178,397 | | | |
| S3.3.2.1 | *Revegetation* | | | | | | | | | | | | | | $46,370 | | |
| S3.3.2.2 | | Reseeding allowance | Seed/Fertilize: broadcast seeding | 5% | of total | 347 | ha requires reseeding at | | | $2,669.89 | /ha | | | $46,370 | | | Assumes 25% of area reseeded over 5 yr PC1 perio |
| S3.3 | **Site Maintenance** | | | | | | | | | | | | | | $99,414 | **$99,414** | |
| S3.3.1 | | Equipment Maintenance | | 1 | ls | | $20,000 | | | | | | | $20,000 | | | Labour included in field support staff |
| S3.3.2 | | Road Maintenance | Grader (assume 40 hrs/month) | 1 | ls | 200 | | $44 | $106 | $150 | $0 | $8,878 | $21,134 | $30,012 | | | Operator cost included in Field support staff |
| S3.3.3 | | Earthwork Repair allowance (assume 20 hrs per month) | | 1 | ls | 100 | $0 | $132 | $344 | $344 | | | $34,402 | $34,402 | | | Task Code C.2.14 |
| S3.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $15,000 | | | | $15,000 | | | Allowance for pump maintenance/fuel etc. |
| S3.4 | **Transportation Costs** | | | | | | | | | | | | | | $64,628 | **$64,628** | |
| S3.4.1 | | Barge Operations | | 3 | months | | | | | $10,832 | | | | $32,497 | | | |
| S3.4.2 | | Staffing Bus trips during barge operation period | | 12 | ea | | | | | $678 | | | | $8,131 | | | One per week |
| S3.4.3 | | Air transport and airstrip operations | | 8 | flights | | | | | $3,000 | | | | $24,000 | | | One flights per week |
| **TOTAL** | | | | | | | | | | | | | | **$1,878,975** | **$1,878,975** | **$1,878,975** | |

## Phase 4 - Annual Care & Maintenance Costs - Post Closure II

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S4.1 | **Water Treatment** | | | | | | | | | | | | | | | **$126,150** | |
| S4.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $91,135 | | |
| S4.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S4.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S4.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S4.2 | **Onsite Management** | | | | | | | | | | | | | | | **$79,830** | |
| S4.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $44,847 | | |
| S4.2.1.1 | | Project Manager | | 0.5 | months | 360 | site working hours per month | | | $23,408 | | | | $11,704 | | | (Notes: staffing costs include cross-shifts) |
| S4.2.1.2 | | Passive Treatment specialist | | 0.5 | months | 360 | site working hours per month | | | $42,120 | | | | $21,060 | | | |
| S4.2.1.3 | | Mechanic | | 0.5 | months | 360 | site working hours per month | | | $17,769 | | | | $8,885 | | | |
| S4.2.1.4 | | General Labour/helpers | | 0.3 | months | 360 | site working hours per month | | | $12,793 | | | | $3,198 | | | |
| S4.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $19,313 | | |
| S4.2.2.1 | | Pick-up trucks (2 required) | | 2.0 | months | | | | | $4,446 | | | | $8,892 | | | |
| S4.2.2.2 | | Mechanic service vehicle | | 0.5 | months | | | | | $11,803 | | | | $5,902 | | | |
| S4.2.2.3 | | Emergency transport vehicle | | 1.0 | months | | | | | $4,519 | | | | $4,519 | | | |
| S4.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $15,670 | | |
| S4.2.3.1 | | Office supplies | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S4.2.3.2 | | Communications | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S4.2.3.3 | | Misc. supplies | | 1 | months | | | | | $500 | | | | $500 | | | |
| S4.2.3 | | Camp Operation | | 120 | man-days | | | | | $80 | | | | $9,600 | | | |
| S4.2.3 | | Power, heat, fuel | | 1 | months | | | | | $3,570 | | | | $3,570 | | | |
| S4.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$0** | |
| S4.3.1 | *Cover repairs* | | | | | | | | | | | | | | $0 | | |
| S4.3.2 | *Revegetation* | | | | | | | | | | | | | | $0 | | |
| S4.3 | **Site Maintenance** | | | | | | | | | | | | | | $29,882 | **$29,882** | |
| S4.3.1 | | Equipment Maintenance (parts, supplies) | | 1 | ls | | $10,000 | | | | | | | $10,000 | | | Labour included in field support staff |
| S4.3.2 | | Road Maintenance | Grader (assume 20 hrs/month) | 1 | ls | 20 | | $44 | $106 | $150 | $0 | $888 | $2,113 | $3,001 | | | Operator cost included in Field support staff |
| S4.3.3 | | Earthwork Repair allowance (assume 20 hrs per month) | | 1 | ls | 20 | $0 | $132 | $344 | $344 | | | $6,880 | $6,880 | | | Task Code C.2.14 |
| S4.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | Allowance for pump maintenance/fuel etc. |
| S4.4 | **Transportation Costs** | | | | | | | | | | | | | | $20,832 | **$20,832** | |
| S4.4.1 | | Barge Operations | | 1 | months | | | | | $10,832 | | | | $10,832 | | | |
| S4.4.2 | | Staffing Bus trips during barge operation period | | 0 | ea | | | | | $678 | | | | $0 | | | Pick-up trucks used (time included in labour rate) |
| S4.4.3 | | Barge mob/demob | | 1 | LS | | | | | $10,000 | | | | $10,000 | | | |
| **TOTAL** | | | | | | | | | | | | | | **$256,693** | **$256,693** | **$256,693** | |

## Phase 5 - Perpetual Care & Maintenance Event Year Annual Costs

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S5.1 | **Water Treatment** | | | | | | | | | | | | | | | **$35,015** | |
| S5.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S5.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S5.2 | **Onsite Management** | | | | | | | | | | | | | | | **$178,636** | |
| S5.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $129,326 | | |
| S5.2.1.1 | | Project Manager | | 1.0 | months | 360 | site working hours per month | | | $23,408 | | | | $23,408 | | | (Notes: staffing costs include cross-shifts) |
| S5.2.1.2 | | Passive Treatment specialist | | 1.0 | months | 360 | site working hours per month | | | $42,120 | | | | $42,120 | | | |
| S5.2.1.3 | | Site Engineer | | 1.0 | months | 360 | site working hours per month | | | $42,120 | | | | $42,120 | | | |
| S5.2.1.4 | | HD mechanic | | 0.5 | months | 360 | site working hours per month | | | $17,769 | | | | $8,885 | | | |
| S5.2.1.5 | | General Labour/helpers | | 1.0 | months | 360 | site working hours per month | | | $12,793 | | | | $12,793 | | | |
| S5.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $19,239 | | |
| S5.2.2.1 | | Pick-up trucks (3 required) | | 3 | months | | | | | $4,446 | | | | $13,338 | | | |
| S5.2.2.2 | | Mechanic service vehicle | | 1 | months | | | | | $11,803 | | | | $5,902 | | | |
| S5.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $30,070 | | |
| S5.2.3.1 | | Office supplies | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S5.2.3.2 | | Communications | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S5.2.3.3 | | Misc. supplies | | 1 | months | | | | | $500 | | | | $500 | | | |
| S5.2.3.4 | | Camp Operation | | 300 | man-days | | | | | $80 | | | | $24,000 | | | |
| S5.2.3.5 | | Power, heat, fuel | | 1 | months | | | | | $3,570 | | | | $3,570 | | | |
| S5.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$0** | |
| S5.4 | **Site Maintenance** | | | | | | | | | | | | | | $108,253 | **$108,253** | |
| S5.4.1 | | Grader Maintenance | Grader (assume 2 weeks, 10hrs/d | 1 | ls | 140 | | $44 | $106 | $150 | $0 | $6,214 | $14,794 | $21,008 | | | Operator cost included in Field support staff |
| S5.4.2 | | Earthwork Repair allowance (assume 3 weeks, 10hrs/day) | | 1 | ls | 210 | $0 | $132 | $344 | $344 | | | $72,245 | $72,245 | | | Task Code C.2.14 |
| S5.4.3 | | Big Creek Bridge - Capital replacement allowance | | 1 | ls | | | | | $15,000 | | | | $15,000 | | | Allowance for supplies, pumping, etc. |
| S5.4.4 | | Sundry allowance | | 1 | ls | | | | | $2,500 | | | | $2,500 | | | Allowance for supplies, pumping, etc. |
| S5.5 | **Transportation Costs** | | | | | | | | | | | | | | $69,943 | **$69,943** | |
| S5.5.1 | | Barge Operations | | 1 | months | | | | | $10,832 | | | | $10,832 | | | |
| S5.5.2 | | Barge mobilization/demob and set up | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | assumed |
| S5.5.3 | | Camp Mob/demob | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | assumed |
| S5.5.4 | | Equipment mobilization and demobilization | | 2 | ls | | | | | $19,555 | | | | $39,110.91 | | | See details on 'mob-demob 'worksheet |
| **TOTAL** | | | | | | | | | | | | | | **$394,347** | **$391,847** | **$391,847** | |

# Worksheet 9 - Peak Liability Estimate - Implementation Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| **DIRECT COSTS** | | | | | | | | | | | | | | | | | | | | | |
| A1 | **Waste Dumps** | | | | | | | | | | | | | | | | | | | **$6,893,723** | |
| A1.1 | *Main Waste Dump (inc. MWDE)* | | | | | | | | | | | | | | | | | | $121,985 | | |
| A1.1.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0 | $44.39 | $0 | $194.68 | $0 | $67.01 | 0 | $0 | $0.00 | $0 | $306.07 | $0 | | | |
| A1.1.1.2 | | | Slopes: Re-grade to 3H:1V | 0 | hrs | C.2.13 | 0 | $44.39 | $0 | $194.68 | $0 | $67.01 | 0 | $0 | $0.00 | $0 | $306.07 | $0 | | | |
| A1.1.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 0 | Cm3 | R.050 | 0.0 | $0.82 | $0 | $2.67 | $0 | $0.88 | 0 | $0 | $0.00 | $0 | $4.37 | $0 | | | |
| A1.1.2.2 | | | Slope area cover material: Load, haul, dump along crest | 0 | Cm3 | R.051 | 0.0 | $0.72 | $0 | $2.37 | $0 | $0.80 | 0 | $0 | $0.00 | $0 | $3.89 | $0 | | | |
| A1.1.2.3 | | | Slope area cover material: Spread down slope | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0 | $194.68 | $0 | $67.01 | 0 | $0 | $0.00 | $0 | $306.07 | $0 | | | |
| A1.1.3.1 | | Revegetate | Seed/Fertilize: tractor application | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0 | $401.72 | $0 | $232.94 | 0 | $0 | $1,005.72 | $0 | $2,670 | $0 | | | |
| A1.1.3.2 | | | Tree seedling application (1,000 stems/ha) | 52 | ha | C.6.06 | 2,668.2 | $1,832.33 | $95,397 | $25.98 | $1,353 | $15.00 | 813 | $781 | $469.71 | $24,455 | $2,343 | $121,985 | | | |
| A1.2 | *Main Waste Dump Wrap* | | | | | | | | | | | | | | | | | | $350,260 | | |
| A1.2.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 6 | hrs | C.2.13 | 6 | $44.39 | $278 | $194.68 | $1,218 | $67.01 | 437 | $419 | $0.00 | $0 | $306.07 | $1,914 | | | |
| A1.2.1.2 | | | Slopes: Re-grade to 3H:1V | 255 | hrs | C.2.13 | 255 | $44.39 | $11,334 | $194.68 | $49,709 | $67.01 | 17,822 | $17,110 | $0.00 | $0 | $306.07 | $78,152 | | | |
| A1.2.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 8,223 | Cm3 | R.050 | 153.4 | $0.82 | $6,757 | $2.67 | $21,957 | $0.88 | 7,527 | $7,226 | $0.00 | $0 | $4.37 | $35,939 | | | |
| A1.2.2.2 | | | Slope area cover material: Load, haul, dump along crest | 42,447 | Cm3 | R.051 | 692.9 | $0.72 | $30,484 | $2.37 | $100,640 | $0.80 | 35,215 | $33,806 | $0.00 | $0 | $3.89 | $164,930 | | | |
| A1.2.2.3 | | | Slope area cover material: Spread down slope | 61 | hrs | C.2.13 | 60.5 | $44.39 | $2,686 | $194.68 | $11,781 | $67.01 | 4,224 | $4,055 | $0.00 | $0 | $306.07 | $18,523 | | | |
| A1.2.3.1 | | Revegetate | Seed/Fertilize: tractor application | 10 | ha | C.6.01 | 335.7 | $1,029.50 | $10,433 | $401.72 | $4,071 | $232.94 | 2,459 | $2,361 | $1,005.72 | $10,192 | $2,670 | $27,057 | | | |
| A1.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 10 | ha | C.6.06 | 519.4 | $1,832.33 | $18,569 | $25.98 | $263 | $15.00 | 158 | $152 | $469.71 | $4,760 | $2,343 | $23,744 | | | |
| A1.3 | *Southwest Dump (excluding high grade waste area)* | | | | | | | | | | | | | | | | | | $147,053 | | |
| A1.3.1 | | Re-grade | Slopes: Re-grade remaining to 3H:1V | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.3.2.1 | | Cover | Load, haul, dump spread | 0 | m3 | R.059 | 0.0 | $0.77 | $0.00 | $2.49 | $0 | $0.82 | 0 | $0.00 | $0.00 | $0.00 | $4.08 | $0 | | | |
| A1.3.3.1 | | Revegetate | Seed/Fertilize: tractor application | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A1.3.3.2 | | | Tree seedling application (1,000 stems/ha) | 62.76 | ha | C.6.06 | 3,216.6 | $1,832.33 | $115,000.98 | $25.98 | $1,631 | $15.00 | 981 | $941.43 | $469.71 | $29,479.97 | $2,343.03 | $147,053 | | | |
| A1.4 | *Southwest Dump High-Grade Waste* | | | | | | | | | | | | | | | | | | $249,632 | | |
| A1.4.1 | | Relocate High-grade waste | Load, haul, dump, spread in pit (below long-term water elevation) | 45,711 | Bm3 | R.069 | 688.0 | $0.66 | $30,283.89 | $2.19 | $100,276 | $0.73 | 34,965 | $33,566.76 | $0.00 | $0.00 | $3.59 | $164,127 | | | |
| A1.4.2 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 31 | hrs | C.2.13 | 31.1 | $44.39 | $1,378.38 | $194.68 | $6,045 | $67.01 | 2,168 | $2,080.81 | $0.00 | $0.00 | $306.07 | $9,505 | | | |
| A1.4.3 | | Cover | Flat area cover material: Load, haul, dump spread | 15,583 | Cm3 | R.060 | 257.8 | $0.73 | $11,362.15 | $2.37 | $36,935 | $0.78 | 12,585 | $12,081.20 | $0.00 | $0.00 | $3.87 | $60,378 | | | |
| A1.4.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.12 | ha | C.6.01 | 103.2 | $1,029.50 | $3,208.44 | $401.72 | $1,252 | $232.94 | 756 | $725.97 | $1,005.72 | $3,134.33 | $2,669.89 | $8,321 | | | |
| A1.4.4.2 | | | Tree seedling application (1,000 stems/ha) | 3.12 | ha | C.6.06 | 159.7 | $1,832.33 | $5,710.47 | $25.98 | $81 | $15.00 | 49 | $46.75 | $469.71 | $1,463.85 | $2,343.03 | $7,302 | | | |
| A1.5 | *Main Pit SAT* | | | | | | | | | | | | | | | | | | $4,009,367 | | |
| A1.5.1 | | Relocate SAT below water | Load, haul, dump, spread in pit | 1,040,000 | Cm3 | R.012 | 17,781.5 | $0.75 | $785,076.51 | $1.86 | $1,935,773 | $0.51 | 555,290 | $533,078.26 | $0.00 | $0.00 | $3.13 | $3,253,928 | | | |
| A1.5.2 | | Backfill SAT Excavation | Load, haul, dump WR to form buttress below MPD | 245,000 | Cm3 | R.013 | 3,226.9 | $0.58 | $142,343.39 | $1.89 | $462,905 | $0.61 | 156,449 | $150,191.13 | $0.00 | $0.00 | $3.08 | $755,439 | | | Cover and revegetation of backfill included in MPD (A1.6) |
| A1.6 | *Main Pit Dump (Incl. SWB, In-Pit Dumps)* | | | | | | | | | | | | | | | | | | $686,521 | | |
| A1.6.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 65 | hrs | C.2.13 | 65.1 | $44.39 | $2,891.84 | $194.68 | $12,683 | $67.01 | 4,547 | $4,365.54 | $0.00 | $0.00 | $306.07 | $19,941 | | | |
| A1.6.1.2 | | | Slopes: Re-grade to 3H:1V | 207 | hrs | C.2.13 | 206.7 | $44.39 | $9,174.86 | $194.68 | $40,240 | $67.01 | 14,428 | $13,850.42 | $0.00 | $0.00 | $306.07 | $63,265 | | | |
| A1.6.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 45,270 | m3 | R.053 | 732.0 | $0.71 | $32,263.18 | $2.32 | $104,877 | $0.76 | 35,734 | $34,304.93 | $0.00 | $0.00 | $3.79 | $171,445 | | | |
| A1.6.2.2 | | | Slope area cover material: Load, haul, dump along crest | 84,053 | m3 | R.054 | 1,165.0 | $0.61 | $51,284.32 | $2.02 | $169,813 | $0.68 | 59,212 | $56,843.70 | $0.00 | $0.00 | $3.31 | $277,941 | | | |
| A1.6.2.3 | | | Slope area cover material: Spread down slope | 79 | hrs | C.2.13 | 79.3 | $44.39 | $3,520.01 | $194.68 | $15,438 | $67.01 | 5,535 | $5,313.82 | $0.00 | $0.00 | $306.07 | $24,272 | | | |
| A1.6.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 25.9 | ha | C.6.01 | 856.8 | $1,029.50 | $26,627.72 | $401.72 | $10,390 | $232.94 | 6,276 | $6,025.02 | $1,005.72 | $26,012.60 | $2,669.89 | $69,056 | | | |
| A1.6.3.2 | | | Tree seedling application (1,000 stems/ha) | 25.9 | ha | C.6.06 | 1,325.6 | $1,832.33 | $47,392.66 | $25.98 | $672 | $15.00 | 404 | $387.97 | $469.71 | $12,148.89 | $2,343.03 | $60,602 | | | |
| A1.6.0.0 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $40,934 | | |
| A1.6.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.6.1.2 | | | Slopes: Re-grade to 3H:1V | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.6.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 0 | m3 | R.056 | 0.0 | $0.90 | $0.00 | $2.91 | $0 | $0.96 | 0 | $0.00 | $0.00 | $0.00 | $4.77 | $0 | | | |
| A1.6.2.2 | | | Slope area cover material: Load, haul, dump along crest | 0 | m3 | R.057 | 0.0 | $0.78 | $0.00 | $2.59 | $0 | $0.87 | 0 | $0.00 | $0.00 | $0.00 | $4.24 | $0 | | | |
| A1.6.2.3 | | | Slope area cover material: Spread down slope | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.6.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A1.6.3.2 | | | Tree seedling application (1,000 stems/ha) | 17.47 | ha | C.6.06 | 895.4 | $1,832.33 | $32,011.85 | $25.98 | $454 | $15.00 | 273 | $262.06 | $469.71 | $8,206.09 | $2,343.03 | $40,934 | | | |
| A1.7.0.0 | *Ridgetop Waste Dump* | | | | | | | | | | | | | | | | | | $1,287,970 | | |
| A1.7.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 88 | hrs | C.2.13 | 88 | $44.39 | $3,903 | $194.68 | $17,119 | $67.01 | 6,138 | $5,892 | $0.00 | $0 | $306.07 | $26,915 | | | |
| A1.7.1.2 | | | Slopes: Re-grade to 3H:1V | 383 | hrs | C.2.13 | 383 | $44.39 | $17,021 | $194.68 | $74,651 | $67.01 | 26,765 | $25,695 | $0.00 | $0 | $306.07 | $117,367 | | | |
| A1.7.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 22,063 | Cm3 | R.063 | 590.5 | $1.18 | $26,007 | $3.83 | $84,514 | $1.26 | 28,971 | $27,812 | $0.00 | $0 | $6.27 | $138,332 | | | |
| A1.7.2.2 | | | Slope area cover material: Load, haul, dump along crest | 142,998 | Cm3 | R.064 | 3,348.7 | $1.03 | $147,324 | $3.40 | $486,381 | $1.14 | 170,188 | $163,381 | $0.00 | $0 | $5.57 | $797,086 | | | |
| A1.7.2.3 | | | Slope area cover material: Spread down slope | 140 | hrs | C.2.13 | 139.8 | $44.39 | $6,205 | $194.68 | $27,213 | $67.01 | 9,757 | $9,367 | $0.00 | $0 | $306.07 | $42,784 | | | |
| A1.7.3.1 | | Revegetate | Seed/Fertilize: tractor application | 33 | ha | C.6.01 | 1,093.6 | $1,029.50 | $33,986 | $401.72 | $13,262 | $232.94 | 8,010 | $7,690 | $1,005.72 | $33,201 | $2,670 | $88,139 | | | |
| A1.7.3.2 | | | Tree seedling application (1,000 stems/ha) | 33 | ha | C.6.06 | 1,691.9 | $1,832.33 | $60,489 | $25.98 | $858 | $15.00 | 516 | $495 | $469.71 | $15,506 | $2,343 | $77,348 | | | |
| A2 | **Overburden Dumps** | | | | | | | | | | | | | | | | | | | **$395,276** | |
| A2.1 | *Area 118 Pit Backfill Dump* | | | | | | | | | | | | | | | | | | $16,268 | | |
| A2.1.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.1.1.2 | | | Slopes: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A2.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 7 | ha | C.6.06 | 355.8 | $1,832.33 | $12,722.54 | $25.98 | $180 | $15.00 | 108 | $104.15 | $469.71 | $3,261.36 | $2,343.03 | $16,268 | | | |
| A2.2 | *Ice-rich Overburden Dump* | | | | | | | | | | | | | | | | | | $13,827 | | |
| A2.2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.2.1.2 | | | Berm: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | WR Berm area included in Southwest Dump |
| A2.2.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.76 | ha | C.6.01 | 91.4 | $1,029.50 | $2,839.68 | $401.72 | $1,108 | $232.94 | 669 | $642.53 | $1,005.72 | $2,774.08 | $2,669.89 | $7,364 | | | |
| A2.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 2.76 | ha | C.6.06 | 141.4 | $1,832.33 | $5,054.12 | $25.98 | $72 | $15.00 | 43 | $41.37 | $469.71 | $1,295.60 | $2,343.03 | $6,463 | | | |
| A2.3 | *Reclamation Overburden Dump* | | | | | | | | | | | | | | | | | | $330,992 | | |
| A2.3.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 594 | hrs | C.2.13 | 593.6 | $44.39 | $26,347.50 | $194.68 | $115,557 | $67.01 | 41,432 | $39,774.35 | $0.00 | $0.00 | $306.07 | $181,679 | | | |
| A2.3.1.2 | | | Slopes: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | Assumes borrow removed in such a manner that significant resloping is not required. |
| A2.3.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 29.79 | ha | C.6.01 | 986.7 | $1,029.50 | $30,664.45 | $401.72 | $11,966 | $232.94 | 7,228 | $6,938.40 | $1,005.72 | $29,956.07 | $2,669.89 | $79,525 | | | |
| A2.3.2.2 | | | Tree seedling application (1,000 stems/ha) | 29.79 | ha | C.6.06 | 1,526.5 | $1,832.33 | $54,577.32 | $25.98 | $774 | $15.00 | 465 | $446.79 | $469.71 | $13,990.64 | $2,343.03 | $69,789 | | | |
| A2.4 | *Ridgetop South Backfill Dump* | | | | | | | | | | | | | | | | | | $34,189 | | |
| A2.4.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 17 | hrs | C.2.13 | 16.9 | $44.39 | $751.05 | $194.68 | $3,294 | $67.01 | 1,181 | $1,133.78 | $0.00 | $0.00 | $306.07 | $5,179 | | | |
| A2.4.1.2 | | | Slopes: Regrade to 3H:1V or flatter | 32 | hrs | C.2.13 | 32.2 | $44.39 | $1,430.97 | $194.68 | $6,276 | $67.01 | 2,250 | $2,160.20 | $0.00 | $0.00 | $306.07 | $9,867 | | | |
| A2.4.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.82 | ha | C.6.01 | 126.5 | $1,029.50 | $3,931.30 | $401.72 | $1,534 | $232.94 | 927 | $889.53 | $1,005.72 | $3,840.48 | $2,669.89 | $10,195 | | | |
| A2.4.2.2 | | | Tree seedling application (1,000 stems/ha) | 3.82 | ha | C.6.06 | 195.7 | $1,832.33 | $6,997.02 | $25.98 | $99 | $15.00 | 60 | $57.28 | $469.71 | $1,793.65 | $2,343.03 | $8,947 | | | |
| **A3** | **Ore Stockpiles** | | | | | | | | | | | | | | | | | | | **$3,331,999** | |
| A3.1 | *High and Medium Grade Sulphide Ore Stockpile (South of Mill)* | | | | | | | | | | | | | | | | | | $3,176,985 | | (North, West, East, and South Stockpiles) |
| A3.1.1.1 | | Relocate to Pit | Ore: Load, haul, dump, spread into Main Pit | 884,785 | m3 | R.044 | 10,408.2 | $0.52 | $458,552.27 | $1.72 | $1,524,620 | $0.57 | 529,049 | $507,886.56 | $0.00 | $0.00 | $2.82 | $2,491,059 | | | |
| A3.1.1.2 | | | Ore Pads (over-excavate): Load, haul, dump spread into Main Pit | 71,007 | m3 | R.044 | 835.3 | $0.52 | $36,800.28 | $1.72 | $122,356 | $0.57 | 42,458 | $40,759.51 | $0.00 | $0.00 | $2.82 | $199,915 | | | |
| A3.1.1.3 | | | Complete confirmation testing | 1,421 | ea | C.3.02 | 236.8 | $7.43 | $10,556.37 | $1.33 | $1,883 | $0.00 | 0 | $0.00 | $13.26 | $18,842.46 | $22.01 | $31,282 | | | |
| A3.1.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 289 | hrs | C.2.13 | 289.4 | $44.39 | $12,843.71 | $194.68 | $56,331 | $67.01 | 20,197 | $19,388.95 | $0.00 | $0.00 | $306.07 | $88,564 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A3.1.3.1 | | Cover | Cover material: Load, haul, dump spread (0.5m) | 69,653 | m3 | R.055 | 1,264.9 | $0.80 | $55,711.18 | $2.60 | $181,043 | $0.86 | 62,060 | $59,577.97 | $0.00 | $0.00 | $4.25 | $296,332 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A3.1.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 13.93 | ha | C.6.01 | 461.5 | $1,029.50 | $14,341.67 | $401.72 | $5,596 | $232.94 | 3,380 | $3,245.07 | $1,005.72 | $14,010.36 | $2,669.89 | $37,193 | | | |
| A3.1.4.2 | | | Tree seedling application (1,000 stems/ha) | 13.93 | ha | C.6.06 | 713.9 | $1,832.33 | $25,525.64 | $25.98 | $362 | $15.00 | 218 | $208.96 | $469.71 | $6,543.38 | $2,343.03 | $32,640 | | | |
| A3.2 | *Low Grade Sulphide Ore Stockpile (Main Dump Area)* | | | | | | | | | | | | | | | | | | $155,014 | | |
| A3.2.1.1 | | Relocate to Pit | Ore: Load, haul, dump, spread into Main Pit | 15,490 | m3 | R.036 | 195.9 | $0.56 | $8,624.35 | $1.84 | $28,557 | $0.62 | 9,958 | $9,559.25 | $0.00 | $0.00 | $3.02 | $46,741 | | | |
| A3.2.1.2 | | | Ore Pad (over-excavate): Load, haul, dump spread into Main Pit | 31,316 | m3 | R.036 | 396.1 | $0.56 | $17,435.36 | $1.84 | $57,732 | $0.62 | 20,131 | $19,325.41 | $0.00 | $0.00 | $3.02 | $94,493 | | | |
| A3.2.1.3 | | | Complete confirmation testing | 626 | ea | C.3.02 | 104.3 | $7.43 | $4,650.45 | $1.33 | $829 | $0.00 | 0 | $0.00 | $13.26 | $8,300.76 | $22.01 | $13,781 | | | |
| A3.2.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.3.1 | | Cover | Cover material: Load, haul, dump spread | 0 | m3 | R.050 | 0.0 | $0.82 | $0.00 | $2.67 | $0 | $0.88 | 0 | $0.00 | $0.00 | $0.00 | $4.37 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.4.2 | | | Tree seedling application (1,000 stems/ha) | 0 | ha | C.6.06 | 0.0 | $1,832.33 | $0.00 | $25.98 | $0 | $15.00 | 0 | $0.00 | $469.71 | $0.00 | $2,343.03 | $0 | | | Included in Main Waste Dump Closure |
| **A4** | **Open Pits** | | | | | | | | | | | | | | | | | | | **$620,582** | |
| A4.1 | *Main Pit* | | | | | | | | | | | | | | | | | | $150,984 | | |
| A4.1.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 7,500 | m2 | C.2.03 | 28.5 | $0.17 | $1,265.55 | $0.49 | $3,658 | $0.13 | 1,048 | $1,005.87 | $0.00 | $0.00 | $0.79 | $5,930 | | | |
| A4.1.1.2 | | | Safety Berm: Construct around highwall perimeter | 4,860 | m3 | C.2.02 | 45.8 | $0.42 | $2,035.14 | $0.89 | $4,333 | $0.25 | 1,267 | $1,215.92 | $0.00 | $0.00 | $1.56 | $7,584 | | | |
| A4.1.1.3 | | | Place large boulders across any pit access points | 52 | m3 | R.001 | 1.6 | $1.39 | $72.20 | $3.03 | $157 | $0.90 | 49 | $46.76 | $0.00 | $0.00 | $5.31 | $276 | | | |
| A4.1.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.1.2.1 | | Exposed tailings cover | Trafficability Layer: Load, haul, dump spread | 17,750 | m3 | R.014 | 554.4 | $1.38 | $24,425.58 | $2.86 | $50,708 | $0.82 | 15,091 | $14,487.41 | $0.00 | $0.00 | $5.05 | $89,621 | | | |
| A4.1.2.2 | | | Overburden Layer: Load, haul, dump spread | 8,875 | m3 | R.052 | 158.4 | $0.79 | $6,976.73 | $2.55 | $22,672 | $0.84 | 7,772 | $7,460.97 | $0.00 | $0.00 | $4.18 | $37,110 | | | |
| A4.1.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2 | ha | C.6.01 | 58.8 | $1,029.50 | $1,827.37 | $401.72 | $713 | $232.94 | 431 | $413.48 | $1,005.72 | $1,785.15 | $2,669.89 | $4,739 | | | |
| A4.1.3.2 | | | Tree seedling application (1,000 stems/ha) | 2 | ha | C.6.06 | 91.0 | $1,832.33 | $3,252.39 | $25.98 | $46 | $15.00 | 28 | $26.63 | $469.71 | $833.74 | $2,343.03 | $4,159 | | | |
| A4.2 | *Area 2 Pit* | | | | | | | | | | | | | | | | | | $10,001 | | |
| A4.2.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | |
| A4.2.1.2 | | | Safety Berm: Construct around highwall perimeter | 5,317 | m3 | C.2.02 | 50.2 | $0.42 | $2,226.54 | $0.89 | $4,740 | $0.25 | 1,386 | $1,330.27 | $0.00 | $0.00 | $1.56 | $8,297 | | | |
| A4.2.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.2.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.3 | *Area 118 Pit* | | | | | | | | | | | | | | | | | | $0 | | |
| A4.3.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | Pit filled it by Area 118 Backfill Dump |
| A4.3.1.2 | | | Safety Berm: Construct around highwall perimeter | 0 | m3 | C.2.02 | 0.0 | $0.42 | $0.00 | $0.89 | $0 | $0.25 | 0 | $0.00 | $0.00 | $0.00 | $1.56 | $0 | | | |
| A4.3.1.3 | | | Place large boulders across any pit access points | 0 | m3 | R.001 | 0.0 | $1.39 | $0.00 | $3.03 | $0 | $0.90 | 0 | $0.00 | $0.00 | $0.00 | $5.31 | $0 | | | |
| A4.3.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 0 | ea | C.5.13 | 0.0 | $40.27 | $0.00 | $15.90 | $0 | $5.57 | 0 | $0.00 | $199.26 | $0.00 | $261.00 | $0 | | | |
| A4.4 | *Minto North Pit* | | | | | | | | | | | | | | | | | | $11,481 | | |
| A4.4.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 5,900 | m2 | C.2.03 | 22.4 | $0.17 | $995.56 | $0.49 | $2,878 | $0.13 | 824 | $791.29 | $0.00 | $0.00 | $0.79 | $4,665 | | | |
| A4.4.1.2 | | | Safety Berm: Construct around highwall perimeter | 3,610 | m | C.2.02 | 34.1 | $0.42 | $1,511.81 | $0.89 | $3,219 | $0.25 | 941 | $903.25 | $0.00 | $0.00 | $1.56 | $5,634 | | | |
| A4.4.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.4.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 4 | ea | C.5.13 | 3.7 | $40.27 | $161.09 | $15.90 | $64 | $5.57 | 23 | $22.26 | $199.26 | $797.04 | $261.00 | $1,044 | | | |
| A4.5 | *Ridgetop North* | | | | | | | | | | | | | | | | | | $448,116 | | |
| A4.5.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 10,110 | m2 | C.2.03 | 38.4 | $0.17 | $1,705.95 | $0.49 | $4,931 | $0.13 | 1,412 | $1,355.92 | $0.00 | $0.00 | $0.79 | $7,993 | | | |
| A4.5.1.2 | | | Safety Berm: Construct around highwall perimeter | 3,648 | m | C.2.02 | 34.4 | $0.42 | $1,527.56 | $0.89 | $3,252 | $0.25 | 951 | $912.66 | $0.00 | $0.00 | $1.56 | $5,692 | | | |
| A4.5.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.5.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.5.2.1 | | Exposed tailings cover | Trafficability Layer: Load, haul, dump spread | 62,477 | m3 | R.068 | 816.5 | $0.58 | $35,941.63 | $1.90 | $119,010 | $0.64 | 41,498 | $39,837.81 | $0.00 | $0.00 | $3.12 | $194,789 | | | |
| A4.5.2.2 | | | Overburden Layer: Load, haul, dump spread | 31,239 | m3 | R.062 | 882.0 | $1.24 | $38,844.69 | $4.04 | $126,233 | $1.33 | 43,272 | $41,540.81 | $0.00 | $0.00 | $6.61 | $206,618 | | | |
| A4.5.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 6 | ha | C.6.01 | 207.0 | $1,029.50 | $6,432.02 | $401.72 | $2,510 | $232.94 | 1,516 | $1,455.36 | $1,005.72 | $6,283.44 | $2,669.89 | $16,681 | | | |
| A4.5.3.2 | | | Tree seedling application (1,000 stems/ha) | 6 | ha | C.6.06 | 320.2 | $1,832.33 | $11,447.87 | $25.98 | $162 | $15.00 | 98 | $93.72 | $469.71 | $2,934.61 | $2,343.03 | $14,639 | | | |
| A4.6 | *Ridgetop South* | | | | | | | | | | | | | | | | | | $0 | | |
| A4.6.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | Piit to be backfilled with overburden from Ridgetop North |
| A4.6.1.2 | | | Safety Berm: Construct around highwall perimeter | 0 | m | C.2.02 | 0.0 | $0.42 | $0.00 | $0.89 | $0 | $0.25 | 0 | $0.00 | $0.00 | $0.00 | $1.56 | $0 | | | |
| A4.6.1.3 | | | Place large boulders across any pit access points | 0 | m3 | R.001 | 0.0 | $1.39 | $0.00 | $3.03 | $0 | $0.90 | 0 | $0.00 | $0.00 | $0.00 | $5.31 | $0 | | | |
| A4.6.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 0 | ea | C.5.13 | 0.0 | $40.27 | $0.00 | $15.90 | $0 | $5.57 | 0 | $0.00 | $199.26 | $0.00 | $261.00 | $0 | | | |
| **A5** | **Underground Openings** | | | | | | | | | | | | | | | | | | | **$81,637** | |
| A5.1 | *Minto North Portal* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.1.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.1.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.2 | *Minto North Portal Egress* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.2.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.2.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.3 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.3.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.3.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.3.2.1 | | Revegetate | Included in Yards (WBS No. A11-10) | | | | | | | | | | | | | | | | | | |
| A5.4 | *Area 118 Vent Raise* | | | | | | | | | | | | | | | | | | $10,691 | | |
| A5.4.1.1 | | Site Preparation | Removal of Heater/Fan included in Demolition | | | | | | | | | | | | | | | | | | |
| A5.4.1.2 | | | Excavate and clean perimeter around shaft to suitable material. | 4 | ea | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.4.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.4.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.4.2.3 | | | Ringwall Rebar: supply and install | 32 | m | C.8.05 | 0.8 | $1.27 | $40.74 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $107.82 | $4.64 | $149 | | | |
| A5.4.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.4.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.4.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| A5.5 | *Minto East Vent Raise* | | | | | | | | | | | | | | | | | | $10,610 | | |
| A5.5.1.2 | | Preparation | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.5.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.5.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.5.2.3 | | | Ringwall Rebar: supply and install | 14 | m | C.8.05 | 0.3 | $1.27 | $18.33 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $48.52 | $4.64 | $67 | | | |
| A5.5.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.5.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.5.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| A5.6 | *Minto East 2 Vent Raise* | | | | | | | | | | | | | | | | | | $10,617 | | |
| A5.6.1.1 | | Site Preparation | Removal of Heater/Fan included in Demolition | | | | | | | | | | | | | | | | | | |
| A5.6.1.2 | | | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.6.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.6.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.6.2.3 | | | Ringwall Rebar: supply and install | 16 | m | C.8.05 | 0.4 | $1.27 | $20.37 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $53.91 | $4.64 | $74 | | | |
| A5.6.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.6.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.6.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| **A6** | **External Tailings Facilities** | | | | | | | | | | | | | | | | | | | **$57,291** | |
| A6.1 | *Dry Stack Tailings Storage Facility* | | | | | | | | | | | | | | | | | | $57,291 | | |
| A6.1.1.1 | | Waste Rock Shell | Regrade WR shell slopes to 4H:1V | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A6.1.1.2 | | | Cover material: Load, haul, dump spread (0.5m) | 0 | m3 | R.048 | 0.0 | $0.86 | $0.00 | $2.78 | $0 | $0.91 | 0 | $0.00 | $0.00 | $0.00 | $4.55 | $0 | | | |
| A6.1.1.3 | | | Scarify surface | 0 | m2 | C.2.16 | 0.0 | $0.03 | $0.00 | $0.07 | $0 | $0.02 | 0 | $0.00 | $0.00 | $0.00 | $0.12 | $0 | | | |
| A6.1.1.4 | | | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A6.1.1.5 | | | Tree seedling application (1,000 stems/ha) | 5.30 | ha | C.6.06 | 271.4 | $1,832.33 | $9,703.52 | $25.98 | $138 | $15.00 | 83 | $79.44 | $469.71 | $2,487.45 | $2,343.03 | $12,408 | | | |
| A6.1.2.1 | | Fill Area at south end of DS | Load, haul, dump, spread | 0 | Cm3 | R.001 | 0.0 | $1.39 | $0.00 | $3.03 | $0 | $0.90 | 0 | $0.00 | $0.00 | $0.00 | $5.31 | $0 | | | Fill from TDD road and/or unsuitable DSTSF cover material |
| A6.1.3.1 | | Tailings surface | Regrade tailings area south of the tailings | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A6.1.3.2 | | | Regrade surface to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A6.1.3.3 | | | Cover: Excavate unsuitable temporary cover material | 0 | m3 | R.003 | 0.0 | $0.51 | $0.00 | $1.70 | $0 | $0.57 | 0 | $0.00 | $0.00 | $0.00 | $2.78 | $0 | | | |
| A6.1.3.4 | | | Cover material: Load, haul, dump spread (0.5m) | 0 | m3 | R.048 | 0.0 | $0.86 | $0.00 | $2.78 | $0 | $0.91 | 0 | $0.00 | $0.00 | $0.00 | $4.55 | $0 | | | |
| A6.1.3.5 | | | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A6.1.3.6 | | | Tree seedling application (1,000 stems/ha) | 19.16 | ha | C.6.06 | 981.8 | $1,832.33 | $35,100.35 | $25.98 | $498 | $15.00 | 299 | $287.34 | $469.71 | $8,997.81 | $2,343.03 | $44,883 | | | |
| **A7** | **Roads** | | | | | | | | | | | | | | | | | | | **$136,050** | |
| A7.1 | *Exploration Roads* | | | | | | | | | | | | | | | | | | $33,589 | | |
| A7.1.1.1 | | Regrade/Scarify | Scarify road surface | 54,285 | m2 | C.2.16 | 0.0 | $0.03 | $1,886.30 | $0.07 | $3,564 | $0.02 | 965 | $926.07 | $0.00 | $0.00 | $0.12 | $6,377 | | | |
| A7.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.43 | ha | C.6.01 | 179.8 | $1,029.50 | $5,588.65 | $401.72 | $2,181 | $232.94 | 1,317 | $1,264.54 | $1,005.72 | $5,459.55 | $2,669.89 | $14,494 | | | |
| A7.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 5.43 | ha | C.6.06 | 278.2 | $1,832.33 | $9,946.82 | $25.98 | $141 | $15.00 | 85 | $81.43 | $469.71 | $2,549.82 | $2,343.03 | $12,719 | | | |
| A7.2 | *Access Roads (excl. Main Site Access Road)* | | | | | | | | | | | | | | | | | | $9,082 | | |
| A7.2.1.1 | | Regrade/Scarify | Regrade side slopes | 9 | hrs | C.2.13 | 9.5 | $44.39 | $419.85 | $194.68 | $1,841 | $67.01 | 660 | $633.81 | $0.00 | $0.00 | $306.07 | $2,895 | | | |
| A7.2.1.2 | | | Scarify road surface | 52,636 | m2 | C.2.16 | 0.0 | $0.03 | $1,829.00 | $0.07 | $3,456 | $0.02 | 935 | $897.94 | $0.00 | $0.00 | $0.12 | $6,183 | | | |
| A7.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.77 | $401.72 | $0 | $232.94 | 0 | $0.17 | $1,005.72 | $0.75 | $2,669.89 | $2 | | | |
| A7.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 0.00 | ha | C.6.06 | 0.0 | $1,832.33 | $1.36 | $25.98 | $0 | $15.00 | 0 | $0.01 | $469.71 | $0.35 | $2,343.03 | $2 | | | |
| A7.3 | *Main Site Access Road* | | | | | | | | | | | | | | | | | | $1,343 | | |
| A7.3.1.1 | | New Access over MVFE | Regrade new access through MVFE | 0 | m3 | | | | | | | | | | | | | | | | |
| A7.3.2.1 | | Signage | Install large sign on east and west side of barge landing on Yukon River | 2 | ea. | C.5.14 | 1.9 | $40.27 | $80.54 | $15.90 | $32 | $5.57 | 12 | $11.13 | $609.74 | $1,219.48 | $671.48 | $1,343 | | | |
| A7.4 | *Haul Roads* | | | | | | | | | | | | | | | | | | $72,436 | | |
| A7.4.1.1 | | Regrade/Scarify | Regrade side slopes | 21 | hrs | C.2.13 | 20.5 | $44.39 | $910.71 | $194.68 | $3,994 | $67.01 | 1,432 | $1,374.82 | $0.00 | $0.00 | $306.07 | $6,280 | | | |
| A7.4.1.2 | | | Scarify road surface | 91,084 | m2 | C.2.16 | 0.0 | $0.03 | $3,164.99 | $0.07 | $5,981 | $0.02 | 1,619 | $1,553.84 | $0.00 | $0.00 | $0.12 | $10,700 | | | |
| A7.4.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 11.06 | ha | C.6.01 | 366.5 | $1,029.50 | $11,389.06 | $401.72 | $4,444 | $232.94 | 2,684 | $2,576.99 | $1,005.72 | $11,125.97 | $2,669.89 | $29,536 | | | |
| A7.4.2.2 | | | Tree seedling application (1,000 stems/ha) | 11.06 | ha | C.6.06 | 567.0 | $1,832.33 | $20,270.53 | $25.98 | $287 | $15.00 | 173 | $165.94 | $469.71 | $5,196.25 | $2,343.03 | $25,920 | | | |
| A7.5 | *Culvert Removal* | | | | | | | | | | | | | | | | | | $19,600 | | |
| A7.5.1.1 | | Excavate culverts | Mobilization allowance for excavation fleet to various sites | 6 | hrs | C.7.01 | 12.0 | $88.22 | $529.34 | $118.29 | $710 | $44.16 | 276 | $264.96 | $0.00 | $0.00 | $250.67 | $1,504 | | | |
| A7.5.1.2 | | | Load, haul, dump, spread (spoil locally) | 18,020 | m3 | R.901 | 59.1 | $0.15 | $2,622.79 | $0.58 | $10,499 | $0.20 | 3,841 | $3,687.10 | $0.00 | $0.00 | $0.93 | $16,809 | | | |
| A7.5.1.2 | | Waste disposal | On-site disposal (demolition debris, etc.) | 190 | Lm3 | R.037 | 8.1 | $1.87 | $356.36 | $3.75 | $713 | $1.14 | 227 | $217.54 | $0.00 | $0.00 | $6.77 | $1,287 | | | |
| **A8** | **Demolition** | | | | | | | | | | | | | | | | | | | **$1,976,253** | |
| A8.1 | *Airstrip Area* | | | | | | | | | | | | | | | | | | $21,059 | | |
| A8.1.1.1 | | Remove tanks/equipment | Dismantle and prep for transport | 7 | hrs | C.1.13 | 28.0 | $168.00 | $1,175.97 | $86.19 | $603 | $14.53 | 106 | $101.70 | $0.00 | $0.00 | $268.71 | $1,881 | | | |
| A8.1.2.1 | | Waste Oil Tanker Secondar | Bedding Material: Load, haul dump bedding material to landfarm | 47 | Cm3 | R.001 | 1.5 | $1.39 | $65.73 | $3.03 | $143 | $0.90 | 44 | $42.57 | $0.00 | $0.00 | $5.31 | $252 | | | |
| A8.1.2.2 | | | Cut and fold liner | 219 | m2 | C.1.15 | 2.5 | $0.43 | $94.83 | $0.19 | $43 | $0.07 | 16 | $15.13 | $0.00 | $0.00 | $0.70 | $152 | | | |
| A8.1.2.3 | | | Regrade area to promote positive drainage | 192 | m2 | C.2.11 | 1.9 | $0.44 | $85.22 | $1.28 | $246 | $0.35 | 71 | $67.74 | $0.00 | $0.00 | $2.08 | $399 | | | |
| A8.1.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 10 | hrs | C.1.22 | 40.0 | $159.30 | $1,592.98 | $95.83 | $958 | $26.93 | 281 | $269.28 | $0.00 | $0.00 | $282.05 | $2,821 | | | |
| A8.1.3.2 | | | Disconnect services | 4 | hrs | C.1.09 | 12.0 | $88.07 | $352.28 | $7.55 | $30 | $4.80 | 20 | $19.20 | $0.00 | $0.00 | $100.42 | $402 | | | |
| A8.1.4.1 | | Demolition | Structural building demolition: wooden buildings/tents | 1,149 | m3 | C.1.08 | 87.7 | $2.88 | $3,310.74 | $1.60 | $1,834 | $0.57 | 680 | $652.51 | $0.00 | $0.00 | $5.05 | $5,797 | | | |
| A8.1.4.2 | | | Other demolition: covered storage, debris, etc. | 530 | m3 | C.1.07 | 52.5 | $3.74 | $1,980.53 | $2.07 | $1,097 | $0.74 | 407 | $390.34 | $0.00 | $0.00 | $6.55 | $3,468 | | | |
| A8.1.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 379 | m3 | R.006 | 12.8 | $1.48 | $562.06 | $2.95 | $1,117 | $0.92 | 361 | $346.89 | $0.00 | $0.00 | $5.35 | $2,026 | | | |
| A8.1.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 4 | m3 | C.7.07 | 34.6 | $355.10 | $1,536.93 | $423.68 | $1,834 | $113.33 | 511 | $490.50 | $0.00 | $0.00 | $892.11 | $3,861 | | | |
| A8.2 | *Airport Laydown Area* | | | | | | | | | | | | | | | | | | $33,408 | | |
| A8.2.1.1 | | Remove tanks/equipment | Dismantle and prep for transport | 2 | hrs | C.1.13 | 8.0 | $168.00 | $335.99 | $86.19 | $172 | $14.53 | 30 | $29.06 | $0.00 | $0.00 | $268.71 | $537 | | | |
| A8.2.2.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.2.2.2 | | | Disconnect services | 4 | hrs | C.1.09 | 12.0 | $88.07 | $352.28 | $7.55 | $30 | $4.80 | 20 | $19.20 | $0.00 | $0.00 | $100.42 | $402 | | | |
| A8.2.3.1 | | Demolition | Structural building demolition: steel structures | 96 | tonnes | C.1.05 | 191.3 | $69.36 | $6,633.00 | $139.08 | $13,301 | $33.84 | 3,371 | $3,236.25 | $0.00 | $0.00 | $242.28 | $23,170 | | | |
| A8.2.3.2 | | | Other demolition: covered storage etc. | 560 | m3 | C.1.07 | 55.5 | $3.74 | $2,093.92 | $2.07 | $1,160 | $0.74 | 430 | $412.69 | $0.00 | $0.00 | $6.55 | $3,667 | | | |
| A8.2.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 393 | Lm3 | R.005 | 15.8 | $1.76 | $693.24 | $3.53 | $1,387 | $1.08 | 441 | $423.19 | $0.00 | $0.00 | $6.37 | $2,504 | | | |
| A8.2.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 3 | trips | C.7.07 | 23.0 | $355.10 | $1,020.92 | $423.68 | $1,218 | $113.33 | 339 | $325.82 | $0.00 | $0.00 | $892.11 | $2,565 | | | |
| A8.3 | *Camp Area* | | | | | | | | | | | | | | | | | | $375,774 | | |
| A8.3.1.1 | | Equipment Removal | Remove salvageable equipment | 48 | hrs | C.1.13 | 192.0 | $168.00 | $8,063.76 | $86.19 | $4,137 | $14.53 | 726 | $697.34 | $0.00 | $0.00 | $268.71 | $12,898 | | | |
| A8.3.2.1 | | Remove modular buildings | Dismantle and prep for transport | 92 | ea. | C.1.20 | 1,794.0 | $850.98 | $78,290.06 | $730.60 | $67,215 | $166.46 | 15,953 | $15,314.69 | $0.00 | $0.00 | $1,748.04 | $160,820 | | | |
| A8.3.2.2 | | | Transport structures off-site (Whitehorse) | 92 | ea. | C.7.04 | 736.0 | $351.24 | $32,314.23 | $303.64 | $27,935 | $113.33 | 10,861 | $10,426.18 | $0.00 | $0.00 | $768.21 | $70,675 | | | |
| A8.3.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 1 | hrs | C.1.22 | 4.0 | $159.30 | $159.30 | $95.83 | $96 | $26.93 | 28 | $26.93 | $0.00 | $0.00 | $282.05 | $282 | | | |
| A8.3.3.2 | | | Disconnect services | 8 | hrs | C.1.09 | 24.0 | $88.07 | $704.56 | $7.55 | $60 | $4.80 | 40 | $38.40 | $0.00 | $0.00 | $100.42 | $803 | | | |
| A8.3.4.1 | | Demolition | Structural building demolition: Steel | 175 | tonnes | C.1.05 | 350.7 | $69.36 | $12,160.50 | $139.08 | $24,385 | $33.84 | 6,180 | $5,933.13 | $0.00 | $0.00 | $242.28 | $42,479 | | | |
| A8.3.4.2 | | | Structural building demolition: Wood/misc. structures | 10,959 | m3 | C.1.08 | 836.7 | $2.88 | $31,584.20 | $1.60 | $17,497 | $0.57 | 6,484 | $6,224.86 | $0.00 | $0.00 | $5.05 | $55,306 | | | |
| A8.3.4.4 | | | Other demolition: Utilidors, etc. | 466 | m3 | C.1.07 | 46.1 | $3.74 | $1,742.09 | $2.07 | $965 | $0.74 | 358 | $343.34 | $0.00 | $0.00 | $6.55 | $3,051 | | | |
| A8.3.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 3,867 | m3 | R.007 | 175.3 | $1.99 | $7,708.84 | $3.99 | $15,425 | $1.22 | 4,902 | $4,705.86 | $0.00 | $0.00 | $7.20 | $27,839 | | | |
| A8.3.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 1 | trips | C.7.07 | 8.0 | $355.10 | $355.10 | $423.68 | $424 | $113.33 | 118 | $113.33 | $0.00 | $0.00 | $892.11 | $892 | | | |
| A8.3.6.1 | | Demolish foundations | Break in place concrete foundations | 51 | m3 | C.1.01 | 4.1 | $2.39 | $122.15 | $9.37 | $479 | $2.48 | 132 | $126.81 | $0.00 | $0.00 | $14.24 | $728 | | | |
| A8.4 | *Explosives Plant and Storage Areas* | | | | | | | | | | | | | | | | | | $30,611 | | |
| A8.4.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 37 | hrs | C.1.13 | 149.3 | $168.00 | $6,271.81 | $86.19 | $3,218 | $14.53 | 565 | $542.38 | $0.00 | $0.00 | $268.71 | $10,032 | | | |
| A8.4.2.1 | | Remove modular buildings | Dismantle and prep for transport | 1 | ea. | C.1.20 | 19.5 | $850.98 | $850.98 | $730.60 | $731 | $166.46 | 173 | $166.46 | $0.00 | $0.00 | $1,748.04 | $1,748 | | | |
| A8.4.2.2 | | | Transport structures off-site (Whitehorse) | 1 | ea. | C.7.04 | 8.0 | $351.24 | $351.24 | $303.64 | $304 | $113.33 | 118 | $113.33 | $0.00 | $0.00 | $768.21 | $768 | | | |
| A8.4.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 4 | hrs | C.1.22 | 16.0 | $159.30 | $637.19 | $95.83 | $383 | $26.93 | 112 | $107.71 | $0.00 | $0.00 | $282.05 | $1,128 | | | |
| A8.4.3.2 | | | Disconnect services | 2 | hrs | C.1.09 | 6.0 | $88.07 | $176.14 | $7.55 | $15 | $4.80 | 10 | $9.60 | $0.00 | $0.00 | $100.42 | $201 | | | |
| A8.4.4.1 | | Demolition | Structural building demolition: Steel | 47 | tonnes | C.1.05 | 94.2 | $69.36 | $3,266.25 | $139.08 | $6,550 | $33.84 | 1,660 | $1,593.61 | $0.00 | $0.00 | $242.28 | $11,410 | | | |
| A8.4.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 103 | m3 | R.008 | 5.4 | $2.32 | $239.23 | $4.65 | $479 | $1.42 | 152 | $146.04 | $0.00 | $0.00 | $8.39 | $864 | | | |
| A8.4.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 5 | trips | C.7.07 | 40.0 | $355.10 | $1,775.51 | $423.68 | $2,118 | $113.33 | 590 | $566.64 | $0.00 | $0.00 | $892.11 | $4,461 | | | |
| A8.5 | *Fuel Storage Area* | | | | | | | | | | | | | | | | | | $114,842 | | |
| A8.5.1.1 | | Remove equipment/dismant | Small equipment: dismantle and prep for transport | 24 | hrs | C.1.13 | 96.0 | $168.00 | $4,031.88 | $86.19 | $2,069 | $14.53 | 363 | $348.67 | $0.00 | $0.00 | $268.71 | $6,449 | | | |
| A8.5.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 192 | hrs | C.1.14 | 1,153.4 | $269.89 | $51,883.26 | $167.56 | $32,213 | $20.53 | 4,111 | $3,946.31 | $0.00 | $0.00 | $457.98 | $88,042 | | | |
| A8.5.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.5.2.2 | | | Disconnect services | 8 | hrs | C.1.09 | 24.0 | $88.07 | $704.56 | $7.55 | $60 | $4.80 | 40 | $38.40 | $0.00 | $0.00 | $100.42 | $803 | | | |
| A8.5.2.3 | | | Clean out tanks, pressure wash, remove sludge | 10 | hrs | C.1.04 | 10.3 | $35.54 | $365.13 | $15.75 | $162 | $2.00 | 21 | $20.55 | $0.00 | $0.00 | $53.29 | $548 | | | |
| A8.5.3.1 | | Demolish structures | Misc. debris/scraps (tanks included in dismantling above) | 75 | m3 | C.1.08 | 5.7 | $2.88 | $216.15 | $1.60 | $120 | $0.57 | 44 | $42.60 | $0.00 | $0.00 | $5.05 | $378 | | | |
| A8.5.4.1 | | Remove secondary containr | Bedding Material: Load, haul dump bedding material to landfarm | 623 | Cm3 | R.009 | 32.8 | $2.32 | $1,442.73 | $4.64 | $2,887 | $1.41 | 917 | $880.71 | $0.00 | $0.00 | $8.37 | $5,210 | | | |
| A8.5.4.2 | | | Cut and fold liner | 1,747 | m2 | C.1.15 | 20.3 | $0.43 | $758.23 | $0.19 | $340 | $0.07 | 126 | $120.97 | $0.00 | $0.00 | $0.70 | $1,219 | | | |
| A8.5.4.3 | | | Regrade area to promote positive drainage | 1,666 | m2 | C.2.11 | 16.7 | $0.44 | $739.50 | $1.28 | $2,138 | $0.35 | 612 | $587.76 | $0.00 | $0.00 | $2.08 | $3,465 | | | |
| A8.5.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 229 | m3 | R.009 | 12.1 | $2.32 | $531.18 | $4.64 | $1,063 | $1.41 | 338 | $324.26 | $0.00 | $0.00 | $8.37 | $1,918 | | | |
| A8.5.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 7 | trips | C.7.07 | 56.0 | $355.10 | $2,485.71 | $423.68 | $2,966 | $113.33 | 826 | $793.30 | $0.00 | $0.00 | $892.11 | $6,245 | | | |
| A8.6 | *Mill Area* | | | | | | | | | | | | | | | | | | $1,265,173 | | Excludes WTP |
| A8.6.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 379 | hrs | C.1.13 | 1,515.0 | $168.00 | $63,626.87 | $86.19 | $32,644 | $14.53 | 5,732 | $5,502.37 | $0.00 | $0.00 | $268.71 | $101,773 | | | |
| A8.6.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 466 | hrs | C.1.14 | 2,796.5 | $269.89 | $125,789.65 | $167.56 | $78,099 | $20.53 | 9,966 | $9,567.74 | $0.00 | $0.00 | $457.98 | $213,456 | | | |
| A8.6.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 65 | hrs | C.1.22 | 260.0 | $159.30 | $10,354.37 | $95.83 | $6,229 | $26.93 | 1,823 | $1,750.32 | $0.00 | $0.00 | $282.05 | $18,333 | | | Off-site disposal included in 'Waste Disposal' |
| A8.6.2.6 | | | Reagents: Disposal and tipping fees | 1.0 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A8.6.2.7 | | | Decontaminate buildings: wash equipment/structures, etc. | 38 | hrs | C.1.04 | 37.8 | $35.54 | $1,342.93 | $15.75 | $595 | $2.00 | 79 | $75.58 | $0.00 | $0.00 | $53.29 | $2,014 | | | |
| A8.6.2.8 | | | Decontaminate buildings: Wash floors etc. | 4,732 | m2 | C.1.03 | 40.8 | $0.31 | $1,448.16 | $0.14 | $642 | $0.02 | 85 | $81.50 | $0.00 | $0.00 | $0.46 | $2,171 | | | |
| A8.6.3.1 | | Demolition | Structural building demolition: Steel | 2,660 | tonnes | C.1.05 | 5,319.1 | $69.36 | $184,463.18 | $139.08 | $369,899 | $33.84 | 93,750 | $89,999.96 | $0.00 | $0.00 | $242.28 | $644,363 | | | |
| A8.6.3.2 | | | Structural building demolition: Wood/misc. structures | 960 | m3 | C.1.08 | 73.3 | $2.88 | $2,766.75 | $1.60 | $1,533 | $0.57 | 568 | $545.29 | $0.00 | $0.00 | $5.05 | $4,845 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A8.6.3.3 | | | Other demolition: Steel | 526 | tonnes | C.1.05 | 1,052.7 | $69.36 | $36,505.48 | $139.08 | $73,204 | $33.84 | 18,553 | $17,811.10 | $0.00 | $0.00 | $242.28 | $127,520 | | | |
| A8.6.3.4 | | | Other demolition: concrete | 602 | m3 | C.1.06 | 323.7 | $15.92 | $9,579.30 | $62.48 | $37,592 | $16.53 | 10,359 | $9,944.51 | $0.00 | $0.00 | $94.92 | $57,116 | | | |
| A8.6.3.5 | | | Other demolition: miscellaneous | 244 | m3 | C.1.07 | 24.1 | $3.74 | $910.78 | $2.07 | $505 | $0.74 | 187 | $179.50 | $0.00 | $0.00 | $6.55 | $1,595 | | | |
| A8.6.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 5,985 | m3 | R.037 | 255.1 | $1.87 | $11,217.23 | $3.75 | $22,445 | $1.14 | 7,133 | $6,847.56 | $0.00 | $0.00 | $6.77 | $40,510 | | | |
| A8.6.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 33 | trips | C.7.07 | 266.0 | $355.10 | $11,806.23 | $423.68 | $14,086 | $113.33 | 3,925 | $3,767.87 | $0.00 | $0.00 | $892 | $29,660 | | | |
| A8.6.5.1 | | Demolish foundations | Break in place concrete foundations | 1,532 | m3 | C.1.01 | 123.7 | $2.39 | $3,659.05 | $9.37 | $14,359 | $2.48 | 3,957 | $3,798.55 | $0.00 | $0.00 | $14.24 | $21,817 | | | |
| A8.7 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $28,525 | | |
| A8.7.1.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 8 | hrs | C.1.22 | 30.0 | $159.30 | $1,194.73 | $95.83 | $719 | $26.93 | 210 | $201.96 | $0.00 | $0.00 | $282.05 | $2,115 | | | |
| A8.7.1.2 | | | Reagents: Disposal and tipping fees | 1 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A8.7.2.1 | | Demolish buildings | Structural building demolition: Wood/misc. structures (Reagent tent) | 1,800 | m3 | C.1.08 | 137.4 | $2.88 | $5,187.66 | $1.60 | $2,874 | $0.57 | 1,065 | $1,022.42 | $0.00 | $0.00 | $5.05 | $9,084 | | | |
| A8.7.3.1 | | Haul waste to landfill | Demolition debris | 594 | m3 | R.037 | 25.3 | $1.87 | $1,113.25 | $3.75 | $2,228 | $1.14 | 708 | $679.58 | $0.00 | $0.00 | $6.77 | $4,020 | | | |
| A8.7.3.2 | | | Remove tires off-site for disposal | 10 | trips | C.7.07 | 78.8 | $355.10 | $3,495.53 | $423.68 | $4,171 | $113.33 | 1,162 | $1,115.57 | $0.00 | $0.00 | $892.11 | $8,782 | | | |
| A8.7.3.3 | | | Misc. debris/scraps | 652 | m3 | R.037 | 27.8 | $1.87 | $1,221.95 | $3.75 | $2,445 | $1.14 | 777 | $745.94 | $0.00 | $0.00 | $6.77 | $4,413 | | | |
| A8.7.4.1 | | Demolish foundations | Break and bury concrete foundations | 8 | m3 | C.1.01 | 0.6 | $2.39 | $18.48 | $9.37 | $73 | $2.48 | 20 | $19.19 | $0.00 | $0.00 | $14.24 | $110 | | | |
| A8.8 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $8,516 | | |
| A8.8.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 6 | hrs | C.1.13 | 24.0 | $168.00 | $1,007.97 | $86.19 | $517 | $14.53 | 91 | $87.17 | $0.00 | $0.00 | $268.71 | $1,612 | | | |
| A8.8.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.8.3.1 | | Demolition | Other demolition: miscellaneous | 462 | m3 | C.1.07 | 45.7 | $3.74 | $1,727.03 | $2.07 | $957 | $0.74 | 355 | $340.38 | $0.00 | $0.00 | $6.55 | $3,024 | | | |
| A8.8.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 462 | m3 | R.043 | 20.9 | $1.99 | $918.18 | $3.98 | $1,837 | $1.21 | 584 | $560.51 | $0.00 | $0.00 | $7.18 | $3,316 | | | |
| A8.9 | *Minto North Portal* | | | | | | | | | | | | | | | | | | $8,981 | | Qntys assumed to be same as Minto South Portal |
| A8.9.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 6 | hrs | C.1.13 | 24.0 | $168.00 | $1,007.97 | $86.19 | $517 | $14.53 | 91 | $87.17 | $0.00 | $0.00 | $268.71 | $1,612 | | | |
| A8.9.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.9.3.1 | | Demolition | Other demolition: miscellaneous | 462 | m3 | C.1.07 | 45.7 | $3.74 | $1,727.03 | $2.07 | $957 | $0.74 | 355 | $340.38 | $0.00 | $0.00 | $6.55 | $3,024 | | | |
| A8.9.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 462 | m3 | R.042 | 23.8 | $2.27 | $1,046.71 | $4.53 | $2,094 | $1.38 | 666 | $638.96 | $0.00 | $0.00 | $8.18 | $3,780 | | | |
| A8.10 | *Pelly Laydown (Includes propane tanks by W15 Sump)* | | | | | | | | | | | | | | | | | | $83,981 | | |
| A8.10.1.1 | | Remove modular buildings/t | Dismantle and prep for transport | 7 | ea. | C.1.20 | 136.5 | $850.98 | $5,956.85 | $730.60 | $5,114 | $166.46 | 1,214 | $1,165.25 | $0.00 | $0.00 | $1,748.04 | $12,236 | | | |
| A8.10.1.2 | | | Transport structures off-site (Whitehorse) | 7 | ea. | C.7.04 | 56.0 | $351.24 | $2,458.69 | $303.64 | $2,125 | $113.33 | 826 | $793.30 | $0.00 | $0.00 | $768.21 | $5,377 | | | |
| A8.10.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.10.3.1 | | Demolish buildings | Structural building demolition: Steel | 80 | tonnes | C.1.05 | 159.4 | $69.36 | $5,527.50 | $139.08 | $11,084 | $33.84 | 2,809 | $2,696.88 | $0.00 | $0.00 | $242.28 | $19,309 | | | |
| A8.10.3.2 | | | Structural building demolition: Wood/misc. structures | 5,672 | m3 | C.1.08 | 433.1 | $2.88 | $16,347.99 | $1.60 | $9,057 | $0.57 | 3,356 | $3,221.99 | $0.00 | $0.00 | $5.05 | $28,627 | | | |
| A8.10.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 2,165 | m3 | R.045 | 100.0 | $2.03 | $4,395.81 | $4.06 | $8,796 | $1.24 | 2,795 | $2,683.42 | $0.00 | $0.00 | $7.33 | $15,875 | | | |
| A8.10.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 2 | trips | C.7.07 | 15.0 | $355.10 | $665.82 | $423.68 | $794 | $113.33 | 221 | $212.49 | $0.00 | $0.00 | $892.11 | $1,673 | | | |
| A8.10.5.1 | | Demolish foundations | Break and bury concrete foundations | 23 | m3 | C.1.01 | 1.8 | $2.39 | $53.73 | $9.37 | $211 | $2.48 | 58 | $55.78 | $0.00 | $0.00 | $14.24 | $320 | | | |
| A8.11 | *Vent Raise - Area 118* | | | | | | | | | | | | | | | | | | $5,381 | | |
| A8.11.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 20 | hrs | C.1.13 | 80.0 | $168.00 | $3,359.90 | $86.19 | $1,724 | $14.53 | 303 | $290.56 | $0.00 | $0.00 | $268.71 | $5,374 | | | |
| A8.11.2.1 | | Waste disposal | Off-site disposal (re-usable equipment, etc.) | 1 | trips | R.043 | 0.0 | $1.99 | $1.99 | $3.98 | $4 | $1.21 | 1 | $1.21 | $0.00 | $0.00 | $7.18 | $7 | | | |
| **A9** | **Surface Infrastructure** | | | | | | | | | | | | | | | | | | | **$169,527** | |
| A9.1 | *Tailings and Water Conveyance Pipelines* | | | | | | | | | | | | | | | | | | $91,886 | | |
| A9.1.1.1 | | Dismantle piping systems | Flush and clean tailings pipeline systems | 8 | ls | C.1.21 | 32.0 | $203.78 | $1,630.27 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $203.78 | $1,630 | | | |
| A9.1.1.2 | | | Cut pipelines and prep for transport (6 to 8" HDPE pipes) | 6,800 | m | C.1.17 | 1,070.9 | $7.21 | $49,056.06 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $7.21 | $49,056 | | | |
| A9.1.1.3 | | | Cut pipelines and prep for transport (10 to 18" HDPE pipes) | 1,740 | m | C.1.18 | 456.7 | $12.02 | $20,920.96 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $12.02 | $20,921 | | | |
| A9.1.1.4 | | | Cut pipelines and prep for transport (20 to 36" HDPE pipes) | 885 | m | C.1.19 | 348.4 | $18.04 | $15,961.25 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $18.04 | $15,961 | | | |
| A9.2.2.1 | | Waste disposal | Haul pipes lines and debris to landfill | 638 | m3 | R.037 | 27.2 | $1.87 | $1,195.62 | $3.75 | $2,392 | $1.14 | 760 | $729.86 | $0.00 | $0.00 | $6.77 | $4,318 | | | |
| A9.2 | *Conveyance Pipeline Equipment* | | | | | | | | | | | | | | | | | | $12,462 | | |
| A9.2.1.1 | | Dismantle piping systems | Remove pumps and prep for transport | 15 | ea. | C.1.24 | 198.0 | $602.98 | $9,044.72 | $24.94 | $374 | $14.40 | 225 | $216.00 | $0.00 | $0.00 | $642.33 | $9,635 | | | |
| A9.2.1.2 | | | Remove barges/Support Equipment prep for transport | 2 | ea. | C.1.23 | 52.8 | $1,205.96 | $2,411.93 | $49.89 | $100 | $28.80 | 60 | $57.60 | $0.00 | $0.00 | $1,284.65 | $2,569 | | | |
| A9.2.2.1 | | Waste disposal | Transport pumps, barge and support equip. offsite (Whitehorse) | 6.7 | tonnes | C.7.02 | 2.7 | $17.56 | $117.67 | $15.18 | $102 | $5.67 | 40 | $37.96 | $0.00 | $0.00 | $38.41 | $257 | | | |
| A9.3 | *Powerlines* | | | | | | | | | | | | | | | | | | $65,179 | | |
| A9.3.1.1 | | Dismantle | Dismantle and collect powerlines | 3.2 | km | C.1.10 | 217.9 | $2,639.96 | $8,342.27 | $940.09 | $2,971 | $251.90 | 829 | $795.99 | $0.00 | $0.00 | $3,831.94 | $12,109 | | | |
| A9.3.1.2 | | | Remove power poles and load for transport off-site | 60 | ea. | C.1.11 | 548.6 | $423.67 | $25,420.14 | $88.51 | $5,311 | $18.29 | 1,143 | $1,097.14 | $0.00 | $0.00 | $530.46 | $31,828 | | | |
| A9.3.1.3 | | | Disconnect transformers and load for transport | 4 | ea. | C.1.12 | 93.3 | $892.89 | $3,571.55 | $317.96 | $1,272 | $85.20 | 355 | $340.78 | $0.00 | $0.00 | $1,296.04 | $5,184 | | | |
| A9.3.2.1 | | Waste disposal | Transport powerlines, poles and transformers off-site | 18 | trips | C.7.07 | 144.0 | $355.10 | $6,391.83 | $423.68 | $7,626 | $113.33 | 2,125 | $2,039.90 | $0.00 | $0.00 | $892.11 | $16,058 | | | |
| **A10** | **Water Detention Structures** | | | | | | | | | | | | | | | | | | | **$786,952** | |
| A10.1 | *W15 Sump* | | | | | | | | | | | | | | | | | | $1,049 | | |
| A10.1.1.1 | | Remove secondary containr | Cut and fold liner | 1,310 | m2 | C.1.15 | 15.2 | $0.43 | $568.50 | $0.19 | $255 | $0.07 | 94 | $90.70 | $0.00 | $0.00 | $0.70 | $914 | | | |
| A10.1.1.2 | | | Haul liner to landfill | 20 | Lm3 | R.070 | 0.8 | $1.90 | $37.35 | $3.80 | $75 | $1.16 | 24 | $22.80 | $0.00 | $0.00 | $6.86 | $135 | | | |
| A10.2 | *Mill Water Pond* | | | | | | | | | | | | | | | | | | $0 | | |
| A10.3 | *Sewage Lagoon (near IROD)* | | | | | | | | | | | | | | | | | | $23,852 | | |
| A10.3.1 | | Remove pond | Backfill pond | 4,488 | m3 | R.001 | 141.4 | $1.39 | $6,231.19 | $3.03 | $13,585 | $0.90 | 4,203 | $4,035.32 | $0.00 | $0.00 | $5.31 | $23,852 | | | |
| A10.4 | *Water Storage Pond Dam* | | | | | | | | | | | | | | | | | | $762,051 | | |
| A10.4.1.1 | | Water Management | Install pump and pump around system | 4 | hrs | C.4.14 | 16.0 | $120.43 | $481.73 | $20.53 | $82 | $6.80 | 28 | $27.20 | $0.00 | $0.00 | $147.76 | $591 | | | |
| A10.4.1.2 | | | Pump pond water to discharge | 400,000 | m3 | C.4.12 | 146.8 | $0.01 | $5,216.05 | $0.05 | $19,052 | $0.01 | 3,058 | $2,935.56 | $0.00 | $0.00 | $0.07 | $27,203 | | | |
| A10.4.1.3 | | | Maintain pump around system during WSP closure activities | 103 | days | C.4.13 | 10.3 | $3.55 | $364.31 | $12.98 | $1,331 | $2.00 | 214 | $205.03 | $0.00 | $0.00 | $18.53 | $1,900 | | | Duration calculated as sum of associated tasks plus 20% contingency |
| A10.4.2.1 | | Breach dam | Granular zones/gen. fill: Load, haul, dump, spread in upstream North ab | 62,301 | m3 | R.001 | 1,963.4 | $1.39 | $86,500.02 | $3.03 | $188,587 | $0.90 | 58,351 | $56,017.38 | $0.00 | $0.00 | $5.31 | $331,104 | | | |
| A10.4.2.2 | | | Dam Core: Load, haul, dump in temporary stockpile | 23,617 | m3 | R.001 | 744.3 | $1.39 | $32,789.73 | $3.03 | $71,488 | $0.90 | 22,119 | $21,234.62 | $0.00 | $0.00 | $5.31 | $125,512 | | | |
| A10.4.2.3 | | | Rip-rap: Sort and stockpile durable rip-rap for reuse | 19,285 | m3 | R.001 | 607.8 | $1.39 | $26,776.14 | $3.03 | $58,377 | $0.90 | 18,063 | $17,340.22 | $0.00 | $0.00 | $5.31 | $102,494 | | | |
| A10.4.2.4 | | | Rip-rap: Load haul, dump unsuitable rip-rap in upstream North abutmen | 19,285 | m3 | R.001 | 607.8 | $1.39 | $26,776.14 | $3.03 | $58,377 | $0.90 | 18,063 | $17,340.22 | $0.00 | $0.00 | $5.31 | $102,494 | | | |
| A10.4.3.1 | | Channel restoration | Excavate stream channel | 5,584 | m3 | R.902 | 97.1 | $0.77 | $4,308.58 | $1.64 | $9,173 | $0.46 | 2,681 | $2,574.22 | $0.00 | $0.00 | $2.88 | $16,056 | | | |
| A10.4.3.2 | | | Bedding layer: Load haul, dump, place granular bedding layer along cha | 726 | m3 | R.001 | 22.9 | $1.39 | $1,008.60 | $3.03 | $2,199 | $0.90 | 680 | $653.17 | $0.00 | $0.00 | $5.31 | $3,861 | | | |
| A10.4.3.3 | | | Rip-rap: Load, haul dump from temporary stockpile | 964 | m3 | R.001 | 30.4 | $1.39 | $1,337.77 | $3.03 | $2,917 | $0.90 | 902 | $866.34 | $0.00 | $0.00 | $5.31 | $5,121 | | | |
| A10.4.3.4 | | | Rip-rap: place and secure | 964 | m3 | R.904 | 10.5 | $0.48 | $465.10 | $0.91 | $877 | $0.32 | 325 | $311.83 | $0.00 | $0.00 | $1.72 | $1,653 | | | |
| A10.4.4.1 | | Cover | Cover material: Load, haul, dump spread (1m) | 6,975 | m3 | R.001 | 219.8 | $1.39 | $9,684.17 | $3.03 | $21,113 | $0.90 | 6,533 | $6,271.47 | $0.00 | $0.00 | $5.31 | $37,069 | | | Cover sourced from dam core material |
| A10.4.5.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 1.4 | ha | C.6.01 | 46.2 | $1,029.50 | $1,436.16 | $401.72 | $560 | $232.94 | 338 | $324.96 | $1,005.72 | $1,402.98 | $2,669.89 | $3,724 | | | |
| A10.4.5.2 | | | Tree seedling application (1,000 stems/ha) | 1.4 | ha | C.6.06 | 71.5 | $1,832.33 | $2,556.10 | $25.98 | $36 | $15.00 | 22 | $20.93 | $469.71 | $655.25 | $2,343.03 | $3,269 | | | |
| **A11** | **Yards/Laydown Areas** | | | | | | | | | | | | | | | | | | | **$758,907** | |
| A11.1 | *Airstrip Area* | | | | | | | | | | | | | | | | | | $39,834 | | |
| A11.1.1.1 | | Re-grade | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.1.1.2 | | | Scarify surface | 64,378 | m2 | C.2.16 | 0.0 | $0.03 | $2,236.99 | $0.07 | $4,227 | $0.02 | 1,144 | $1,098.24 | $0.00 | $0.00 | $0.12 | $7,562 | | | |
| A11.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 6.4 | ha | C.6.01 | 213.3 | $1,029.50 | $6,627.68 | $401.72 | $2,586 | $232.94 | 1,562 | $1,499.64 | $1,005.72 | $6,474.57 | $2,669.89 | $17,188 | | | |
| A11.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 6.4 | ha | C.6.06 | 329.9 | $1,832.33 | $11,796.10 | $25.98 | $167 | $15.00 | 101 | $96.57 | $469.71 | $3,023.88 | $2,343.03 | $15,084 | | | |
| A11.2 | *Airport Laydown Area* | | | | | | | | | | | | | | | | | | $13,165 | | |
| A11.2.1.1 | | Re-grade | Scarify surface | 21,277 | m2 | C.2.16 | 0.0 | $0.03 | $739.33 | $0.07 | $1,397 | $0.02 | 378 | $362.97 | $0.00 | $0.00 | $0.12 | $2,499 | | | |
| A11.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.1 | ha | C.6.01 | 70.5 | $1,029.50 | $2,190.47 | $401.72 | $855 | $232.94 | 516 | $495.64 | $1,005.72 | $2,139.87 | $2,669.89 | $5,681 | | | |
| A11.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 2.1 | ha | C.6.06 | 109.0 | $1,832.33 | $3,898.65 | $25.98 | $55 | $15.00 | 33 | $31.92 | $469.71 | $999.40 | $2,343.03 | $4,985 | | | |
| A11.3 | *Camp Area* | | | | | | | | | | | | | | | | | | $118,708 | | |
| A11.3.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 7 | hrs | C.2.13 | 6.9 | $44.39 | $306.20 | $194.68 | $1,343 | $67.01 | 481 | $462.24 | $0.00 | $0.00 | $306.07 | $2,111 | | | |
| A11.3.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 24 | hrs | C.2.13 | 24.5 | $44.39 | $1,086.58 | $194.68 | $4,766 | $67.01 | 1,709 | $1,640.31 | $0.00 | $0.00 | $306.07 | $7,493 | | | Slope between camp and main access road |
| A11.3.1.3 | | | Scarify surfaces | 20,626 | m2 | C.2.16 | 0.0 | $0.03 | $716.72 | $0.07 | $1,354 | $0.02 | 367 | $351.87 | $0.00 | $0.00 | $0.12 | $2,423 | | | |
| A11.3.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 10,313 | Cm3 | R.046 | 198.2 | $0.85 | $8,729.48 | $2.75 | $28,368 | $0.91 | 9,724 | $9,335.37 | $0.00 | $0.00 | $4.50 | $46,433 | | | |
| A11.3.2.2 | | | Slope area cover material: Load, haul, dump along crest | 9,349 | Cm3 | R.047 | 157.2 | $0.74 | $6,916.70 | $2.44 | $22,835 | $0.82 | 7,990 | $7,670.53 | $0.00 | $0.00 | $4.00 | $37,422 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A11.3.2.3 | | Revegetate | Slope area cover material: Spread down slope | 10 | hrs | C.2.13 | 10.2 | $44.39 | $451.46 | $194.68 | $1,980 | $67.01 | 710 | $681.52 | $0.00 | $0.00 | $306.07 | $3,113 | | | |
| A11.3.3.1 | | | Seed/Fertilize: broadcast seeding | 3.93 | ha | C.6.01 | 130.3 | $1,029.50 | $4,048.49 | $401.72 | $1,580 | $232.94 | 954 | $916.05 | $1,005.72 | $3,954.97 | $2,669.89 | $10,499 | | | |
| A11.3.3.2 | | | Tree seedling application (1,000 stems/ha) | 3.93 | ha | C.6.06 | 201.5 | $1,832.33 | $7,205.60 | $25.98 | $102 | $15.00 | 61 | $58.99 | $469.71 | $1,847.12 | $2,343.03 | $9,214 | | | |
| A11.4 | *Crusher Area* | | | | | | | | | | | | | | | | | | $73,635 | | |
| A11.2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 9 | hrs | C.2.13 | 9.0 | $44.39 | $400.28 | $194.68 | $1,756 | $67.01 | 629 | $604.27 | $0.00 | $0.00 | $306.07 | $2,760 | | | |
| A11.2.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 13,482 | m3 | R.055 | 244.8 | $0.80 | $10,783.37 | $2.60 | $35,042 | $0.86 | 12,012 | $11,531.82 | $0.00 | $0.00 | $4.25 | $57,358 | | | |
| A11.2.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.70 | ha | C.6.01 | 89.3 | $1,029.50 | $2,775.95 | $401.72 | $1,083 | $232.94 | 654 | $628.11 | $1,005.72 | $2,711.82 | $2,669.89 | $7,199 | | | |
| A11.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 3 | ha | C.6.06 | 138.2 | $1,832.33 | $4,940.70 | $25.98 | $70 | $15.00 | 42 | $40.45 | $469.71 | $1,266.53 | $2,343.03 | $6,318 | | | |
| A11.5 | *Exploration Disturbances* | | | | | | | | | | | | | | | | | | $21,519 | | |
| A11.5.1.1 | | Ridgetop Area | Scarify surfaces | 34,778 | m2 | C.2.16 | 0.0 | $0.03 | $1,208.47 | $0.07 | $2,284 | $0.02 | 618 | $593.29 | $0.00 | $0.00 | $0.12 | $4,085 | | | |
| A11.5.1.2 | | | Seed/Fertilize: broadcast seeding | 3 | ha | C.6.01 | 115.2 | $1,029.50 | $3,580.40 | $401.72 | $1,397 | $232.94 | 844 | $810.13 | $1,005.72 | $3,497.69 | $2,669.89 | $9,285 | | | |
| A11.5.1.3 | | | Tree seedling application (1,000 stems/ha) | 3 | ha | C.6.06 | 178.2 | $1,832.33 | $6,372.49 | $25.98 | $90 | $15.00 | 54 | $52.17 | $469.71 | $1,633.56 | $2,343.03 | $8,149 | | | |
| A11.6 | *Explosives Plant and Storage Areas* | | | | | | | | | | | | | | | | | | $43,165 | | |
| A11.6.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 30 | hrs | C.2.13 | 29.6 | $44.39 | $1,314.39 | $194.68 | $5,765 | $67.01 | 2,067 | $1,984.22 | $0.00 | $0.00 | $306.07 | $9,063 | | | |
| A11.6.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.6.1.3 | | | Scarify surfaces | 55,113 | m2 | C.2.16 | 0.0 | $0.03 | $1,915.08 | $0.07 | $3,619 | $0.02 | 979 | $940.20 | $0.00 | $0.00 | $0.12 | $6,474 | | | |
| A11.6.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.5 | ha | C.6.01 | 182.6 | $1,029.50 | $5,673.94 | $401.72 | $2,214 | $232.94 | 1,337 | $1,283.83 | $1,005.72 | $5,542.86 | $2,669.89 | $14,715 | | | |
| A11.6.2.2 | | | Tree seedling application (1,000 stems/ha) | 5.5 | ha | C.6.06 | 282.5 | $1,832.33 | $10,098.61 | $25.98 | $143 | $15.00 | 86 | $82.67 | $469.71 | $2,588.73 | $2,343.03 | $12,913 | | | |
| A11.7 | *Fuel Storage Areas* | | | | | | | | | | | | | | | | | | $24,758 | | |
| A11.7.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 5 | hrs | C.2.13 | 4.5 | $44.39 | $200.33 | $194.68 | $879 | $67.01 | 315 | $302.42 | $0.00 | $0.00 | $306.07 | $1,381 | | | |
| A11.7.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 4,200 | m3 | R.049 | 81.8 | $0.86 | $3,603.19 | $2.79 | $11,709 | $0.92 | 4,014 | $3,853.28 | $0.00 | $0.00 | $4.56 | $19,166 | | | |
| A11.7.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.84 | ha | C.6.01 | 27.8 | $1,029.50 | $864.78 | $401.72 | $337 | $232.94 | 204 | $195.67 | $1,005.72 | $844.80 | $2,669.89 | $2,243 | | | |
| A11.7.3.2 | | | Tree seedling application (1,000 stems/ha) | 1 | ha | C.6.06 | 43.1 | $1,832.33 | $1,539.16 | $25.98 | $22 | $15.00 | 13 | $12.60 | $469.71 | $394.56 | $2,343.03 | $1,968 | | | |
| A11.8 | *IROD Laydown Area* | | | | | | | | | | | | | | | | | | $18,300 | | |
| A11.8.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 15 | hrs | C.2.13 | 14.8 | $44.39 | $654.96 | $194.68 | $2,873 | $67.01 | 1,030 | $988.72 | $0.00 | $0.00 | $306.07 | $4,516 | | | |
| A11.8.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.8.1.3 | | | Scarify surface | 18,106 | m2 | C.2.16 | 0.0 | $0.03 | $629.15 | $0.07 | $1,189 | $0.02 | 322 | $308.88 | $0.00 | $0.00 | $0.12 | $2,127 | | | |
| A11.8.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.33 | ha | C.6.01 | 77.0 | $1,029.50 | $2,393.91 | $401.72 | $934 | $232.94 | 564 | $541.67 | $1,005.72 | $2,338.60 | $2,669.89 | $6,208 | | | |
| A11.8.2.2 | | | Tree seedling application (1,000 stems/ha) | 2.33 | ha | C.6.06 | 119.2 | $1,832.33 | $4,260.73 | $25.98 | $60 | $15.00 | 36 | $34.88 | $469.71 | $1,092.22 | $2,343.03 | $5,448 | | | |
| A11.9 | *Mill Area* | | | | | | | | | | | | | | | | | | $134,673 | | |
| A11.9.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 60 | hrs | C.2.13 | 59.9 | $44.39 | $2,659.96 | $194.68 | $11,666 | $67.01 | 4,183 | $4,015.50 | $0.00 | $0.00 | $306.07 | $18,342 | | | |
| A11.9.1.2 | | | Scarify surface | 42,365 | m2 | C.2.16 | 0.0 | $0.03 | $1,472.09 | $0.07 | $2,782 | $0.02 | 753 | $722.72 | $0.00 | $0.00 | $0.12 | $4,977 | | | |
| A11.9.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 21,182 | m3 | R.055 | 384.7 | $0.80 | $16,942.37 | $2.60 | $55,057 | $0.86 | 18,873 | $18,118.30 | $0.00 | $0.00 | $4.25 | $90,118 | | | |
| A11.9.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 4.24 | ha | C.6.01 | 140.3 | $1,029.50 | $4,361.46 | $401.72 | $1,702 | $232.94 | 1,028 | $986.86 | $1,005.72 | $4,260.70 | $2,669.89 | $11,311 | | | |
| A11.9.3.2 | | | Tree seedling application (1,000 stems/ha) | 4.24 | ha | C.6.06 | 217.1 | $1,832.33 | $7,762.62 | $25.98 | $110 | $15.00 | 66 | $63.55 | $469.71 | $1,989.91 | $2,343.03 | $9,926 | | | |
| A11.10 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $0 | | |
| A11.10.1 | | Costs included in Waste Rock Dump Section (WBS#: A1.5) | | 0 | hrs | | | | | | | | | | | | | | | | |
| A11.11 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $87,165 | | |
| A11.11.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 51 | hrs | C.2.13 | 51.5 | $44.39 | $2,284.70 | $194.68 | $10,020 | $67.01 | 3,593 | $3,449.00 | $0.00 | $0.00 | $306.07 | $15,754 | | | |
| A11.11.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 28 | hrs | C.2.13 | 28.0 | $44.39 | $1,244.58 | $194.68 | $5,459 | $67.01 | 1,957 | $1,878.82 | $0.00 | $0.00 | $306.07 | $8,582 | | | |
| A11.11.1.3 | | | Scarify surface | 62,765 | m2 | C.2.16 | 0.0 | $0.03 | $2,180.95 | $0.07 | $4,121 | $0.02 | 1,115 | $1,070.73 | $0.00 | $0.00 | $0.12 | $7,373 | | | |
| A11.11.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 11.1 | ha | C.6.01 | 366.5 | $1,029.50 | $11,389.08 | $401.72 | $4,444 | $232.94 | 2,684 | $2,576.99 | $1,005.72 | $11,125.98 | $2,669.89 | $29,536 | | | |
| A11.11.2.2 | | | Tree seedling application (1,000 stems/ha) | 11.1 | ha | C.6.06 | 567.0 | $1,832.33 | $20,270.56 | $25.98 | $287 | $15.00 | 173 | $165.94 | $469.71 | $5,196.26 | $2,343.03 | $25,920 | | | |
| A11.12 | *Pelly Laydown Area* | | | | | | | | | | | | | | | | | | $147,962 | | |
| A11.12.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 107 | hrs | C.2.13 | 107.4 | $44.39 | $4,767.52 | $194.68 | $20,910 | $67.01 | 7,497 | $7,197.08 | $0.00 | $0.00 | $306.07 | $32,874 | | | |
| A11.12.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 25,855 | m3 | R.058 | 380.7 | $0.65 | $16,779.44 | $2.11 | $54,545 | $0.69 | 18,585 | $17,841.31 | $0.00 | $0.00 | $3.45 | $89,165 | | | |
| A11.12.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.17 | ha | C.6.01 | 171.3 | $1,029.50 | $5,323.56 | $401.72 | $2,077 | $232.94 | 1,255 | $1,204.55 | $1,005.72 | $5,200.58 | $2,669.89 | $13,806 | | | |
| A11.12.3.2 | | | Tree seedling application (1,000 stems/ha) | 5.17 | ha | C.6.06 | 265.0 | $1,832.33 | $9,474.99 | $25.98 | $134 | $15.00 | 81 | $77.57 | $469.71 | $2,428.87 | $2,343.03 | $12,116 | | | |
| A11.13 | *W15 Sump Area Laydown* | | | | | | | | | | | | | | | | | | $36,022 | | |
| A11.13.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 9 | hrs | C.2.13 | 8.8 | $44.39 | $390.13 | $194.68 | $1,711 | $67.01 | 613 | $588.94 | $0.00 | $0.00 | $306.07 | $2,690 | | | |
| A11.13.1.2 | | | Slopes: Re-grade to 3H:1V | 1 | hrs | C.2.13 | 1.2 | $44.39 | $55.15 | $194.68 | $242 | $67.01 | 87 | $83.26 | $0.00 | $0.00 | $306.07 | $380 | | | |
| A11.13.1.3 | | | Scarify surface | 9,484 | m2 | C.2.16 | 0.0 | $0.03 | $329.54 | $0.07 | $623 | $0.02 | 169 | $161.79 | $0.00 | $0.00 | $0.12 | $1,114 | | | |
| A11.13.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 6,974 | m3 | R.065 | 106.1 | $0.67 | $4,675.54 | $2.18 | $15,199 | $0.71 | 5,179 | $4,971.43 | $0.00 | $0.00 | $3.56 | $24,846 | | | |
| A11.13.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 1.39 | ha | C.6.01 | 46.2 | $1,029.50 | $1,435.97 | $401.72 | $560 | $232.94 | 338 | $324.92 | $1,005.72 | $1,402.80 | $2,669.89 | $3,724 | | | |
| A11.13.3.2 | | | Tree seedling application (1,000 stems/ha) | 1.39 | ha | C.6.06 | 71.5 | $1,832.33 | $2,555.78 | $25.98 | $36 | $15.00 | 22 | $20.92 | $469.71 | $655.16 | $2,343.03 | $3,268 | | | |
| **A12** | **Waste Disposal** | | | | | | | | | | | | | | | | | | | **$452,923** | |
| A12.1 | *Hydrocarbon contaminated soils* | | | | | | | | | | | | | | | | | | $66,551 | | |
| A12.1.1.1 | | Excavate HC contaminated | Complete testing for contaminated soils | 48 | test pits | C.3.03 | 24.0 | $22.24 | $1,067.53 | $2.89 | $139 | $2.92 | 146 | $139.97 | $204.00 | $9,792.00 | $232.05 | $11,138 | | | |
| A12.1.1.2 | | | Excavate and haul contaminated soils to on-site landfarm facility | 726 | m3 | R.038 | 26.0 | $1.58 | $1,144.07 | $3.17 | $2,298 | $0.96 | 723 | $693.78 | $0.00 | $0.00 | $5.70 | $4,136 | | | |
| A12.1.2.1 | | Construct landfarm | Existing Facility assumed to have sufficient capacity | 0 | m3 | | | | | | | | | | | | | | | | |
| A12.1.3.1 | | Operate landfarm | Aerate contaminated soils (mix) | 12 | event | C.3.04 | 270.0 | $999.20 | $11,990.37 | $923.10 | $11,077 | $333.60 | 4,170 | $4,003.20 | $0.00 | $0.00 | $2,255.90 | $27,071 | | | |
| A12.1.3.2 | | | Annual confirmation sampling | 3 | years | C.3.05 | 48.0 | $711.69 | $2,135.06 | $92.63 | $278 | $93.31 | 292 | $279.94 | $1,224.00 | $3,672.00 | $2,121.63 | $6,365 | | | |
| A12.1.4.1 | | Close landfarm | Remove soils and collect liner | 726 | m3 | R.001 | 22.9 | $1.39 | $1,007.57 | $3.03 | $2,197 | $0.90 | 680 | $652.50 | $0.00 | $0.00 | $5.31 | $3,857 | | | |
| A12.1.4.2 | | | Cut/fold liner and place into waste disposal container | 4,265 | m2 | C.1.15 | 49.6 | $0.43 | $1,850.89 | $0.19 | $830 | $0.07 | 308 | $295.29 | $0.00 | $0.00 | $0.70 | $2,976 | | | |
| A12.1.4.3 | | | Regrade area | 4,265 | m2 | C.2.11 | 42.7 | $0.44 | $1,893.14 | $1.28 | $5,472 | $0.35 | 1,567 | $1,504.69 | $0.00 | $0.00 | $2.08 | $8,870 | | | |
| A12.1.4.4 | | | Revegetation: Seed/Fertilizer: broadcast seeding | 0.43 | ha | C.6.01 | 14.1 | $1,029.50 | $439.08 | $401.72 | $171 | $232.94 | 103 | $99.35 | $1,005.72 | $428.94 | $2,669.89 | $1,139 | | | |
| A12.1.4.5 | | | Tree seedling application (1,000 stems/ha) | 0.43 | ha | C.6.06 | 21.9 | $1,832.33 | $781.49 | $25.98 | $11 | $15.00 | 7 | $6.40 | $469.71 | $200.33 | $2,343.03 | $999 | | | |
| | *Metal Contaminated soils* | | | | | | | | | | | | | | | | | | $159,118 | | |
| A12.2.1.1 | | Crusher area | Delineate contaminated soil areas | 197 | test pits | C.3.01 | 98.5 | $22.24 | $4,381.32 | $2.89 | $570 | $2.92 | 598 | $574.45 | $265.20 | $52,244.40 | $293.25 | $57,770 | | | |
| A12.2.1.2 | | | Load, haul, dump contaminated soils to underground | 2,949 | m3 | R.039 | 102.1 | $1.53 | $4,499.64 | $3.33 | $9,810 | $0.99 | 3,035 | $2,913.97 | $0.00 | $0.00 | $5.84 | $17,224 | | | |
| A12.2.1.3 | | | Complete confirmation testing | 197 | ea | C.3.02 | 32.8 | $7.43 | $1,463.48 | $1.33 | $261 | $0.00 | 0 | $0.00 | $13.26 | $2,612.22 | $22.01 | $4,337 | | | |
| A12.2.2.1 | | Mill Area | Delineate contaminated soil areas | 198 | test pits | C.3.01 | 99.0 | $22.24 | $4,403.56 | $2.89 | $573 | $2.92 | 601 | $577.37 | $265.20 | $52,509.60 | $293.25 | $58,064 | | | |
| A12.2.2.2 | | | Load, haul, dump contaminated soils to underground | 2,973 | m3 | R.039 | 103.0 | $1.53 | $4,536.49 | $3.33 | $9,890 | $0.99 | 3,060 | $2,937.83 | $0.00 | $0.00 | $5.84 | $17,365 | | | |
| A12.2.2.3 | | | Complete confirmation testing | 198 | ea | C.3.02 | 33.0 | $7.43 | $1,470.91 | $1.33 | $262 | $0.00 | 0 | $0.00 | $13.26 | $2,625.48 | $22.01 | $4,359 | | | |
| A12.3 | *Solid Waste Landfill* | | | | | | | | | | | | | | | | | | $217,134 | | |
| A12.3.1.1 | | Construction landfill | Place waste from site facilities | 12,920 | LCM | C.2.07 | 550.6 | $1.89 | $24,440.80 | $8.30 | $107,194 | $2.86 | 38,433 | $36,895.99 | $0.00 | $0.00 | $13.04 | $168,531 | | | |
| A12.3.1.2 | | | Place fill to minimize voids in the debris | 3,371 | m3 | R.001 | 106.2 | $1.39 | $4,679.67 | $3.03 | $10,203 | $0.90 | 3,157 | $3,030.55 | $0.00 | $0.00 | $5.31 | $17,913 | | | |
| A12.3.2.1 | | Close landfill | Soil Cover: Load haul, dump spread, compact (0.6m) | 5,024 | m3 | R.002 | 190.0 | $1.61 | $8,100.50 | $3.21 | $16,144 | $0.99 | 5,196 | $4,988.33 | $0.00 | $0.00 | $5.82 | $29,233 | | | |
| A12.3.2.2 | | | Revegetation: Seed/Fertilizer: broadcast seeding | 0.55 | ha | C.6.01 | 18.1 | $1,029.50 | $562.06 | $401.72 | $219 | $232.94 | 132 | $127.18 | $1,005.72 | $549.07 | $2,669.89 | $1,458 | | | |
| A12.4 | *Hazardous Material Off-Site Disposal* | | | | | | | | | | | | | | | | | | $10,120 | | |
| A12.4.1.1 | | Hazardous Waste | From Building Demo: Transport off-site for disposal | 2 | trip | C.7.04 | 14.5 | $351.24 | $634.94 | $303.64 | $549 | $113.33 | 213 | $204.86 | $0.00 | $0.00 | $768.21 | $1,389 | | | |
| A12.4.3.3 | | | Hazardous materials: Disposal and Tipping fees. | 1 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0 | $0 | | | |
| A12.4.2.1 | | Reagents | Reagents: Transport to Whitehorse | 25 | hrs | C.1.22 | 99.3 | $159.30 | $3,955.90 | $95.83 | $2,380 | $26.93 | 697 | $668.71 | $0.00 | $0.00 | $282.05 | $7,004 | | | |
| A12.4.2.2 | | | Reagents: Disposal and tipping fees | 2.2 | trips | C.7.04 | 18.0 | $351.24 | $789.50 | $303.64 | $682 | $113.33 | 265 | $254.73 | $0.00 | $0.00 | $768.21 | $1,727 | | | |
| **A13** | **Surface Water Conveyance** | | | | | | | | | | | | | | | | | | | **$3,287,496** | |
| A13.1 | *Channel A - W-15 to Main Pit* | | | | | | | | | | | | | | | | | | $207,036 | | |
| A13.1.1.1 | | Excavate channel | Load, haul, dump locally | 40,300 | m3 | R.902 | 700.5 | $0.77 | $31,093.04 | $1.64 | $66,199 | $0.46 | 19,351 | $18,576.93 | $0.00 | $0.00 | $2.88 | $115,869 | | | |
| A13.1.2.1 | | Place channel materials | Geotextile: Supply and place | 7,785 | m3 | C.5.08 | 221.4 | $1.09 | $8,520.21 | $0.11 | $854 | $0.11 | 897 | $860.72 | $2.16 | $16,802.77 | $3.47 | $27,038 | | | |
| A13.1.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 3,855 | m3 | C.2.15 | 0.0 | $2.54 | $9,777.29 | $6.06 | $23,344 | $1.86 | 7,462 | $7,163.19 | $0.00 | $0.00 | $10.45 | $40,285 | | | |
| A13.1.2.3 | | | Rip-rap: Load, haul, dump | 3,855 | m3 | R.018 | 102.2 | $1.17 | $4,501.31 | $2.55 | $9,814 | $0.76 | 3,037 | $2,915.04 | $0.00 | $0.00 | $4.47 | $17,230 | | | |
| A13.1.2.4 | | | Rip-rap: Place and secure | 3,855 | m3 | R.904 | 41.9 | $0.48 | $1,860.68 | $0.91 | $3,507 | $0.32 | 1,299 | $1,247.51 | $0.00 | $0.00 | $1.72 | $6,615 | | | |
| A13.2 | *Channel B - W-35 to Area 2 Pit* | | | | | | | | | | | | | | | | | | $198,304 | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A13.2.1.1 | | Excavate channel | Load, haul, dump locally | 48,038 | m3 | R.902 | 835.0 | $0.77 | $37,063.29 | $1.64 | $78,910 | $0.46 | 23,067 | $22,143.92 | $0.00 | $0.00 | $2.88 | $138,117 | | | |
| A13.2.2.1 | | Place channel materials | Geotextile: Supply and place | 4,682 | m2 | C.5.08 | 133.1 | $1.09 | $5,124.06 | $0.11 | $514 | $0.11 | 539 | $517.64 | $2.16 | $10,105.20 | $3.47 | $16,261 | | | |
| A13.2.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,554 | m3 | C.2.15 | 0.0 | $2.54 | $6,477.46 | $6.06 | $15,465 | $1.86 | 4,943 | $4,745.61 | $0.00 | $0.00 | $10.45 | $26,689 | | | |
| A13.2.2.3 | | | Rip-rap: Load, haul, dump | 2,554 | m3 | R.020 | 76.2 | $1.32 | $3,358.44 | $2.87 | $7,322 | $0.85 | 2,266 | $2,174.93 | $0.00 | $0.00 | $5.03 | $12,855 | | | |
| A13.2.2.4 | | | Rip-rap: Place and secure | 2,554 | m3 | R.904 | 27.8 | $0.48 | $1,232.70 | $0.91 | $2,323 | $0.32 | 861 | $826.47 | $0.00 | $0.00 | $1.72 | $4,382 | | | |
| A13.3 | *Channel C - Main Pit to Main Access Road* | | | | | | | | | | | | | | | | | | $125,034 | | |
| A13.3.2.1 | | Excavate channel | Load, haul, dump locally | 8,656 | m3 | R.902 | 150.5 | $0.77 | $6,678.68 | $1.64 | $14,219 | $0.46 | 4,157 | $3,990.26 | $0.00 | $0.00 | $2.88 | $24,888 | | | |
| A13.3.3.1 | | Intake structure | Excavate soils to competent foundation materials | 2,450 | Bm3 | R.902 | 42.6 | $0.77 | $1,890.07 | $1.64 | $4,024 | $0.46 | 1,176 | $1,129.25 | $0.00 | $0.00 | $2.88 | $7,043 | | | |
| A13.3.3.2 | | | Supply an install precast-concrete intake wingwall intake structure | 1 | ls | C.5.12 | 140.0 | $5,946 | $5,945.57 | $3,583 | $3,583 | $643.84 | 671 | $643.84 | $37,000 | $37,000.00 | $47,172 | $47,172 | | | |
| A13.3.3.6 | | | Backfill and compact around structure | 2,450 | Cm3 | C.2.04 | 237.3 | $2.58 | $6,323.25 | $3.01 | $7,367 | $1.03 | 2,638 | $2,532.57 | $0.00 | $0.00 | $6.62 | $16,223 | | | |
| A13.3.4.1 | | Place channel materials | Geotextile: Supply and place | 3,171 | m2 | C.5.08 | 90.2 | $1.09 | $3,470.31 | $0.11 | $348 | $0.11 | 365 | $350.57 | $2.16 | $6,843.83 | $3.47 | $11,013 | | | |
| A13.3.4.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 1,037 | m3 | C.2.15 | 0.0 | $2.54 | $2,631.28 | $6.06 | $6,282 | $1.86 | 2,008 | $1,927.76 | $0.00 | $0.00 | $10.45 | $10,841 | | | |
| A13.3.4.3 | | | Rip-rap: Load, haul, dump | 1,037 | m3 | R.022 | 36.4 | $1.54 | $1,600.27 | $3.33 | $3,452 | $0.98 | 1,064 | $1,021.09 | $0.00 | $0.00 | $5.85 | $6,073 | | | |
| A13.3.4.4 | | | Rip-rap: Place and secure | 1,037 | m3 | R.904 | 11.3 | $0.48 | $500.75 | $0.91 | $944 | $0.32 | 350 | $335.73 | $0.00 | $0.00 | $1.72 | $1,780 | | | |
| A13.4 | *Channel D - Area 2 Pit to Channel E* | | | | | | | | | | | | | | | | | | $195,636 | | |
| A13.4.1.1 | | Excavate channel | Load, haul, dump locally | 17,840 | m3 | R.902 | 310.1 | $0.77 | $13,763.89 | $1.64 | $29,304 | $0.46 | 8,566 | $8,223.41 | $0.00 | $0.00 | $2.88 | $51,291 | | | |
| A13.4.2.1 | | Intake structure | Excavate soils to competent foundation materials | 4,453 | Bm3 | R.902 | 77.4 | $0.77 | $3,435.48 | $1.64 | $7,314 | $0.46 | 2,138 | $2,052.57 | $0.00 | $0.00 | $2.88 | $12,802 | | | |
| A13.4.2.2 | | | Supply an install precast-concrete intake wingwall intake structure | 1 | ls | C.5.12 | 140.0 | $5,946 | $5,945.57 | $3,583 | $3,583 | $643.84 | 671 | $643.84 | $37,000 | $37,000.00 | $47,172 | $47,172 | | | |
| A13.4.2.6 | | | Backfill and compact around structure | 4,453 | Cm3 | C.2.04 | 431.4 | $2.58 | $11,493.42 | $3.01 | $13,390 | $1.03 | 4,795 | $4,603.31 | $0.00 | $0.00 | $6.62 | $29,487 | | | |
| A13.4.3.1 | | Place channel materials | Geotextile: Supply and place | 4,910 | m2 | C.5.08 | 139.6 | $1.09 | $5,373.23 | $0.11 | $539 | $0.11 | 565 | $542.81 | $2.16 | $10,596.59 | $3.47 | $17,051 | | | |
| A13.4.3.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,199 | m3 | C.2.15 | 0.0 | $2.54 | $5,578.78 | $6.06 | $13,320 | $1.86 | 4,258 | $4,087.21 | $0.00 | $0.00 | $10.45 | $22,986 | | | |
| A13.4.3.3 | | | Rip-rap: Load, haul, dump | 2,199 | m3 | R.020 | 65.7 | $1.32 | $2,892.50 | $2.87 | $6,306 | $0.85 | 1,951 | $1,873.18 | $0.00 | $0.00 | $5.03 | $11,072 | | | |
| A13.4.3.4 | | | Rip-rap: Place and secure | 2,199 | m3 | R.904 | 23.9 | $0.48 | $1,061.68 | $0.91 | $2,001 | $0.32 | 741 | $711.81 | $0.00 | $0.00 | $1.72 | $3,774 | | | |
| A13.5 | *Channel E - Main Access Road to toe of MVFE* | | | | | | | | | | | | | | | | | | $739,690 | | |
| A13.5.1.1 | | Construct channel | Bulk fill to grade: Load, haul, dump, spread | 29,750 | m3 | | | | | | | | | | | | | | | | |
| A13.5.1.2 | | | Excavate/form Channel: Load, haul, dump locally | 46,386 | m3 | R.001 | 1,461.8 | $1.39 | $64,402.28 | $3.03 | $140,409 | $0.90 | 43,445 | $41,706.89 | $0.00 | $0.00 | $5.31 | $246,519 | | | |
| A13.5.2.1 | | Place channel materials | Geotextile: Supply and place | 27,307 | m2 | C.5.08 | 776.5 | $1.09 | $29,885.47 | $0.11 | $2,997 | $0.11 | 3,145 | $3,019.05 | $2.16 | $58,937.36 | $3.47 | $94,839 | | | |
| A13.5.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 20,558 | m3 | C.2.15 | 0.0 | $2.54 | $52,143.07 | $6.06 | $124,496 | $1.86 | 39,794 | $38,201.83 | $0.00 | $0.00 | $10.45 | $214,841 | | | |
| A13.5.2.3 | | | Rip-rap: Load, haul, dump | 20,558 | m3 | R.025 | 845.7 | $1.81 | $37,226.38 | $3.91 | $80,296 | $1.16 | 24,743 | $23,753.12 | $0.00 | $0.00 | $6.87 | $141,275 | | | |
| A13.5.2.4 | | | Rip-rap: Place and secure | 20,558 | m3 | R.904 | 223.6 | $0.48 | $9,923.17 | $0.91 | $18,701 | $0.32 | 6,930 | $6,653.05 | $0.00 | $0.00 | $1.72 | $35,277 | | | |
| A13.5.3.1 | | Stilling basin/Energy Dissipa | Excavate basin (spoil locally) | 645 | m3 | R.902 | 11.2 | $0.77 | $497.87 | $1.64 | $1,060 | $0.46 | 310 | $297.46 | $0.00 | $0.00 | $2.88 | $1,855 | | | |
| A13.5.3.2 | | | Geotextile: Supply and place | 540 | m2 | C.5.08 | 15.4 | $1.09 | $591.07 | $0.11 | $59 | $0.11 | 62 | $59.71 | $2.16 | $1,165.65 | $3.47 | $1,876 | | | |
| A13.5.3.3 | | | Bedding layer: Screen and stockpile | 131 | m3 | C.2.01 | 2.7 | $0.96 | $125.01 | $2.11 | $276 | $0.44 | 60 | $57.55 | $0.00 | $0.00 | $3.51 | $459 | | | |
| A13.5.3.4 | | | Bedding layer: Load, haul, dump and place | 131 | m3 | R.028 | 7.7 | $2.59 | $337.69 | $5.78 | $755 | $1.69 | 229 | $220.12 | $0.00 | $0.00 | $10.05 | $1,312 | | | |
| A13.5.3.5 | | | Rip-rap (at inlet and outlet): Screen and stockpile | 75 | m3 | C.2.15 | 0.0 | $2.54 | $190.23 | $6.06 | $454 | $1.86 | 145 | $139.37 | $0.00 | $0.00 | $10.45 | $784 | | | |
| A13.5.3.6 | | | Rip-rap (at inlet and outlet): Load, haul, dump | 75 | m3 | R.027 | 3.2 | $1.86 | $139.15 | $3.97 | $298 | $1.17 | 91 | $87.84 | $0.00 | $0.00 | $7.00 | $525 | | | |
| A13.5.3.7 | | | Rip-rap (at inlet and outlet): Place and secure | 75 | m3 | R.904 | 0.8 | $0.48 | $36.20 | $0.91 | $68 | $0.32 | 25 | $24.27 | $0.00 | $0.00 | $1.72 | $129 | | | |
| A13.6 | *Minto Creek Wetland By-Pass Channel* | | | | | | | | | | | | | | | | | | $231,721 | | |
| A13.6.1.1 | | Excavate channel | Load, haul, dump locally | 29,668 | m3 | R.902 | 515.7 | $0.77 | $22,889.69 | $1.64 | $48,733 | $0.46 | 14,246 | $13,675.73 | $0.00 | $0.00 | $2.88 | $85,299 | | | |
| A13.6.2.1 | | Place channel materials | Geotextile: Supply and place | 12,212 | m2 | C.5.08 | 347.3 | $1.09 | $13,364.91 | $0.11 | $1,340 | $0.11 | 1,406 | $1,350.13 | $2.16 | $26,357.04 | $3.47 | $42,412 | | | |
| A13.6.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 5,950 | m3 | C.2.15 | 0.0 | $2.54 | $15,091.24 | $6.06 | $36,032 | $1.86 | 11,517 | $11,056.37 | $0.00 | $0.00 | $10.45 | $62,179 | | | |
| A13.6.2.3 | | | Rip-rap: Load, haul, dump | 5,950 | m3 | R.001 | 187.5 | $1.39 | $8,260.73 | $3.03 | $18,010 | $0.90 | 5,573 | $5,349.64 | $0.00 | $0.00 | $5.31 | $31,620 | | | Assumes WSP rip-rap can be re-used |
| A13.6.2.4 | | | Rip-rap: Place and secure | 5,950 | m3 | R.904 | 64.7 | $0.48 | $2,871.96 | $0.91 | $5,412 | $0.32 | 2,006 | $1,925.52 | $0.00 | $0.00 | $1.72 | $10,210 | | | |
| A13.7 | *Allowance: Minto North Spillway* | | | | | | | | | | | | | | | | | | $83,528 | | |
| A13.7.1.1 | | Excavate channel | Load, haul, dump locally | 13,035 | m3 | R.902 | 226.6 | $0.77 | $10,056.98 | $1.64 | $21,412 | $0.46 | 6,259 | $6,008.67 | $0.00 | $0.00 | $2.88 | $37,477 | | | |
| A13.7.2.1 | | Place channel materials | Geotextile: Supply and place | 4,136 | m2 | C.5.08 | 117.6 | $1.09 | $4,526.14 | $0.11 | $454 | $0.11 | 476 | $457.23 | $2.16 | $8,926.04 | $3.47 | $14,363 | | | |
| A13.7.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 1,943 | m3 | C.2.15 | 0.0 | $2.54 | $4,929.10 | $6.06 | $11,769 | $1.86 | 3,762 | $3,611.23 | $0.00 | $0.00 | $10.45 | $20,309 | | | |
| A13.7.2.3 | | | Rip-rap: Load, haul, dump | 1,943 | m3 | R.024 | 47.7 | $1.08 | $2,101.36 | $2.36 | $4,581 | $0.70 | 1,418 | $1,360.84 | $0.00 | $0.00 | $4.14 | $8,044 | | | Assumes WSP rip-rap can be re-used |
| A13.7.2.4 | | | Rip-rap: Place and secure | 1,943 | m3 | R.904 | 21.1 | $0.48 | $938.04 | $0.91 | $1,768 | $0.32 | 655 | $628.91 | $0.00 | $0.00 | $1.72 | $3,335 | | | |
| A13.8 | *Ridgetop North Outlet Channel* | | | | | | | | | | | | | | | | | | $74,863 | | |
| A13.8.1.1 | | Excavate channel | Load, haul, dump locally | 7,758 | m3 | R.902 | 134.9 | $0.77 | $5,985.73 | $1.64 | $12,744 | $0.46 | 3,725 | $3,576.25 | $0.00 | $0.00 | $2.88 | $22,306 | | | |
| A13.8.2.1 | | Place channel materials | Geotextile: Supply and place | 3,995 | m2 | C.5.08 | 113.6 | $1.09 | $4,371.69 | $0.11 | $438 | $0.11 | 460 | $441.63 | $2.16 | $8,621.43 | $3.47 | $13,873 | | | |
| A13.8.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,531 | m3 | C.2.15 | 0.0 | $2.54 | $6,419.56 | $6.06 | $15,327 | $1.86 | 4,899 | $4,703.20 | $0.00 | $0.00 | $10.45 | $26,450 | | | |
| A13.8.2.3 | | | Rip-rap: Load, haul, dump | 2,531 | m3 | R.068 | 33.1 | $0.58 | $1,455.99 | $1.90 | $4,821 | $0.64 | 1,681 | $1,613.82 | $0.00 | $0.00 | $3.12 | $7,891 | | | Assumes WSP rip-rap can be re-used |
| A13.8.2.4 | | | Rip-rap: Place and secure | 2,531 | m3 | R.904 | 27.5 | $0.48 | $1,221.69 | $0.91 | $2,302 | $0.32 | 853 | $819.09 | $0.00 | $0.00 | $1.72 | $4,343 | | | |
| A13.9 | *Secondary Catchment Channels* | | | | | | | | | | | | | | | | | | $791,748 | | |
| A13.9.1.1 | | Southwest Dump | Excavate mild-graded channels (good access), spoil locally | 10,787 | Bm3 | R.902 | 187.5 | $0.77 | $8,322.78 | $1.64 | $17,720 | $0.46 | 5,180 | $4,972.55 | $0.00 | $0.00 | $2.88 | $31,015 | | | |
| A13.9.1.2 | | | Excavate steep-graded channels (poor access), spoil locally | 6,640 | Bm3 | R.903 | 131.0 | $0.88 | $5,815.42 | $1.86 | $12,381 | $0.52 | 3,619 | $3,474.49 | $0.00 | $0.00 | $3.26 | $21,671 | | | |
| A13.9.1.3 | | | Geotextile: Supply and place | 25,206 | m2 | C.5.08 | 716.7 | $1.09 | $27,585.63 | $0.11 | $2,766 | $0.11 | 2,903 | $2,786.72 | $2.16 | $54,401.82 | $3.47 | $87,541 | | | |
| A13.9.1.4 | | | Bedding layer: Screen and stockpile | 2,054 | Cm3 | C.2.01 | 41.8 | $0.96 | $1,967.27 | $2.11 | $4,343 | $0.44 | 943 | $905.70 | $0.00 | $0.00 | $3.51 | $7,216 | | | |
| A13.9.1.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 2,054 | Cm3 | R.032 | 72.2 | $1.55 | $3,176.63 | $3.34 | $6,852 | $0.99 | 2,111 | $2,026.92 | $0.00 | $0.00 | $5.87 | $12,055 | | | |
| A13.9.1.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 6,806 | Cm3 | C.2.15 | 0.0 | $2.54 | $17,263.99 | $6.06 | $41,219 | $1.86 | 13,175 | $12,648.20 | $0.00 | $0.00 | $10.45 | $71,131 | | | |
| A13.9.1.7 | | | Rip-rap: Load, haul, dump | 6,806 | m3 | R.031 | 223.5 | $1.45 | $9,846.77 | $3.15 | $21,468 | $0.94 | 6,642 | $6,376.76 | $0.00 | $0.00 | $5.54 | $37,691 | | | |
| A13.9.1.8 | | | Rip-rap: Place in mild-graded channels (good access) | 3,787 | m3 | R.904 | 41.2 | $0.48 | $1,828.10 | $0.91 | $3,445 | $0.32 | 1,277 | $1,225.66 | $0.00 | $0.00 | $1.72 | $6,499 | | | |
| A13.9.1.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 3,019 | m3 | R.905 | 74.5 | $1.10 | $3,308.57 | $2.33 | $7,044 | $0.65 | 2,059 | $1,976.75 | $0.00 | $0.00 | $4.08 | $12,329 | | | |
| A13.9.2.1 | | Main Waste Dump | Excavate mild-graded channels (good access), spoil locally | 6,477 | Bm3 | R.902 | 112.6 | $0.77 | $4,997.00 | $1.64 | $10,639 | $0.46 | 3,110 | $2,985.52 | $0.00 | $0.00 | $2.88 | $18,621 | | | |
| A13.9.2.2 | | | Excavate steep-graded channels (poor access), spoil locally | 3,986 | Bm3 | R.903 | 78.6 | $0.88 | $3,490.67 | $1.86 | $7,432 | $0.52 | 2,172 | $2,085.55 | $0.00 | $0.00 | $3.26 | $13,008 | | | |
| A13.9.2.3 | | | Geotextile: Supply and place | 15,132 | m2 | C.5.08 | 430.3 | $1.09 | $16,560.93 | $0.11 | $1,661 | $0.11 | 1,743 | $1,672.99 | $2.16 | $32,659.93 | $3.47 | $52,555 | | | |
| A13.9.2.4 | | | Bedding layer: Screen and stockpile | 1,233 | Cm3 | C.2.01 | 25.1 | $0.96 | $1,180.84 | $2.11 | $2,607 | $0.44 | 566 | $543.64 | $0.00 | $0.00 | $3.51 | $4,331 | | | |
| A13.9.2.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 1,233 | Cm3 | R.030 | 34.8 | $1.25 | $1,535.65 | $2.76 | $3,401 | $0.82 | 1,059 | $1,016.39 | $0.00 | $0.00 | $4.83 | $5,953 | | | |
| A13.9.2.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 4,086 | Cm3 | C.2.15 | 0.0 | $2.54 | $10,364.11 | $6.06 | $24,745 | $1.86 | 7,909 | $7,593.11 | $0.00 | $0.00 | $10.45 | $42,702 | | | |
| A13.9.2.7 | | | Rip-rap: Load, haul, dump | 4,086 | m3 | R.029 | 101.4 | $1.09 | $4,473.09 | $2.42 | $9,908 | $0.72 | 3,084 | $2,960.56 | $0.00 | $0.00 | $4.24 | $17,341 | | | |
| A13.9.2.8 | | | Rip-rap: Place in mild-graded channels (good access) | 2,274 | m3 | R.904 | 24.7 | $0.48 | $1,097.59 | $0.91 | $2,068 | $0.32 | 767 | $735.89 | $0.00 | $0.00 | $1.72 | $3,902 | | | |
| A13.9.2.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 1,812 | m3 | R.905 | 44.7 | $1.10 | $1,985.96 | $2.33 | $4,228 | $0.65 | 1,236 | $1,186.53 | $0.00 | $0.00 | $4.08 | $7,401 | | | |
| A13.9.3.1 | | Reclamation Overburden Du | Excavate mild-graded channels (good access), spoil locally | 4,886 | Bm3 | R.902 | 84.9 | $0.77 | $3,769.89 | $1.64 | $8,026 | $0.46 | 2,346 | $2,252.36 | $0.00 | $0.00 | $2.88 | $14,049 | | | |
| A13.9.3.2 | | | Excavate steep-graded channels (poor access), spoil locally | 3,007 | Bm3 | R.903 | 59.3 | $0.88 | $2,633.47 | $1.86 | $5,607 | $0.52 | 1,639 | $1,573.40 | $0.00 | $0.00 | $3.26 | $9,814 | | | |
| A13.9.3.3 | | | Geotextile: Supply and place | 11,416 | m2 | C.5.08 | 324.6 | $1.09 | $12,494.07 | $0.11 | $1,253 | $0.11 | 1,315 | $1,262.16 | $2.16 | $24,639.65 | $3.47 | $39,649 | | | |
| A13.9.3.4 | | | Bedding layer: Screen and stockpile | 930 | Cm3 | C.2.01 | 18.9 | $0.96 | $890.86 | $2.11 | $1,967 | $0.44 | 427 | $410.14 | $0.00 | $0.00 | $3.51 | $3,268 | | | |
| A13.9.3.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 930 | Cm3 | R.034 | 34.7 | $1.64 | $1,527.43 | $3.58 | $3,330 | $1.06 | 1,030 | $989.17 | $0.00 | $0.00 | $6.29 | $5,847 | | | |
| A13.9.3.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 3,083 | Cm3 | C.2.15 | 0.0 | $2.54 | $7,819.00 | $6.06 | $18,669 | $1.86 | 5,967 | $5,728.47 | $0.00 | $0.00 | $10.45 | $32,216 | | | |
| A13.9.3.7 | | | Rip-rap: Load, haul, dump | 3,083 | m3 | R.033 | 97.0 | $1.39 | $4,271.96 | $3.02 | $9,314 | $0.90 | 2,882 | $2,766.52 | $0.00 | $0.00 | $5.30 | $16,352 | | | |
| A13.9.3.8 | | | Rip-rap: Place in mild-graded channels (good access) | 1,715 | m3 | R.904 | 18.7 | $0.48 | $828.06 | $0.91 | $1,561 | $0.32 | 578 | $555.18 | $0.00 | $0.00 | $1.72 | $2,944 | | | |
| A13.9.3.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 1,367 | m3 | R.905 | 33.8 | $1.10 | $1,498.27 | $2.33 | $3,190 | $0.65 | 932 | $895.16 | $0.00 | $0.00 | $4.08 | $5,583 | | | |
| A13.9.4.1 | | DSTSF & MVFE | Excavate mild-graded channels (good access), spoil locally | 7,378 | Bm3 | R.902 | 128.3 | $0.77 | $5,692.78 | $1.64 | $12,120 | $0.46 | 3,543 | $3,401.22 | $0.00 | $0.00 | $2.88 | $21,214 | | | |
| A13.9.4.2 | | | Excavate steep-graded channels (poor access), spoil locally | 4,541 | Bm3 | R.903 | 89.6 | $0.88 | $3,976.72 | $1.86 | $8,467 | $0.52 | 2,475 | $2,375.94 | $0.00 | $0.00 | $3.26 | $14,819 | | | |
| A13.9.4.3 | | | Geotextile: Supply and place | 17,239 | m2 | C.5.08 | 490.2 | $1.09 | $18,866.88 | $0.11 | $1,892 | $0.11 | 1,985 | $1,905.94 | $2.16 | $37,207.52 | $3.47 | $59,872 | | | |
| A13.9.4.4 | | | Bedding layer: Screen and stockpile | 1,405 | Cm3 | C.2.01 | 28.6 | $0.96 | $1,345.27 | $2.11 | $2,970 | $0.44 | 645 | $619.34 | $0.00 | $0.00 | $3.51 | $4,935 | | | |
| A13.9.4.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 1,405 | Cm3 | R.028 | 82.5 | $2.59 | $3,633.88 | $5.78 | $8,121 | $1.69 | 2,467 | $2,368.79 | $0.00 | $0.00 | $10.05 | $14,124 | | | |
| A13.9.4.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 4,655 | Cm3 | C.2.15 | 0.0 | $2.54 | $11,807.22 | $6.06 | $28,191 | $1.86 | 9,011 | $8,650.38 | $0.00 | $0.00 | $10.45 | $48,648 | | | |
| A13.9.4.7 | | | Rip-rap: Load, haul, dump | 4,655 | m3 | R.027 | 196.3 | $1.86 | $8,636.41 | $3.97 | $18,485 | $1.17 | 5,679 | $5,451.80 | $0.00 | $0.00 | $7.00 | $32,573 | | | |
| A13.9.4.8 | | | Rip-rap: Place in mild-graded channels (good access) | 2,590 | m3 | R.904 | 28.2 | $0.48 | $1,250.42 | $0.91 | $2,356 | $0.32 | 873 | $838.35 | $0.00 | $0.00 | $1.72 | $4,445 | | | |
| A13.9.4.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 2,065 | m3 | R.905 | 51.0 | $1.10 | $2,262.48 | $2.33 | $4,817 | $0.65 | 1,408 | $1,351.75 | $0.00 | $0.00 | $4.08 | $8,431 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A13.9.5.1 | | Ridgetop Waste Dump | Excavate mild-graded channels (good access), spoil locally | 574 | Bm3 | R.902 | 10.0 | $0.77 | $442.77 | $1.64 | $943 | $0.46 | 276 | $264.54 | $0.00 | $0.00 | $2.88 | $1,650 | | | |
| A13.9.5.2 | | | Excavate steep-graded channels (poor access), spoil locally | 353 | Bm3 | R.903 | 7.0 | $0.88 | $309.30 | $1.86 | $659 | $0.52 | 192 | $184.80 | $0.00 | $0.00 | $3.26 | $1,153 | | | |
| A13.9.5.3 | | | Geotextile: Supply and place | 876 | m2 | C.5.08 | 24.9 | $1.09 | $958.89 | $0.11 | $96 | $0.11 | 101 | $96.87 | $2.16 | $1,891.03 | $3.47 | $3,043 | | | |
| A13.9.5.4 | | | Bedding layer: Screen and stockpile | 465 | Cm3 | C.2.01 | 9.4 | $0.96 | $444.99 | $2.11 | $982 | $0.44 | 213 | $204.86 | $0.00 | $0.00 | $3.51 | $1,632 | | | |
| A13.9.5.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 109 | Cm3 | R.063 | 2.9 | $1.18 | $128.79 | $3.83 | $419 | $1.26 | 143 | $137.73 | $0.00 | $0.00 | $6.27 | $685 | | | |
| A13.9.5.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 362 | Cm3 | C.2.15 | 0.0 | $2.54 | $918.34 | $6.06 | $2,193 | $1.86 | 701 | $672.81 | $0.00 | $0.00 | $10.45 | $3,784 | | | |
| A13.9.5.7 | | | Rip-rap: Load, haul, dump | 362 | m3 | R.064 | 8.5 | $1.03 | $373.01 | $3.40 | $1,231 | $1.14 | 431 | $413.67 | $0.00 | $0.00 | $5.57 | $2,018 | | | |
| A13.9.5.8 | | | Rip-rap: Place in mild-graded channels (good access) | 201 | m3 | R.904 | 2.2 | $0.48 | $97.26 | $0.91 | $183 | $0.32 | 68 | $65.21 | $0.00 | $0.00 | $1.72 | $346 | | | |
| A13.9.5.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 161 | m3 | R.905 | 4.0 | $1.10 | $175.97 | $2.33 | $375 | $0.65 | 110 | $105.14 | $0.00 | $0.00 | $4.08 | $656 | | | |
| A13.10 | *Tailings Diversion Ditch* | | | | | | | | | | | | | | | | | | $624,970 | | |
| A13.10.1.2 | | Regrade | Slopes: Re-grade to 3H:1V | 28 | hrs | C.2.13 | 28 | $44.39 | $1,226 | $194.68 | $5,376 | $67.01 | 1,928 | $1,850 | $0.00 | $0 | $306.07 | $8,452 | | | |
| A13.10.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 25,182 | Cm3 | R.066 | 562.3 | $0.98 | $24,763 | $3.20 | $80,473 | $1.05 | 27,585 | $26,482 | $0.00 | $0 | $5.23 | $131,718 | | | |
| A13.10.2.2 | | | Slope area cover material: Load, haul, dump along crest | 18,049 | Cm3 | R.067 | 352.6 | $0.86 | $15,513 | $2.84 | $51,216 | $0.95 | 17,921 | $17,204 | $0.00 | $0 | $4.65 | $83,933 | | | |
| A13.10.2.3 | | | Slope area cover material: Spread down slope | 14 | hrs | C.2.13 | 14.0 | $44.39 | $621 | $194.68 | $2,724 | $67.01 | 977 | $937 | $0.00 | $0 | $306.07 | $4,282 | | | |
| A13.10.3.1 | | Revegetate | Seed/Fertilize: tractor application | 9 | ha | C.6.01 | 286.4 | $1,029.50 | $8,901 | $401.72 | $3,473 | $232.94 | 2,098 | $2,014 | $1,005.72 | $8,696 | $2,670 | $23,085 | | | |
| A13.10.3.2 | | | Tree seedling application (1,000 stems/ha) | 9 | ha | C.6.06 | 443.1 | $1,832.33 | $15,843 | $25.98 | $225 | $15.00 | 135 | $130 | $469.71 | $4,061 | $2,343 | $20,258 | | | |
| A13.10.4.1 | | Extend Channel to WSP | Clear and grub footprint | 13,889 | m2 | C.2.03 | 52.8 | $0.17 | $2,344 | $0.49 | $6,774 | $0.13 | 1,940 | $1,863 | $0.00 | $0 | $0.79 | $10,981 | | | |
| A13.10.4.2 | | | Geotextile: Supply and place | 13,889 | m2 | C.5.08 | 394.9 | $1.09 | $15,200 | $0.11 | $1,524 | $0.11 | 1,600 | $1,536 | $2.16 | $29,976 | $3.47 | $48,236 | | | |
| A13.10.4.3 | | | Rip-rap (angular, high quality): Screen and stockpile | 13,169 | m3 | C.2.15 | 0.0 | $2.54 | $33,403 | $6.06 | $79,753 | $1.86 | 25,492 | $24,472 | $0.00 | $0 | $10.45 | $137,629 | | | |
| A13.10.4.4 | | | Rip-rap: Load, haul, dump | 13,169 | m3 | R.035 | 618.4 | $2.07 | $27,207 | $4.42 | $58,233 | $1.30 | 17,890 | $17,175 | $0.00 | $0 | $7.79 | $102,615 | | | |
| A13.10.4.5 | | | Rip-rap: Place in steep-graded channels (poor access) | 13,169 | m3 | R.905 | 325.1 | $1.10 | $14,432 | $2.33 | $30,726 | $0.65 | 8,982 | $8,622 | $0.00 | $0 | $4.08 | $53,780 | | | |
| **A14** | **Water Treatment** | | | | | | | | | | | | | | | | | | | **$483,085** | |
| A14.1 | *Passive Treatment System - Minto Creek Valley* | | | | | | | | | | | | | | | | | | $397,994 | | |
| A14.1.1.1 | | Water Management | Install pump and pump around system | 8 | hrs | C.4.14 | 32.0 | $120.43 | $963.46 | $20.53 | $164 | $6.80 | 57 | $54.40 | $0.00 | $0.00 | $147.76 | $1,182 | | | Assumed |
| A14.1.1.2 | | | Maintain pump around system during wetland construction activities | 1,440 | hrs | C.4.13 | 144.0 | $3.55 | $5,117.32 | $12.98 | $18,691 | $2.00 | 3,000 | $2,880.00 | $0.00 | $0.00 | $18.53 | $26,689 | | | Assumes wetlands constructed over 2 months |
| A14.1.2.1 | | Valley Fill placement | Load, haul, dump material from the WSP excavation | 85,918 | m3 | n/a - costed | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.1.2.1 | | | Load, haul dump valley fill material | 0 | m3 | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | Fill from WSP excavation exceeds the required amount. |
| A14.1.3.1 | | Construct wetlands | Excavate cells: Load, haul dump, spoil locally | 14,459 | m3 | R.902 | 251.3 | $0.77 | $11,155.61 | $1.64 | $23,751 | $0.46 | 6,943 | $6,665.06 | $0.00 | $0.00 | $2.88 | $41,572 | | | |
| A14.1.3.2 | | | Subgrade preparation: remove sharp objects, place fill as required | 9,273 | m2 | C.2.18 | 317.0 | $1.31 | $12,142.93 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $1.31 | $12,143 | | | |
| A14.1.3.3 | | | Geotextile: Supply and install | 10,201 | m2 | C.5.08 | 290.1 | $1.09 | $11,163.84 | $0.11 | $1,120 | $0.11 | 1,175 | $1,127.78 | $2.16 | $22,016.30 | $3.47 | $35,428 | | | |
| A14.1.3.4 | | | HDPE liner: Supply and install | 10,201 | m2 | C.5.11 | 1,187.0 | $4.74 | $48,319.12 | $0.27 | $2,749 | $0.27 | 2,884 | $2,769.07 | $9.38 | $95,723.03 | $14.66 | $149,560 | | | |
| A14.1.3.5 | | | Organics: Mulch organics, produce and stockpile | 5,122 | Cm3 | C.2.10 | 577.1 | $4.50 | $23,023.50 | $4.87 | $24,922 | $1.82 | 9,720 | $9,331.25 | $0.00 | $0.00 | $11.18 | $57,277 | | | |
| A14.1.3.6 | | | Organics: Load, haul, dump, place in cell | 5,122 | Cm3 | R.001 | 161.4 | $1.39 | $7,111.43 | $3.03 | $15,504 | $0.90 | 4,797 | $4,605.36 | $0.00 | $0.00 | $5.31 | $27,221 | | | |
| A14.1.3.7 | | | Plant wetland vegetation | 0.9 | ha | C.6.05 | 40.6 | $1,443.27 | $1,338.39 | $307.03 | $285 | $180.00 | 174 | $166.92 | $1,159.23 | $1,074.99 | $3,089.53 | $2,865 | | | |
| A14.1.4.1 | | Conveyance channels | Excavate channels: Load, haul, dump locally | 1,402 | m3 | R.902 | 24.4 | $0.77 | $1,081.90 | $1.64 | $2,303 | $0.46 | 673 | $646.39 | $0.00 | $0.00 | $2.88 | $4,032 | | | |
| A14.1.4.2 | | | Surface preparation: remove sharp objects, place fill as required | 1,858 | m2 | C.2.18 | 63.5 | $1.31 | $2,432.63 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $1.31 | $2,433 | | | |
| A14.1.4.3 | | | Geotextile: Supply and place | 1,858 | m2 | C.5.08 | 52.8 | $1.09 | $2,033.17 | $0.11 | $204 | $0.11 | 214 | $205.39 | $2.16 | $4,009.63 | $3.47 | $6,452 | | | |
| A14.1.4.4 | | | HDPE Liner: Supply and install | 1,858 | m2 | C.5.11 | 216.2 | $4.74 | $8,799.92 | $0.27 | $501 | $0.27 | 525 | $504.31 | $9.38 | $17,433.16 | $14.66 | $27,238 | | | |
| A14.1.4.5 | | | Bedding/Protection layer: Screen and stockpile | 442 | m3 | C.2.01 | 9.0 | $0.96 | $423.54 | $2.11 | $935 | $0.44 | 203 | $194.99 | $0.00 | $0.00 | $3.51 | $1,554 | | | |
| A14.1.4.6 | | | Bedding/Protection layer: Load, haul, dump and place | 442 | m3 | R.001 | 13.9 | $1.39 | $614.04 | $3.03 | $1,339 | $0.90 | 414 | $397.65 | $0.00 | $0.00 | $5.31 | $2,350 | | | Assumes WSP fill can be re-used |
| A14.1.5.1 | | Operation and maintenance | System to be started Yr. 1 post-closure | 0 | yr | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.2 | *Southwest Wetlands* | | | | | | | | | | | | | | | | | | $15,944 | | |
| A14.2.1 | | Berm construction | Construct 3 berms across valley | 3,000 | m3 | R.001 | 94.5 | $1.39 | $4,165.24 | $3.03 | $9,081 | $0.90 | 2,810 | $2,697.41 | $0.00 | $0.00 | $5.31 | $15,944 | | | Assumed |
| A14.2.2 | | Outlet structures | Excavate outlet channels through berms | 1 | ls | | | | | | | | | | | | | | | | Allowance |
| A14.3 | *Decommission/demolish Water Treatment System* | | | | | | | | | | | | | | | | | | $69,147 | | |
| A14.3.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 17 | hrs | C.1.13 | 67.1 | $168.00 | $2,819.22 | $86.19 | $1,446 | $14.53 | 254 | $243.80 | $0.00 | $0.00 | $268.71 | $4,509 | | | |
| A14.3.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 29 | hrs | C.1.14 | 175.7 | $269.89 | $7,903.93 | $167.56 | $4,907 | $20.53 | 626 | $601.18 | $0.00 | $0.00 | $457.98 | $13,412 | | | |
| A14.3.2.1 | | Prepare for demolition | Reagents: Load for transport | 25 | hrs | C.1.22 | 99.3 | $159.30 | $3,955.90 | $95.83 | $2,380 | $26.93 | 697 | $668.71 | $0.00 | $0.00 | $282.05 | $7,004 | | | |
| A14.3.2.2 | | | Reagents: Transport to Whitehorse | 2.2 | trips | C.7.04 | 18.0 | $351.24 | $789.50 | $303.64 | $682 | $113.33 | 265 | $254.73 | $0.00 | $0.00 | $768.21 | $1,727 | | | |
| A14.3.2.3 | | | Reagents: Disposal and tipping fees | 1.0 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.3.3.1 | | Demolition | Structural building demolition | 163 | tonnes | C.1.05 | 325.0 | $69.36 | $11,272.12 | $139.08 | $22,604 | $33.84 | 5,729 | $5,499.69 | $0.00 | $0.00 | $242.28 | $39,376 | | | |
| A14.3.3.2 | | | Other demolition: miscellaneous | 15 | m3 | C.1.07 | 1.5 | $3.74 | $56.09 | $2.07 | $31 | $0.74 | 12 | $11.05 | $0.00 | $0.00 | $6.55 | $98 | | | |
| A14.3.4.1 | | Waste disposal | Off-site disposal (re-usable equipment, etc.) | 3 | trips | C.7.07 | 27.1 | $355.10 | $1,202.32 | $423.68 | $1,435 | $113.33 | 400 | $383.71 | $0.00 | $0.00 | $892 | $3,021 | | | |
| **Subtotal Direct Costs - Active Closure** | | | | | | | **125,316** | | **$5,342,835** | | **$9,935,632** | | | **$3,059,285** | | **$1,093,950** | | | | **$19,431,701** | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Peak Liability Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| **INDIRECT COSTS** | | | | | | | | | | | | | | | | | | | | | |
| **B1** | **Mobilization-Demobilization** | | | | | | | | | | | | | | | | | | | **$324,077** | |
| B1.1 | | Mobilization | Year 0 | 1 | LS | | | | | | | | | | | | $162,039 | $162,038.53 | | | |
| B1.2 | | Demobilization | Year 3 (end of Active Closure) | 1 | LS | | | | | | | | | | | | $144,406 | $144,405.50 | | | |
| B1.4 | | Demobilization | End of Passive closure | 1 | LS | | | | | | | | | | | | $17,633 | $17,633.03 | | | |
| **B2** | **Transportation Costs** | | | | | | | | | | | | | | | | | | | **$419,142** | |
| B2.1.1 | | Barge Operations | | 15 | month | | | | | | | | | | | | $10,832 | $162,486 | | | |
| | | Staffing Bus trips during barge operation period | | 60 | ea (one per week) | | | | | | | | | | | | $678 | $40,656 | | | Turnaround labour costs included in labour build-up |
| B2.2.2 | | Air transport and airstrip operations | | 72 | flights | | | | | | | | | | | | $3,000 | $216,000 | | | Three flights per week |
| **B3** | **Site/Road Maintenance** | | | | | | | | | | | | | | | | | | | **$791,662** | |
| B3.1 | *Road Maintenance* | | | | | | | | | | | | | | | | | | $727,887 | | |
| B3.1.1 | | Water Truck | Assume needed 150 hrs per month | 21 | month | | | | | | | | | | | | $12,153 | $255,205 | | | |
| B3.1.2 | | Grader | Assume needed 150 hrs per month (16H + Operator) | 21 | month | | | | | | | | | | | | $22,509 | $472,682 | | | Includes Main Access Road throughout closure period. |
| B3.2 | *Soil Erosion* | | | | | | | | | | | | | | | | | | $63,775 | | |
| B3.2.1 | | Erosion control allowance | Silt fencing: supply, install remove at strategic locations | 7024 | m | C.2.17 | 283.5 | $3.23 | $22,661.96 | $1.93 | $13,533 | $0.68 | 4,941 | $4,743.08 | $0.92 | $6,485.58 | $6.75 | $47,424 | | | |
| B3.2.2 | | | Supply and install erosion control matting | 10000 | m2 | C.2.09 | 175.4 | $0.66 | $6,622.75 | $0.09 | $912 | $0.05 | 548 | $526.32 | $0.83 | $8,290.76 | $1.64 | $16,352 | | | |
| **B4** | **Construction Support** | | | | | | | | | | | | | | | | | | | **$5,344,480** | |
| B4.1 | *Field Support Staff* | | | | | | | | | | | | | | | | | | $3,235,218 | | Turnaround labour costs included in labour build-up |
| B4.1.1 | | Mine Manager | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $23,408 | $491,578 | | | |
| B4.1.2 | | Office/Camp manager | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $22,267 | $467,614 | | | |
| B4.1.3 | | Security/Administrative Assistant | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $16,600 | $348,591 | | | |
| B4.1.4 | | Foreman | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $373,152 | | | |
| B4.1.5 | | Mechanic | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $373,152 | | | |
| B4.1.6 | | Surveyor | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $373,152 | | | |
| B4.1.7 | | Engineering technician | Material & QA/QC testing | 10.5 | month | | | ( 360 ) site working hours per month | | | | | | | | | $42,120 | $442,260 | | | Assumed needed 1/2 of time |
| B4.1.8 | | Medic/H&S supervisor | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,415 | $365,718 | | | |
| B4.2 | *Field support Vehicles* | | | | | | | | | | | | | | | | | | $862,785 | | |
| B4.2.1 | | Pick-up trucks (4 required) | | 84 | month | | | | | | | | | | | | $4,446 | $373,452 | | | |
| B4.2.2 | | Fuel truck | | 21 | month | | | | | | | | | | | | $4,720 | $99,123 | | | |
| B4.2.3 | | Mechanic service vehicle | | 21 | month | | | | | | | | | | | | $11,803 | $247,873 | | | |
| B4.2.4 | | Emergency transport vehicle | | 21 | month | | | | | | | | | | | | $4,519 | $94,901 | | | |
| B4.2.5 | | Passenger bus | | 21 | month | | | | | | | | | | | | $2,259 | $47,436 | | | |
| B4.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | | | | | $1,246,477 | | |
| B4.3.1 | | Light Towers | | 21 | month | | | 2 # of Units | | | | | | | | | $3,356 | $70,476 | | | |
| B4.3.2 | | Material/Laboratory testing allowance | | 21 | month | | | | | | | | | | | | $1,000 | $21,000 | | | |
| B4.4 | | Construction, Environmental, and H&S Management Plans | | 1 | LS | | | | | | | | | | | | $25,000 | $25,000 | | | |
| B4.5 | | Office supplies | | 21 | month | | | | | | | | | | | | $1,000 | $21,000 | | | |
| B4.6 | | Communications | | 21 | month | | | | | | | | | | | | $1,000 | $21,000 | | | |
| B4.7 | | Misc. supplies | | 21 | month | | | | | | | | | | | | $500 | $10,500 | | | |
| B4.8 | | Camp costs | Includes catering and housekeeping | 12,532 | man-day | | | | | | | | | | | | $80 | $1,002,531 | | | |
| B4.9 | | Power and heat | | 21 | month | | | | | | | | | | | | $3,570 | $74,970 | | | |
| **B5** | **QA and Project Management** | | | | | | | | | | | | | | | | | | | **$1,752,126** | |
| B5.1 | | Project Manager | | 21 | month | | | ( 160 ) site working hours per month | | | | | | | | | $9,897 | $207,828 | | | |
| B5.2 | | Design Engineer | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $48,600 | $1,020,600 | | | |
| B5.3 | | Environmental Monitor | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $16,046 | $336,972 | | | |
| B5.4 | | Engineering , Design, and Construction plans (included in Planning and Permitting Costs) | | | | | | | | | | | | | | | $0.00 | $0 | | | |
| B5.5 | | Field support vehicles (2 vehicles) | | 42 | month | | | | | | | | | | | | $4,446 | $186,726 | | | |
| **Subtotal Indirect Costs - Active Closure** | | | | | | | | | | | | | | | | | | | | **$8,631,488** | |
| **CLOSURE IMPLEMENTATION COSTS - TOTAL** | | | | | | | | | | | | | | | | | | | | **$28,063,189** | |

# Worksheet 10 - Peak Liability Estimate - Schedule Details

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## A: Year 0 Site Access Schedule

| Stage | Flight Months | Helicopter Months | Barge Months | Total Months | Month | | | | | | | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| Interim Care | 2 | 5 | 5 | 12 | H | H | H | F | F | B | B | B | B | B | H | H | |
| **SUB-TOTAL INTERIM CARE** | **2** | **5** | **5** | **12** | | | | | | | | | | | | | |
| Active Closure 1 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| Active Closure 2 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| Active Closure 3 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| **SUB-TOTAL ACTIVE CLOSURE** | **6** | **0** | **15** | **21** | | | | | | | | | | | | | |
| Post-Closure 1 | 2 | 0 | 3 | 5 | | | | F | F | B | B | B | | | | | |
| **SUB-TOTAL POST-CLOSURE 1** | **2** | **0** | **3** | **5** | | | | | | | | | | | | | |
| Post-Closure 2 | 0 | 0 | 1 | 1 | | | | | | B | | | | | | | |
| **SUB-TOTAL POST-CLOSURE 2** | **0** | **0** | **1** | **1** | | | | | | | | | | | | | |

## B: Annual C&M Staffing Schedule - Interim Operations

| # | Role | | Months Required | Month | | | | | | | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| **Months Active at Site** | | | **12** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 4 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 2 | Office/Camp Mgr | | 6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 3 | Payroll/Accounting/HR | | 4 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Warehouse/Water Treatment Operator | | 5 | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | | | |
| 2 | Environmental Manager | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 3 | Environmental Technician | | 7 | 0.5 | 0.5 | 0.5 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 10 | | | | | | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | | | |
| 5 | Equipment operators | | 13 | | | | 2.0 | 3.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | | | |
| 6 | HD Mechanic | | 2 | | | | 0.5 | 0.3 | 0.3 | 0.3 | 0.25 | 0.25 | 0.25 | | | |
| 7 | Tradesmen | | 2 | | | | 0.5 | 0.3 | 0.3 | 0.3 | 0.25 | 0.25 | 0.5 | | | |
| 8 | Labour/Helpers | | 10 | 1 | 1 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | 1.0 | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 2 | | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.0 | | |
| **TOTAL** | | | **66.5** | **2.0** | **2.0** | **2.0** | **8.8** | **8.3** | **8.3** | **8.3** | **8.3** | **7.3** | **7.5** | **2.0** | **2.0** | |
| | | **Annual man-days:** | **1,995** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## C: Annual C&M Staffing Schedule - During Active Phase

| # | Role | | Months Required | Month | | | | | | | | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| **Months Active at Site** | | | **7** | | | | **1** | **1** | **1** | **1** | **1** | **1** | **1** | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Warehouse/Water Treatment Operator | | 5 | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | | | |
| 2 | Environmental Manager | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 3 | Environmental Technician | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| **TOTAL** | | | **13** | **0** | **0** | **0** | **3** | **2** | **2** | **2** | **2** | **1** | **1** | **0** | **0** | |
| | | **Annual man-days:** | **390** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)

## D: Annual C&M Staffing Schedule - Post Closure 1

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **5** | | | | **1** | **1** | **1** | **1** | **1** | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 2 | Office/Camp Mgr | | 3 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 3 | Payroll/Accounting/HR | | 1 | | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Operator | | 2 | | | | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | | | | | |
| 2 | Environmental Manager | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 3 | Environmental Technician | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 6 | | | | | | 2.0 | 2.0 | 2.0 | | | | | |
| 5 | Equipment operators | | 10 | | | | 2.0 | 3.0 | 1.5 | 1.5 | 1.5 | | | | | |
| 6 | HD Mechanic | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| 7 | Tradesmen | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| 8 | Labour/Helpers | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.5 | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 1 | | | | 0.25 | | | | 0.25 | | | | | |
| **TOTAL** | | | **36** | **0** | **0** | **0** | **9** | **7** | **7** | **7** | **7** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **1,073** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## E: Annual C&M Staffing Schedule - Post Closure 2

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **1** | | | | | | **1** | | | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 1 | | | | | | 0.5 | | | | | | | |
| 2 | Office/Camp Mgr | | 0 | | | | | | 0.0 | | | | | | | |
| 3 | Payroll/Accounting/HR | | 0 | | | | | | 0.00 | | | | | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Passive Treatment Scientist | | 1 | | | | | | 0.5 | | | | | | | |
| 2 | Environmental Manager | | 0 | | | | | | | | | | | | | |
| 3 | Environmental Technician | | 0 | | | | | | | | | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 1 | | | | | | 1.0 | | | | | | | |
| 5 | Equipment operators | | 1 | | | | | | 1.0 | | | | | | | |
| 6 | HD Mechanic | | 1 | | | | | | 0.50 | | | | | | | |
| 7 | Tradesmen | | 0 | | | | | | | | | | | | | |
| 8 | Labour/Helpers | | 0 | | | | | | 0.25 | | | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | | | 0.0 | | | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 0 | | | | | | 0.25 | | | | | | | |
| **TOTAL** | | | **4** | **0** | **0** | **0** | **0** | **0** | **4** | **0** | **0** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **120** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## E: Annual C&M Staffing Schedule - Long-term perpetual maintenance year

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **1** | | | | | | | **1** | | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Project Manager/Foreman | | 1 | | | | | | | 1.0 | | | | | | |
| **Water Treatment/Engineering Staffing** | | | | | | | | | | | | | | | | |
| 1 | Passive Treatment Scientist | | 1 | | | | | | | 1.0 | | | | | | |
| 2 | Site Engineer | | 1 | | | | | | | 1.0 | | | | | | |
| 3 | Environmental Technician | | 0 | | | | | | | | | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 1 | | | | | | | 1.0 | | | | | | Assumed required 1/2 the time (near mob and demob) |
| 5 | Equipment operators | | 4 | | | | | | | 4.0 | | | | | | |
| 6 | HD Mechanic | | 1 | | | | | | | 0.50 | | | | | | |
| 7 | Tradesmen | | 0 | | | | | | | | | | | | | |
| 8 | Labour/Helpers | | 1 | | | | | | | 1.00 | | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | | | | | | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 1 | | | | | | | 0.50 | | | | | | |
| **TOTAL** | | | **10** | **0** | **0** | **0** | **0** | **0** | **0** | **10** | **0** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **300** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

# Worksheet 11- Peak Liability Estimate - Planning and Permitting Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## Planning And Permitting

| WBS | Facility/Area | Task | Activity | Qnty | Unit | Total Unit Rate ($/unit) | Activity Total | Subtotal | Source / Comments |
|---|---|---|---|---|---|---|---|---|---|
| M1 | **Planning and Permitting** | | | | | | | | |
| M1.1 | *Reclamation Research/Planning* | | | | | | | $400,000 | |
| M1.1.1 | | Complete reclamation closure and research plan | | 2 | yr | $200,000 | $400,000 | | |
| M1.2 | *Technical studies and investigations* | | | | | | | $58,500 | |
| M1.2.1 | | Allowance for additional technical studies | | 1 | ls | $58,500 | $58,500 | | |
| M1.3 | *Monitoring and Management Plans* | | | | | | | $209,158 | |
| M1.3.1 | | Adaptive Mgmt Plans | Physcial, water quality, etc | 1 | ls | $15,000 | $15,000 | | |
| M1.3.2 | | Revegetation plan | | 1 | ls | $30,000 | $30,000 | | |
| M1.3.3 | | Waste Management Plan | Water treatment, sludge, landfarm, etc. | 1 | ls | $50,000 | $50,000 | | |
| M1.3.4 | | MMER Final Monitoring Study | | 1 | ls | $114,158 | $114,158 | | |
| M1.4 | *Engineering, Design, and Construction Plans* | | | | | | | $971,585 | |
| M1.4.1 | | Percentage of direct implementation costs | | 5% | of | $19,431,701 | $971,585 | | |
| M1.5 | *Permitting* | | | | | | | $0 | |
| M1.5.1.1 | | Permit Staffing | Permitting Manager | 0 | ls | $0 | $0 | | Staffing costs included in tasks above |
| M1.5.1.2 | | | Environmental Manager | 0 | ls | $0 | $0 | | |
| M1.5.1.3 | | | Technical Consultants | 0 | ls | $0 | $0 | | |
| **TOTAL** | | | | | | | | **$1,639,243** | |

# Worksheet 12 - End-of-Mine Liability Estimate - Cashflow Calculations

Project: Minto Mine Closure Cost Estimate - RCP 2018-01
Project No.: 1CM002.045
Client: Minto Explorations Ltd.
Date: February 6, 2018
File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## NPV CALCULATION INPUTS

**NOTE: Columns between Years 2049 and 2128 are hidden for printing purposes.**

**Input Parameters**

| | | |
|---|---|---|
| Scenario: | EOM - 2022 | |
| Current Year: | 2018 | Year that the estimate is costed |
| Closure Year 1: | 2022 | |
| Closure Period: | 3 | yrs |
| Post-Closure Year 1: | 2025 | |

**Short-Term Interest Rate (Interim Care/Implementation Costs)**

| ## | Inflation Rate | Years in effect | Start Year | End Year |
|---|---|---|---|---|
| 1 | 2.0% | 100 | 2018 | 2118 |

**Long-Term Monitoring/Maintenance NPV Discount Rates**

| ## | Discount Rate | Years in effect | Start Year | End Year |
|---|---|---|---|---|
| 1 | 2.35% | 2 | 2018 | 2020 |
| 2 | 2.5% | 3 | 2021 | 2024 |
| 3 | 2.8% | - | 2025 | |

## SCHEDULE

**Implementation Schedule**

| | Area | Closure Year: | OPERATIONS | | | | CLOSURE | | | POST CLOSURE | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 27 | Year 28 | Year 107 | Year 108 |
| | | Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
| Direct Costs | Waste Dumps | 100% | | | | | 40% | 60% | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Overburden Dumps | 100% | | | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ore Stockpiles | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Open Pits | 100% | | | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Underground Openings | 100% | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | External Tailings Facilities | 100% | | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Roads | 100% | | | | | | | 100% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Demolition | 100% | | | | | 10% | 75% | 15% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Surface Infrastructure | 100% | | | | | 25% | 50% | 25% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water Detention Structures | 100% | | | | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Yards/Laydown Areas | 100% | | | | | 25% | 25% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Waste Disposal | 100% | | | | | | 12% | 75% | 2% | 2% | 2% | 6% | | | | | | | | | | | | | | | | | | | | | | | |
| | Surface Water Conveyance | 100% | | | | | 20% | 30% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Water Treatment | 100% | | | | | | | 86% | | | | | 14% | | | | | | | | | | | | | | | | | | | | | | |
| Indirect | Mobilization-Demobilization | 100% | | | | | 50% | | 45% | | | | | 5% | | | | | | | | | | | | | | | | | | | | | | |
| | Transport Costs | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Road Maintenance | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Construction Support | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | QA and Pro. Mgmt. | 100% | | | | | 34% | 33% | 33% | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Monitoring Schedule**

| | | | Set Monitoring/C&M Stage: | | | | 2 - Active | 2 - Active | 2 - Active | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 3 - PC 1 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | 4 - PC 2 | | | | | | | | | 5 - Perpetual | | 5 - Perpetual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Post-Closure Year: | Year -7 | Year -6 | Year -5 | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 104 | Year 105 |
| | | Sum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Planning and permitting | Reclamation Research and Planning | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Technical Studies and Investigations | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Engineering, Design, and Construction Plans | 100% | | | 30% | 40% | 10% | 10% | 10% | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Monitoring and Management Plans | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Permitting | 100% | | | 50% | 50% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monitoring | Water Quality Monitoring (surface and groundwater) | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | 1 | | 1 |
| | Sediment Monitoring | | | | | | 1 | 1 | 1 | 1 | | 1 | | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | 1 | | 1 |
| | Biological Monitoring | | | | | | 1 | 1 | 1 | 1 | | 1 | | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | 1 | | 1 |
| | Geotechnical Monitoring | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | 1 | | 1 |
| | Revegetation Monitoring | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | 1 | | 1 |
| | Annual Inspection Reporting | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | | 1 | | | | | | | | | | 1 | | 1 |

**Care and Maintenance Schedule**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Treatment/Management | Active System | | | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | | | | | | | | | | | |
| | Passive System | | | | | | | | | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | | x |
| Reclamation Maintenance | Revegetation, cover repair, etc. | | | | | | | | | x | x | x | x | x | | | | | x | | | | | | | | | | | | | | x | | x |
| Site Maintenance | | | | | | | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | | x |
| On-site Management | | | | | | | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | | x |
| Transportation Costs | | | | | | | x | x | x | x | x | x | x | x | | | | | x | | | | | x | | | | | | | | | | x | | x |

## UNDISCOUNTED CASH FLOW (TO 100 YEARS POST CLOSURE)

**Implementation Costs**

| | Area | | Total | % of Total | Check Sum | Year -4 | Year -3 | Year -2 | Year -1 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 | Year 26 | Year 27 | Year 28 | Year 107 | Year 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
| Direct Costs | Waste Dumps | | $6,987,586 | 27% | $6,987,586 | $0 | $0 | $0 | $0 | $2,795,034 | $4,192,552 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Overburden Dumps | | $395,276 | 2% | $395,276 | $0 | $0 | $0 | $0 | $0 | $0 | $395,276 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Ore Stockpiles | | $794,200 | 3% | $794,200 | $0 | $0 | $0 | $0 | $794,200 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Open Pits | | $620,582 | 2% | $620,582 | $0 | $0 | $0 | $0 | $0 | $310,291 | $310,291 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Underground Openings | | $81,637 | 0% | $81,637 | $0 | $0 | $0 | $0 | $81,637 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | External Tailings Facilities | | $57,291 | 0% | $57,291 | $0 | $0 | $0 | $0 | $28,646 | $28,646 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Roads | | $136,050 | 1% | $136,050 | $0 | $0 | $0 | $0 | $0 | $0 | $136,050 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Demolition | | $1,976,253 | 8% | $1,976,253 | $0 | $0 | $0 | $0 | $197,625 | $1,482,189 | $296,438 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Infrastructure | | $169,527 | 1% | $169,527 | $0 | $0 | $0 | $0 | $42,382 | $84,763 | $42,382 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Detention Structures | | $786,952 | 3% | $786,952 | $0 | $0 | $0 | $0 | $0 | $393,476 | $393,476 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Yards/Laydown Areas | | $758,907 | 3% | $758,907 | $0 | $0 | $0 | $0 | $189,727 | $189,727 | $379,454 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Waste Disposal | | $452,923 | 2% | $452,923 | $0 | $0 | $0 | $0 | $0 | $54,828 | $339,692 | $11,145 | $11,145 | $11,145 | $24,967 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Water Conveyance | | $3,287,496 | 13% | $3,287,496 | $0 | $0 | $0 | $0 | $657,499 | $986,249 | $1,643,748 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Treatment | | $483,085 | 2% | $483,085 | $0 | $0 | $0 | $0 | $0 | $0 | $413,938 | $0 | $0 | $0 | $0 | $69,147 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect | Mobilization-Demobilization | | $324,077 | 1% | $324,077 | $0 | $0 | $0 | $0 | $162,039 | $0 | $144,406 | $0 | $0 | $0 | $0 | $17,633 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Transport Costs | | $419,142 | 2% | $419,142 | $0 | $0 | $0 | $0 | $142,508 | $138,317 | $138,317 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Site/Road Maintenance | | $791,662 | 3% | $791,662 | $0 | $0 | $0 | $0 | $269,165 | $261,249 | $261,249 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Construction Support | | $5,263,751 | 21% | $5,263,751 | $0 | $0 | $0 | $0 | $1,789,675 | $1,737,038 | $1,737,038 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | QA and Pro. Mgmt. | | $1,752,126 | 7% | $1,752,126 | $0 | $0 | $0 | $0 | $595,723 | $578,202 | $578,202 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Subtotal - Closure Implementation Costs** | | | **$25,538,523** | | $25,538,523 | **$0** | **$0** | **$0** | **$0** | **$7,745,860** | **$10,437,526** | **$7,209,955** | **$11,145** | **$11,145** | **$11,145** | **$24,967** | **$86,780** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

**Monitoring Costs**

| | | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Planning and | Reclamation Research and Planning | | $200,000 | 6% | $200,000 | $0 | $0 | $100,000 | $100,000 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | Permitting | Technical Studies and Investigations | | $58,500 | 2% | $58,500 | $0 | $0 | $29,250 | $29,250 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Engineering, Design, and Construction Plans | | $849,388 | 24% | $849,388 | $0 | $0 | $254,816 | $339,755 | $84,939 | $84,939 | $84,939 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Monitoring and Management Plans | | $209,158 | 6% | $209,158 | $0 | $0 | $104,579 | $104,579 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Permitting | | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 1 | Monitoring | Water Quality Monitoring | | $1,172,423 | 33% | $1,172,423 | $0 | $0 | $0 | $0 | $130,437 | $130,437 | $130,437 | $51,987 | $51,987 | $51,987 | $51,987 | $51,987 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $27,220 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $27,664 | $0 | $27,664 |
| 2 | | Sediment Monitoring | | $57,596 | 2% | $57,596 | $0 | $0 | $0 | $0 | $3,388 | $3,388 | $3,388 | $3,388 | $0 | $3,388 | $0 | $3,388 | $0 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $0 | $3,388 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $3,388 | $0 | $3,388 |
| 3 | | Biological Monitoring | | $208,999 | 6% | $208,999 | $0 | $0 | $0 | $0 | $12,294 | $12,294 | $12,294 | $12,294 | $0 | $12,294 | $0 | $12,294 | $0 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $0 | $12,294 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $12,294 | $0 | $12,294 |
| 4 | | Geotechnical Monitoring | | $354,653 | 10% | $354,653 | $0 | $0 | $0 | $0 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $12,409 | $0 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $0 | $23,216 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,216 | $0 | $23,216 |
| 5 | | Revegetation Monitoring | | $200,071 | 6% | $200,071 | $0 | $0 | $0 | $0 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $10,530 | $0 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $0 | $10,530 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,530 | $0 | $10,530 |
| 6 | | Annual Inspection Reporting | | $281,876 | 8% | $281,876 | $0 | $0 | $0 | $0 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $2,372 | $0 | $0 | $0 | $0 | $23,900 | $0 | $0 | $0 | $0 | $23,900 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $23,900 | $0 | $23,900 |
| **Post Closure Costs Subtotal** | | | | **$3,592,664** | | $3,592,664 | **$0** | **$0** | **$488,645** | **$573,584** | **$256,369** | **$256,369** | **$256,369** | **$92,981** | **$77,299** | **$92,981** | **$77,299** | **$92,981** | **$27,220** | **$27,220** | **$27,220** | **$27,220** | **$100,548** | **$27,220** | **$27,220** | **$27,220** | **$27,220** | **$100,548** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$100,993** | **$0** | **$100,993** |

**Care and Maintenance Costs**

| | | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | | $6,567,079 | 39% | $6,567,079 | $0 | $0 | $0 | $0 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $706,967 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $91,135 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | | $560,239 | 3% | $560,239 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $35,015 | $35,015 | $35,015 | $35,015 | $35,015 | $0 | $0 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $0 | $35,015 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $35,015 | $0 | $35,015 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | | $1,386,205 | 8% | $1,386,205 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $277,241 | $277,241 | $277,241 | $277,241 | $277,241 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | | $1,760,177 | 10% | $1,760,177 | $0 | $0 | $0 | $0 | $30,000 | $30,000 | $30,000 | $99,414 | $99,414 | $99,414 | $99,414 | $99,414 | $0 | $0 | $0 | $0 | $99,414 | $0 | $0 | $0 | $0 | $99,414 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $108,253 | $0 | $108,253 |
| 5 | On-site Management | | | $5,728,488 | 34% | $5,728,488 | $0 | $0 | $0 | $0 | $310,135 | $310,135 | $310,135 | $606,140 | $606,140 | $606,140 | $606,140 | $606,140 | $0 | $0 | $0 | $0 | $79,830 | $0 | $0 | $0 | $0 | $79,830 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $178,636 | $0 | $178,636 |
| 6 | Transportation Costs | | | $994,297 | 6% | $994,297 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $64,628 | $64,628 | $64,628 | $64,628 | $64,628 | $0 | $0 | $0 | $0 | $20,832 | $0 | $0 | $0 | $0 | $20,832 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $69,943 | $0 | $69,943 |
| **Post Closure Costs Subtotal** | | | | **$16,996,485** | | $16,996,485 | **$0** | **$0** | **$0** | **$0** | **$1,047,102** | **$1,047,102** | **$1,047,102** | **$1,789,405** | **$1,789,405** | **$1,789,405** | **$1,789,405** | **$1,789,405** | **$91,135** | **$91,135** | **$91,135** | **$91,135** | **$326,226** | **$91,135** | **$91,135** | **$91,135** | **$91,135** | **$326,226** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$391,847** | **$0** | **$391,847** |

**Other Add-on Costs**

| | | | | Total | % of Total | Check Sum | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | | $5,535,321 | | $5,535,321 | $0 | $0 | $58,637 | $68,830 | $1,085,920 | $1,408,920 | $1,021,611 | $227,224 | $225,342 | $227,224 | $227,000 | $236,300 | $14,203 | $14,203 | $14,203 | $14,203 | $51,213 | $14,203 | $14,203 | $14,203 | $14,203 | $51,213 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $59,141 | $0 | $59,141 |
| 2 | Worker's compensation | 0% (Included in labour rates) | | $0 | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 1.5% % of above labour costs | | $199,509 | | $199,509 | $0 | $0 | $2,113 | $2,481 | $39,140 | $50,782 | $36,822 | $8,190 | $8,122 | $8,190 | $8,182 | $8,517 | $512 | $512 | $512 | $512 | $1,846 | $512 | $512 | $512 | $512 | $1,846 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $2,132 | $0 | $2,132 |
| 4 | Bonding | 3% % of Implem. & C&M costs | | $1,276,050 | | $1,276,050 | $0.00 | $0.00 | $0.00 | $0 | $263,789 | $344,539 | $247,712 | $54,017 | $54,017 | $54,017 | $54,431 | $56,286 | $2,734 | $2,734 | $2,734 | $2,734 | $9,787 | $2,734 | $2,734 | $2,734 | $2,734 | $9,787 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $11,755 | $0 | $11,755 |
| 5 | Contractor Profit | 10% % of above costs | | $4,612,767 | | $4,612,767 | $0 | $0 | $48,865 | $57,358 | $904,933 | $1,174,100 | $851,343 | $189,353 | $187,785 | $189,353 | $189,167 | $196,917 | $11,835 | $11,835 | $11,835 | $11,835 | $42,677 | $11,835 | $11,835 | $11,835 | $11,835 | $42,677 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $49,284 | $0 | $49,284 |
| 6 | Contract Administration | 5% % of above costs | | $2,306,384 | | $2,306,384 | $0 | $0 | $24,432 | $28,679 | $452,467 | $587,050 | $425,671 | $94,677 | $93,892 | $94,677 | $94,584 | $98,458 | $5,918 | $5,918 | $5,918 | $5,918 | $21,339 | $5,918 | $5,918 | $5,918 | $5,918 | $21,339 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $24,642 | $0 | $24,642 |
| **Other Add-On Costs Subtotal** | | | | **$13,930,031** | | $13,930,031 | **$0** | **$0** | **$134,048** | **$157,349** | **$2,746,248** | **$3,565,390** | **$2,583,159** | **$573,460** | **$569,158** | **$573,460** | **$573,364** | **$596,477** | **$35,202** | **$35,202** | **$35,202** | **$35,202** | **$126,862** | **$35,202** | **$35,202** | **$35,202** | **$35,202** | **$126,862** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$146,954** | **$0** | **$146,954** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** | | | **$60,057,703** | | **$60,057,703** | **$0** | **$0** | **$622,693** | **$730,933** | **$11,795,580** | **$15,306,387** | **$11,096,585** | **$2,466,991** | **$2,447,007** | **$2,466,991** | **$2,465,034** | **$2,565,643** | **$153,556** | **$153,556** | **$153,556** | **$153,556** | **$553,635** | **$153,556** | **$153,556** | **$153,556** | **$153,556** | **$553,635** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$639,794** | **$0** | **$639,794** |

## INFLATION FACTORED INTERIM CARE AND CLOSURE IMPLEMENTATION COSTS

| | Area | Present Value | % of Total | Future Value | Year -4 2018 | Year -3 2019 | Year -2 2020 | Year -1 2021 | Year 1 2022 | Year 2 2023 | Year 3 2024 | Year 4 2025 | Year 5 2026 | Year 6 2027 | Year 7 2028 | Year 8 2029 | Year 9 2030 | Year 10 2031 | Year 11 2032 | Year 12 2033 | Year 13 2034 | Year 14 2035 | Year 15 2036 | Year 16 2037 | Year 17 2038 | Year 18 2039 | Year 19 2040 | Year 20 2041 | Year 21 2042 | Year 22 2043 | Year 23 2044 | Year 24 2045 | Year 25 2046 | Year 26 2047 | Year 27 2048 | Year 28 2049 | Year 107 2128 | Year 108 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direct Costs | Waste Dumps | $6,987,586 | 27% | $7,654,351 | $0 | $0 | $0 | $0 | $3,025,435 | $4,628,916 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Overburden Dumps | $395,276 | 2% | $445,145 | $0 | $0 | $0 | $0 | $0 | $0 | $445,145 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Ore Stockpiles | $794,200 | 3% | $859,667 | $0 | $0 | $0 | $0 | $859,667 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Open Pits | $620,582 | 2% | $692,025 | $0 | $0 | $0 | $0 | $0 | $342,587 | $349,438 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Underground Openings | $81,637 | 0% | $88,367 | $0 | $0 | $0 | $0 | $88,367 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | External Tailings Facilities | $57,291 | 0% | $62,634 | $0 | $0 | $0 | $0 | $31,007 | $31,627 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Roads | $136,050 | 1% | $153,214 | $0 | $0 | $0 | $0 | $0 | $0 | $153,214 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Demolition | $1,976,253 | 8% | $2,184,210 | $0 | $0 | $0 | $0 | $213,916 | $1,636,457 | $333,837 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Infrastructure | $169,527 | 1% | $187,190 | $0 | $0 | $0 | $0 | $45,875 | $93,586 | $47,729 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Detention Structures | $786,952 | 3% | $877,547 | $0 | $0 | $0 | $0 | $0 | $434,429 | $443,118 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Yards/Laydown Areas | $758,907 | 3% | $842,166 | $0 | $0 | $0 | $0 | $205,366 | $209,474 | $427,326 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Waste Disposal | $452,923 | 2% | $512,699 | $0 | $0 | $0 | $0 | $0 | $60,535 | $382,549 | $12,802 | $13,058 | $13,320 | $30,434 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Surface Water Conveyance | $3,287,496 | 13% | $3,651,724 | $0 | $0 | $0 | $0 | $711,698 | $1,088,898 | $1,851,127 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Water Treatment | $483,085 | 2% | $552,137 | $0 | $0 | $0 | $0 | $0 | $0 | $466,161 | $0 | $0 | $0 | $0 | $85,976 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Indirect | Mobilization-Demobilization | $324,077 | 1% | $359,944 | $0 | $0 | $0 | $0 | $175,396 | $0 | $162,624 | $0 | $0 | $0 | $0 | $21,924 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Transport Costs | $419,142 | 2% | $462,736 | $0 | $0 | $0 | $0 | $154,256 | $152,713 | $155,767 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Road Maintenance | $791,662 | 3% | $874,001 | $0 | $0 | $0 | $0 | $291,353 | $288,440 | $294,208 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | Construction Support | $5,263,751 | 21% | $5,811,219 | $0 | $0 | $0 | $0 | $1,937,202 | $1,917,830 | $1,956,187 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| | QA and Pro. Mgmt. | $1,752,126 | 7% | $1,934,360 | $0 | $0 | $0 | $0 | $644,830 | $638,381 | $651,149 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Subtotal - Closure Implementation Costs** | | **$25,538,523** | | **$28,205,335** | **$0** | **$0** | **$0** | **$0** | **$8,384,368** | **$11,523,872** | **$8,119,580** | **$12,802** | **$13,058** | **$13,320** | **$30,434** | **$107,900** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Monitoring Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Planning and permitting | Reclamation Research and Planning | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Technical Studies and Investigations | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Engineering, Design, and Construction Plans | $254,816 | 7% | $281,375 | $0 | $0 | $0 | $0 | $91,941 | $93,779 | $95,655 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Monitoring and Management Plans | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Permitting | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 1 | Monitoring | Water Quality Monitoring | $391,312 | 11% | $432,097 | $0 | $0 | $0 | $0 | $141,190 | $144,014 | $146,894 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Sediment Monitoring | $10,164 | 0% | $11,223 | $0 | $0 | $0 | $0 | $3,667 | $3,741 | $3,815 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | | Biological Monitoring | $36,882 | 1% | $40,726 | $0 | $0 | $0 | $0 | $13,307 | $13,574 | $13,845 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | | Geotechnical Monitoring | $37,227 | 1% | $41,107 | $0 | $0 | $0 | $0 | $13,432 | $13,701 | $13,975 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | | Revegetation Monitoring | $31,590 | 1% | $34,883 | $0 | $0 | $0 | $0 | $11,398 | $11,626 | $11,859 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | | Annual Inspection Reporting | $7,116 | 0% | $7,858 | $0 | $0 | $0 | $0 | $2,568 | $2,619 | $2,671 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Post Closure Costs Subtotal** | | | **$769,108** | | **$849,269** | **$0** | **$0** | **$0** | **$0** | **$277,503** | **$283,053** | **$288,714** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Care and Maintenance Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $2,120,900 | 12% | $2,341,951 | $0 | $0 | $0 | $0 | $765,243 | $780,548 | $796,159 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $90,000 | 1% | $99,380 | $0 | $0 | $0 | $0 | $32,473 | $33,122 | $33,785 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | On-site Management | | $930,406 | 5% | $1,027,378 | $0 | $0 | $0 | $0 | $335,701 | $342,415 | $349,263 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | Transportation Costs | | $0 | 0% | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Post Closure Costs Subtotal** | | | **$3,141,306** | | $3,468,709 | **$0** | **$0** | **$0** | **$0** | **$1,133,417** | **$1,156,085** | **$1,179,207** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

### Other Add-on Costs

| | | | Present Value | % of Total | Future Value | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $3,516,451 | | $3,881,496 | $0 | $0 | $0 | $0 | $1,175,435 | $1,555,561 | $1,150,500 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 2% % of above labour costs | $126,743 | | $139,900 | $0 | $0 | $0 | $0 | $42,366 | $56,067 | $41,467 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $856,039 | | $944,896 | $0 | $0 | $0 | $0 | $285,534 | $380,399 | $278,964 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 5 | Contractor Profit | 10% % of above costs | $2,930,376 | | $3,234,580 | $0 | $0 | $0 | $0 | $979,529 | $1,296,301 | $958,750 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 6 | Contract Administration | 5% % of above costs | $1,465,188 | | $1,617,290 | $0 | $0 | $0 | $0 | $489,764 | $648,150 | $479,375 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Other Add-On Costs Subtotal** | | | **$8,894,796** | | $9,818,162 | **$0** | **$0** | **$0** | **$0** | **$2,972,627** | **$3,936,478** | **$2,909,056** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** | | | **$38,343,734** | | **$42,341,475** | **$0** | **$0** | **$0** | **$0** | **$12,767,915** | **$16,899,488** | **$12,496,557** | **$12,802** | **$13,058** | **$13,320** | **$30,434** | **$107,900** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |

## NET PRESENT VALUE CALCULATIONS - LONG TERM MONITORING AND MAINTENANCE

### Monitoring Costs

| | | | Undiscounted | % of Total | NPV - 2018 | Year -4 2018 | Year -3 2019 | Year -2 2020 | Year -1 2021 | Year 1 2022 | Year 2 2023 | Year 3 2024 | Year 4 2025 | Year 5 2026 | Year 6 2027 | Year 7 2028 | Year 8 2029 | Year 9 2030 | Year 10 2031 | Year 11 2032 | Year 12 2033 | Year 13 2034 | Year 14 2035 | Year 15 2036 | Year 16 2037 | Year 17 2038 | Year 18 2039 | Year 19 2040 | Year 20 2041 | Year 21 2042 | Year 22 2043 | Year 23 2044 | Year 24 2045 | Year 25 2046 | Year 26 2047 | Year 27 2048 | Year 28 2049 | Year 107 2128 | Year 108 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Monitoring | Water Quality Monitoring | $781,111 | 22% | $440,095 | | | | | | | | $44,829 | $43,608 | $42,420 | $41,265 | $40,141 | $20,444 | $19,888 | $19,346 | $18,819 | $18,306 | $17,808 | $17,323 | $16,851 | $16,392 | $15,945 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $12,295 | $0 | $1,350 |
| 2 | | Sediment Monitoring | $47,432 | 1% | $18,286 | | | | | | | | $2,921 | $0 | $2,765 | $0 | $2,616 | $0 | $0 | $0 | $0 | $2,279 | $0 | $0 | $0 | $0 | $1,985 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $1,506 | $0 | $165 |
| 3 | | Biological Monitoring | $172,117 | 5% | $66,354 | | | | | | | | $10,601 | $0 | $10,032 | $0 | $9,493 | $0 | $0 | $0 | $0 | $8,268 | $0 | $0 | $0 | $0 | $7,202 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $5,464 | $0 | $600 |
| 4 | | Geotechnical Monitoring | $317,426 | 9% | $119,080 | | | | | | | | $10,700 | $10,409 | $10,125 | $9,850 | $9,581 | $0 | $0 | $0 | $0 | $15,614 | $0 | $0 | $0 | $0 | $13,600 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,319 | $0 | $1,133 |
| 5 | | Revegetation Monitoring | $168,481 | 5% | $74,024 | | | | | | | | $9,080 | $8,833 | $8,592 | $8,358 | $8,131 | $0 | $0 | $0 | $0 | $7,082 | $0 | $0 | $0 | $0 | $6,169 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $4,680 | $0 | $514 |
| 6 | | Annual Inspection Reporting | $274,760 | 8% | $80,114 | | | | | | | | $2,045 | $1,990 | $1,935 | $1,883 | $1,831 | $0 | $0 | $0 | $0 | $16,074 | $0 | $0 | $0 | $0 | $14,001 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,622 | $0 | $1,166 |
| **Post Closure Costs Subtotal** | | | **$1,761,326** | | **$797,952** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$80,177** | **$64,839** | **$75,869** | **$61,355** | **$71,793** | **$20,444** | **$19,888** | **$19,346** | **$18,819** | **$67,623** | **$17,808** | **$17,323** | **$16,851** | **$16,392** | **$58,902** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$44,886** | **$0** | **$4,928** |

### Care and Maintenance Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Water Treatment | Active System | $4,446,180 | 26% | $3,492,933 | | | | | | | | $609,619 | $593,015 | $576,862 | $561,150 | $545,866 | $68,451 | $66,586 | $64,773 | $63,008 | $61,292 | $59,623 | $57,999 | $56,419 | $54,882 | $53,388 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2 | | Passive System | $560,239 | 3% | $246,147 | | | | | | | | $30,193 | $29,371 | $28,571 | $27,793 | $27,036 | $0 | $0 | $0 | $0 | $23,549 | $0 | $0 | $0 | $0 | $20,512 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $15,562 | $0 | $1,709 |
| 3 | Reclamation Maintenance | (Cover/Reveg Repairs) | $1,386,205 | 8% | $1,131,962 | | | | | | | | $239,066 | $232,554 | $226,220 | $220,058 | $214,064 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 4 | Site Maintenance | | $1,670,177 | 10% | $713,783 | | | | | | | | $85,725 | $83,390 | $81,119 | $78,909 | $76,760 | $0 | $0 | $0 | $0 | $66,860 | $0 | $0 | $0 | $0 | $58,238 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $48,113 | $0 | $5,282 |
| 5 | On-site Management | | $4,798,081 | 28% | $2,876,918 | | | | | | | | $522,676 | $508,440 | $494,591 | $481,120 | $468,016 | $0 | $0 | $0 | $0 | $53,689 | $0 | $0 | $0 | $0 | $46,765 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $79,395 | $0 | $8,717 |
| 6 | Transportation Costs | | $994,297 | 6% | $408,186 | | | | | | | | $55,729 | $54,211 | $52,735 | $51,298 | $49,901 | $0 | $0 | $0 | $0 | $14,011 | $0 | $0 | $0 | $0 | $12,204 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $31,086 | $0 | $3,413 |
| **Post Closure Costs Subtotal** | | | **$13,855,178** | | $8,869,929 | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$1,543,008** | **$1,500,981** | **$1,460,098** | **$1,420,329** | **$1,381,643** | **$68,451** | **$66,586** | **$64,773** | **$63,008** | **$219,402** | **$59,623** | **$57,999** | **$56,419** | **$54,882** | **$191,106** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$174,157** | **$0** | **$19,120** |

### Other Add-on Costs

| | | | Undiscounted | % of Total | NPV - 2018 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 | 2048 | 2049 | 2128 | 2129 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Contingency | 12% % of above costs | $1,891,402 | | $1,173,931 | | | | | | | | $195,936 | $189,020 | $185,407 | $180,180 | $182,453 | $10,667 | $10,377 | $10,094 | $9,819 | $34,443 | $9,292 | $9,039 | $8,792 | $8,553 | $30,001 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $26,285 | $0 | $2,886 |
| 2 | Worker's compensation | 0% (Included in labour rates) | $0 | | $0 | | | | | | | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 3 | Insurance | 2% % of above labour costs | $68,172 | | $42,312 | | | | | | | | $7,062 | $6,813 | $6,683 | $6,494 | $6,576 | $384 | $374 | $364 | $354 | $1,241 | $335 | $326 | $317 | $308 | $1,081 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $947 | $0 | $104 |
| 4 | Bonding | 3% % of Implem. & C&M costs | $420,011 | | $269,544 | | | | | | | | $46,579 | $45,310 | $44,076 | $43,204 | $43,459 | $2,054 | $1,998 | $1,943 | $1,890 | $6,582 | $1,789 | $1,740 | $1,693 | $1,646 | $5,733 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $5,225 | $0 | $574 |
| 5 | Contractor Profit | 10% % of above costs | $1,576,169 | | $978,276 | | | | | | | | $163,280 | $157,517 | $154,506 | $150,150 | $152,044 | $8,890 | $8,647 | $8,412 | $8,183 | $28,702 | $7,743 | $7,532 | $7,327 | $7,127 | $25,001 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $21,904 | $0 | $2,405 |
| 6 | Contract Administration | 5% % of above costs | $788,084 | | $489,138 | | | | | | | | $81,640 | $78,758 | $77,253 | $75,075 | $76,022 | $4,445 | $4,324 | $4,206 | $4,091 | $14,351 | $3,872 | $3,766 | $3,663 | $3,564 | $12,500 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $10,952 | $0 | $1,202 |
| **Other Add-On Costs Subtotal** | | | **$4,743,838** | | $2,953,201 | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$494,496** | **$477,418** | **$467,925** | **$455,104** | **$460,555** | **$26,440** | **$25,720** | **$25,019** | **$24,338** | **$85,320** | **$23,030** | **$22,403** | **$21,792** | **$21,199** | **$74,317** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$65,314** | **$0** | **$7,171** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** | | | **$20,360,342** | | **$12,621,082** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$2,117,681** | **$2,043,238** | **$2,003,892** | **$1,936,788** | **$1,913,990** | **$115,335** | **$112,193** | **$109,138** | **$106,165** | **$372,345** | **$100,460** | **$97,724** | **$95,062** | **$92,473** | **$324,325** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$284,358** | **$0** | **$31,219** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GRAND-TOTAL** | | | | | **$54,962,557** | **$0** | **$0** | **$0** | **$0** | **$12,767,915** | **$16,899,488** | **$12,496,557** | **$2,130,484** | **$2,056,297** | **$2,017,212** | **$1,967,223** | **$2,021,890** | **$115,335** | **$112,193** | **$109,138** | **$106,165** | **$372,345** | **$100,460** | **$97,724** | **$95,062** | **$92,473** | **$324,325** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$284,358** | **$0** | **$31,219** |

# Worksheet 13 - End-of-Mine Liability Estimate - Annual C&M Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## Summary of Annual Care and Maintenance Costs

| | | Annual Cost Per Phase | | | | | | Number of Years | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual | n/a | Total Cost | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual |
| 1 | Active Water Treatment System | | $706,967 | $706,967 | $91,135 | $0 | $0 | $6,567,079 | 0 | 3 | 5 | 10 | 0 |
| 2 | Passive Treatment System | | $0 | $35,015 | $35,015 | $35,015 | $0 | $560,239 | 0 | 3 | 5 | 2 | 9 |
| 3 | Reclamation Maintenance | | $0 | $277,241 | $0 | $0 | $0 | $1,386,205 | 0 | 3 | 5 | 2 | 9 |
| 4 | Site Maintenance | | $30,000 | $99,414 | $99,414 | $108,253 | $0 | $1,760,177 | 0 | 3 | 5 | 2 | 9 |
| 5 | On-site Management | | $310,135 | $606,140 | $79,830 | $178,636 | $0 | $5,728,488 | 0 | 3 | 5 | 2 | 9 |
| 6 | Transportation Costs | | $0 | $64,628 | $20,832 | $69,943 | $0 | $994,297 | 0 | 3 | 5 | 2 | 9 |

**NOTES:**
1. This table is used as a check to the NPV calculation spreadsheet.

## Phase 1 - Annual Care & Maintenance Costs - Prior to Closure

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S1.1 | **Water Treatment** | | | | | | | | | | | | | | | **$706,967** | |
| S1.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S1.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S1.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S1.2 | **Onsite Management** | | | | | | | | | | | | | | | **$180,419** | |
| S1.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $0 | | |
| S1.2.1.1 | | Mine Manager | | 0 | months | 360 | site working hours per month | | | $23,408 | | | | $0 | | | (Notes: staffing costs include cross-shifts) |
| S1.2.1.2 | | Office/Camp manager | | 0 | months | 360 | site working hours per month | | | $22,267 | | | | $0 | | | |
| S1.2.1.3 | | Administrative Assistants/HR/Accounting | | 0 | months | 360 | site working hours per month | | | $16,600 | | | | $0 | | | |
| S1.2.1.4 | | Water Treatment Staff Operator | | 0 | months | 360 | site working hours per month | | | $18,912 | | | | $0 | | | |
| S1.2.1.5 | | Environmental/Safety Manager | | 0 | months | 360 | site working hours per month | | | $22,267 | | | | $0 | | | |
| S1.2.1.6 | | Environmental Technicians | | 0 | months | 360 | site working hours per month | | | $16,046 | | | | $0 | | | |
| S1.2.1.7 | | Mechanic | | 0 | months | 360 | site working hours per month | | | $17,769 | | | | $0 | | | |
| S1.2.1.8 | | Tradesmen | | 0 | months | 360 | site working hours per month | | | $18,912 | | | | $0 | | | |
| S1.2.1.9 | | General Labour/helpers | | 0 | months | 360 | site working hours per month | | | $12,793 | | | | $0 | | | |
| S1.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $107,579 | | |
| S1.2.2.1 | | Pick-up trucks (3 required) | | 12 | months | | | | | $4,446 | | | | $53,350 | | | |
| S1.2.2.2 | | Mechanic service vehicle | | 0 | months | | | | | $11,803 | | | | $0 | | | |
| S1.2.2.3 | | Emergency transport vehicle | | 12 | months | | | | | $4,519 | | | | $54,229 | | | |
| S1.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $72,840 | | |
| S1.2.3.1 | | Office supplies | | 12 | months | | | | | $1,000 | | | | $12,000 | | | |
| S1.2.3.2 | | Communications | | 12 | months | | | | | $1,000 | | | | $12,000 | | | |
| S1.2.3.3 | | Misc. supplies | | 12 | months | | | | | $500 | | | | $6,000 | | | |
| S1.2.3 | | Camp Operation | | 0 | man-days | | | | | $80 | | | | $0 | | | |
| S1.2.3 | | Power, heat, fuel | | 12 | months | | | | | $3,570 | | | | $42,840 | | | |
| S1.3 | **Site Maintenance** | | | | | | | | | | | | | | $359,187 | **$359,187** | |
| S1.3.1 | | Equipment Maintenance | | 1 | ls | | $20,000 | | | | | | | $20,000 | | | Labour included in field support staff |
| S1.3.2 | | Road Maintenance | Grader (assume 80 hrs/month) | 1 | ls | 960 | | $44 | $106 | $150 | $0 | $42,612 | $101,443 | $144,056 | | | Operator cost included in Field support staff |
| S1.3.3 | | Earthwork Repair allowance (assume 40 hrs per month) | | 1 | ls | 480 | $0 | $132 | $344 | $344 | | | $165,132 | $165,132 | | | Task Code C.2.14 |
| S1.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $30,000 | | | | $30,000 | | | Allowance for pump maintenance/fuel etc. |
| S1.4 | **Transportation Costs** | | | | | | | | | | | | | | $0 | **$0** | |
| S1.4.1 | | Barge Operations | | 0 | months | | | | | $10,832 | | | | $0 | | | |
| S1.4.2 | | Staffing Bus trips during barge operation period | | 0 | ea | | | | | $678 | | | | $0 | | | One per week |
| S1.4.3 | | Air transport and airstrip operations | | 0 | flights | | | | | $3,000 | | | | $0 | | | One flight per week |
| S1.4.4 | | Helicopter transport | | 0 | flights | | | | | $3,000 | | | | $0 | | | One flight per week |
| **TOTAL** | | | | | | | | | | | | | | **$1,246,573** | **$1,246,573** | **$1,246,573** | |

## Phase 2 - Annual Care & Maintenance Costs During Active Closure

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S2.1 | **Water Treatment** | | | | | | | | | | | | | | | **$706,967** | |
| S2.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S2.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S2.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S2.2 | **Onsite Management** | | | | | | | | | | | | | | | **$310,135** | |
| S2.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $247,815 | | |
| S2.2.1.1 | | Water Treatment Staff Operator | | 5 | months | 360 | site working hours per month | | | $18,912 | | | | $94,560 | | | |
| S2.2.1.2 | | Environmental/Safety Manager | | 4 | months | 360 | site working hours per month | | | $22,267 | | | | $89,069 | | | |
| S2.2.1.3 | | Environmental Technicians | | 4 | months | 360 | site working hours per month | | | $16,046 | | | | $64,185 | | | |
| S2.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $31,121 | | |
| S2.2.2.1 | | Pick-up trucks (1 required) | | 7 | months | | | | | $4,446 | | | | $31,121 | | | |
| S2.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $31,200 | | |
| S2.2.3.1 | | Camp Operation | | 390 | man-days | | | | | $80 | | | | $31,200 | | | |
| S2.3 | **Site Maintenance** | | | | | | | | | | | | | | $30,000 | **$30,000** | |
| S2.3.1 | | Pumping equipment/consumables allowance | | 1 | ls | | | | | $30,000 | | | | $30,000 | | | Allowance for pump maintenance/fuel etc. |
| S2.4 | **Transportation Costs** | | | | | | | | | | | | | | $0 | **$0** | |
| S2.4.1 | | Barge Operations | | 0 | months | | | | | $10,832 | | | | $0 | | | Included in construction indirect costs |
| **TOTAL** | | | | | | | | | | | | | | **$1,047,102** | **$1,047,102** | **$1,047,102** | |

## Phase 3 - Annual Care & Maintenance Costs - Post Closure I

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S3.1 | **Water Treatment** | | | | | | | | | | | | | | | **$741,982** | |
| S3.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $706,967 | | |
| S3.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $511,807 | $65,194 | $38,831 | $615,832 | | | See details on 'Water Treatment' worksheet. |
| S3.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S3.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S3.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S3.2 | **Onsite Management** | | | | | | | | | | | | | | | **$606,140** | |
| S3.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $377,100 | | |
| S3.2.1.1 | | Mine Manager | | 3 | months | 360 | site working hours per month | | | $23,408 | | | | $58,521 | | | (Notes: staffing costs include cross-shifts) |
| S3.2.1.2 | | Office/Camp manager | | 3 | months | 360 | site working hours per month | | | $22,267 | | | | $66,802 | | | |
| S3.2.1.3 | | Administrative Assistants/HR/Accounting | | 1 | months | 360 | site working hours per month | | | $16,600 | | | | $20,749 | | | |
| S3.2.1.4 | | Water Treatment Staff Operator | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $33,096 | | | |
| S3.2.1.5 | | Environmental/Safety Manager | | 3 | months | 360 | site working hours per month | | | $22,267 | | | | $55,668 | | | |
| S3.2.1.6 | | Environmental Technicians | | 3 | months | 360 | site working hours per month | | | $16,046 | | | | $40,116 | | | |
| S3.2.1.7 | | Mechanic | | 2 | months | 360 | site working hours per month | | | $17,769 | | | | $35,538 | | | |
| S3.2.1.8 | | Tradesmen | | 2 | months | 360 | site working hours per month | | | $18,912 | | | | $37,824 | | | |
| S3.2.1.9 | | General Labour/helpers | | 2 | months | 360 | site working hours per month | | | $12,793 | | | | $28,785 | | | |
| S3.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $112,890 | | |
| S3.2.2.1 | | Pick-up trucks (3 required) | | 15 | months | | | | | $4,446 | | | | $66,688 | | | |
| S3.2.2.2 | | Mechanic service vehicle | | 2 | months | | | | | $11,803 | | | | $23,607 | | | |
| S3.2.2.3 | | Emergency transport vehicle | | 5 | months | | | | | $4,519 | | | | $22,596 | | | |
| S3.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $116,150 | | |
| S3.2.3.1 | | Office supplies | | 5 | months | | | | | $1,000 | | | | $5,000 | | | |
| S3.2.3.2 | | Communications | | 5 | months | | | | | $1,000 | | | | $5,000 | | | |
| S3.2.3.3 | | Misc. supplies | | 5 | months | | | | | $500 | | | | $2,500 | | | |
| S3.2.3 | | Camp Operation | | 1,073 | man-days | | | | | $80 | | | | $85,800 | | | |
| S3.2.3 | | Power, heat, fuel | | 5 | months | | | | | $3,570 | | | | $17,850 | | | |
| S3.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$277,241** | |
| S3.3.1 | *Cover repairs* | | | | | | | | | | | | | | $249,419 | | |
| S3.3.1.1 | | Cover Repair allowance | Load, haul, dump, spread (spoil lo | 1% | of total | 1,336,364 | m3 of cover required replacement at: | | | $5.31 | /m3 | | | $71,022 | | | Assumes 5% of area reseeded over 5 yr PC1 period. |
| S3.3.1.2 | | | Seed/Fertilize: broadcast seeding | 67 | ha | | | | | $2,669.89 | /ha | | | $178,397 | | | |
| S3.3.2.1 | *Revegetation* | | | | | | | | | | | | | | $27,822 | | |
| S3.3.2.2 | | Reseeding allowance | Seed/Fertilize: broadcast seeding | 3% | of total | 347 | ha requires reseeding at | | | $2,669.89 | /ha | | | $27,822 | | | Assumes 15% of area reseeded over 5 yr PC1 perio |
| S3.3 | **Site Maintenance** | | | | | | | | | | | | | | $99,414 | **$99,414** | |
| S3.3.1 | | Equipment Maintenance | | 1 | ls | | $20,000 | | | | | | | $20,000 | | | Labour included in field support staff |
| S3.3.2 | | Road Maintenance | Grader (assume 40 hrs/month) | 1 | ls | 200 | | $44 | $106 | $150 | $0 | $8,878 | $21,134 | $30,012 | | | Operator cost included in Field support staff |
| S3.3.3 | | Earthwork Repair allowance (assume 20 hrs per month) | | 1 | ls | 100 | $0 | $132 | $344 | $344 | | | $34,402 | $34,402 | | | Task Code C.2.14 |
| S3.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $15,000 | | | | $15,000 | | | Allowance for pump maintenance/fuel etc. |
| S3.4 | **Transportation Costs** | | | | | | | | | | | | | | $64,628 | **$64,628** | |
| S3.4.1 | | Barge Operations | | 3 | months | | | | | $10,832 | | | | $32,497 | | | |
| S3.4.2 | | Staffing Bus trips during barge operation period | | 12 | ea | | | | | $678 | | | | $8,131 | | | One per week |
| S3.4.3 | | Air transport and airstrip operations | | 8 | flights | | | | | $3,000 | | | | $24,000 | | | One flights per week |
| **TOTAL** | | | | | | | | | | | | | | **$1,789,405** | **$1,789,405** | **$1,789,405** | |

## Phase 4 - Annual Care & Maintenance Costs - Post Closure II

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S4.1 | **Water Treatment** | | | | | | | | | | | | | | | **$126,150** | |
| S4.1.1 | *Active Treatment System* | | | | | | | | | | | | | | $91,135 | | |
| S4.1.1.2 | | Capital Replacement | annual allowance | 1 | yr | | | | | | $86,932 | $4,203 | $0 | $91,135 | | | See details on 'Water Treatment' worksheet. |
| S4.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S4.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S4.2 | **Onsite Management** | | | | | | | | | | | | | | | **$79,830** | |
| S4.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $44,847 | | |
| S4.2.1.1 | | Project Manager | | 0.5 | months | 360 | site working hours per month | | | $23,408 | | | | $11,704 | | | (Notes: staffing costs include cross-shifts) |
| S4.2.1.2 | | Passive Treatment specialist | | 0.5 | months | 360 | site working hours per month | | | $42,120 | | | | $21,060 | | | |
| S4.2.1.3 | | Mechanic | | 0.5 | months | 360 | site working hours per month | | | $17,769 | | | | $8,885 | | | |
| S4.2.1.4 | | General Labour/helpers | | 0.3 | months | 360 | site working hours per month | | | $12,793 | | | | $3,198 | | | |
| S4.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $19,313 | | |
| S4.2.2.1 | | Pick-up trucks (2 required) | | 2.0 | months | | | | | $4,446 | | | | $8,892 | | | |
| S4.2.2.2 | | Mechanic service vehicle | | 0.5 | months | | | | | $11,803 | | | | $5,902 | | | |
| S4.2.2.3 | | Emergency transport vehicle | | 1.0 | months | | | | | $4,519 | | | | $4,519 | | | |
| S4.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $15,670 | | |
| S4.2.3.1 | | Office supplies | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S4.2.3.2 | | Communications | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S4.2.3.3 | | Misc. supplies | | 1 | months | | | | | $500 | | | | $500 | | | |
| S4.2.3 | | Camp Operation | | 120 | man-days | | | | | $80 | | | | $9,600 | | | |
| S4.2.3 | | Power, heat, fuel | | 1 | months | | | | | $3,570 | | | | $3,570 | | | |
| S4.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$0** | |
| S4.3.1 | *Cover repairs* | | | | | | | | | | | | | | $0 | | |
| S4.3.2 | *Revegetation* | | | | | | | | | | | | | | $0 | | |
| S4.3 | **Site Maintenance** | | | | | | | | | | | | | | $29,882 | **$29,882** | |
| S4.3.1 | | Equipment Maintenance (parts, supplies) | | 1 | ls | | $10,000 | | | | | | | $10,000 | | | Labour included in field support staff |
| S4.3.2 | | Road Maintenance | Grader (assume 20 hrs/month) | 1 | ls | 20 | | $44 | $106 | $150 | $0 | $888 | $2,113 | $3,001 | | | Operator cost included in Field support staff |
| S4.3.3 | | Earthwork Repair allowance (assume 20 hrs per month) | | 1 | ls | 20 | $0 | $132 | $344 | $344 | | | $6,880 | $6,880 | | | Task Code C.2.14 |
| S4.3.4 | | Sundry equipment/consumables allowance | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | Allowance for pump maintenance/fuel etc. |
| S4.4 | **Transportation Costs** | | | | | | | | | | | | | | $20,832 | **$20,832** | |
| S4.4.1 | | Barge Operations | | 1 | months | | | | | $10,832 | | | | $10,832 | | | |
| S4.4.2 | | Staffing Bus trips during barge operation period | | 0 | ea | | | | | $678 | | | | $0 | | | Pick-up trucks used (time included in labour rate) |
| S4.4.3 | | Barge mob/demob | | 1 | LS | | | | | $10,000 | | | | $10,000 | | | |
| **TOTAL** | | | | | | | | | | | | | | **$256,693** | **$256,693** | **$256,693** | |

## Phase 5 - Perpetual Care & Maintenance Event Year Annual Costs

| | | | | | | | Unit Rates | | | | Activity Totals | | | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | Qnty | Unit | Hours or Cost Code Ref. | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Total Unit Rate ($/unit) | Material Cost | Labour Cost | Equipment Cost | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| S5.1 | **Water Treatment** | | | | | | | | | | | | | | | **$35,015** | |
| S5.1.1 | *Passive Treatment System* | | | | | | | | | | | | | | $35,015 | | |
| S5.1.1.1 | | Operation and maintenance | | 1 | yr | | | | | | $10,000 | $11,986 | $13,029 | $35,015 | | | See details on 'Water Treatment' worksheet. |
| S5.2 | **Onsite Management** | | | | | | | | | | | | | | | **$178,636** | |
| S5.2.1 | *Field Support Staff* | | | | | | | | | | | | | | $129,326 | | |
| S5.2.1.1 | | Project Manager | | 1.0 | months | 360 | site working hours per month | | | $23,408 | | | | $23,408 | | | (Notes: staffing costs include cross-shifts) |
| S5.2.1.2 | | Passive Treatment specialist | | 1.0 | months | 360 | site working hours per month | | | $42,120 | | | | $42,120 | | | |
| S5.2.1.3 | | Site Engineer | | 1.0 | months | 360 | site working hours per month | | | $42,120 | | | | $42,120 | | | |
| S5.2.1.4 | | HD mechanic | | 0.5 | months | 360 | site working hours per month | | | $17,769 | | | | $8,885 | | | |
| S5.2.1.5 | | General Labour/helpers | | 1.0 | months | 360 | site working hours per month | | | $12,793 | | | | $12,793 | | | |
| S5.2.2 | *Field support Vehicles* | | | | | | | | | | | | | | $19,239 | | |
| S5.2.2.1 | | Pick-up trucks (3 required) | | 3 | months | | | | | $4,446 | | | | $13,338 | | | |
| S5.2.2.2 | | Mechanic service vehicle | | 1 | months | | | | | $11,803 | | | | $5,902 | | | |
| S5.2.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | $30,070 | | |
| S5.2.3.1 | | Office supplies | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S5.2.3.2 | | Communications | | 1 | months | | | | | $1,000 | | | | $1,000 | | | |
| S5.2.3.3 | | Misc. supplies | | 1 | months | | | | | $500 | | | | $500 | | | |
| S5.2.3.4 | | Camp Operation | | 300 | man-days | | | | | $80 | | | | $24,000 | | | |
| S5.2.3.5 | | Power, heat, fuel | | 1 | months | | | | | $3,570 | | | | $3,570 | | | |
| S5.3 | **Reclamation Maintenance** | | | | | | | | | | | | | | | **$0** | |
| S5.4 | **Site Maintenance** | | | | | | | | | | | | | | $108,253 | **$108,253** | |
| S5.4.1 | | Grader Maintenance | Grader (assume 2 weeks, 10hrs/d | 1 | ls | 140 | | $44 | $106 | $150 | $0 | $6,214 | $14,794 | $21,008 | | | Operator cost included in Field support staff |
| S5.4.2 | | Earthwork Repair allowance (assume 3 weeks, 10hrs/day) | | 1 | ls | 210 | $0 | $132 | $344 | $344 | | | $72,245 | $72,245 | | | Task Code C.2.14 |
| S5.4.3 | | Big Creek Bridge - Capital replacement allowance | | 1 | ls | | | | | $15,000 | | | | $15,000 | | | Allowance for supplies, pumping, etc. |
| S5.4.4 | | Sundry allowance | | 1 | ls | | | | | $2,500 | | | | $2,500 | | | Allowance for supplies, pumping, etc. |
| S5.5 | **Transportation Costs** | | | | | | | | | | | | | | $69,943 | **$69,943** | |
| S5.5.1 | | Barge Operations | | 1 | months | | | | | $10,832 | | | | $10,832 | | | |
| S5.5.2 | | Barge mobilization/demob and set up | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | assumed |
| S5.5.3 | | Camp Mob/demob | | 1 | ls | | | | | $10,000 | | | | $10,000 | | | assumed |
| S5.5.4 | | Equipment mobilization and demobilization | | 2 | ls | | | | | $19,555 | | | | $39,110.91 | | | See details on 'mob-demob 'worksheet |
| **TOTAL** | | | | | | | | | | | | | | **$394,347** | **$391,847** | **$391,847** | |

# Worksheet 14 - End-of-Mine Liability Estimate - Implementation Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| **DIRECT COSTS** | | | | | | | | | | | | | | | | | | | | | |
| A1 | **Waste Dumps** | | | | | | | | | | | | | | | | | | | **$6,987,586** | |
| A1.1 | *Main Waste Dump (inc. MWDE)* | | | | | | | | | | | | | | | | | | $121,985 | | |
| A1.1.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0 | $44.39 | $0 | $194.68 | $0 | $67.01 | 0 | $0 | $0.00 | $0 | $306.07 | $0 | | | |
| A1.1.1.2 | | | Slopes: Re-grade to 3H:1V | 0 | hrs | C.2.13 | 0 | $44.39 | $0 | $194.68 | $0 | $67.01 | 0 | $0 | $0.00 | $0 | $306.07 | $0 | | | |
| A1.1.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 0 | Cm3 | R.050 | 0.0 | $0.82 | $0 | $2.67 | $0 | $0.88 | 0 | $0 | $0.00 | $0 | $4.37 | $0 | | | |
| A1.1.2.2 | | | Slope area cover material: Load, haul, dump along crest | 0 | Cm3 | R.051 | 0.0 | $0.72 | $0 | $2.37 | $0 | $0.80 | 0 | $0 | $0.00 | $0 | $3.89 | $0 | | | |
| A1.1.2.3 | | | Slope area cover material: Spread down slope | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0 | $194.68 | $0 | $67.01 | 0 | $0 | $0.00 | $0 | $306.07 | $0 | | | |
| A1.1.3.1 | | Revegetate | Seed/Fertilize: tractor application | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0 | $401.72 | $0 | $232.94 | 0 | $0 | $1,005.72 | $0 | $2,670 | $0 | | | |
| A1.1.3.2 | | | Tree seedling application (1,000 stems/ha) | 52 | ha | C.6.06 | 2,668.2 | $1,832.33 | $95,397 | $25.98 | $1,353 | $15.00 | 813 | $781 | $469.71 | $24,455 | $2,343 | $121,985 | | | |
| A1.2 | *Main Waste Dump Wrap* | | | | | | | | | | | | | | | | | | $350,260 | | |
| A1.2.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 6 | hrs | C.2.13 | 6 | $44.39 | $278 | $194.68 | $1,218 | $67.01 | 437 | $419 | $0.00 | $0 | $306.07 | $1,914 | | | |
| A1.2.1.2 | | | Slopes: Re-grade to 3H:1V | 255 | hrs | C.2.13 | 255 | $44.39 | $11,334 | $194.68 | $49,709 | $67.01 | 17,822 | $17,110 | $0.00 | $0 | $306.07 | $78,152 | | | |
| A1.2.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 8,223 | Cm3 | R.050 | 153.4 | $0.82 | $6,757 | $2.67 | $21,957 | $0.88 | 7,527 | $7,226 | $0.00 | $0 | $4.37 | $35,939 | | | |
| A1.2.2.2 | | | Slope area cover material: Load, haul, dump along crest | 42,447 | Cm3 | R.051 | 692.9 | $0.72 | $30,484 | $2.37 | $100,640 | $0.80 | 35,215 | $33,806 | $0.00 | $0 | $3.89 | $164,930 | | | |
| A1.2.2.3 | | | Slope area cover material: Spread down slope | 61 | hrs | C.2.13 | 60.5 | $44.39 | $2,686 | $194.68 | $11,781 | $67.01 | 4,224 | $4,055 | $0.00 | $0 | $306.07 | $18,523 | | | |
| A1.2.3.1 | | Revegetate | Seed/Fertilize: tractor application | 10 | ha | C.6.01 | 335.7 | $1,029.50 | $10,433 | $401.72 | $4,071 | $232.94 | 2,459 | $2,361 | $1,005.72 | $10,192 | $2,670 | $27,057 | | | |
| A1.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 10 | ha | C.6.06 | 519.4 | $1,832.33 | $18,569 | $25.98 | $263 | $15.00 | 158 | $152 | $469.71 | $4,760 | $2,343 | $23,744 | | | |
| A1.3 | *Southwest Dump (excluding high grade waste area)* | | | | | | | | | | | | | | | | | | $147,053 | | |
| A1.3.1 | | Re-grade | Slopes: Re-grade remaining to 3H:1V | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.3.2.1 | | Cover | Load, haul, dump spread | 0 | m3 | R.059 | 0.0 | $0.77 | $0.00 | $2.49 | $0 | $0.82 | 0 | $0.00 | $0.00 | $0.00 | $4.08 | $0 | | | |
| A1.3.3.1 | | Revegetate | Seed/Fertilize: tractor application | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A1.3.3.2 | | | Tree seedling application (1,000 stems/ha) | 62.76 | ha | C.6.06 | 3,216.6 | $1,832.33 | $115,000.98 | $25.98 | $1,631 | $15.00 | 981 | $941.43 | $469.71 | $29,479.97 | $2,343.03 | $147,053 | | | |
| A1.4 | *Southwest Dump High-Grade Waste* | | | | | | | | | | | | | | | | | | $249,632 | | |
| A1.4.1 | | Relocate High-grade waste | Load, haul, dump, spread in pit (below long-term water elevation) | 45,711 | Bm3 | R.069 | 688.0 | $0.66 | $30,283.89 | $2.19 | $100,276 | $0.73 | 34,965 | $33,566.76 | $0.00 | $0.00 | $3.59 | $164,127 | | | |
| A1.4.2 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 31 | hrs | C.2.13 | 31.1 | $44.39 | $1,378.38 | $194.68 | $6,045 | $67.01 | 2,168 | $2,080.81 | $0.00 | $0.00 | $306.07 | $9,505 | | | |
| A1.4.3 | | Cover | Flat area cover material: Load, haul, dump spread | 15,583 | Cm3 | R.060 | 257.8 | $0.73 | $11,362.15 | $2.37 | $36,935 | $0.78 | 12,585 | $12,081.20 | $0.00 | $0.00 | $3.87 | $60,378 | | | |
| A1.4.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.12 | ha | C.6.01 | 103.2 | $1,029.50 | $3,208.44 | $401.72 | $1,252 | $232.94 | 756 | $725.97 | $1,005.72 | $3,134.33 | $2,669.89 | $8,321 | | | |
| A1.4.4.2 | | | Tree seedling application (1,000 stems/ha) | 3.12 | ha | C.6.06 | 159.7 | $1,832.33 | $5,710.47 | $25.98 | $81 | $15.00 | 49 | $46.75 | $469.71 | $1,463.85 | $2,343.03 | $7,302 | | | |
| A1.5 | *Main Pit SAT* | | | | | | | | | | | | | | | | | | $4,103,230 | | |
| A1.5.1.1 | | Relocate SAT below water | Load, haul, dump, spread in pit | 1,040,000 | Cm3 | R.012 | 17,781.5 | $0.75 | $785,076.51 | $1.86 | $1,935,773 | $0.51 | 555,290 | $533,078.26 | $0.00 | $0.00 | $3.13 | $3,253,928 | | | |
| A1.5.1.2 | | | Allowance for additional SAT material from SAT Dump | 30,000 | Cm3 | R.012 | 512.9 | $0.75 | $22,646.44 | $1.86 | $55,840 | $0.51 | 16,018 | $15,377.26 | $0.00 | $0.00 | $3.13 | $93,863 | | | |
| A1.5.2 | | Backfill SAT Excavation | Load, haul, dump WR to form buttress below MPD | 245,000 | Cm3 | R.013 | 3,226.9 | $0.58 | $142,343.39 | $1.89 | $462,905 | $0.61 | 156,449 | $150,191.13 | $0.00 | $0.00 | $3.08 | $755,439 | | | Cover and revegetation of backfill included in MPD (A1.6) |
| A1.6 | *Main Pit Dump (Incl. SWB, In-Pit Dumps)* | | | | | | | | | | | | | | | | | | $686,521 | | |
| A1.6.2.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 65 | hrs | C.2.13 | 65.1 | $44.39 | $2,891.84 | $194.68 | $12,683 | $67.01 | 4,547 | $4,365.54 | $0.00 | $0.00 | $306.07 | $19,941 | | | |
| A1.6.2.2 | | | Slopes: Re-grade to 3H:1V | 207 | hrs | C.2.13 | 206.7 | $44.39 | $9,174.86 | $194.68 | $40,240 | $67.01 | 14,428 | $13,850.42 | $0.00 | $0.00 | $306.07 | $63,265 | | | |
| A1.6.3.1 | | Cover | Flat area cover material: Load, haul, dump spread | 45,270 | m3 | R.053 | 732.0 | $0.71 | $32,263.18 | $2.32 | $104,877 | $0.76 | 35,734 | $34,304.93 | $0.00 | $0.00 | $3.79 | $171,445 | | | |
| A1.6.3.2 | | | Slope area cover material: Load, haul, dump along crest | 84,053 | m3 | R.054 | 1,165.0 | $0.61 | $51,284.32 | $2.02 | $169,813 | $0.68 | 59,212 | $56,843.70 | $0.00 | $0.00 | $3.31 | $277,941 | | | |
| A1.6.3.3 | | | Slope area cover material: Spread down slope | 79 | hrs | C.2.13 | 79.3 | $44.39 | $3,520.01 | $194.68 | $15,438 | $67.01 | 5,535 | $5,313.82 | $0.00 | $0.00 | $306.07 | $24,272 | | | |
| A1.6.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 25.9 | ha | C.6.01 | 856.8 | $1,029.50 | $26,627.72 | $401.72 | $10,390 | $232.94 | 6,276 | $6,025.02 | $1,005.72 | $26,012.60 | $2,669.89 | $69,056 | | | |
| A1.6.4.2 | | | Tree seedling application (1,000 stems/ha) | 25.9 | ha | C.6.06 | 1,325.6 | $1,832.33 | $47,392.66 | $25.98 | $672 | $15.00 | 404 | $387.97 | $469.71 | $12,148.89 | $2,343.03 | $60,602 | | | |
| A1.7.0.0 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $40,934 | | |
| A1.7.1.1 | | Complete Fill Placement | Waste Rock fill: Load, haul, dump spread | 0 | m3 | R.041 | 0.0 | $0.97 | $0.00 | $3.15 | $0 | $1.04 | 0 | $0.00 | $0.00 | $0.00 | $5.15 | $0 | | | |
| A1.7.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.7.2.2 | | | Slopes: Re-grade to 3H:1V | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.7.3.1 | | Cover | Flat area cover material: Load, haul, dump spread | 0 | m3 | R.056 | 0.0 | $0.90 | $0.00 | $2.91 | $0 | $0.96 | 0 | $0.00 | $0.00 | $0.00 | $4.77 | $0 | | | |
| A1.7.3.2 | | | Slope area cover material: Load, haul, dump along crest | 0 | m3 | R.057 | 0.0 | $0.78 | $0.00 | $2.59 | $0 | $0.87 | 0 | $0.00 | $0.00 | $0.00 | $4.24 | $0 | | | |
| A1.7.3.3 | | | Slope area cover material: Spread down slope | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A1.7.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A1.7.4.2 | | | Tree seedling application (1,000 stems/ha) | 17.47 | ha | C.6.06 | 895.4 | $1,832.33 | $32,011.85 | $25.98 | $454 | $15.00 | 273 | $262.06 | $469.71 | $8,206.09 | $2,343.03 | $40,934 | | | |
| A1.8.0.0 | *Ridgetop Waste Dump* | | | | | | | | | | | | | | | | | | $1,287,970 | | |
| A1.8.1.1 | | Regrade | Flat areas: Re-grade to form tertiary drainage catchments | 88 | hrs | C.2.13 | 88 | $44.39 | $3,903 | $194.68 | $17,119 | $67.01 | 6,138 | $5,892 | $0.00 | $0 | $306.07 | $26,915 | | | |
| A1.8.1.2 | | | Slopes: Re-grade to 3H:1V | 383 | hrs | C.2.13 | 383 | $44.39 | $17,021 | $194.68 | $74,651 | $67.01 | 26,765 | $25,695 | $0.00 | $0 | $306.07 | $117,367 | | | |
| A1.8.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 22,063 | Cm3 | R.063 | 590.5 | $1.18 | $26,007 | $3.83 | $84,514 | $1.26 | 28,971 | $27,812 | $0.00 | $0 | $6.27 | $138,332 | | | |
| A1.8.2.2 | | | Slope area cover material: Load, haul, dump along crest | 142,998 | Cm3 | R.064 | 3,348.7 | $1.03 | $147,324 | $3.40 | $486,381 | $1.14 | 170,188 | $163,381 | $0.00 | $0 | $5.57 | $797,086 | | | |
| A1.8.2.3 | | | Slope area cover material: Spread down slope | 140 | hrs | C.2.13 | 139.8 | $44.39 | $6,205 | $194.68 | $27,213 | $67.01 | 9,757 | $9,367 | $0.00 | $0 | $306.07 | $42,784 | | | |
| A1.8.3.1 | | Revegetate | Seed/Fertilize: tractor application | 33 | ha | C.6.01 | 1,093.6 | $1,029.50 | $33,986 | $401.72 | $13,262 | $232.94 | 8,010 | $7,690 | $1,005.72 | $33,201 | $2,670 | $88,139 | | | |
| A1.8.3.2 | | | Tree seedling application (1,000 stems/ha) | 33 | ha | C.6.06 | 1,691.9 | $1,832.33 | $60,489 | $25.98 | $858 | $15.00 | 516 | $495 | $469.71 | $15,506 | $2,343 | $77,348 | | | |
| A2 | **Overburden Dumps** | | | | | | | | | | | | | | | | | | | **$395,276** | |
| A2.1 | *Area 118 Pit Backfill Dump* | | | | | | | | | | | | | | | | | | $16,268 | | |
| A2.1.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.1.1.2 | | | Berm: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A2.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 7 | ha | C.6.06 | 355.8 | $1,832.33 | $12,722.54 | $25.98 | $180 | $15.00 | 108 | $104.15 | $469.71 | $3,261.36 | $2,343.03 | $16,268 | | | |
| A2.2 | *Ice-rich Overburden Dump* | | | | | | | | | | | | | | | | | | $13,827 | | |
| A2.2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A2.2.1.2 | | | Berm: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | WR Berm area included in Southwest Dump |
| A2.2.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.76 | ha | C.6.01 | 91.4 | $1,029.50 | $2,839.68 | $401.72 | $1,108 | $232.94 | 669 | $642.53 | $1,005.72 | $2,774.08 | $2,669.89 | $7,364 | | | |
| A2.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 2.76 | ha | C.6.06 | 141.4 | $1,832.33 | $5,054.12 | $25.98 | $72 | $15.00 | 43 | $41.37 | $469.71 | $1,295.60 | $2,343.03 | $6,463 | | | |
| A2.3 | *Reclamation Overburden Dump* | | | | | | | | | | | | | | | | | | $330,992 | | |
| A2.3.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 594 | hrs | C.2.13 | 593.6 | $44.39 | $26,347.50 | $194.68 | $115,557 | $67.01 | 41,432 | $39,774.35 | $0.00 | $0.00 | $306.07 | $181,679 | | | |
| A2.3.1.2 | | | Slopes: Regrade to 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | Assumes borrow removed in such a manner that significant resloping is not required. |
| A2.3.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 29.79 | ha | C.6.01 | 986.7 | $1,029.50 | $30,664.45 | $401.72 | $11,966 | $232.94 | 7,228 | $6,938.40 | $1,005.72 | $29,956.07 | $2,669.89 | $79,525 | | | |
| A2.3.2.2 | | | Tree seedling application (1,000 stems/ha) | 29.79 | ha | C.6.06 | 1,526.5 | $1,832.33 | $54,577.32 | $25.98 | $774 | $15.00 | 465 | $446.79 | $469.71 | $13,990.64 | $2,343.03 | $69,789 | | | |
| A2.4 | *Ridgetop South Backfill Dump* | | | | | | | | | | | | | | | | | | $34,189 | | |
| A2.4.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 17 | hrs | C.2.13 | 16.9 | $44.39 | $751.05 | $194.68 | $3,294 | $67.01 | 1,181 | $1,133.78 | $0.00 | $0.00 | $306.07 | $5,179 | | | |
| A2.4.1.2 | | | Slopes: Regrade to 3H:1V or flatter | 32 | hrs | C.2.13 | 32.2 | $44.39 | $1,430.97 | $194.68 | $6,276 | $67.01 | 2,250 | $2,160.20 | $0.00 | $0.00 | $306.07 | $9,867 | | | |
| A2.4.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.82 | ha | C.6.01 | 126.5 | $1,029.50 | $3,931.30 | $401.72 | $1,534 | $232.94 | 927 | $889.53 | $1,005.72 | $3,840.48 | $2,669.89 | $10,195 | | | |
| A2.4.2.2 | | | Tree seedling application (1,000 stems/ha) | 3.82 | ha | C.6.06 | 195.7 | $1,832.33 | $6,997.02 | $25.98 | $99 | $15.00 | 60 | $57.28 | $469.71 | $1,793.65 | $2,343.03 | $8,947 | | | |
| **A3** | **Ore Stockpiles** | | | | | | | | | | | | | | | | | | | **$794,200** | |
| A3.1 | *High and Medium Grade Sulphide Ore Stockpile (South of Mill)* | | | | | | | | | | | | | | | | | | $685,926 | | (North, West, East, and South Stockpiles) |
| A3.1.1.1 | | Relocate to Pit | Ore: Load, haul, dump, spread into Main Pit | 0 | m3 | R.044 | 0.0 | $0.52 | $0.00 | $1.72 | $0 | $0.57 | 0 | $0.00 | $0.00 | $0.00 | $2.82 | $0 | | | |
| A3.1.1.2 | | | Ore Pads (over-excavate): Load, haul, dump spread into Main Pit | 71,007 | m3 | R.044 | 835.3 | $0.52 | $36,800.28 | $1.72 | $122,356 | $0.57 | 42,458 | $40,759.51 | $0.00 | $0.00 | $2.82 | $199,915 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A3.1.1.3 | | | Complete confirmation testing | 1,421 | ea | C.3.02 | 236.8 | $7.43 | $10,556.37 | $1.33 | $1,883 | $0.00 | 0 | $0.00 | $13.26 | $18,842.46 | $22.01 | $31,282 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A3.1.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 289 | hrs | C.2.13 | 289.4 | $44.39 | $12,843.71 | $194.68 | $56,331 | $67.01 | 20,197 | $19,388.95 | $0.00 | $0.00 | $306.07 | $88,564 | | | |
| A3.1.3.1 | | Cover | Cover material: Load, haul, dump spread (0.5m) | 69,653 | m3 | R.055 | 1,264.9 | $0.80 | $55,711.18 | $2.60 | $181,043 | $0.86 | 62,060 | $59,577.97 | $0.00 | $0.00 | $4.25 | $296,332 | | | |
| A3.1.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 13.93 | ha | C.6.01 | 461.5 | $1,029.50 | $14,341.67 | $401.72 | $5,596 | $232.94 | 3,380 | $3,245.07 | $1,005.72 | $14,010.36 | $2,669.89 | $37,193 | | | |
| A3.1.4.2 | | | Tree seedling application (1,000 stems/ha) | 13.93 | ha | C.6.06 | 713.9 | $1,832.33 | $25,525.64 | $25.98 | $362 | $15.00 | 218 | $208.96 | $469.71 | $6,543.38 | $2,343.03 | $32,640 | | | |
| A3.2 | *Low Grade Sulphide Ore Stockpile (Main Dump Area)* | | | | | | | | | | | | | | | | | | $108,273 | | |
| A3.2.1.1 | | Relocate to Pit | Ore: Load, haul, dump, spread into Main Pit | 0 | m3 | R.036 | 0.0 | $0.56 | $0.00 | $1.84 | $0 | $0.62 | 0 | $0.00 | $0.00 | $0.00 | $3.02 | $0 | | | |
| A3.2.1.2 | | | Ore Pad (over-excavate): Load, haul, dump spread into Main Pit | 31,316 | m3 | R.036 | 396.1 | $0.56 | $17,435.36 | $1.84 | $57,732 | $0.62 | 20,131 | $19,325.41 | $0.00 | $0.00 | $3.02 | $94,493 | | | |
| A3.2.1.3 | | | Complete confirmation testing | 626 | ea | C.3.02 | 104.3 | $7.43 | $4,650.45 | $1.33 | $829 | $0.00 | 0 | $0.00 | $13.26 | $8,300.76 | $22.01 | $13,781 | | | |
| A3.2.2.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.3.1 | | Cover | Cover material: Load, haul, dump spread | 0 | m3 | R.050 | 0.0 | $0.82 | $0.00 | $2.67 | $0 | $0.88 | 0 | $0.00 | $0.00 | $0.00 | $4.37 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.4.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | Included in Main Waste Dump Closure |
| A3.2.4.2 | | | Tree seedling application (1,000 stems/ha) | 0 | ha | C.6.06 | 0.0 | $1,832.33 | $0.00 | $25.98 | $0 | $15.00 | 0 | $0.00 | $469.71 | $0.00 | $2,343.03 | $0 | | | Included in Main Waste Dump Closure |
| **A4** | **Open Pits** | | | | | | | | | | | | | | | | | | | **$620,582** | |
| A4.1 | *Main Pit* | | | | | | | | | | | | | | | | | | $150,984 | | |
| A4.1.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 7,500 | m2 | C.2.03 | 28.5 | $0.17 | $1,265.55 | $0.49 | $3,658 | $0.13 | 1,048 | $1,005.87 | $0.00 | $0.00 | $0.79 | $5,930 | | | |
| A4.1.1.2 | | | Safety Berm: Construct around highwall perimeter | 4,860 | m3 | C.2.02 | 45.8 | $0.42 | $2,035.14 | $0.89 | $4,333 | $0.25 | 1,267 | $1,215.92 | $0.00 | $0.00 | $1.56 | $7,584 | | | |
| A4.1.1.3 | | | Place large boulders across any pit access points | 52 | m3 | R.001 | 1.6 | $1.39 | $72.20 | $3.03 | $157 | $0.90 | 49 | $46.76 | $0.00 | $0.00 | $5.31 | $276 | | | |
| A4.1.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.1.2.1 | | Exposed tailings cover | Trafficability Layer: Load, haul, dump spread | 17,750 | m3 | R.014 | 554.4 | $1.38 | $24,425.58 | $2.86 | $50,708 | $0.82 | 15,091 | $14,487.41 | $0.00 | $0.00 | $5.05 | $89,621 | | | |
| A4.1.2.2 | | | Overburden Layer: Load, haul, dump spread | 8,875 | m3 | R.052 | 158.4 | $0.79 | $6,976.73 | $2.55 | $22,672 | $0.84 | 7,772 | $7,460.97 | $0.00 | $0.00 | $4.18 | $37,110 | | | |
| A4.1.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2 | ha | C.6.01 | 58.8 | $1,029.50 | $1,827.37 | $401.72 | $713 | $232.94 | 431 | $413.48 | $1,005.72 | $1,785.15 | $2,669.89 | $4,739 | | | |
| A4.1.3.2 | | | Tree seedling application (1,000 stems/ha) | 2 | ha | C.6.06 | 91.0 | $1,832.33 | $3,252.39 | $25.98 | $46 | $15.00 | 28 | $26.63 | $469.71 | $833.74 | $2,343.03 | $4,159 | | | |
| A4.2 | *Area 2 Pit* | | | | | | | | | | | | | | | | | | $10,001 | | |
| A4.2.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | |
| A4.2.1.2 | | | Safety Berm: Construct around highwall perimeter | 5,317 | m3 | C.2.02 | 50.2 | $0.42 | $2,226.54 | $0.89 | $4,740 | $0.25 | 1,386 | $1,330.27 | $0.00 | $0.00 | $1.56 | $8,297 | | | |
| A4.2.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.2.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.3 | *Area 118 Pit* | | | | | | | | | | | | | | | | | | $0 | | |
| A4.3.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | Pit filled it by Area 118 Backfill Dump |
| A4.3.1.2 | | | Safety Berm: Construct around highwall perimeter | 0 | m3 | C.2.02 | 0.0 | $0.42 | $0.00 | $0.89 | $0 | $0.25 | 0 | $0.00 | $0.00 | $0.00 | $1.56 | $0 | | | |
| A4.3.1.3 | | | Place large boulders across any pit access points | 0 | m3 | R.001 | 0.0 | $1.39 | $0.00 | $3.03 | $0 | $0.90 | 0 | $0.00 | $0.00 | $0.00 | $5.31 | $0 | | | |
| A4.3.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 0 | ea | C.5.13 | 0.0 | $40.27 | $0.00 | $15.90 | $0 | $5.57 | 0 | $0.00 | $199.26 | $0.00 | $261.00 | $0 | | | |
| A4.4 | *Minto North Pit* | | | | | | | | | | | | | | | | | | $11,481 | | |
| A4.4.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 5,900 | m2 | C.2.03 | 22.4 | $0.17 | $995.56 | $0.49 | $2,878 | $0.13 | 824 | $791.29 | $0.00 | $0.00 | $0.79 | $4,665 | | | |
| A4.4.1.2 | | | Safety Berm: Construct around highwall perimeter | 3,610 | m | C.2.02 | 34.1 | $0.42 | $1,511.81 | $0.89 | $3,219 | $0.25 | 941 | $903.25 | $0.00 | $0.00 | $1.56 | $5,634 | | | |
| A4.4.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.4.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 4 | ea | C.5.13 | 3.7 | $40.27 | $161.09 | $15.90 | $64 | $5.57 | 23 | $22.26 | $199.26 | $797.04 | $261.00 | $1,044 | | | |
| A4.5 | *Ridgetop North* | | | | | | | | | | | | | | | | | | $448,116 | | |
| A4.5.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 10,110 | m2 | C.2.03 | 38.4 | $0.17 | $1,705.95 | $0.49 | $4,931 | $0.13 | 1,412 | $1,355.92 | $0.00 | $0.00 | $0.79 | $7,993 | | | |
| A4.5.1.2 | | | Safety Berm: Construct around highwall perimeter | 3,648 | m | C.2.02 | 34.4 | $0.42 | $1,527.56 | $0.89 | $3,252 | $0.25 | 951 | $912.66 | $0.00 | $0.00 | $1.56 | $5,692 | | | |
| A4.5.1.3 | | | Place large boulders across any pit access points | 26 | m3 | R.001 | 0.8 | $1.39 | $36.10 | $3.03 | $79 | $0.90 | 24 | $23.38 | $0.00 | $0.00 | $5.31 | $138 | | | |
| A4.5.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 6 | ea | C.5.13 | 5.6 | $40.27 | $241.63 | $15.90 | $95 | $5.57 | 35 | $33.39 | $199.26 | $1,195.57 | $261.00 | $1,566 | | | |
| A4.5.2.1 | | Exposed tailings cover | Trafficability Layer: Load, haul, dump spread | 62,477 | m3 | R.068 | 816.5 | $0.58 | $35,941.63 | $1.90 | $119,010 | $0.64 | 41,498 | $39,837.81 | $0.00 | $0.00 | $3.12 | $194,789 | | | |
| A4.5.2.2 | | | Overburden Layer: Load, haul, dump spread | 31,239 | m3 | R.062 | 882.0 | $1.24 | $38,844.69 | $4.04 | $126,233 | $1.33 | 43,272 | $41,540.81 | $0.00 | $0.00 | $6.61 | $206,618 | | | |
| A4.5.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 6 | ha | C.6.01 | 207.0 | $1,029.50 | $6,432.02 | $401.72 | $2,510 | $232.94 | 1,516 | $1,455.36 | $1,005.72 | $6,283.44 | $2,669.89 | $16,681 | | | |
| A4.5.3.2 | | | Tree seedling application (1,000 stems/ha) | 6 | ha | C.6.06 | 320.2 | $1,832.33 | $11,447.87 | $25.98 | $162 | $15.00 | 98 | $93.72 | $469.71 | $2,934.61 | $2,343.03 | $14,639 | | | |
| A4.6 | *Ridgetop South* | | | | | | | | | | | | | | | | | | $0 | | |
| A4.6.1.1 | | Secure Access | Safety Berm: Clear land around highwall perimeter (10m width) | 0 | m2 | C.2.03 | 0.0 | $0.17 | $0.00 | $0.49 | $0 | $0.13 | 0 | $0.00 | $0.00 | $0.00 | $0.79 | $0 | | | Pit to be backfilled |
| A4.6.1.2 | | | Safety Berm: Construct around highwall perimeter | 0 | m | C.2.02 | 0.0 | $0.42 | $0.00 | $0.89 | $0 | $0.25 | 0 | $0.00 | $0.00 | $0.00 | $1.56 | $0 | | | |
| A4.6.1.3 | | | Place large boulders across any pit access points | 0 | m3 | R.001 | 0.0 | $1.39 | $0.00 | $3.03 | $0 | $0.90 | 0 | $0.00 | $0.00 | $0.00 | $5.31 | $0 | | | |
| A4.6.1.4 | | | Allowance: Install warning signs around pit perimeter at key locations | 0 | ea | C.5.13 | 0.0 | $40.27 | $0.00 | $15.90 | $0 | $5.57 | 0 | $0.00 | $199.26 | $0.00 | $261.00 | $0 | | | |
| **A5** | **Underground Openings** | | | | | | | | | | | | | | | | | | | **$81,637** | |
| A5.1 | *Minto North Portal* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.1.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.1.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.2 | *Minto North Portal Egress* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.2.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.2.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.3 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $16,573 | | |
| A5.3.1.1 | | Seal portal | Load, Haul, Dump backfill plug | 2,588 | m3 | R.001 | 81.5 | $1.39 | $3,592.52 | $3.03 | $7,832 | $0.90 | 2,423 | $2,326.51 | $0.00 | $0.00 | $5.31 | $13,751 | | | Material sourced from nearby laydown area rockfill |
| A5.3.1.2 | | | Doze backfill plug into portal with small dozer | 16 | hrs | C.2.19 | 0.0 | $44.39 | $723.90 | $105.36 | $1,718 | $23.28 | 395 | $379.66 | $0.00 | $0.00 | $173.02 | $2,822 | | | |
| A5.3.2.1 | | Revegetate | Included in Yards (WBS No. A11-10) | | | | | | | | | | | | | | | | | | |
| A5.4 | *Area 118 Vent Raise* | | | | | | | | | | | | | | | | | | $10,691 | | |
| A5.4.1.1 | | Site Preparation | Removal of Heater/Fan included in Demolition | | | | | | | | | | | | | | | | | | |
| A5.4.1.2 | | | Excavate and clean perimeter around shaft to suitable material. | 4 | ea | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.4.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.4.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.4.2.3 | | | Ringwall Rebar: supply and install | 32 | m | C.8.05 | 0.8 | $1.27 | $40.74 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $107.82 | $4.64 | $149 | | | |
| A5.4.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.4.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.4.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| A5.5 | *Minto East Vent Raise* | | | | | | | | | | | | | | | | | | $10,610 | | |
| A5.5.1.2 | | Preparation | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.5.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.5.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.5.2.3 | | | Ringwall Rebar: supply and install | 14 | m | C.8.05 | 0.3 | $1.27 | $18.33 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $48.52 | $4.64 | $67 | | | |
| A5.5.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.5.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.5.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| A5.6 | *Minto East 2 Vent Raise* | | | | | | | | | | | | | | | | | | $10,617 | | |
| A5.6.1.1 | | Site Preparation | Removal of Heater/Fan included in Demolition | | | | | | | | | | | | | | | | | | |
| A5.6.1.2 | | | Excavate and clean perimeter around shaft to suitable material. | 4 | m3 | C.8.01 | 8.0 | $84.00 | $335.99 | $13.66 | $55 | $6.83 | 28 | $27.33 | $0.00 | $0.00 | $104.49 | $418 | | | |
| A5.6.2.1 | | Concrete Cap installation | Structural steel - Supply and install I-Beam structural support | 8 | m | C.8.02 | 9.8 | $50.19 | $401.48 | $15.95 | $128 | $6.05 | 50 | $48.37 | $16.09 | $128.68 | $88.27 | $706 | | | |
| A5.6.2.2 | | | Formwork: Supply and install concrete ring-wall formwork | 8 | m2 | C.8.03 | 51.3 | $309.43 | $2,475.43 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.54 | $28.32 | $312.97 | $2,504 | | | |
| A5.6.2.3 | | | Ringwall Rebar: supply and install | 16 | m | C.8.05 | 0.4 | $1.27 | $20.37 | $0.00 | $0 | $0.00 | 0 | $0.00 | $3.37 | $53.91 | $4.64 | $74 | | | |
| A5.6.2.4 | | | Concrete slab: supply and install | 8.6 | m3 | C.8.06 | 61.1 | $329.23 | $2,844.57 | $10.63 | $92 | $3.50 | 31 | $30.21 | $386.22 | $3,336.96 | $729.58 | $6,304 | | | Includes slab formwork, rebar, finishing. |
| A5.6.2.5 | | | Vent Raise Pipe Supply and install | 1 | ea. | C.8.07 | 0.5 | $17.77 | $17.77 | $0.00 | $0 | $0.00 | 0 | $0.00 | $460.62 | $460.62 | $478.39 | $478 | | | |
| A5.6.3.1 | | Backfill cap area | Backfill: Load, haul, dump, place over concrete cap | 25 | m3 | R.001 | 0.8 | $1.39 | $34.71 | $3.03 | $76 | $0.90 | 23 | $22.48 | $0.00 | $0.00 | $5.31 | $133 | | | |
| **A6** | **External Tailings Facilities** | | | | | | | | | | | | | | | | | | | **$57,291** | |
| A6.1 | *Dry Stack Tailings Storage Facility* | | | | | | | | | | | | | | | | | | $57,291 | | |
| A6.1.1.1 | | Waste Rock Shell | Regrade WR shell slopes to 4H:1V | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A6.1.1.2 | | | Cover material: Load, haul, dump spread (0.5m) | 0 | m3 | R.048 | 0.0 | $0.86 | $0.00 | $2.78 | $0 | $0.91 | 0 | $0.00 | $0.00 | $0.00 | $4.55 | $0 | | | |
| A6.1.1.3 | | | Scarify surface | 0 | m2 | C.2.16 | 0.0 | $0.03 | $0.00 | $0.07 | $0 | $0.02 | 0 | $0.00 | $0.00 | $0.00 | $0.12 | $0 | | | |
| A6.1.1.4 | | | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A6.1.1.5 | | | Tree seedling application (1,000 stems/ha) | 5.30 | ha | C.6.06 | 271.4 | $1,832.33 | $9,703.52 | $25.98 | $138 | $15.00 | 83 | $79.44 | $469.71 | $2,487.45 | $2,343.03 | $12,408 | | | |
| A6.1.2.1 | | Fill Area at south end of DS | Load, haul, dump, spread | 0 | Cm3 | R.001 | 0.0 | $1.39 | $0.00 | $3.03 | $0 | $0.90 | 0 | $0.00 | $0.00 | $0.00 | $5.31 | $0 | | | Fill from TDD road and/or unsuitable DSTSF cover material |
| A6.1.3.1 | | Tailings surface | Regrade tailings area south of the tailings | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A6.1.3.2 | | | Regrade surface to form tertiary drainage catchments | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A6.1.3.3 | | | Cover: Excavate unsuitable temporary cover material | 0 | m3 | R.003 | 0.0 | $0.51 | $0.00 | $1.70 | $0 | $0.57 | 0 | $0.00 | $0.00 | $0.00 | $2.78 | $0 | | | |
| A6.1.3.4 | | | Cover material: Load, haul, dump spread (0.5m) | 0 | m3 | R.048 | 0.0 | $0.86 | $0.00 | $2.78 | $0 | $0.91 | 0 | $0.00 | $0.00 | $0.00 | $4.55 | $0 | | | |
| A6.1.3.5 | | | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.00 | $401.72 | $0 | $232.94 | 0 | $0.00 | $1,005.72 | $0.00 | $2,669.89 | $0 | | | |
| A6.1.3.6 | | | Tree seedling application (1,000 stems/ha) | 19.16 | ha | C.6.06 | 981.8 | $1,832.33 | $35,100.35 | $25.98 | $498 | $15.00 | 299 | $287.34 | $469.71 | $8,997.81 | $2,343.03 | $44,883 | | | |
| **A7** | **Roads** | | | | | | | | | | | | | | | | | | | **$136,050** | |
| A7.1 | *Exploration Roads* | | | | | | | | | | | | | | | | | | $33,589 | | |
| A7.1.1.1 | | Regrade/Scarify | Scarify road surface | 54,285 | m2 | C.2.16 | 0.0 | $0.03 | $1,886.30 | $0.07 | $3,564 | $0.02 | 965 | $926.07 | $0.00 | $0.00 | $0.12 | $6,377 | | | |
| A7.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.43 | ha | C.6.01 | 179.8 | $1,029.50 | $5,588.65 | $401.72 | $2,181 | $232.94 | 1,317 | $1,264.54 | $1,005.72 | $5,459.55 | $2,669.89 | $14,494 | | | |
| A7.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 5.43 | ha | C.6.06 | 278.2 | $1,832.33 | $9,946.82 | $25.98 | $141 | $15.00 | 85 | $81.43 | $469.71 | $2,549.82 | $2,343.03 | $12,719 | | | |
| A7.2 | *Access Roads (excl. Main Site Access Road)* | | | | | | | | | | | | | | | | | | $9,082 | | |
| A7.2.1.1 | | Regrade/Scarify | Regrade side slopes | 9 | hrs | C.2.13 | 9.5 | $44.39 | $419.85 | $194.68 | $1,841 | $67.01 | 660 | $633.81 | $0.00 | $0.00 | $306.07 | $2,895 | | | |
| A7.2.1.2 | | | Scarify road surface | 52,636 | m2 | C.2.16 | 0.0 | $0.03 | $1,829.00 | $0.07 | $3,456 | $0.02 | 935 | $897.94 | $0.00 | $0.00 | $0.12 | $6,183 | | | |
| A7.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.00 | ha | C.6.01 | 0.0 | $1,029.50 | $0.77 | $401.72 | $0 | $232.94 | 0 | $0.17 | $1,005.72 | $0.75 | $2,669.89 | $2 | | | |
| A7.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 0.00 | ha | C.6.06 | 0.0 | $1,832.33 | $1.36 | $25.98 | $0 | $15.00 | 0 | $0.01 | $469.71 | $0.35 | $2,343.03 | $2 | | | |
| A7.3 | *Main Site Access Road* | | | | | | | | | | | | | | | | | | $1,343 | | |
| A7.3.1.1 | | New Access over MVFE | Regrade new access through MVFE | 0 | m3 | | | | | | | | | | | | | | | | |
| A7.3.2.1 | | Signage | Install large sign on east and west side of barge landing on Yukon River | 2 | ea. | C.5.14 | 1.9 | $40.27 | $80.54 | $15.90 | $32 | $5.57 | 12 | $11.13 | $609.74 | $1,219.48 | $671.48 | $1,343 | | | |
| A7.4 | *Haul Roads* | | | | | | | | | | | | | | | | | | $72,436 | | |
| A7.4.1.1 | | Regrade/Scarify | Regrade side slopes | 21 | hrs | C.2.13 | 20.5 | $44.39 | $910.71 | $194.68 | $3,994 | $67.01 | 1,432 | $1,374.82 | $0.00 | $0.00 | $306.07 | $6,280 | | | |
| A7.4.1.2 | | | Scarify road surface | 91,084 | m2 | C.2.16 | 0.0 | $0.03 | $3,164.99 | $0.07 | $5,981 | $0.02 | 1,619 | $1,553.84 | $0.00 | $0.00 | $0.12 | $10,700 | | | |
| A7.4.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 11.06 | ha | C.6.01 | 366.5 | $1,029.50 | $11,389.06 | $401.72 | $4,444 | $232.94 | 2,684 | $2,576.99 | $1,005.72 | $11,125.97 | $2,669.89 | $29,536 | | | |
| A7.4.2.2 | | | Tree seedling application (1,000 stems/ha) | 11.06 | ha | C.6.06 | 567.0 | $1,832.33 | $20,270.53 | $25.98 | $287 | $15.00 | 173 | $165.94 | $469.71 | $5,196.25 | $2,343.03 | $25,920 | | | |
| A7.5 | *Culvert Removal* | | | | | | | | | | | | | | | | | | $19,600 | | |
| A7.5.1.1 | | Excavate culverts | Mobilization allowance for excavation fleet to various sites | 6 | hrs | C.7.01 | 12.0 | $88.22 | $529.34 | $118.29 | $710 | $44.16 | 276 | $264.96 | $0.00 | $0.00 | $250.67 | $1,504 | | | |
| A7.5.1.2 | | | Load, haul, dump, spread (spoil locally) | 18,020 | m3 | R.901 | 59.1 | $0.15 | $2,622.79 | $0.58 | $10,499 | $0.20 | 3,841 | $3,687.10 | $0.00 | $0.00 | $0.93 | $16,809 | | | |
| A7.5.1.2 | | Waste disposal | On-site disposal (demolition debris, etc.) | 190 | Lm3 | R.037 | 8.1 | $1.87 | $356.36 | $3.75 | $713 | $1.14 | 227 | $217.54 | $0.00 | $0.00 | $6.77 | $1,287 | | | |
| **A8** | **Demolition** | | | | | | | | | | | | | | | | | | | **$1,976,253** | |
| A8.1 | *Airstrip Area* | | | | | | | | | | | | | | | | | | $21,059 | | |
| A8.1.1.1 | | Remove tanks/equipment | Dismantle and prep for transport | 7 | hrs | C.1.13 | 28.0 | $168.00 | $1,175.97 | $86.19 | $603 | $14.53 | 106 | $101.70 | $0.00 | $0.00 | $268.71 | $1,881 | | | |
| A8.1.2.1 | | Waste Oil Tanker Secondar | Bedding Material: Load, haul dump bedding material to landfarm | 47 | Cm3 | R.001 | 1.5 | $1.39 | $65.73 | $3.03 | $143 | $0.90 | 44 | $42.57 | $0.00 | $0.00 | $5.31 | $252 | | | |
| A8.1.2.2 | | | Cut and fold liner | 219 | m2 | C.1.15 | 2.5 | $0.43 | $94.83 | $0.19 | $43 | $0.07 | 16 | $15.13 | $0.00 | $0.00 | $0.70 | $152 | | | |
| A8.1.2.3 | | | Regrade area to promote positive drainage | 192 | m2 | C.2.11 | 1.9 | $0.44 | $85.22 | $1.28 | $246 | $0.35 | 71 | $67.74 | $0.00 | $0.00 | $2.08 | $399 | | | |
| A8.1.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 10 | hrs | C.1.22 | 40.0 | $159.30 | $1,592.98 | $95.83 | $958 | $26.93 | 281 | $269.28 | $0.00 | $0.00 | $282.05 | $2,821 | | | |
| A8.1.3.2 | | | Disconnect services | 4 | hrs | C.1.09 | 12.0 | $88.07 | $352.28 | $7.55 | $30 | $4.80 | 20 | $19.20 | $0.00 | $0.00 | $100.42 | $402 | | | |
| A8.1.4.1 | | Demolition | Structural building demolition: wooden buildings/tents | 1,149 | m3 | C.1.08 | 87.7 | $2.88 | $3,310.74 | $1.60 | $1,834 | $0.57 | 680 | $652.51 | $0.00 | $0.00 | $5.05 | $5,797 | | | |
| A8.1.4.2 | | | Other demolition: covered storage, debris, etc. | 530 | m3 | C.1.07 | 52.5 | $3.74 | $1,980.53 | $2.07 | $1,097 | $0.74 | 407 | $390.34 | $0.00 | $0.00 | $6.55 | $3,468 | | | |
| A8.1.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 379 | m3 | R.006 | 12.8 | $1.48 | $562.06 | $2.95 | $1,117 | $0.92 | 361 | $346.89 | $0.00 | $0.00 | $5.35 | $2,026 | | | |
| A8.1.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 4 | m3 | C.7.07 | 34.6 | $355.10 | $1,536.93 | $423.68 | $1,834 | $113.33 | 511 | $490.50 | $0.00 | $0.00 | $892.11 | $3,861 | | | |
| A8.2 | *Airport Laydown Area* | | | | | | | | | | | | | | | | | | $33,408 | | |
| A8.2.1.1 | | Remove tanks/equipment | Dismantle and prep for transport | 2 | hrs | C.1.13 | 8.0 | $168.00 | $335.99 | $86.19 | $172 | $14.53 | 30 | $29.06 | $0.00 | $0.00 | $268.71 | $537 | | | |
| A8.2.2.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.2.2.2 | | | Disconnect services | 4 | hrs | C.1.09 | 12.0 | $88.07 | $352.28 | $7.55 | $30 | $4.80 | 20 | $19.20 | $0.00 | $0.00 | $100.42 | $402 | | | |
| A8.2.3.1 | | Demolition | Structural building demolition: steel structures | 96 | tonnes | C.1.05 | 191.3 | $69.36 | $6,633.00 | $139.08 | $13,301 | $33.84 | 3,371 | $3,236.25 | $0.00 | $0.00 | $242.28 | $23,170 | | | |
| A8.2.3.2 | | | Other demolition: covered storage etc. | 560 | m3 | C.1.07 | 55.5 | $3.74 | $2,093.92 | $2.07 | $1,160 | $0.74 | 430 | $412.69 | $0.00 | $0.00 | $6.55 | $3,667 | | | |
| A8.2.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 393 | Lm3 | R.005 | 15.8 | $1.76 | $693.24 | $3.53 | $1,387 | $1.08 | 441 | $423.19 | $0.00 | $0.00 | $6.37 | $2,504 | | | |
| A8.2.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 3 | trips | C.7.07 | 23.0 | $355.10 | $1,020.92 | $423.68 | $1,218 | $113.33 | 339 | $325.82 | $0.00 | $0.00 | $892.11 | $2,565 | | | |
| A8.3 | *Camp Area* | | | | | | | | | | | | | | | | | | $375,774 | | |
| A8.3.1.1 | | Equipment Removal | Remove salvageable equipment | 48 | hrs | C.1.13 | 192.0 | $168.00 | $8,063.76 | $86.19 | $4,137 | $14.53 | 726 | $697.34 | $0.00 | $0.00 | $268.71 | $12,898 | | | |
| A8.3.2.1 | | Remove modular buildings | Dismantle and prep for transport | 92 | ea. | C.1.20 | 1,794.0 | $850.98 | $78,290.06 | $730.60 | $67,215 | $166.46 | 15,953 | $15,314.69 | $0.00 | $0.00 | $1,748.04 | $160,820 | | | |
| A8.3.2.2 | | | Transport structures off-site (Whitehorse) | 92 | ea. | C.7.04 | 736.0 | $351.24 | $32,314.23 | $303.64 | $27,935 | $113.33 | 10,861 | $10,426.18 | $0.00 | $0.00 | $768.21 | $70,675 | | | |
| A8.3.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 1 | hrs | C.1.22 | 4.0 | $159.30 | $159.30 | $95.83 | $96 | $26.93 | 28 | $26.93 | $0.00 | $0.00 | $282.05 | $282 | | | |
| A8.3.3.2 | | | Disconnect services | 8 | hrs | C.1.09 | 24.0 | $88.07 | $704.56 | $7.55 | $60 | $4.80 | 40 | $38.40 | $0.00 | $0.00 | $100.42 | $803 | | | |
| A8.3.4.1 | | Demolition | Structural building demolition: Steel | 175 | tonnes | C.1.05 | 350.7 | $69.36 | $12,160.50 | $139.08 | $24,385 | $33.84 | 6,180 | $5,933.13 | $0.00 | $0.00 | $242.28 | $42,479 | | | |
| A8.3.4.2 | | | Structural building demolition: Wood/misc. structures | 10,959 | m3 | C.1.08 | 836.7 | $2.88 | $31,584.20 | $1.60 | $17,497 | $0.57 | 6,484 | $6,224.86 | $0.00 | $0.00 | $5.05 | $55,306 | | | |
| A8.3.4.4 | | | Other demolition: Utilidors, etc. | 466 | m3 | C.1.07 | 46.1 | $3.74 | $1,742.09 | $2.07 | $965 | $0.74 | 358 | $343.34 | $0.00 | $0.00 | $6.55 | $3,051 | | | |
| A8.3.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 3,867 | m3 | R.007 | 175.3 | $1.99 | $7,708.84 | $3.99 | $15,425 | $1.22 | 4,902 | $4,705.86 | $0.00 | $0.00 | $7.20 | $27,839 | | | |
| A8.3.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 1 | trips | C.7.07 | 8.0 | $355.10 | $355.10 | $423.68 | $424 | $113.33 | 118 | $113.33 | $0.00 | $0.00 | $892.11 | $892 | | | |
| A8.3.6.1 | | Demolish foundations | Break in place concrete foundations | 51 | m3 | C.1.01 | 4.1 | $2.39 | $122.15 | $9.37 | $479 | $2.48 | 132 | $126.81 | $0.00 | $0.00 | $14.24 | $728 | | | |
| A8.4 | *Explosives Plant and Storage Areas* | | | | | | | | | | | | | | | | | | $30,611 | | |
| A8.4.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 37 | hrs | C.1.13 | 149.3 | $168.00 | $6,271.81 | $86.19 | $3,218 | $14.53 | 565 | $542.38 | $0.00 | $0.00 | $268.71 | $10,032 | | | |
| A8.4.2.1 | | Remove modular buildings | Dismantle and prep for transport | 1 | ea. | C.1.20 | 19.5 | $850.98 | $850.98 | $730.60 | $731 | $166.46 | 173 | $166.46 | $0.00 | $0.00 | $1,748.04 | $1,748 | | | |
| A8.4.2.2 | | | Transport structures off-site (Whitehorse) | 1 | ea. | C.7.04 | 8.0 | $351.24 | $351.24 | $303.64 | $304 | $113.33 | 118 | $113.33 | $0.00 | $0.00 | $768.21 | $768 | | | |
| A8.4.3.1 | | Prepare for demolition | Remove hazardous materials/prep for transport offsite | 4 | hrs | C.1.22 | 16.0 | $159.30 | $637.19 | $95.83 | $383 | $26.93 | 112 | $107.71 | $0.00 | $0.00 | $282.05 | $1,128 | | | |
| A8.4.3.2 | | | Disconnect services | 2 | hrs | C.1.09 | 6.0 | $88.07 | $176.14 | $7.55 | $15 | $4.80 | 10 | $9.60 | $0.00 | $0.00 | $100.42 | $201 | | | |
| A8.4.4.1 | | Demolition | Structural building demolition: Steel | 47 | tonnes | C.1.05 | 94.2 | $69.36 | $3,266.25 | $139.08 | $6,550 | $33.84 | 1,660 | $1,593.61 | $0.00 | $0.00 | $242.28 | $11,410 | | | |
| A8.4.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 103 | m3 | R.008 | 5.4 | $2.32 | $239.23 | $4.65 | $479 | $1.42 | 152 | $146.04 | $0.00 | $0.00 | $8.39 | $864 | | | |
| A8.4.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 5 | trips | C.7.07 | 40.0 | $355.10 | $1,775.51 | $423.68 | $2,118 | $113.33 | 590 | $566.64 | $0.00 | $0.00 | $892.11 | $4,461 | | | |
| A8.5 | *Fuel Storage Area* | | | | | | | | | | | | | | | | | | $114,842 | | |
| A8.5.1.1 | | Remove equipment/dismant | Small equipment: dismantle and prep for transport | 24 | hrs | C.1.13 | 96.0 | $168.00 | $4,031.88 | $86.19 | $2,069 | $14.53 | 363 | $348.67 | $0.00 | $0.00 | $268.71 | $6,449 | | | |
| A8.5.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 192 | hrs | C.1.14 | 1,153.4 | $269.89 | $51,883.26 | $167.56 | $32,213 | $20.53 | 4,111 | $3,946.31 | $0.00 | $0.00 | $457.98 | $88,042 | | | |
| A8.5.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.5.2.2 | | | Disconnect services | 8 | hrs | C.1.09 | 24.0 | $88.07 | $704.56 | $7.55 | $60 | $4.80 | 40 | $38.40 | $0.00 | $0.00 | $100.42 | $803 | | | |
| A8.5.2.3 | | | Clean out tanks, pressure wash, remove sludge | 10 | hrs | C.1.04 | 10.3 | $35.54 | $365.13 | $15.75 | $162 | $2.00 | 21 | $20.55 | $0.00 | $0.00 | $53.29 | $548 | | | |
| A8.5.3.1 | | Demolish structures | Misc. debris/scraps (tanks included in dismantling above) | 75 | m3 | C.1.08 | 5.7 | $2.88 | $216.15 | $1.60 | $120 | $0.57 | 44 | $42.60 | $0.00 | $0.00 | $5.05 | $378 | | | |
| A8.5.4.1 | | Remove secondary containi | Bedding Material: Load, haul dump bedding material to landfarm | 623 | Cm3 | R.009 | 32.8 | $2.32 | $1,442.73 | $4.64 | $2,887 | $1.41 | 917 | $880.71 | $0.00 | $0.00 | $8.37 | $5,210 | | | |
| A8.5.4.2 | | | Cut and fold liner | 1,747 | m2 | C.1.15 | 20.3 | $0.43 | $758.23 | $0.19 | $340 | $0.07 | 126 | $120.97 | $0.00 | $0.00 | $0.70 | $1,219 | | | |
| A8.5.4.3 | | | Regrade area to promote positive drainage | 1,666 | m2 | C.2.11 | 16.7 | $0.44 | $739.50 | $1.28 | $2,138 | $0.35 | 612 | $587.76 | $0.00 | $0.00 | $2.08 | $3,465 | | | |
| A8.5.5.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 229 | m3 | R.009 | 12.1 | $2.32 | $531.18 | $4.64 | $1,063 | $1.41 | 338 | $324.26 | $0.00 | $0.00 | $8.37 | $1,918 | | | |
| A8.5.5.2 | | | Off-site disposal (re-usable equipment, etc.) | 7 | trips | C.7.07 | 56.0 | $355.10 | $2,485.71 | $423.68 | $2,966 | $113.33 | 826 | $793.30 | $0.00 | $0.00 | $892.11 | $6,245 | | | |
| A8.6 | *Mill Area* | | | | | | | | | | | | | | | | | | $1,265,173 | | Excludes WTP |
| A8.6.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 379 | hrs | C.1.13 | 1,515.0 | $168.00 | $63,626.87 | $86.19 | $32,644 | $14.53 | 5,732 | $5,502.37 | $0.00 | $0.00 | $268.71 | $101,773 | | | |
| A8.6.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 466 | hrs | C.1.14 | 2,796.5 | $269.89 | $125,789.65 | $167.56 | $78,099 | $20.53 | 9,966 | $9,567.74 | $0.00 | $0.00 | $457.98 | $213,456 | | | |
| A8.6.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 65 | hrs | C.1.22 | 260.0 | $159.30 | $10,354.37 | $95.83 | $6,229 | $26.93 | 1,823 | $1,750.32 | $0.00 | $0.00 | $282.05 | $18,333 | | | Off-site disposal included in 'Waste Disposal' |
| A8.6.2.6 | | | Reagents: Disposal and tipping fees | 1.0 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A8.6.2.7 | | | Decontaminate buildings: wash equipment/structures, etc. | 38 | hrs | C.1.04 | 37.8 | $35.54 | $1,342.93 | $15.75 | $595 | $2.00 | 79 | $75.58 | $0.00 | $0.00 | $53.29 | $2,014 | | | |
| A8.6.2.8 | | | Decontaminate buildings: Wash floors etc. | 4,732 | m2 | C.1.03 | 40.8 | $0.31 | $1,448.16 | $0.14 | $642 | $0.02 | 85 | $81.50 | $0.00 | $0.00 | $0.46 | $2,171 | | | |
| A8.6.3.1 | | Demolition | Structural building demolition: Steel | 2,660 | tonnes | C.1.05 | 5,319.1 | $69.36 | $184,463.18 | $139.08 | $369,899 | $33.84 | 93,750 | $89,999.96 | $0.00 | $0.00 | $242.28 | $644,363 | | | |
| A8.6.3.2 | | | Structural building demolition: Wood/misc. structures | 960 | m3 | C.1.08 | 73.3 | $2.88 | $2,766.75 | $1.60 | $1,533 | $0.57 | 568 | $545.29 | $0.00 | $0.00 | $5.05 | $4,845 | | | |
| A8.6.3.3 | | | Other demolition: Steel | 526 | tonnes | C.1.05 | 1,052.7 | $69.36 | $36,505.48 | $139.08 | $73,204 | $33.84 | 18,553 | $17,811.10 | $0.00 | $0.00 | $242.28 | $127,520 | | | |
| A8.6.3.4 | | | Other demolition: concrete | 602 | m3 | C.1.06 | 323.7 | $15.92 | $9,579.30 | $62.48 | $37,592 | $16.53 | 10,359 | $9,944.51 | $0.00 | $0.00 | $94.92 | $57,116 | | | |
| A8.6.3.5 | | | Other demolition: miscellaneous | 244 | m3 | C.1.07 | 24.1 | $3.74 | $910.78 | $2.07 | $505 | $0.74 | 187 | $179.50 | $0.00 | $0.00 | $6.55 | $1,595 | | | |
| A8.6.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 5,985 | m3 | R.037 | 255.1 | $1.87 | $11,217.23 | $3.75 | $22,445 | $1.14 | 7,133 | $6,847.56 | $0.00 | $0.00 | $6.77 | $40,510 | | | |
| A8.6.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 33 | trips | C.7.07 | 266.0 | $355.10 | $11,806.23 | $423.68 | $14,086 | $113.33 | 3,925 | $3,767.87 | $0.00 | $0.00 | $892 | $29,660 | | | |
| A8.6.5.1 | | Demolish foundations | Break in place concrete foundations | 1,532 | m3 | C.1.01 | 123.7 | $2.39 | $3,659.05 | $9.37 | $14,359 | $2.48 | 3,957 | $3,798.55 | $0.00 | $0.00 | $14.24 | $21,817 | | | |
| A8.7 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $28,525 | | |
| A8.7.1.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 8 | hrs | C.1.22 | 30.0 | $159.30 | $1,194.73 | $95.83 | $719 | $26.93 | 210 | $201.96 | $0.00 | $0.00 | $282.05 | $2,115 | | | |
| A8.7.1.2 | | | Reagents: Disposal and tipping fees | 1 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A8.7.2.1 | | Demolish buildings | Structural building demolition: Wood/misc. structures (Reagent tent) | 1,800 | m3 | C.1.08 | 137.4 | $2.88 | $5,187.66 | $1.60 | $2,874 | $0.57 | 1,065 | $1,022.42 | $0.00 | $0.00 | $5.05 | $9,084 | | | |
| A8.7.3.1 | | Haul waste to landfill | Demolition debris | 594 | m3 | R.037 | 25.3 | $1.87 | $1,113.25 | $3.75 | $2,228 | $1.14 | 708 | $679.58 | $0.00 | $0.00 | $6.77 | $4,020 | | | |
| A8.7.3.2 | | | Remove tires off-site for disposal | 10 | trips | C.7.07 | 78.8 | $355.10 | $3,495.53 | $423.68 | $4,171 | $113.33 | 1,162 | $1,115.57 | $0.00 | $0.00 | $892.11 | $8,782 | | | |
| A8.7.3.3 | | | Misc. debris/scraps | 652 | m3 | R.037 | 27.8 | $1.87 | $1,221.95 | $3.75 | $2,445 | $1.14 | 777 | $745.94 | $0.00 | $0.00 | $6.77 | $4,413 | | | |
| A8.7.4.1 | | Demolish foundations | Break and bury concrete foundations | 8 | m3 | C.1.01 | 0.6 | $2.39 | $18.48 | $9.37 | $73 | $2.48 | 20 | $19.19 | $0.00 | $0.00 | $14.24 | $110 | | | |
| A8.8 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $8,516 | | |
| A8.8.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 6 | hrs | C.1.13 | 24.0 | $168.00 | $1,007.97 | $86.19 | $517 | $14.53 | 91 | $87.17 | $0.00 | $0.00 | $268.71 | $1,612 | | | |
| A8.8.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.8.3.1 | | Demolition | Other demolition: miscellaneous | 462 | m3 | C.1.07 | 45.7 | $3.74 | $1,727.03 | $2.07 | $957 | $0.74 | 355 | $340.38 | $0.00 | $0.00 | $6.55 | $3,024 | | | |
| A8.8.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 462 | m3 | R.043 | 20.9 | $1.99 | $918.18 | $3.98 | $1,837 | $1.21 | 584 | $560.51 | $0.00 | $0.00 | $7.18 | $3,316 | | | |
| A8.9 | *Minto North Portal* | | | | | | | | | | | | | | | | | | $8,981 | | |
| A8.9.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 6 | hrs | C.1.13 | 24.0 | $168.00 | $1,007.97 | $86.19 | $517 | $14.53 | 91 | $87.17 | $0.00 | $0.00 | $268.71 | $1,612 | | | Qnty assumed to be same as Minto South Portal |
| A8.9.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | Qnty assumed to be same as Minto South Portal |
| A8.9.3.1 | | Demolition | Other demolition: miscellaneous | 462 | m3 | C.1.07 | 45.7 | $3.74 | $1,727.03 | $2.07 | $957 | $0.74 | 355 | $340.38 | $0.00 | $0.00 | $6.55 | $3,024 | | | Qnty assumed to be same as Minto South Portal |
| A8.9.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 462 | m3 | R.042 | 23.8 | $2.27 | $1,046.71 | $4.53 | $2,094 | $1.38 | 666 | $638.96 | $0.00 | $0.00 | $8.18 | $3,780 | | | Qnty assumed to be same as Minto South Portal |
| A8.10 | *Pelly Laydown (Includes propane tanks by W15 Sump)* | | | | | | | | | | | | | | | | | | $83,981 | | |
| A8.10.1.1 | | Remove modular buildings/t | Dismantle and prep for transport | 7 | ea. | C.1.20 | 136.5 | $850.98 | $5,956.85 | $730.60 | $5,114 | $166.46 | 1,214 | $1,165.25 | $0.00 | $0.00 | $1,748.04 | $12,236 | | | |
| A8.10.1.2 | | | Transport structures off-site (Whitehorse) | 7 | ea. | C.7.04 | 56.0 | $351.24 | $2,458.69 | $303.64 | $2,125 | $113.33 | 826 | $793.30 | $0.00 | $0.00 | $768.21 | $5,377 | | | |
| A8.10.2.1 | | Prepare for demolition | Hazardous materials: Gather and prep for transport offsite | 2 | hrs | C.1.22 | 8.0 | $159.30 | $318.60 | $95.83 | $192 | $26.93 | 56 | $53.86 | $0.00 | $0.00 | $282.05 | $564 | | | |
| A8.10.3.1 | | Demolish buildings | Structural building demolition: Steel | 80 | tonnes | C.1.05 | 159.4 | $69.36 | $5,527.50 | $139.08 | $11,084 | $33.84 | 2,809 | $2,696.88 | $0.00 | $0.00 | $242.28 | $19,309 | | | |
| A8.10.3.2 | | | Structural building demolition: Wood/misc. structures | 5,672 | m3 | C.1.08 | 433.1 | $2.88 | $16,347.99 | $1.60 | $9,057 | $0.57 | 3,356 | $3,221.99 | $0.00 | $0.00 | $5.05 | $28,627 | | | |
| A8.10.4.1 | | Waste disposal | On-site disposal (demolition debris, etc.) | 2,165 | m3 | R.045 | 100.0 | $2.03 | $4,395.81 | $4.06 | $8,796 | $1.24 | 2,795 | $2,683.42 | $0.00 | $0.00 | $7.33 | $15,875 | | | |
| A8.10.4.2 | | | Off-site disposal (re-usable equipment, etc.) | 2 | trips | C.7.07 | 15.0 | $355.10 | $665.82 | $423.68 | $794 | $113.33 | 221 | $212.49 | $0.00 | $0.00 | $892.11 | $1,673 | | | |
| A8.10.5.1 | | Demolish foundations | Break and bury concrete foundations | 23 | m3 | C.1.01 | 1.8 | $2.39 | $53.73 | $9.37 | $211 | $2.48 | 58 | $55.78 | $0.00 | $0.00 | $14.24 | $320 | | | |
| A8.11 | *Vent Raise - Area 118* | | | | | | | | | | | | | | | | | | $5,381 | | |
| A8.11.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 20 | hrs | C.1.13 | 80.0 | $168.00 | $3,359.90 | $86.19 | $1,724 | $14.53 | 303 | $290.56 | $0.00 | $0.00 | $268.71 | $5,374 | | | |
| A8.11.2.1 | | Waste disposal | Off-site disposal (re-usable equipment, etc.) | 1 | trips | R.043 | 0.0 | $1.99 | $1.99 | $3.98 | $4 | $1.21 | 1 | $1.21 | $0.00 | $0.00 | $7.18 | $7 | | | |
| **A9** | **Surface Infrastructure** | | | | | | | | | | | | | | | | | | | **$169,527** | |
| A9.1 | *Tailings and Water Conveyance Pipelines* | | | | | | | | | | | | | | | | | | $91,886 | | |
| A9.1.1.1 | | Dismantle piping systems | Flush and clean tailings pipeline systems | 8 | ls | C.1.21 | 32.0 | $203.78 | $1,630.27 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $203.78 | $1,630 | | | |
| A9.1.1.2 | | | Cut pipelines and prep for transport (6 to 8" HDPE pipes) | 6,800 | m | C.1.17 | 1,070.9 | $7.21 | $49,056.06 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $7.21 | $49,056 | | | |
| A9.1.1.3 | | | Cut pipelines and prep for transport (10 to 18" HDPE pipes) | 1,740 | m | C.1.18 | 456.7 | $12.02 | $20,920.96 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $12.02 | $20,921 | | | |
| A9.1.1.4 | | | Cut pipelines and prep for transport (20 to 36" HDPE pipes) | 885 | m | C.1.19 | 348.4 | $18.04 | $15,961.25 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $18.04 | $15,961 | | | |
| A9.2.2.1 | | Waste disposal | Haul pipes lines and debris to landfill | 638 | m3 | R.037 | 27.2 | $1.87 | $1,195.62 | $3.75 | $2,392 | $1.14 | 760 | $729.86 | $0.00 | $0.00 | $6.77 | $4,318 | | | |
| A9.2 | *Conveyance Pipeline Equipment* | | | | | | | | | | | | | | | | | | $12,462 | | |
| A9.2.1.1 | | Dismantle piping systems | Remove pumps and prep for transport | 15 | ea. | C.1.24 | 198.0 | $602.98 | $9,044.72 | $24.94 | $374 | $14.40 | 225 | $216.00 | $0.00 | $0.00 | $642.33 | $9,635 | | | |
| A9.2.1.2 | | | Remove barges/Support Equipment prep for transport | 2 | ea. | C.1.23 | 52.8 | $1,205.96 | $2,411.93 | $49.89 | $100 | $28.80 | 60 | $57.60 | $0.00 | $0.00 | $1,284.65 | $2,569 | | | |
| A9.2.2.1 | | Waste disposal | Transport pumps, barge and support equip. offsite (Whitehorse) | 6.7 | tonnes | C.7.02 | 2.7 | $17.56 | $117.67 | $15.18 | $102 | $5.67 | 40 | $37.96 | $0.00 | $0.00 | $38.41 | $257 | | | |
| A9.3 | *Powerlines* | | | | | | | | | | | | | | | | | | $65,179 | | |
| A9.3.1.1 | | Dismantle | Dismantle and collect powerlines | 3.2 | km | C.1.10 | 217.9 | $2,639.96 | $8,342.27 | $940.09 | $2,971 | $251.90 | 829 | $795.99 | $0.00 | $0.00 | $3,831.94 | $12,109 | | | |
| A9.3.1.2 | | | Remove power poles and load for transport off-site | 60 | ea. | C.1.11 | 548.6 | $423.67 | $25,420.14 | $88.51 | $5,311 | $18.29 | 1,143 | $1,097.14 | $0.00 | $0.00 | $530.46 | $31,828 | | | |
| A9.3.1.3 | | | Disconnect transformers and load for transport | 4 | ea. | C.1.12 | 93.3 | $892.89 | $3,571.55 | $317.96 | $1,272 | $85.20 | 355 | $340.78 | $0.00 | $0.00 | $1,296.04 | $5,184 | | | |
| A9.3.2.1 | | Waste disposal | Transport powerlines, poles and transformers off-site | 18 | trips | C.7.07 | 144.0 | $355.10 | $6,391.83 | $423.68 | $7,626 | $113.33 | 2,125 | $2,039.90 | $0.00 | $0.00 | $892.11 | $16,058 | | | |
| **A10** | **Water Detention Structures** | | | | | | | | | | | | | | | | | | | **$786,952** | |
| A10.1 | *W15 Sump* | | | | | | | | | | | | | | | | | | $1,049 | | |
| A10.1.1.1 | | Remove secondary containr | Cut and fold liner | 1,310 | m2 | C.1.15 | 15.2 | $0.43 | $568.50 | $0.19 | $255 | $0.07 | 94 | $90.70 | $0.00 | $0.00 | $0.70 | $914 | | | |
| A10.1.1.2 | | | Haul liner to landfill | 20 | Lm3 | R.070 | 0.8 | $1.90 | $37.35 | $3.80 | $75 | $1.16 | 24 | $22.80 | $0.00 | $0.00 | $6.86 | $135 | | | |
| A10.2 | *Mill Water Pond* | | | | | | | | | | | | | | | | | | $0 | | |
| A10.3 | *Sewage Lagoon (near IROD)* | | | | | | | | | | | | | | | | | | $23,852 | | |
| A10.3.1 | | Remove pond | Backfill pond | 4,488 | m3 | R.001 | 141.4 | $1.39 | $6,231.19 | $3.03 | $13,585 | $0.90 | 4,203 | $4,035.32 | $0.00 | $0.00 | $5.31 | $23,852 | | | |
| A10.4 | *Water Storage Pond Dam* | | | | | | | | | | | | | | | | | | $762,051 | | |
| A10.4.1.1 | | Water Management | Install pump and pump around system | 4 | hrs | C.4.14 | 16.0 | $120.43 | $481.73 | $20.53 | $82 | $6.80 | 28 | $27.20 | $0.00 | $0.00 | $147.76 | $591 | | | |
| A10.4.1.2 | | | Pump pond water to discharge | 400,000 | m3 | C.4.12 | 146.8 | $0.01 | $5,216.05 | $0.05 | $19,052 | $0.01 | 3,058 | $2,935.56 | $0.00 | $0.00 | $0.07 | $27,203 | | | |
| A10.4.1.3 | | | Maintain pump around system during WSP closure activities | 103 | days | C.4.13 | 10.3 | $3.55 | $364.31 | $12.98 | $1,331 | $2.00 | 214 | $205.03 | $0.00 | $0.00 | $18.53 | $1,900 | | | Duration calculated as sum of associated tasks plus 20% contingency |
| A10.4.2.1 | | Breach dam | Granular zones/gen. fill: Load, haul, dump, spread in upstream North ab | 62,301 | m3 | R.001 | 1,963.4 | $1.39 | $86,500.02 | $3.03 | $188,587 | $0.90 | 58,351 | $56,017.38 | $0.00 | $0.00 | $5.31 | $331,104 | | | |
| A10.4.2.2 | | | Dam Core: Load, haul, dump in temporary stockpile | 23,617 | m3 | R.001 | 744.3 | $1.39 | $32,789.73 | $3.03 | $71,488 | $0.90 | 22,119 | $21,234.62 | $0.00 | $0.00 | $5.31 | $125,512 | | | |
| A10.4.2.3 | | | Rip-rap: Sort and stockpile durable rip-rap for reuse | 19,285 | m3 | R.001 | 607.8 | $1.39 | $26,776.14 | $3.03 | $58,377 | $0.90 | 18,063 | $17,340.22 | $0.00 | $0.00 | $5.31 | $102,494 | | | |
| A10.4.2.4 | | | Rip-rap: Load haul, dump unsuitable rip-rap in upstream North abutmen | 19,285 | m3 | R.001 | 607.8 | $1.39 | $26,776.14 | $3.03 | $58,377 | $0.90 | 18,063 | $17,340.22 | $0.00 | $0.00 | $5.31 | $102,494 | | | |
| A10.4.3.1 | | Channel restoration | Excavate stream channel | 5,584 | m3 | R.902 | 97.1 | $0.77 | $4,308.58 | $1.64 | $9,173 | $0.46 | 2,681 | $2,574.22 | $0.00 | $0.00 | $2.88 | $16,056 | | | |
| A10.4.3.2 | | | Bedding layer: Load haul, dump, place granular bedding layer along cha | 726 | m3 | R.001 | 22.9 | $1.39 | $1,008.60 | $3.03 | $2,199 | $0.90 | 680 | $653.17 | $0.00 | $0.00 | $5.31 | $3,861 | | | |
| A10.4.3.3 | | | Rip-rap: Load, haul dump from temporary stockpile | 964 | m3 | R.001 | 30.4 | $1.39 | $1,337.77 | $3.03 | $2,917 | $0.90 | 902 | $866.34 | $0.00 | $0.00 | $5.31 | $5,121 | | | |
| A10.4.3.4 | | | Rip-rap: place and secure | 964 | m3 | R.904 | 10.5 | $0.48 | $465.10 | $0.91 | $877 | $0.32 | 325 | $311.83 | $0.00 | $0.00 | $1.72 | $1,653 | | | |
| A10.4.4.1 | | Cover | Cover material: Load, haul, dump spread (1m) | 6,975 | m3 | R.001 | 219.8 | $1.39 | $9,684.17 | $3.03 | $21,113 | $0.90 | 6,533 | $6,271.47 | $0.00 | $0.00 | $5.31 | $37,069 | | | Cover sourced from dam core material |
| A10.4.5.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 1.4 | ha | C.6.01 | 46.2 | $1,029.50 | $1,436.16 | $401.72 | $560 | $232.94 | 338 | $324.96 | $1,005.72 | $1,402.98 | $2,669.89 | $3,724 | | | |
| A10.4.5.2 | | | Tree seedling application (1,000 stems/ha) | 1.4 | ha | C.6.06 | 71.5 | $1,832.33 | $2,556.10 | $25.98 | $36 | $15.00 | 22 | $20.93 | $469.71 | $655.25 | $2,343.03 | $3,269 | | | |
| **A11** | **Yards/Laydown Areas** | | | | | | | | | | | | | | | | | | | **$758,907** | |
| A11.1 | *Airstrip Area* | | | | | | | | | | | | | | | | | | $39,834 | | |
| A11.1.1.1 | | Re-grade | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.1.1.2 | | | Scarify surface | 64,378 | m2 | C.2.16 | 0.0 | $0.03 | $2,236.99 | $0.07 | $4,227 | $0.02 | 1,144 | $1,098.24 | $0.00 | $0.00 | $0.12 | $7,562 | | | |
| A11.1.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 6.4 | ha | C.6.01 | 213.3 | $1,029.50 | $6,627.68 | $401.72 | $2,586 | $232.94 | 1,562 | $1,499.64 | $1,005.72 | $6,474.57 | $2,669.89 | $17,188 | | | |
| A11.1.2.2 | | | Tree seedling application (1,000 stems/ha) | 6.4 | ha | C.6.06 | 329.9 | $1,832.33 | $11,796.10 | $25.98 | $167 | $15.00 | 101 | $96.57 | $469.71 | $3,023.88 | $2,343.03 | $15,084 | | | |
| A11.2 | *Airport Laydown Area* | | | | | | | | | | | | | | | | | | $13,165 | | |
| A11.2.1.1 | | Re-grade | Scarify surface | 21,277 | m2 | C.2.16 | 0.0 | $0.03 | $739.33 | $0.07 | $1,397 | $0.02 | 378 | $362.97 | $0.00 | $0.00 | $0.12 | $2,499 | | | |
| A11.2.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.1 | ha | C.6.01 | 70.5 | $1,029.50 | $2,190.47 | $401.72 | $855 | $232.94 | 516 | $495.64 | $1,005.72 | $2,139.87 | $2,669.89 | $5,681 | | | |
| A11.2.2.2 | | | Tree seedling application (1,000 stems/ha) | 2.1 | ha | C.6.06 | 109.0 | $1,832.33 | $3,898.65 | $25.98 | $55 | $15.00 | 33 | $31.92 | $469.71 | $999.40 | $2,343.03 | $4,985 | | | |
| A11.3 | *Camp Area* | | | | | | | | | | | | | | | | | | $118,708 | | |
| A11.3.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 7 | hrs | C.2.13 | 6.9 | $44.39 | $306.20 | $194.68 | $1,343 | $67.01 | 481 | $462.24 | $0.00 | $0.00 | $306.07 | $2,111 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A11.3.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 24 | hrs | C.2.13 | 24.5 | $44.39 | $1,086.58 | $194.68 | $4,766 | $67.01 | 1,709 | $1,640.31 | $0.00 | $0.00 | $306.07 | $7,493 | | | Slope between camp and main access road |
| A11.3.1.3 | | | Scarify surfaces | 20,626 | m2 | C.2.16 | 0.0 | $0.03 | $716.72 | $0.07 | $1,354 | $0.02 | 367 | $351.87 | $0.00 | $0.00 | $0.12 | $2,423 | | | |
| A11.3.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 10,313 | Cm3 | R.046 | 198.2 | $0.85 | $8,729.48 | $2.75 | $28,368 | $0.91 | 9,724 | $9,335.37 | $0.00 | $0.00 | $4.50 | $46,433 | | | |
| A11.3.2.2 | | | Slope area cover material: Load, haul, dump along crest | 9,349 | Cm3 | R.047 | 157.2 | $0.74 | $6,916.70 | $2.44 | $22,835 | $0.82 | 7,990 | $7,670.53 | $0.00 | $0.00 | $4.00 | $37,422 | | | |
| A11.3.2.3 | | | Slope area cover material: Spread down slope | 10 | hrs | C.2.13 | 10.2 | $44.39 | $451.46 | $194.68 | $1,980 | $67.01 | 710 | $681.52 | $0.00 | $0.00 | $306.07 | $3,113 | | | |
| A11.3.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 3.93 | ha | C.6.01 | 130.3 | $1,029.50 | $4,048.49 | $401.72 | $1,580 | $232.94 | 954 | $916.05 | $1,005.72 | $3,954.97 | $2,669.89 | $10,499 | | | |
| A11.3.3.2 | | | Tree seedling application (1,000 stems/ha) | 3.93 | ha | C.6.06 | 201.5 | $1,832.33 | $7,205.60 | $25.98 | $102 | $15.00 | 61 | $58.99 | $469.71 | $1,847.12 | $2,343.03 | $9,214 | | | |
| A11.4 | *Crusher Area* | | | | | | | | | | | | | | | | | | $73,635 | | |
| A11.2.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 9 | hrs | C.2.13 | 9.0 | $44.39 | $400.28 | $194.68 | $1,756 | $67.01 | 629 | $604.27 | $0.00 | $0.00 | $306.07 | $2,760 | | | |
| A11.2.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 13,482 | m3 | R.055 | 244.8 | $0.80 | $10,783.37 | $2.60 | $35,042 | $0.86 | 12,012 | $11,531.82 | $0.00 | $0.00 | $4.25 | $57,358 | | | |
| A11.2.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.70 | ha | C.6.01 | 89.3 | $1,029.50 | $2,775.95 | $401.72 | $1,083 | $232.94 | 654 | $628.11 | $1,005.72 | $2,711.82 | $2,669.89 | $7,199 | | | |
| A11.2.3.2 | | | Tree seedling application (1,000 stems/ha) | 3 | ha | C.6.06 | 138.2 | $1,832.33 | $4,940.70 | $25.98 | $70 | $15.00 | 42 | $40.45 | $469.71 | $1,266.53 | $2,343.03 | $6,318 | | | |
| A11.5 | *Exploration Disturbances* | | | | | | | | | | | | | | | | | | $21,519 | | |
| A11.5.1.1 | | Ridgetop Area | Scarify surfaces | 34,778 | m2 | C.2.16 | 0.0 | $0.03 | $1,208.47 | $0.07 | $2,284 | $0.02 | 618 | $593.29 | $0.00 | $0.00 | $0.12 | $4,085 | | | |
| A11.5.1.2 | | | Seed/Fertilize: broadcast seeding | 3 | ha | C.6.01 | 115.2 | $1,029.50 | $3,580.40 | $401.72 | $1,397 | $232.94 | 844 | $810.13 | $1,005.72 | $3,497.69 | $2,669.89 | $9,285 | | | |
| A11.5.1.3 | | | Tree seedling application (1,000 stems/ha) | 3 | ha | C.6.06 | 178.2 | $1,832.33 | $6,372.49 | $25.98 | $90 | $15.00 | 54 | $52.17 | $469.71 | $1,633.56 | $2,343.03 | $8,149 | | | |
| A11.6 | *Explosives Plant and Storage Areas* | | | | | | | | | | | | | | | | | | $43,165 | | |
| A11.6.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 30 | hrs | C.2.13 | 29.6 | $44.39 | $1,314.39 | $194.68 | $5,765 | $67.01 | 2,067 | $1,984.22 | $0.00 | $0.00 | $306.07 | $9,063 | | | |
| A11.6.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.6.1.3 | | | Scarify surfaces | 55,113 | m2 | C.2.16 | 0.0 | $0.03 | $1,915.08 | $0.07 | $3,619 | $0.02 | 979 | $940.20 | $0.00 | $0.00 | $0.12 | $6,474 | | | |
| A11.6.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.5 | ha | C.6.01 | 182.6 | $1,029.50 | $5,673.94 | $401.72 | $2,214 | $232.94 | 1,337 | $1,283.83 | $1,005.72 | $5,542.86 | $2,669.89 | $14,715 | | | |
| A11.6.2.2 | | | Tree seedling application (1,000 stems/ha) | 5.5 | ha | C.6.06 | 282.5 | $1,832.33 | $10,098.61 | $25.98 | $143 | $15.00 | 86 | $82.67 | $469.71 | $2,588.73 | $2,343.03 | $12,913 | | | |
| A11.7 | *Fuel Storage Areas* | | | | | | | | | | | | | | | | | | $24,758 | | |
| A11.7.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 5 | hrs | C.2.13 | 4.5 | $44.39 | $200.33 | $194.68 | $879 | $67.01 | 315 | $302.42 | $0.00 | $0.00 | $306.07 | $1,381 | | | |
| A11.7.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 4,200 | m3 | R.049 | 81.8 | $0.86 | $3,603.19 | $2.79 | $11,709 | $0.92 | 4,014 | $3,853.28 | $0.00 | $0.00 | $4.56 | $19,166 | | | |
| A11.7.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 0.84 | ha | C.6.01 | 27.8 | $1,029.50 | $864.78 | $401.72 | $337 | $232.94 | 204 | $195.67 | $1,005.72 | $844.80 | $2,669.89 | $2,243 | | | |
| A11.7.3.2 | | | Tree seedling application (1,000 stems/ha) | 1 | ha | C.6.06 | 43.1 | $1,832.33 | $1,539.16 | $25.98 | $22 | $15.00 | 13 | $12.60 | $469.71 | $394.56 | $2,343.03 | $1,968 | | | |
| A11.8 | *IROD Laydown Area* | | | | | | | | | | | | | | | | | | $18,300 | | |
| A11.8.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 15 | hrs | C.2.13 | 14.8 | $44.39 | $654.96 | $194.68 | $2,873 | $67.01 | 1,030 | $988.72 | $0.00 | $0.00 | $306.07 | $4,516 | | | |
| A11.8.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 0 | hrs | C.2.13 | 0.0 | $44.39 | $0.00 | $194.68 | $0 | $67.01 | 0 | $0.00 | $0.00 | $0.00 | $306.07 | $0 | | | |
| A11.8.1.3 | | | Scarify surface | 18,106 | m2 | C.2.16 | 0.0 | $0.03 | $629.15 | $0.07 | $1,189 | $0.02 | 322 | $308.88 | $0.00 | $0.00 | $0.12 | $2,127 | | | |
| A11.8.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 2.33 | ha | C.6.01 | 77.0 | $1,029.50 | $2,393.91 | $401.72 | $934 | $232.94 | 564 | $541.67 | $1,005.72 | $2,338.60 | $2,669.89 | $6,208 | | | |
| A11.8.2.2 | | | Tree seedling application (1,000 stems/ha) | 2.33 | ha | C.6.06 | 119.2 | $1,832.33 | $4,260.73 | $25.98 | $60 | $15.00 | 36 | $34.88 | $469.71 | $1,092.22 | $2,343.03 | $5,448 | | | |
| A11.9 | *Mill Area* | | | | | | | | | | | | | | | | | | $134,673 | | |
| A11.9.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 60 | hrs | C.2.13 | 59.9 | $44.39 | $2,659.96 | $194.68 | $11,666 | $67.01 | 4,183 | $4,015.50 | $0.00 | $0.00 | $306.07 | $18,342 | | | |
| A11.9.1.2 | | | Scarify surface | 42,365 | m2 | C.2.16 | 0.0 | $0.03 | $1,472.09 | $0.07 | $2,782 | $0.02 | 753 | $722.72 | $0.00 | $0.00 | $0.12 | $4,977 | | | |
| A11.9.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 21,182 | m3 | R.055 | 384.7 | $0.80 | $16,942.37 | $2.60 | $55,057 | $0.86 | 18,873 | $18,118.30 | $0.00 | $0.00 | $4.25 | $90,118 | | | |
| A11.9.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 4.24 | ha | C.6.01 | 140.3 | $1,029.50 | $4,361.46 | $401.72 | $1,702 | $232.94 | 1,028 | $986.86 | $1,005.72 | $4,260.70 | $2,669.89 | $11,311 | | | |
| A11.9.3.2 | | | Tree seedling application (1,000 stems/ha) | 4.24 | ha | C.6.06 | 217.1 | $1,832.33 | $7,762.62 | $25.98 | $110 | $15.00 | 66 | $63.55 | $469.71 | $1,989.91 | $2,343.03 | $9,926 | | | |
| A11.10 | *Mill Valley Fill Extension (Stage 1 and 2)* | | | | | | | | | | | | | | | | | | $0 | | |
| A11.10.1 | | Costs included in Waste Rock Dump Section (WBS#: A1.5) | | #VALUE! | hrs | | | | | | | | | | | | | | | | |
| A11.11 | *Minto South Portal* | | | | | | | | | | | | | | | | | | $87,165 | | |
| A11.11.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 51 | hrs | C.2.13 | 51.5 | $44.39 | $2,284.70 | $194.68 | $10,020 | $67.01 | 3,593 | $3,449.00 | $0.00 | $0.00 | $306.07 | $15,754 | | | |
| A11.11.1.2 | | | Re-grade slopes to be 3H:1V or flatter | 28 | hrs | C.2.13 | 28.0 | $44.39 | $1,244.58 | $194.68 | $5,459 | $67.01 | 1,957 | $1,878.82 | $0.00 | $0.00 | $306.07 | $8,582 | | | |
| A11.11.1.3 | | | Scarify surface | 62,765 | m2 | C.2.16 | 0.0 | $0.03 | $2,180.95 | $0.07 | $4,121 | $0.02 | 1,115 | $1,070.73 | $0.00 | $0.00 | $0.12 | $7,373 | | | |
| A11.11.2.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 11.1 | ha | C.6.01 | 366.5 | $1,029.50 | $11,389.08 | $401.72 | $4,444 | $232.94 | 2,684 | $2,576.99 | $1,005.72 | $11,125.98 | $2,669.89 | $29,536 | | | |
| A11.11.2.2 | | | Tree seedling application (1,000 stems/ha) | 11.1 | ha | C.6.06 | 567.0 | $1,832.33 | $20,270.56 | $25.98 | $287 | $15.00 | 173 | $165.94 | $469.71 | $5,196.26 | $2,343.03 | $25,920 | | | |
| A11.12 | *Pelly Laydown Area* | | | | | | | | | | | | | | | | | | $147,962 | | |
| A11.12.1.1 | | Re-grade | Flat areas: Re-grade to form tertiary drainage catchments | 107 | hrs | C.2.13 | 107.4 | $44.39 | $4,767.52 | $194.68 | $20,910 | $67.01 | 7,497 | $7,197.08 | $0.00 | $0.00 | $306.07 | $32,874 | | | |
| A11.12.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 25,855 | m3 | R.058 | 380.7 | $0.65 | $16,779.44 | $2.11 | $54,545 | $0.69 | 18,585 | $17,841.31 | $0.00 | $0.00 | $3.45 | $89,165 | | | |
| A11.12.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 5.17 | ha | C.6.01 | 171.3 | $1,029.50 | $5,323.56 | $401.72 | $2,077 | $232.94 | 1,255 | $1,204.55 | $1,005.72 | $5,200.58 | $2,669.89 | $13,806 | | | |
| A11.12.3.2 | | | Tree seedling application (1,000 stems/ha) | 5.17 | ha | C.6.06 | 265.0 | $1,832.33 | $9,474.99 | $25.98 | $134 | $15.00 | 81 | $77.57 | $469.71 | $2,428.87 | $2,343.03 | $12,116 | | | |
| A11.13 | *W15 Sump Area Laydown* | | | | | | | | | | | | | | | | | | $36,022 | | |
| A11.13.1.1 | | Re-grade | Flat areas: Re-grade to ensure positive drainage | 9 | hrs | C.2.13 | 8.8 | $44.39 | $390.13 | $194.68 | $1,711 | $67.01 | 613 | $588.94 | $0.00 | $0.00 | $306.07 | $2,690 | | | |
| A11.13.1.2 | | | Slopes: Re-grade to 3H:1V | 1 | hrs | C.2.13 | 1.2 | $44.39 | $55.15 | $194.68 | $242 | $67.01 | 87 | $83.26 | $0.00 | $0.00 | $306.07 | $380 | | | |
| A11.13.1.3 | | | Scarify surface | 9,484 | m2 | C.2.16 | 0.0 | $0.03 | $329.54 | $0.07 | $623 | $0.02 | 169 | $161.79 | $0.00 | $0.00 | $0.12 | $1,114 | | | |
| A11.13.2.1 | | Cover | Load, haul, dump spread 0.5 m overburden cover | 6,974 | m3 | R.065 | 106.1 | $0.67 | $4,675.54 | $2.18 | $15,199 | $0.71 | 5,179 | $4,971.43 | $0.00 | $0.00 | $3.56 | $24,846 | | | |
| A11.13.3.1 | | Revegetate | Seed/Fertilize: broadcast seeding | 1.39 | ha | C.6.01 | 46.2 | $1,029.50 | $1,435.97 | $401.72 | $560 | $232.94 | 338 | $324.92 | $1,005.72 | $1,402.80 | $2,669.89 | $3,724 | | | |
| A11.13.3.2 | | | Tree seedling application (1,000 stems/ha) | 1.39 | ha | C.6.06 | 71.5 | $1,832.33 | $2,555.78 | $25.98 | $36 | $15.00 | 22 | $20.92 | $469.71 | $655.16 | $2,343.03 | $3,268 | | | |
| **A12** | **Waste Disposal** | | | | | | | | | | | | | | | | | | | **$452,923** | |
| A12.1 | *Hydrocarbon contaminated soils* | | | | | | | | | | | | | | | | | | $66,551 | | |
| A12.1.1.1 | | Excavate HC contaminated | Complete testing for contaminated soils | 48 | test pits | C.3.03 | 24.0 | $22.24 | $1,067.53 | $2.89 | $139 | $2.92 | 146 | $139.97 | $204.00 | $9,792.00 | $232.05 | $11,138 | | | |
| A12.1.1.2 | | | Excavate and haul contaminated soils to on-site landfarm facility | 726 | m3 | R.038 | 26.0 | $1.58 | $1,144.07 | $3.17 | $2,298 | $0.96 | 723 | $693.78 | $0.00 | $0.00 | $5.70 | $4,136 | | | |
| A12.1.2.1 | | Construct landfarm | Existing Facility assumed to have sufficient capacity | 0 | m3 | | | | | | | | | | | | | | | | |
| A12.1.3.1 | | Operate landfarm | Aerate contaminated soils (mix) | 12 | event | C.3.04 | 270.0 | $999.20 | $11,990.37 | $923.10 | $11,077 | $333.60 | 4,170 | $4,003.20 | $0.00 | $0.00 | $2,255.90 | $27,071 | | | |
| A12.1.3.2 | | | Annual confirmation sampling | 3 | years | C.3.05 | 48.0 | $711.69 | $2,135.06 | $92.63 | $278 | $93.31 | 292 | $279.94 | $1,224.00 | $3,672.00 | $2,121.63 | $6,365 | | | |
| A12.1.4.1 | | Close landfarm | Remove soils and collect liner | 726 | m3 | R.001 | 22.9 | $1.39 | $1,007.57 | $3.03 | $2,197 | $0.90 | 680 | $652.50 | $0.00 | $0.00 | $5.31 | $3,857 | | | |
| A12.1.4.2 | | | Cut/fold liner and place into waste disposal container | 4,265 | m2 | C.1.15 | 49.6 | $0.43 | $1,850.89 | $0.19 | $830 | $0.07 | 308 | $295.29 | $0.00 | $0.00 | $0.70 | $2,976 | | | |
| A12.1.4.3 | | | Regrade area | 4,265 | m2 | C.2.11 | 42.7 | $0.44 | $1,893.14 | $1.28 | $5,472 | $0.35 | 1,567 | $1,504.69 | $0.00 | $0.00 | $2.08 | $8,870 | | | |
| A12.1.4.4 | | | Revegetation: Seed/Fertilizer: broadcast seeding | 0.43 | ha | C.6.01 | 14.1 | $1,029.50 | $439.08 | $401.72 | $171 | $232.94 | 103 | $99.35 | $1,005.72 | $428.94 | $2,669.89 | $1,139 | | | |
| A12.1.4.5 | | | Tree seedling application (1,000 stems/ha) | 0.43 | ha | C.6.06 | 21.9 | $1,832.33 | $781.49 | $25.98 | $11 | $15.00 | 7 | $6.40 | $469.71 | $200.33 | $2,343.03 | $999 | | | |
| A12.2 | *Metal Contaminated soils* | | | | | | | | | | | | | | | | | | $159,118 | | |
| A12.2.1.1 | | Crusher area | Delineate contaminated soil areas | 197 | test pits | C.3.01 | 98.5 | $22.24 | $4,381.32 | $2.89 | $570 | $2.92 | 598 | $574.45 | $265.20 | $52,244.40 | $293.25 | $57,770 | | | |
| A12.2.1.2 | | | Load, haul, dump contaminated soils to underground | 2,949 | m3 | R.039 | 102.1 | $1.53 | $4,499.64 | $3.33 | $9,810 | $0.99 | 3,035 | $2,913.97 | $0.00 | $0.00 | $5.84 | $17,224 | | | |
| A12.2.1.3 | | | Complete confirmation testing | 197 | ea | C.3.02 | 32.8 | $7.43 | $1,463.48 | $1.33 | $261 | $0.00 | 0 | $0.00 | $13.26 | $2,612.22 | $22.01 | $4,337 | | | |
| A12.2.2.1 | | Mill Area | Delineate contaminated soil areas | 198 | test pits | C.3.01 | 99.0 | $22.24 | $4,403.56 | $2.89 | $573 | $2.92 | 601 | $577.37 | $265.20 | $52,509.60 | $293.25 | $58,064 | | | |
| A12.2.2.2 | | | Load, haul, dump contaminated soils to underground | 2,973 | m3 | R.039 | 103.0 | $1.53 | $4,536.49 | $3.33 | $9,890 | $0.99 | 3,060 | $2,937.83 | $0.00 | $0.00 | $5.84 | $17,365 | | | |
| A12.2.2.3 | | | Complete confirmation testing | 198 | ea | C.3.02 | 33.0 | $7.43 | $1,470.91 | $1.33 | $262 | $0.00 | 0 | $0.00 | $13.26 | $2,625.48 | $22.01 | $4,359 | | | |
| A12.3 | *Solid Waste Landfill* | | | | | | | | | | | | | | | | | | $217,134 | | |
| A12.3.1.1 | | Construction landfill | Place waste from site facilities | 12,920 | LCM | C.2.07 | 550.6 | $1.89 | $24,440.80 | $8.30 | $107,194 | $2.86 | 38,433 | $36,895.99 | $0.00 | $0.00 | $13.04 | $168,531 | | | |
| A12.3.1.2 | | | Place fill to minimize voids in the debris | 3,371 | m3 | R.001 | 106.2 | $1.39 | $4,679.67 | $3.03 | $10,203 | $0.90 | 3,157 | $3,030.55 | $0.00 | $0.00 | $5.31 | $17,913 | | | |
| A12.3.2.1 | | Close landfill | Soil Cover: Load haul, dump spread, compact (0.6m) | 5,024 | m3 | R.002 | 190.0 | $1.61 | $8,100.50 | $3.21 | $16,144 | $0.99 | 5,196 | $4,988.33 | $0.00 | $0.00 | $5.82 | $29,233 | | | |
| A12.3.2.2 | | | Revegetation: Seed/Fertilizer: broadcast seeding | 0.55 | ha | C.6.01 | 18.1 | $1,029.50 | $562.06 | $401.72 | $219 | $232.94 | 132 | $127.18 | $1,005.72 | $549.07 | $2,669.89 | $1,458 | | | |
| A12.4 | *Hazardous Material Off-Site Disposal* | | | | | | | | | | | | | | | | | | $10,120 | | |
| A12.4.1.1 | | Hazardous Waste | From Building Demo: Transport off-site for disposal | 2 | trip | C.7.04 | 14.5 | $351.24 | $634.94 | $303.64 | $549 | $113.33 | 213 | $204.86 | $0.00 | $0.00 | $768.21 | $1,389 | | | |
| A12.4.3.3 | | | Hazardous materials: Disposal and Tipping fees. | 1 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A12.4.2.1 | | Reagents | Reagents: Transport to Whitehorse | 25 | hrs | C.1.22 | 99.3 | $159.30 | $3,955.90 | $95.83 | $2,380 | $26.93 | 697 | $668.71 | $0.00 | $0.00 | $282.05 | $7,004 | | | |
| A12.4.2.2 | | | Reagents: Disposal and tipping fees | 2.2 | trips | C.7.04 | 18.0 | $351.24 | $789.50 | $303.64 | $682 | $113.33 | 265 | $254.73 | $0.00 | $0.00 | $768.21 | $1,727 | | | |
| **A13** | **Surface Water Conveyance** | | | | | | | | | | | | | | | | | | | **$3,287,496** | |
| A13.1 | *Channel A - W-15 to Main Pit* | | | | | | | | | | | | | | | | | | $207,036 | | |
| A13.1.1.1 | | Excavate channel | Load, haul, dump locally | 40,300 | m3 | R.902 | 700.5 | $0.77 | $31,093.04 | $1.64 | $66,199 | $0.46 | 19,351 | $18,576.93 | $0.00 | $0.00 | $2.88 | $115,869 | | | |
| A13.1.2.1 | | Place channel materials | Geotextile: Supply and place | 7,785 | m3 | C.5.08 | 221.4 | $1.09 | $8,520.21 | $0.11 | $854 | $0.11 | 897 | $860.72 | $2.16 | $16,802.77 | $3.47 | $27,038 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A13.1.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 3,855 | m3 | C.2.15 | 0.0 | $2.54 | $9,777.29 | $6.06 | $23,344 | $1.86 | 7,462 | $7,163.19 | $0.00 | $0.00 | $10.45 | $40,285 | | | |
| A13.1.2.3 | | | Rip-rap: Load, haul, dump | 3,855 | m3 | R.018 | 102.2 | $1.17 | $4,501.31 | $2.55 | $9,814 | $0.76 | 3,037 | $2,915.04 | $0.00 | $0.00 | $4.47 | $17,230 | | | |
| A13.1.2.4 | | | Rip-rap: Place and secure | 3,855 | m3 | R.904 | 41.9 | $0.48 | $1,860.68 | $0.91 | $3,507 | $0.32 | 1,299 | $1,247.51 | $0.00 | $0.00 | $1.72 | $6,615 | | | |
| A13.2 | *Channel B - W-35 to Area 2 Pit* | | | | | | | | | | | | | | | | | | $198,304 | | |
| A13.2.1.1 | | Excavate channel | Load, haul, dump locally | 48,038 | m3 | R.902 | 835.0 | $0.77 | $37,063.29 | $1.64 | $78,910 | $0.46 | 23,067 | $22,143.92 | $0.00 | $0.00 | $2.88 | $138,117 | | | |
| A13.2.2.1 | | Place channel materials | Geotextile: Supply and place | 4,682 | m2 | C.5.08 | 133.1 | $1.09 | $5,124.06 | $0.11 | $514 | $0.11 | 539 | $517.64 | $2.16 | $10,105.20 | $3.47 | $16,261 | | | |
| A13.2.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,554 | m3 | C.2.15 | 0.0 | $2.54 | $6,477.46 | $6.06 | $15,465 | $1.86 | 4,943 | $4,745.61 | $0.00 | $0.00 | $10.45 | $26,689 | | | |
| A13.2.2.3 | | | Rip-rap: Load, haul, dump | 2,554 | m3 | R.020 | 76.2 | $1.32 | $3,358.44 | $2.87 | $7,322 | $0.85 | 2,266 | $2,174.93 | $0.00 | $0.00 | $5.03 | $12,855 | | | |
| A13.2.2.4 | | | Rip-rap: Place and secure | 2,554 | m3 | R.904 | 27.8 | $0.48 | $1,232.70 | $0.91 | $2,323 | $0.32 | 861 | $826.47 | $0.00 | $0.00 | $1.72 | $4,382 | | | |
| A13.3 | *Channel C - Main Pit to Main Access Road* | | | | | | | | | | | | | | | | | | $125,034 | | |
| A13.3.2.1 | | Excavate channel | Load, haul, dump locally | 8,656 | m3 | R.902 | 150.5 | $0.77 | $6,678.68 | $1.64 | $14,219 | $0.46 | 4,157 | $3,990.26 | $0.00 | $0.00 | $2.88 | $24,888 | | | |
| A13.3.3.1 | | Intake structure | Excavate soils to competent foundation materials | 2,450 | Bm3 | R.902 | 42.6 | $0.77 | $1,890.07 | $1.64 | $4,024 | $0.46 | 1,176 | $1,129.25 | $0.00 | $0.00 | $2.88 | $7,043 | | | |
| A13.3.3.2 | | | Supply an install precast-concrete intake wingwall intake structure | 1 | ls | C.5.12 | 140.0 | $5,946 | $5,945.57 | $3,583 | $3,583 | $643.84 | 671 | $643.84 | $37,000 | $37,000.00 | $47,172 | $47,172 | | | |
| A13.3.3.6 | | | Backfill and compact around structure | 2,450 | Cm3 | C.2.04 | 237.3 | $2.58 | $6,323.25 | $3.01 | $7,367 | $1.03 | 2,638 | $2,532.57 | $0.00 | $0.00 | $6.62 | $16,223 | | | |
| A13.3.4.1 | | Place channel materials | Geotextile: Supply and place | 3,171 | m2 | C.5.08 | 90.2 | $1.09 | $3,470.31 | $0.11 | $348 | $0.11 | 365 | $350.57 | $2.16 | $6,843.83 | $3.47 | $11,013 | | | |
| A13.3.4.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 1,037 | m3 | C.2.15 | 0.0 | $2.54 | $2,631.28 | $6.06 | $6,282 | $1.86 | 2,008 | $1,927.76 | $0.00 | $0.00 | $10.45 | $10,841 | | | |
| A13.3.4.3 | | | Rip-rap: Load, haul, dump | 1,037 | m3 | R.022 | 36.4 | $1.54 | $1,600.27 | $3.33 | $3,452 | $0.98 | 1,064 | $1,021.09 | $0.00 | $0.00 | $5.85 | $6,073 | | | |
| A13.3.4.4 | | | Rip-rap: Place and secure | 1,037 | m3 | R.904 | 11.3 | $0.48 | $500.75 | $0.91 | $944 | $0.32 | 350 | $335.73 | $0.00 | $0.00 | $1.72 | $1,780 | | | |
| A13.4 | *Channel D - Area 2 Pit to Channel E* | | | | | | | | | | | | | | | | | | $195,636 | | |
| A13.4.1.1 | | Excavate channel | Load, haul, dump locally | 17,840 | m3 | R.902 | 310.1 | $0.77 | $13,763.89 | $1.64 | $29,304 | $0.46 | 8,566 | $8,223.41 | $0.00 | $0.00 | $2.88 | $51,291 | | | |
| A13.4.2.1 | | Intake structure | Excavate soils to competent foundation materials | 4,453 | Bm3 | R.902 | 77.4 | $0.77 | $3,435.48 | $1.64 | $7,314 | $0.46 | 2,138 | $2,052.57 | $0.00 | $0.00 | $2.88 | $12,802 | | | |
| A13.4.2.2 | | | Supply an install precast-concrete intake wingwall intake structure | 1 | ls | C.5.12 | 140.0 | $5,946 | $5,945.57 | $3,583 | $3,583 | $643.84 | 671 | $643.84 | $37,000 | $37,000.00 | $47,172 | $47,172 | | | |
| A13.4.2.6 | | | Backfill and compact around structure | 4,453 | Cm3 | C.2.04 | 431.4 | $2.58 | $11,493.42 | $3.01 | $13,390 | $1.03 | 4,795 | $4,603.31 | $0.00 | $0.00 | $6.62 | $29,487 | | | |
| A13.4.3.1 | | Place channel materials | Geotextile: Supply and place | 4,910 | m2 | C.5.08 | 139.6 | $1.09 | $5,373.23 | $0.11 | $539 | $0.11 | 565 | $542.81 | $2.16 | $10,596.59 | $3.47 | $17,051 | | | |
| A13.4.3.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,199 | m3 | C.2.15 | 0.0 | $2.54 | $5,578.78 | $6.06 | $13,320 | $1.86 | 4,258 | $4,087.21 | $0.00 | $0.00 | $10.45 | $22,986 | | | |
| A13.4.3.3 | | | Rip-rap: Load, haul, dump | 2,199 | m3 | R.020 | 65.7 | $1.32 | $2,892.50 | $2.87 | $6,306 | $0.85 | 1,951 | $1,873.18 | $0.00 | $0.00 | $5.03 | $11,072 | | | |
| A13.4.3.4 | | | Rip-rap: Place and secure | 2,199 | m3 | R.904 | 23.9 | $0.48 | $1,061.68 | $0.91 | $2,001 | $0.32 | 741 | $711.81 | $0.00 | $0.00 | $1.72 | $3,774 | | | |
| A13.5 | *Channel E - Main Access Road to toe of MVFE* | | | | | | | | | | | | | | | | | | $739,690 | | |
| A13.5.1.1 | | Construct channel | Bulk fill to grade: Load, haul, dump, spread | 29,750 | m3 | | | | | | | | | | | | | | | | |
| A13.5.1.2 | | | Excavate/form Channel: Load, haul, dump locally | 46,386 | m3 | R.001 | 1,461.8 | $1.39 | $64,402.28 | $3.03 | $140,409 | $0.90 | 43,445 | $41,706.89 | $0.00 | $0.00 | $5.31 | $246,519 | | | |
| A13.5.2.1 | | Place channel materials | Geotextile: Supply and place | 27,307 | m2 | C.5.08 | 776.5 | $1.09 | $29,885.47 | $0.11 | $2,997 | $0.11 | 3,145 | $3,019.05 | $2.16 | $58,937.36 | $3.47 | $94,839 | | | |
| A13.5.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 20,558 | m3 | C.2.15 | 0.0 | $2.54 | $52,143.07 | $6.06 | $124,496 | $1.86 | 39,794 | $38,201.83 | $0.00 | $0.00 | $10.45 | $214,841 | | | |
| A13.5.2.3 | | | Rip-rap: Load, haul, dump | 20,558 | m3 | R.025 | 845.7 | $1.81 | $37,226.38 | $3.91 | $80,296 | $1.16 | 24,743 | $23,753.12 | $0.00 | $0.00 | $6.87 | $141,275 | | | |
| A13.5.2.4 | | | Rip-rap: Place and secure | 20,558 | m3 | R.904 | 223.6 | $0.48 | $9,923.17 | $0.91 | $18,701 | $0.32 | 6,930 | $6,653.05 | $0.00 | $0.00 | $1.72 | $35,277 | | | |
| A13.5.3.1 | | Stilling basin/Energy Dissipa | Excavate basin (spoil locally) | 645 | m3 | R.902 | 11.2 | $0.77 | $497.87 | $1.64 | $1,060 | $0.46 | 310 | $297.46 | $0.00 | $0.00 | $2.88 | $1,855 | | | |
| A13.5.3.2 | | | Geotextile: Supply and place | 540 | m2 | C.5.08 | 15.4 | $1.09 | $591.07 | $0.11 | $59 | $0.11 | 62 | $59.71 | $2.16 | $1,165.65 | $3.47 | $1,876 | | | |
| A13.5.3.3 | | | Bedding layer: Screen and stockpile | 131 | m3 | C.2.01 | 2.7 | $0.96 | $125.01 | $2.11 | $276 | $0.44 | 60 | $57.55 | $0.00 | $0.00 | $3.51 | $459 | | | |
| A13.5.3.4 | | | Bedding layer: Load, haul, dump and place | 131 | m3 | R.028 | 7.7 | $2.59 | $337.69 | $5.78 | $755 | $1.69 | 229 | $220.12 | $0.00 | $0.00 | $10.05 | $1,312 | | | |
| A13.5.3.5 | | | Rip-rap (at inlet and outlet): Screen and stockpile | 75 | m3 | C.2.15 | 0.0 | $2.54 | $190.23 | $6.06 | $454 | $1.86 | 145 | $139.37 | $0.00 | $0.00 | $10.45 | $784 | | | |
| A13.5.3.6 | | | Rip-rap (at inlet and outlet): Load, haul, dump | 75 | m3 | R.027 | 3.2 | $1.86 | $139.15 | $3.97 | $298 | $1.17 | 91 | $87.84 | $0.00 | $0.00 | $7.00 | $525 | | | |
| A13.5.3.7 | | | Rip-rap (at inlet and outlet): Place and secure | 75 | m3 | R.904 | 0.8 | $0.48 | $36.20 | $0.91 | $68 | $0.32 | 25 | $24.27 | $0.00 | $0.00 | $1.72 | $129 | | | |
| A13.6 | *Minto Creek Wetland By-Pass Channel* | | | | | | | | | | | | | | | | | | $231,721 | | |
| A13.6.1.1 | | Excavate channel | Load, haul, dump locally | 29,668 | m3 | R.902 | 515.7 | $0.77 | $22,889.69 | $1.64 | $48,733 | $0.46 | 14,246 | $13,675.73 | $0.00 | $0.00 | $2.88 | $85,299 | | | |
| A13.6.2.1 | | Place channel materials | Geotextile: Supply and place | 12,212 | m2 | C.5.08 | 347.3 | $1.09 | $13,364.91 | $0.11 | $1,340 | $0.11 | 1,406 | $1,350.13 | $2.16 | $26,357.04 | $3.47 | $42,412 | | | |
| A13.6.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 5,950 | m3 | C.2.15 | 0.0 | $2.54 | $15,091.24 | $6.06 | $36,032 | $1.86 | 11,517 | $11,056.37 | $0.00 | $0.00 | $10.45 | $62,179 | | | |
| A13.6.2.3 | | | Rip-rap: Load, haul, dump | 5,950 | m3 | R.001 | 187.5 | $1.39 | $8,260.73 | $3.03 | $18,010 | $0.90 | 5,573 | $5,349.64 | $0.00 | $0.00 | $5.31 | $31,620 | | | Assumes WSP rip-rap can be re-used |
| A13.6.2.4 | | | Rip-rap: Place and secure | 5,950 | m3 | R.904 | 64.7 | $0.48 | $2,871.96 | $0.91 | $5,412 | $0.32 | 2,006 | $1,925.52 | $0.00 | $0.00 | $1.72 | $10,210 | | | |
| A13.7 | *Allowance: Minto North Spillway* | | | | | | | | | | | | | | | | | | $83,528 | | |
| A13.7.1.1 | | Excavate channel | Load, haul, dump locally | 13,035 | m3 | R.902 | 226.6 | $0.77 | $10,056.98 | $1.64 | $21,412 | $0.46 | 6,259 | $6,008.67 | $0.00 | $0.00 | $2.88 | $37,477 | | | |
| A13.7.2.1 | | Place channel materials | Geotextile: Supply and place | 4,136 | m2 | C.5.08 | 117.6 | $1.09 | $4,526.14 | $0.11 | $454 | $0.11 | 476 | $457.23 | $2.16 | $8,926.04 | $3.47 | $14,363 | | | |
| A13.7.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 1,943 | m3 | C.2.15 | 0.0 | $2.54 | $4,929.10 | $6.06 | $11,769 | $1.86 | 3,762 | $3,611.23 | $0.00 | $0.00 | $10.45 | $20,309 | | | |
| A13.7.2.3 | | | Rip-rap: Load, haul, dump | 1,943 | m3 | R.024 | 47.7 | $1.08 | $2,101.36 | $2.36 | $4,581 | $0.70 | 1,418 | $1,360.84 | $0.00 | $0.00 | $4.14 | $8,044 | | | Assumes WSP rip-rap can be re-used |
| A13.7.2.4 | | | Rip-rap: Place and secure | 1,943 | m3 | R.904 | 21.1 | $0.48 | $938.04 | $0.91 | $1,768 | $0.32 | 655 | $628.91 | $0.00 | $0.00 | $1.72 | $3,335 | | | |
| A13.8 | *Ridgetop North Outlet Channel* | | | | | | | | | | | | | | | | | | $74,863 | | |
| A13.8.1.1 | | Excavate channel | Load, haul, dump locally | 7,758 | m3 | R.902 | 134.9 | $0.77 | $5,985.73 | $1.64 | $12,744 | $0.46 | 3,725 | $3,576.25 | $0.00 | $0.00 | $2.88 | $22,306 | | | |
| A13.8.2.1 | | Place channel materials | Geotextile: Supply and place | 3,995 | m2 | C.5.08 | 113.6 | $1.09 | $4,371.69 | $0.11 | $438 | $0.11 | 460 | $441.63 | $2.16 | $8,621.43 | $3.47 | $13,873 | | | |
| A13.8.2.2 | | | Rip-rap (angular, high quality): Screen and stockpile | 2,531 | m3 | C.2.15 | 0.0 | $2.54 | $6,419.56 | $6.06 | $15,327 | $1.86 | 4,899 | $4,703.20 | $0.00 | $0.00 | $10.45 | $26,450 | | | |
| A13.8.2.3 | | | Rip-rap: Load, haul, dump | 2,531 | m3 | R.068 | 33.1 | $0.58 | $1,455.99 | $1.90 | $4,821 | $0.64 | 1,681 | $1,613.82 | $0.00 | $0.00 | $3.12 | $7,891 | | | Assumes WSP rip-rap can be re-used |
| A13.8.2.4 | | | Rip-rap: Place and secure | 2,531 | m3 | R.904 | 27.5 | $0.48 | $1,221.69 | $0.91 | $2,302 | $0.32 | 853 | $819.09 | $0.00 | $0.00 | $1.72 | $4,343 | | | |
| A13.9 | *Secondary Catchment Channels* | | | | | | | | | | | | | | | | | | $791,748 | | |
| A13.9.1.1 | | Southwest Dump | Excavate mild-graded channels (good access), spoil locally | 10,787 | Bm3 | R.902 | 187.5 | $0.77 | $8,322.78 | $1.64 | $17,720 | $0.46 | 5,180 | $4,972.55 | $0.00 | $0.00 | $2.88 | $31,015 | | | |
| A13.9.1.2 | | | Excavate steep-graded channels (poor access), spoil locally | 6,640 | Bm3 | R.903 | 131.0 | $0.88 | $5,815.42 | $1.86 | $12,381 | $0.52 | 3,619 | $3,474.49 | $0.00 | $0.00 | $3.26 | $21,671 | | | |
| A13.9.1.3 | | | Geotextile: Supply and place | 25,206 | m2 | C.5.08 | 716.7 | $1.09 | $27,585.63 | $0.11 | $2,766 | $0.11 | 2,903 | $2,786.72 | $2.16 | $54,401.82 | $3.47 | $87,541 | | | |
| A13.9.1.4 | | | Bedding layer: Screen and stockpile | 2,054 | Cm3 | C.2.01 | 41.8 | $0.96 | $1,967.27 | $2.11 | $4,343 | $0.44 | 943 | $905.70 | $0.00 | $0.00 | $3.51 | $7,216 | | | |
| A13.9.1.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 2,054 | Cm3 | R.032 | 72.2 | $1.55 | $3,176.63 | $3.34 | $6,852 | $0.99 | 2,111 | $2,026.92 | $0.00 | $0.00 | $5.87 | $12,055 | | | |
| A13.9.1.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 6,806 | Cm3 | C.2.15 | 0.0 | $2.54 | $17,263.99 | $6.06 | $41,219 | $1.86 | 13,175 | $12,648.20 | $0.00 | $0.00 | $10.45 | $71,131 | | | |
| A13.9.1.7 | | | Rip-rap: Load, haul, dump | 6,806 | m3 | R.031 | 223.5 | $1.45 | $9,846.77 | $3.15 | $21,468 | $0.94 | 6,642 | $6,376.76 | $0.00 | $0.00 | $5.54 | $37,691 | | | |
| A13.9.1.8 | | | Rip-rap: Place in mild-graded channels (good access) | 3,787 | m3 | R.904 | 41.2 | $0.48 | $1,828.10 | $0.91 | $3,445 | $0.32 | 1,277 | $1,225.66 | $0.00 | $0.00 | $1.72 | $6,499 | | | |
| A13.9.1.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 3,019 | m3 | R.905 | 74.5 | $1.10 | $3,308.57 | $2.33 | $7,044 | $0.65 | 2,059 | $1,976.75 | $0.00 | $0.00 | $4.08 | $12,329 | | | |
| A13.9.2.1 | | Main Waste Dump | Excavate mild-graded channels (good access), spoil locally | 6,477 | Bm3 | R.902 | 112.6 | $0.77 | $4,997.00 | $1.64 | $10,639 | $0.46 | 3,110 | $2,985.52 | $0.00 | $0.00 | $2.88 | $18,621 | | | |
| A13.9.2.2 | | | Excavate steep-graded channels (poor access), spoil locally | 3,986 | Bm3 | R.903 | 78.6 | $0.88 | $3,490.67 | $1.86 | $7,432 | $0.52 | 2,172 | $2,085.55 | $0.00 | $0.00 | $3.26 | $13,008 | | | |
| A13.9.2.3 | | | Geotextile: Supply and place | 15,132 | m2 | C.5.08 | 430.3 | $1.09 | $16,560.93 | $0.11 | $1,661 | $0.11 | 1,743 | $1,672.99 | $2.16 | $32,659.93 | $3.47 | $52,555 | | | |
| A13.9.2.4 | | | Bedding layer: Screen and stockpile | 1,233 | Cm3 | C.2.01 | 25.1 | $0.96 | $1,180.84 | $2.11 | $2,607 | $0.44 | 566 | $543.64 | $0.00 | $0.00 | $3.51 | $4,331 | | | |
| A13.9.2.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 1,233 | Cm3 | R.030 | 34.8 | $1.25 | $1,535.65 | $2.76 | $3,401 | $0.82 | 1,059 | $1,016.39 | $0.00 | $0.00 | $4.83 | $5,953 | | | |
| A13.9.2.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 4,086 | Cm3 | C.2.15 | 0.0 | $2.54 | $10,364.11 | $6.06 | $24,745 | $1.86 | 7,909 | $7,593.11 | $0.00 | $0.00 | $10.45 | $42,702 | | | |
| A13.9.2.7 | | | Rip-rap: Load, haul, dump | 4,086 | m3 | R.029 | 101.4 | $1.09 | $4,473.09 | $2.42 | $9,908 | $0.72 | 3,084 | $2,960.56 | $0.00 | $0.00 | $4.24 | $17,341 | | | |
| A13.9.2.8 | | | Rip-rap: Place in mild-graded channels (good access) | 2,274 | m3 | R.904 | 24.7 | $0.48 | $1,097.59 | $0.91 | $2,068 | $0.32 | 767 | $735.89 | $0.00 | $0.00 | $1.72 | $3,902 | | | |
| A13.9.2.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 1,812 | m3 | R.905 | 44.7 | $1.10 | $1,985.96 | $2.33 | $4,228 | $0.65 | 1,236 | $1,186.53 | $0.00 | $0.00 | $4.08 | $7,401 | | | |
| A13.9.3.1 | | Reclamation Overburden Di | Excavate mild-graded channels (good access), spoil locally | 4,886 | Bm3 | R.902 | 84.9 | $0.77 | $3,769.89 | $1.64 | $8,026 | $0.46 | 2,346 | $2,252.36 | $0.00 | $0.00 | $2.88 | $14,049 | | | |
| A13.9.3.2 | | | Excavate steep-graded channels (poor access), spoil locally | 3,007 | Bm3 | R.903 | 59.3 | $0.88 | $2,633.47 | $1.86 | $5,607 | $0.52 | 1,639 | $1,573.40 | $0.00 | $0.00 | $3.26 | $9,814 | | | |
| A13.9.3.3 | | | Geotextile: Supply and place | 11,416 | m2 | C.5.08 | 324.6 | $1.09 | $12,494.07 | $0.11 | $1,253 | $0.11 | 1,315 | $1,262.16 | $2.16 | $24,639.65 | $3.47 | $39,649 | | | |
| A13.9.3.4 | | | Bedding layer: Screen and stockpile | 930 | Cm3 | C.2.01 | 18.9 | $0.96 | $890.86 | $2.11 | $1,967 | $0.44 | 427 | $410.14 | $0.00 | $0.00 | $3.51 | $3,268 | | | |
| A13.9.3.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 930 | Cm3 | R.034 | 34.7 | $1.64 | $1,527.43 | $3.58 | $3,330 | $1.06 | 1,030 | $989.17 | $0.00 | $0.00 | $6.29 | $5,847 | | | |
| A13.9.3.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 3,083 | Cm3 | C.2.15 | 0.0 | $2.54 | $7,819.00 | $6.06 | $18,669 | $1.86 | 5,967 | $5,728.47 | $0.00 | $0.00 | $10.45 | $32,216 | | | |
| A13.9.3.7 | | | Rip-rap: Load, haul, dump | 3,083 | m3 | R.033 | 97.0 | $1.39 | $4,271.96 | $3.02 | $9,314 | $0.90 | 2,882 | $2,766.52 | $0.00 | $0.00 | $5.30 | $16,352 | | | |
| A13.9.3.8 | | | Rip-rap: Place in mild-graded channels (good access) | 1,715 | m3 | R.904 | 18.7 | $0.48 | $828.06 | $0.91 | $1,561 | $0.32 | 578 | $555.18 | $0.00 | $0.00 | $1.72 | $2,944 | | | |
| A13.9.3.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 1,367 | m3 | R.905 | 33.8 | $1.10 | $1,498.27 | $2.33 | $3,190 | $0.65 | 932 | $895.16 | $0.00 | $0.00 | $4.08 | $5,583 | | | |
| A13.9.4.1 | | DSTSF & MVFE | Excavate mild-graded channels (good access), spoil locally | 7,378 | Bm3 | R.902 | 128.3 | $0.77 | $5,692.78 | $1.64 | $12,120 | $0.46 | 3,543 | $3,401.22 | $0.00 | $0.00 | $2.88 | $21,214 | | | |
| A13.9.4.2 | | | Excavate steep-graded channels (poor access), spoil locally | 4,541 | Bm3 | R.903 | 89.6 | $0.88 | $3,976.72 | $1.86 | $8,467 | $0.52 | 2,475 | $2,375.94 | $0.00 | $0.00 | $3.26 | $14,819 | | | |
| A13.9.4.3 | | | Geotextile: Supply and place | 17,239 | m2 | C.5.08 | 490.2 | $1.09 | $18,866.88 | $0.11 | $1,892 | $0.11 | 1,985 | $1,905.94 | $2.16 | $37,207.52 | $3.47 | $59,872 | | | |
| A13.9.4.4 | | | Bedding layer: Screen and stockpile | 1,405 | Cm3 | C.2.01 | 28.6 | $0.96 | $1,345.27 | $2.11 | $2,970 | $0.44 | 645 | $619.34 | $0.00 | $0.00 | $3.51 | $4,935 | | | |
| A13.9.4.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 1,405 | Cm3 | R.028 | 82.5 | $2.59 | $3,633.88 | $5.78 | $8,121 | $1.69 | 2,467 | $2,368.79 | $0.00 | $0.00 | $10.05 | $14,124 | | | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| A13.9.4.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 4,655 | Cm3 | C.2.15 | 0.0 | $2.54 | $11,807.22 | $6.06 | $28,191 | $1.86 | 9,011 | $8,650.38 | $0.00 | $0.00 | $10.45 | $48,648 | | | |
| A13.9.4.7 | | | Rip-rap: Load, haul, dump | 4,655 | m3 | R.027 | 196.3 | $1.86 | $8,636.41 | $3.97 | $18,485 | $1.17 | 5,679 | $5,451.80 | $0.00 | $0.00 | $7.00 | $32,573 | | | |
| A13.9.4.8 | | | Rip-rap: Place in mild-graded channels (good access) | 2,590 | m3 | R.904 | 28.2 | $0.48 | $1,250.42 | $0.91 | $2,356 | $0.32 | 873 | $838.35 | $0.00 | $0.00 | $1.72 | $4,445 | | | |
| A13.9.4.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 2,065 | m3 | R.905 | 51.0 | $1.10 | $2,262.48 | $2.33 | $4,817 | $0.65 | 1,408 | $1,351.75 | $0.00 | $0.00 | $4.08 | $8,431 | | | |
| A13.9.5.1 | | Ridgetop Waste Dump | Excavate mild-graded channels (good access), spoil locally | 574 | Bm3 | R.902 | 10.0 | $0.77 | $442.77 | $1.64 | $943 | $0.46 | 276 | $264.54 | $0.00 | $0.00 | $2.88 | $1,650 | | | |
| A13.9.5.2 | | | Excavate steep-graded channels (poor access), spoil locally | 353 | Bm3 | R.903 | 7.0 | $0.88 | $309.30 | $1.86 | $659 | $0.52 | 192 | $184.80 | $0.00 | $0.00 | $3.26 | $1,153 | | | |
| A13.9.5.3 | | | Geotextile: Supply and place | 876 | m2 | C.5.08 | 24.9 | $1.09 | $958.89 | $0.11 | $96 | $0.11 | 101 | $96.87 | $2.16 | $1,891.03 | $3.47 | $3,043 | | | |
| A13.9.5.4 | | | Bedding layer: Screen and stockpile | 465 | Cm3 | C.2.01 | 9.4 | $0.96 | $444.99 | $2.11 | $982 | $0.44 | 213 | $204.86 | $0.00 | $0.00 | $3.51 | $1,632 | | | |
| A13.9.5.5 | | | Bedding layer: Load, haul, dump and place in steep areas | 109 | Cm3 | R.063 | 2.9 | $1.18 | $128.79 | $3.83 | $419 | $1.26 | 143 | $137.73 | $0.00 | $0.00 | $6.27 | $685 | | | |
| A13.9.5.6 | | | Rip-rap (angular, high quality): Screen and stockpile | 362 | Cm3 | C.2.15 | 0.0 | $2.54 | $918.34 | $6.06 | $2,193 | $1.86 | 701 | $672.81 | $0.00 | $0.00 | $10.45 | $3,784 | | | |
| A13.9.5.7 | | | Rip-rap: Load, haul, dump | 362 | m3 | R.064 | 8.5 | $1.03 | $373.01 | $3.40 | $1,231 | $1.14 | 431 | $413.67 | $0.00 | $0.00 | $5.57 | $2,018 | | | |
| A13.9.5.8 | | | Rip-rap: Place in mild-graded channels (good access) | 201 | m3 | R.904 | 2.2 | $0.48 | $97.26 | $0.91 | $183 | $0.32 | 68 | $65.21 | $0.00 | $0.00 | $1.72 | $346 | | | |
| A13.9.5.9 | | | Rip-rap: Place in steep-graded channels (poor access) | 161 | m3 | R.905 | 4.0 | $1.10 | $175.97 | $2.33 | $375 | $0.65 | 110 | $105.14 | $0.00 | $0.00 | $4.08 | $656 | | | |
| A13.10 | *Tailings Diversion Ditch* | | | | | | | | | | | | | | | | | | $624,970 | | |
| A13.10.1.2 | | Regrade | Slopes: Re-grade to 3H:1V | 28 | hrs | C.2.13 | 28 | $44.39 | $1,226 | $194.68 | $5,376 | $67.01 | 1,928 | $1,850 | $0.00 | $0 | $306.07 | $8,452 | | | |
| A13.10.2.1 | | Cover | Flat area cover material: Load, haul, dump spread | 25,182 | Cm3 | R.066 | 562.3 | $0.98 | $24,763 | $3.20 | $80,473 | $1.05 | 27,585 | $26,482 | $0.00 | $0 | $5.23 | $131,718 | | | |
| A13.10.2.2 | | | Slope area cover material: Load, haul, dump along crest | 18,049 | Cm3 | R.067 | 352.6 | $0.86 | $15,513 | $2.84 | $51,216 | $0.95 | 17,921 | $17,204 | $0.00 | $0 | $4.65 | $83,933 | | | |
| A13.10.2.3 | | | Slope area cover material: Spread down slope | 14 | hrs | C.2.13 | 14.0 | $44.39 | $621 | $194.68 | $2,724 | $67.01 | 977 | $937 | $0.00 | $0 | $306.07 | $4,282 | | | |
| A13.10.3.1 | | Revegetate | Seed/Fertilize: tractor application | 9 | ha | C.6.01 | 286.4 | $1,029.50 | $8,901 | $401.72 | $3,473 | $232.94 | 2,098 | $2,014 | $1,005.72 | $8,696 | $2,670 | $23,085 | | | |
| A13.10.3.2 | | | Tree seedling application (1,000 stems/ha) | 9 | ha | C.6.06 | 443.1 | $1,832.33 | $15,843 | $25.98 | $225 | $15.00 | 135 | $130 | $469.71 | $4,061 | $2,343 | $20,258 | | | |
| A13.10.4.1 | | Extend Channel to WSP | Clear and grub footprint | 13,889 | m2 | C.2.03 | 52.8 | $0.17 | $2,344 | $0.49 | $6,774 | $0.13 | 1,940 | $1,863 | $0.00 | $0 | $0.79 | $10,981 | | | |
| A13.10.4.2 | | | Geotextile: Supply and place | 13,889 | m2 | C.5.08 | 394.9 | $1.09 | $15,200 | $0.11 | $1,524 | $0.11 | 1,600 | $1,536 | $2.16 | $29,976 | $3.47 | $48,236 | | | |
| A13.10.4.3 | | | Rip-rap (angular, high quality): Screen and stockpile | 13,169 | m3 | C.2.15 | 0.0 | $2.54 | $33,403 | $6.06 | $79,753 | $1.86 | 25,492 | $24,472 | $0.00 | $0 | $10.45 | $137,629 | | | |
| A13.10.4.4 | | | Rip-rap: Load, haul, dump | 13,169 | m3 | R.035 | 618.4 | $2.07 | $27,207 | $4.42 | $58,233 | $1.30 | 17,890 | $17,175 | $0.00 | $0 | $7.79 | $102,615 | | | |
| A13.10.4.5 | | | Rip-rap: Place in steep-graded channels (poor access) | 13,169 | m3 | R.905 | 325.1 | $1.10 | $14,432 | $2.33 | $30,726 | $0.65 | 8,982 | $8,622 | $0.00 | $0 | $4.08 | $53,780 | | | |
| **A14** | **Water Treatment** | | | | | | | | | | | | | | | | | | | **$483,085** | |
| A14.1 | *Passive Treatment System - Minto Creek Valley* | | | | | | | | | | | | | | | | | | $397,994 | | |
| A14.1.1.1 | | Water Management | Install pump and pump around system | 8 | hrs | C.4.14 | 32.0 | $120.43 | $963.46 | $20.53 | $164 | $6.80 | 57 | $54.40 | $0.00 | $0.00 | $147.76 | $1,182 | | | Assumed |
| A14.1.1.2 | | | Maintain pump around system during wetland construction activities | 1,440 | hrs | C.4.13 | 144.0 | $3.55 | $5,117.32 | $12.98 | $18,691 | $2.00 | 3,000 | $2,880.00 | $0.00 | $0.00 | $18.53 | $26,689 | | | Assumes wetlands constructed over 2 months |
| A14.1.2.1 | | Valley Fill placement | Load, haul, dump material from the WSP excavation | 85,918 | m3 | n/a - costed | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.1.2.1 | | | Load, haul dump valley fill material | 0 | m3 | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | Fill from WSP excavation exceeds the required amount. |
| A14.1.3.1 | | Construct wetlands | Excavate cells: Load, haul dump, spoil locally | 14,459 | m3 | R.902 | 251.3 | $0.77 | $11,155.61 | $1.64 | $23,751 | $0.46 | 6,943 | $6,665.06 | $0.00 | $0.00 | $2.88 | $41,572 | | | |
| A14.1.3.2 | | | Subgrade preparation: remove sharp objects, place fill as required | 9,273 | m2 | C.2.18 | 317.0 | $1.31 | $12,142.93 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $1.31 | $12,143 | | | |
| A14.1.3.3 | | | Geotextile: Supply and install | 10,201 | m2 | C.5.08 | 290.1 | $1.09 | $11,163.84 | $0.11 | $1,120 | $0.11 | 1,175 | $1,127.78 | $2.16 | $22,016.30 | $3.47 | $35,428 | | | |
| A14.1.3.4 | | | HDPE liner: Supply and install | 10,201 | m2 | C.5.11 | 1,187.0 | $4.74 | $48,319.12 | $0.27 | $2,749 | $0.27 | 2,884 | $2,769.07 | $9.38 | $95,723.03 | $14.66 | $149,560 | | | |
| A14.1.3.5 | | | Organics: Mulch organics, produce and stockpile | 5,122 | Cm3 | C.2.10 | 577.1 | $4.50 | $23,023.50 | $4.87 | $24,922 | $1.82 | 9,720 | $9,331.25 | $0.00 | $0.00 | $11.18 | $57,277 | | | |
| A14.1.3.6 | | | Organics: Load, haul, dump, place in cell | 5,122 | Cm3 | R.001 | 161.4 | $1.39 | $7,111.43 | $3.03 | $15,504 | $0.90 | 4,797 | $4,605.36 | $0.00 | $0.00 | $5.31 | $27,221 | | | |
| A14.1.3.7 | | | Plant wetland vegetation | 0.9 | ha | C.6.05 | 40.6 | $1,443.27 | $1,338.39 | $307.03 | $285 | $180.00 | 174 | $166.92 | $1,159.23 | $1,074.99 | $3,089.53 | $2,865 | | | |
| A14.1.4.1 | | Conveyance channels | Excavate channels: Load, haul, dump locally | 1,402 | m3 | R.902 | 24.4 | $0.77 | $1,081.90 | $1.64 | $2,303 | $0.46 | 673 | $646.39 | $0.00 | $0.00 | $2.88 | $4,032 | | | |
| A14.1.4.2 | | | Surface preparation: remove sharp objects, place fill as required | 1,858 | m2 | C.2.18 | 63.5 | $1.31 | $2,432.63 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $1.31 | $2,433 | | | |
| A14.1.4.3 | | | Geotextile: Supply and place | 1,858 | m2 | C.5.08 | 52.8 | $1.09 | $2,033.17 | $0.11 | $204 | $0.11 | 214 | $205.39 | $2.16 | $4,009.63 | $3.47 | $6,452 | | | |
| A14.1.4.4 | | | HDPE Liner: Supply and install | 1,858 | m2 | C.5.11 | 216.2 | $4.74 | $8,799.92 | $0.27 | $501 | $0.27 | 525 | $504.31 | $9.38 | $17,433.16 | $14.66 | $27,238 | | | |
| A14.1.4.5 | | | Bedding/Protection layer: Screen and stockpile | 442 | m3 | C.2.01 | 9.0 | $0.96 | $423.54 | $2.11 | $935 | $0.44 | 203 | $194.99 | $0.00 | $0.00 | $3.51 | $1,554 | | | |
| A14.1.4.6 | | | Bedding/Protection layer: Load, haul, dump and place | 442 | m3 | R.001 | 13.9 | $1.39 | $614.04 | $3.03 | $1,339 | $0.90 | 414 | $397.65 | $0.00 | $0.00 | $5.31 | $2,350 | | | Assumes WSP fill can be re-used |
| A14.1.5.1 | | Operation and maintenance | System to be started Yr. 1 post-closure | 0 | yr | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.2 | *Southwest Wetlands* | | | | | | | | | | | | | | | | | | $15,944 | | |
| A14.2.1 | | Berm construction | Construct 3 berms across valley | 3,000 | m3 | R.001 | 94.5 | $1.39 | $4,165.24 | $3.03 | $9,081 | $0.90 | 2,810 | $2,697.41 | $0.00 | $0.00 | $5.31 | $15,944 | | | Assumed |
| A14.2.2 | | Outlet structures | Excavate outlet channels through berms | 1 | ls | | | | | | | | | | | | | | | | Allowance |
| A14.3 | *Decommission/demolish Water Treatment System* | | | | | | | | | | | | | | | | | | $69,147 | | |
| A14.3.1.1 | | Remove equipment | Small equipment: dismantle and prep for transport | 17 | hrs | C.1.13 | 67.1 | $168.00 | $2,819.22 | $86.19 | $1,446 | $14.53 | 254 | $243.80 | $0.00 | $0.00 | $268.71 | $4,509 | | | |
| A14.3.1.2 | | | Large equipment (crane req'd): dismantle and prep for transport | 29 | hrs | C.1.14 | 175.7 | $269.89 | $7,903.93 | $167.56 | $4,907 | $20.53 | 626 | $601.18 | $0.00 | $0.00 | $457.98 | $13,412 | | | |
| A14.3.2.1 | | Prepare for demolition | Reagents: Load for transport | 25 | hrs | C.1.22 | 99.3 | $159.30 | $3,955.90 | $95.83 | $2,380 | $26.93 | 697 | $668.71 | $0.00 | $0.00 | $282.05 | $7,004 | | | |
| A14.3.2.2 | | | Reagents: Transport to Whitehorse | 2.2 | trips | C.7.04 | 18.0 | $351.24 | $789.50 | $303.64 | $682 | $113.33 | 265 | $254.73 | $0.00 | $0.00 | $768.21 | $1,727 | | | |
| A14.3.2.3 | | | Reagents: Disposal and tipping fees | 1.0 | ls | n/a | 0.0 | $0.00 | $0.00 | $0.00 | $0 | $0.00 | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0 | | | |
| A14.3.3.1 | | Demolition | Structural building demolition | 163 | tonnes | C.1.05 | 325.0 | $69.36 | $11,272.12 | $139.08 | $22,604 | $33.84 | 5,729 | $5,499.69 | $0.00 | $0.00 | $242.28 | $39,376 | | | |
| A14.3.3.2 | | | Other demolition: miscellaneous | 15 | m3 | C.1.07 | 1.5 | $3.74 | $56.09 | $2.07 | $31 | $0.74 | 12 | $11.05 | $0.00 | $0.00 | $6.55 | $98 | | | |
| A14.3.4.1 | | Waste disposal | Off-site disposal (re-usable equipment, etc.) | 3 | trips | C.7.07 | 27.1 | $355.10 | $1,202.32 | $423.68 | $1,435 | $113.33 | 400 | $383.71 | $0.00 | $0.00 | $892 | $3,021 | | | |
| **Subtotal Direct Costs - Active Closure** | | | | | | | **115,225** | | **$4,898,304** | | **$8,438,294** | | | **$2,557,216** | | **$1,093,950** | | | | **$16,987,765** | |

| | | | | | | | Labour | | | Equipment | | Fuel | | | Material | | Activity Totals | | Subtotals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Activity | EOM Qnty | Units | Cost Code | Total Mhrs | Unit Rate | Cost | Unit Rate | Cost | Unit Rate | Consumed (L) | Cost | Unit Rate | Cost | Unit Rate | Cost | WBS Level 2 | WBS Level 1 | Source / Comments |
| **INDIRECT COSTS** | | | | | | | | | | | | | | | | | | | | | |
| **B1** | **Mobilization-Demobilization** | | | | | | | | | | | | | | | | | | | **$324,077** | |
| B1.1 | | Mobilization | Year 0 | 1 | LS | | | | | | | | | | | | $162,039 | $162,038.53 | | | |
| B1.2 | | Demobilization | Year 3 (end of Active Closure) | 1 | LS | | | | | | | | | | | | $144,406 | $144,405.50 | | | |
| B1.4 | | Demobilization | End of Passive closure | 1 | LS | | | | | | | | | | | | $17,633 | $17,633.03 | | | |
| **B2** | **Transportation Costs** | | | | | | | | | | | | | | | | | | | **$419,142** | |
| B2.1.1 | | Barge Operations | | 15 | month | | | | | | | | | | | | $10,832 | $162,486 | | | |
| | | Staffing Bus trips during barge operation period | | 60 | ea (one per week) | | | | | | | | | | | | $678 | $40,656 | | | Turnaround labour costs included in labour build-up |
| B2.2.2 | | Air transport and airstrip operations | | 72 | flights | | | | | | | | | | | | $3,000 | $216,000 | | | Three flights per week |
| **B3** | **Site/Road Maintenance** | | | | | | | | | | | | | | | | | | | **$791,662** | |
| B3.1 | *Road Maintenance* | | | | | | | | | | | | | | | | | | $727,887 | | |
| B3.1.1 | | Water Truck | Assume needed 150 hrs per month | 21 | month | | | | | | | | | | | | $12,153 | $255,205 | | | |
| B3.1.2 | | Grader | Assume needed 150 hrs per month (16H + Operator) | 21 | month | | | | | | | | | | | | $22,509 | $472,682 | | | Includes Main Access Road throughout closure period. |
| B3.2 | *Soil Erosion* | | | | | | | | | | | | | | | | | | $63,775 | | |
| B3.2.1 | | Erosion control allowance | Silt fencing: supply, install remove at strategic locations | 7024 | m | C.2.17 | 283.5 | $3.23 | $22,661.96 | $1.93 | $13,533 | $0.68 | 4,941 | $4,743.08 | $0.92 | $6,485.58 | $6.75 | $47,424 | | | |
| B3.2.2 | | | Supply and install erosion control matting | 10000 | m2 | C.2.09 | 175.4 | $0.66 | $6,622.75 | $0.09 | $912 | $0.05 | 548 | $526.32 | $0.83 | $8,290.76 | $1.64 | $16,352 | | | | |
| **B4** | **Construction Support** | | | | | | | | | | | | | | | | | | | **$5,263,751** | |
| B4.1 | *Field Support Staff* | | | | | | | | | | | | | | | | | | $3,235,218 | | Turnaround labour costs included in labour build-up |
| B4.1.1 | | Mine Manager | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $23,408 | $491,578 | | | |
| B4.1.2 | | Office/Camp manager | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $22,267 | $467,614 | | | |
| B4.1.3 | | Security/Administrative Assistant | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $16,600 | $348,591 | | | |
| B4.1.4 | | Foreman | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $373,152 | | | |
| B4.1.5 | | Mechanic | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $373,152 | | | |
| B4.1.6 | | Surveyor | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,769 | $373,152 | | | |
| B4.1.7 | | Engineering technician | Material & QA/QC testing | 10.5 | month | | | ( 360 ) site working hours per month | | | | | | | | | $42,120 | $442,260 | | | Assumed needed 1/2 of time |
| B4.1.8 | | Medic/H&S supervisor | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $17,415 | $365,718 | | | |
| B4.2 | *Field support Vehicles* | | | | | | | | | | | | | | | | | | $862,785 | | |
| B4.2.1 | | Pick-up trucks (4 required) | | 84 | month | | | | | | | | | | | | $4,446 | $373,452 | | | |
| B4.2.2 | | Fuel truck | | 21 | month | | | | | | | | | | | | $4,720 | $99,123 | | | |
| B4.2.3 | | Mechanic service vehicle | | 21 | month | | | | | | | | | | | | $11,803 | $247,873 | | | |
| B4.2.4 | | Emergency transport vehicle | | 21 | month | | | | | | | | | | | | $4,519 | $94,901 | | | |
| B4.2.5 | | Passenger bus | | 21 | month | | | | | | | | | | | | $2,259 | $47,436 | | | |
| B4.3 | *Field Support Equipment/Supplies* | | | | | | | | | | | | | | | | | | $1,165,748 | | |
| B4.3.1 | | Light Towers | | 21 | month | | | 2 # of Units | | | | | | | | | $3,356 | $70,476 | | | |
| B4.3.2 | | Material/Laboratory testing allowance | | 21 | month | | | | | | | | | | | | $1,000 | $21,000 | | | |
| B4.4 | | Construction, Environmental, and H&S Management Plans | | 1 | LS | | | | | | | | | | | | $25,000 | $25,000 | | | |
| B4.5 | | Office supplies | | 21 | month | | | | | | | | | | | | $1,000 | $21,000 | | | |
| B4.6 | | Communications | | 21 | month | | | | | | | | | | | | $1,000 | $21,000 | | | |
| B4.7 | | Misc. supplies | | 21 | month | | | | | | | | | | | | $500 | $10,500 | | | |
| B4.8 | | Camp costs | Includes catering and housekeeping | 11,523 | man-day | | | | | | | | | | | | $80 | $921,801 | | | |
| B4.9 | | Power and heat | | 21 | month | | | | | | | | | | | | $3,570 | $74,970 | | | |
| **B5** | **QA and Project Management** | | | | | | | | | | | | | | | | | | | **$1,752,126** | |
| B5.1 | | Project Manager | | 21 | month | | | ( 160 ) site working hours per month | | | | | | | | | $9,897 | $207,828 | | | |
| B5.2 | | Design Engineer | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $48,600 | $1,020,600 | | | |
| B5.3 | | Environmental Monitor | | 21 | month | | | ( 360 ) site working hours per month | | | | | | | | | $16,046 | $336,972 | | | |
| B5.4 | | Engineering , Design, and Construction plans (included in Planning and Permitting Costs) | | | | | | | | | | | | | | | $0.00 | $0 | | | |
| B5.5 | | Field support vehicles (2 vehicles) | | 42 | month | | | | | | | | | | | | $4,446 | $186,726 | | | |
| **Subtotal Indirect Costs - Active Closure** | | | | | | | | | | | | | | | | | | | | **$8,550,758** | |
| **CLOSURE IMPLEMENTATION COSTS - TOTAL** | | | | | | | | | | | | | | | | | | | | **$25,538,523** | |

# Worksheet 15 - End-of-Mine Liability Estimate - Schedule Details

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## A: Year 0 Site Access Schedule

| Stage | Flight Months | Helicopter Months | Barge Months | Total Months | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interim Care | 0 | 0 | 0 | 0 | | | | | | | | | | | | | |
| **SUB-TOTAL INTERIM CARE** | **0** | **0** | **0** | **0** | | | | | | | | | | | | | |
| Active Closure 1 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| Active Closure 2 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| Active Closure 3 | 2 | 0 | 5 | 7 | | | | F | F | B | B | B | B | B | | | |
| **SUB-TOTAL ACTIVE CLOSURE** | **6** | **0** | **15** | **21** | | | | | | | | | | | | | |
| Post-Closure 1 | 2 | 0 | 3 | 5 | | | | F | F | B | B | B | | | | | |
| **SUB-TOTAL POST-CLOSURE 1** | **2** | **0** | **3** | **5** | | | | | | | | | | | | | |
| Post-Closure 2 | 0 | 0 | 1 | 1 | | | | | | B | | | | | | | |
| **SUB-TOTAL POST-CLOSURE 2** | **0** | **0** | **1** | **1** | | | | | | | | | | | | | |

## B: Annual C&M Staffing Schedule - Interim Operations

No Interim operations included under the EOM scenario.

## C: Annual C&M Staffing Schedule - During Active Phase

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **7** | | | | **1** | **1** | **1** | **1** | **1** | **1** | **1** | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Warehouse/Water Treatment Operator | | 5 | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | | | |
| 2 | Environmental Manager | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| 3 | Environmental Technician | | 4 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | |
| **TOTAL** | | | **13** | **0** | **0** | **0** | **3** | **2** | **2** | **2** | **2** | **1** | **1** | **0** | **0** | |
| | **Annual man-days:** | | **390** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)

## D: Annual C&M Staffing Schedule - Post Closure 1

| # | Role | | Months Required | Month: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Months Active at Site** | | | **5** | | | | **1** | **1** | **1** | **1** | **1** | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 2 | Office/Camp Mgr | | 3 | | | | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 3 | Payroll/Accounting/HR | | 1 | | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Operator | | 2 | | | | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | | | | | |
| 2 | Environmental Manager | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| 3 | Environmental Technician | | 3 | | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 6 | | | | | | 2.0 | 2.0 | 2.0 | | | | | |
| 5 | Equipment operators | | 10 | | | | 2.0 | 3.0 | 1.5 | 1.5 | 1.5 | | | | | |
| 6 | HD Mechanic | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| 7 | Tradesmen | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.25 | | | | | |
| 8 | Labour/Helpers | | 2 | | | | 1.0 | 0.25 | 0.25 | 0.25 | 0.5 | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 1 | | | | 0.25 | | | | 0.25 | | | | | |
| **TOTAL** | | | **36** | **0** | **0** | **0** | **9** | **7** | **7** | **7** | **7** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **1,073** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## E: Annual C&M Staffing Schedule - Post Closure 2

| | | | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Role | | Months Required | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
| **Months Active at Site** | | | **1** | | | | | | **1** | | | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Mine Manager | | 1 | | | | | | 0.5 | | | | | | | |
| 2 | Office/Camp Mgr | | 0 | | | | | | 0.0 | | | | | | | |
| 3 | Payroll/Accounting/HR | | 0 | | | | | | 0.00 | | | | | | | |
| **Water Treatment/Environmental Staffing** | | | | | | | | | | | | | | | | |
| 1 | Passive Treatment Scientist | | 1 | | | | | | 0.5 | | | | | | | |
| 2 | Environmental Manager | | 0 | | | | | | | | | | | | | |
| 3 | Environmental Technician | | 0 | | | | | | | | | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 1 | | | | | | 1.0 | | | | | | | |
| 5 | Equipment operators | | 1 | | | | | | 1.0 | | | | | | | |
| 6 | HD Mechanic | | 1 | | | | | | 0.50 | | | | | | | |
| 7 | Tradesmen | | 0 | | | | | | | | | | | | | |
| 8 | Labour/Helpers | | 0 | | | | | | 0.25 | | | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | | | 0.0 | | | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 0 | | | | | | 0.25 | | | | | | | |
| **TOTAL** | | | **4** | **0** | **0** | **0** | **0** | **0** | **4** | **0** | **0** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **120** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

## E: Annual C&M Staffing Schedule - Long-term perpetual maintenance year

| | | | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Role | | Months Required | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Comments/Notes |
| **Months Active at Site** | | | **1** | | | | | | | **1** | | | | | | |
| **Administration/Office** | | | | | | | | | | | | | | | | |
| 1 | Project Manager/Foreman | | 1 | | | | | | | 1.0 | | | | | | |
| **Water Treatment/Engineering Staffing** | | | | | | | | | | | | | | | | |
| 1 | Passive Treatment Scientist | | 1 | | | | | | | 1.0 | | | | | | |
| 2 | Site Engineer | | 1 | | | | | | | 1.0 | | | | | | |
| 3 | Environmental Technician | | 0 | | | | | | | | | | | | | |
| **Operations** | | | | | | | | | | | | | | | | |
| 4 | Barge Operator | | 1 | | | | | | | 1.0 | | | | | | Assumed required 1/2 the time (near mob and demob) |
| 5 | Equipment operators | | 4 | | | | | | | 4.0 | | | | | | |
| 6 | HD Mechanic | | 1 | | | | | | | 0.50 | | | | | | |
| 7 | Tradesmen | | 0 | | | | | | | | | | | | | |
| 8 | Labour/Helpers | | 1 | | | | | | | 1.00 | | | | | | |
| **Camp/Support** | | | | | | | | | | | | | | | | |
| 1 | Cooks/Housecleaning etc. | | 0 | | | | | | | | | | | | | Contract (accounted for in camp costs) |
| **Other** | | | | | | | | | | | | | | | | |
| 1 | Visitors | | 1 | | | | | | | 0.50 | | | | | | |
| **TOTAL** | | | **10** | **0** | **0** | **0** | **0** | **0** | **0** | **10** | **0** | **0** | **0** | **0** | **0** | |
| | **Annual man-days:** | | **300** | | | | | | | | | | | | | |

**Notes:**
1. 0.5 personnel indicates staff on site 50% of time (i.e. no cross shift)
2. Orange highlighted cells are used for camp-man day calculations only.

# Worksheet 16 - End-of-Mine Liability Estimate - Planning and Permitting Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## Planning And Permitting

| WBS | Facility/Area | Task | Activity | Qnty | Unit | Total Unit Rate ($/unit) | Activity Total | Subtotal | Source / Comments |
|---|---|---|---|---|---|---|---|---|---|
| M1 | **Planning and Permitting** | | | | | | | | |
| M1.1 | *Reclamation Research/Planning* | | | | | | | $200,000 | |
| M1.1.1 | | Complete reclamation closure and research plan | | 1 | yr | $200,000 | $200,000 | | |
| M1.2 | *Technical studies and investigations* | | | | | | | $58,500 | |
| M1.2.1 | | Allowance for additional technical studies | | 1 | ls | $58,500 | $58,500 | | |
| M1.3 | *Monitoring and Management Plans* | | | | | | | $209,158 | |
| M1.3.1 | | Adaptive Mgmt Plans | Physcial, water quality, etc | 1 | ls | $15,000 | $15,000 | | |
| M1.3.2 | | Revegetation plan | | 1 | ls | $30,000 | $30,000 | | |
| M1.3.3 | | Waste Management Plan | Water treatment, sludge, landfarm, etc. | 1 | ls | $50,000 | $50,000 | | |
| M1.3.4 | | MMER Final Monitoring Study | | 1 | ls | $114,158 | $114,158 | | Quote: Minnow |
| M1.4 | *Engineering, Design, and Construction Plans* | | | | | | | $849,388 | |
| M1.4.1 | | Percentage of direct implementation costs | | 5% | of | $16,987,765 | $849,388 | | |
| M1.5 | *Permitting* | | | | | | | $0 | |
| M1.5.1.1 | | Permit Staffing | Permitting Manager | 0 | ls | $0 | $0 | | Staffing costs included in tasks above |
| M1.5.1.2 | | | Environmental Manager | 0 | ls | $0 | $0 | | |
| M1.5.1.3 | | | Technical Consultants | 0 | ls | $0 | $0 | | |
| **TOTAL** | | | | | | | | **$1,317,046** | |

# Worksheet 17 - Labour Rate Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## LABOUR RATES

**Benefit Factors**

| | | | |
|---|---|---|---|
| Employment Insurance (EI) percentage: | 1.63% | of base earnings | 2017 Source: http://www.cra-arc.gc.ca/tx/bsnss/tpcs/pyrll/clcltng/ei/hstrc-eng.html |
| EI salary limit | $51,300 | | 2017 Source: http://www.cra-arc.gc.ca/tx/bsnss/tpcs/pyrll/clcltng/ei/hstrc-eng.html |
| Canada Pension Plan (CPP) percentage: | 4.95% | of base earnings | 2017 Source: http://www.cra-arc.gc.ca/tx/bsnss/tpcs/pyrll/clcltng/cpp-rpc/hstrc-eng.html |
| CPP salary limit: | $55,300 | | 2017 Source: http://www.cra-arc.gc.ca/tx/bsnss/tpcs/pyrll/clcltng/cpp-rpc/hstrc-eng.html |
| MSP/Health Benefits: | $0 | per month | Yukon Territory has no employer or employee premiums or payroll taxes for health care (Source: CostMine 2014) |
| Small tools/safety gear allowance: | $250 | per year | Estimated based on a BC mine site (CostMine 2014) |
| **Workers Compensation:** | | | 2017 YWC rates http://www.wcb.yk.ca/QuestionResults/Assessments/Rates/Q0269.aspx |
| Resources (low) | 3.17% | | Metal mining, gravel crushing and screening, air services |
| Resources (med.) | 4.79% | | **DEFAULT** - Reclamation, Exploration, short haul trucking |
| Resources (high) | 7.94% | | Diamond drilling, forestry, long haul trucking, oil/gas |
| Services (med.) | 1.42% | | Catering, Housekeeping, Consultants doing fieldwork |

| | | | | | | | Rotation Details | | | | | | Travel Costs | | | | | | Overtime | | Other | | Hours | | | | Annual Totals | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost Code | Item | Base Hourly Wage ($/hr) | Loading Rate (%) | Rate Used in Estimate ($/hr) | Source (See Notes) | Include Loading Calculations? | Rotation Type | Weeks Onsite per Year | Hours Worked per Day | Days per Week | Site Hours per Year | Travel Hours per year | Travel Time (1 way) (hrs) | Travel Origin | Flights (1 way) | Hotel (1 way) | Meals (1 way) | Total Per Rotation | Overtime Multiplier | Overtime Hourly Wage | Small Tool Allowance ? | Worker's Comp Classification | Base Work Hours per Year | Overtime Work Hours per Year | Vacation Hours | Stat Hours | Total Hours Paid per Year | Base Earnings ($/yr) | Base Salary | Overtime Salary | EI | CPP | Worker's Comp. | Small Tool Allowance | MSP/Health Benefits | Travel Cost | Annual Total |
| P.01 | Camp Labourer | $23.72 | 150% | $35.53 | 1 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 70 | 2.5 | Pelly | $0 | $0 | $0 | $0 | 1.5 | $35.58 | No | Services (med.) | 1120 | 1470 | 80 | 88 | 2590 | $55,789 | $26,566 | $52,303 | $836 | $2,737 | $1,120 | $0 | $0 | $0 | $83,562 |
| P.02 | Design Engineer | $150.00 | 90% | $135.00 | 3, 4 | | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 140 | 5 | Vancouver | $400 | $100 | $50 | $1,100 | 1 | $150.00 | No | Resources (med.) | 1120 | 1620 | 160 | 88 | 2740 | $352,800 | $168,000 | $243,000 | $836 | $2,737 | $19,687 | $0 | $0 | $154,000 | $588,260 |
| P.03 | Driller / Blaster | $29.47 | 151% | $44.39 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $44.21 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $86,642 | $41,258 | $79,628 | $836 | $2,737 | $5,790 | $250 | $0 | $0 | $130,500 |
| P.04 | Engineering Technician (Consultant) | $130.00 | 90% | $117.00 | 3, 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P.05 | Environmental Monitor | $29.47 | 151% | $44.57 | 3 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $44.21 | No | Services (med.) | 1120 | 1512 | 80 | 88 | 2632 | $69,313 | $33,006 | $66,838 | $836 | $2,737 | $1,418 | $0 | $0 | $0 | $104,836 |
| P.06 | Environmental Scientist (Consultant) | $130.00 | 90% | $117.00 | 3, 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P.07 | Foreman | $32.87 | 150% | $49.36 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $6,458 | $250 | $0 | $0 | $145,115 |
| P.08 | Head Camp Cook | $32.87 | 145% | $47.73 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | No | Services (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $1,915 | $0 | $0 | $0 | $140,321 |
| P.09 | Health and Safety Supervisor | $32.00 | 151% | $48.38 | 3 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $48.00 | Yes | Services (med.) | 1120 | 1512 | 80 | 88 | 2632 | $75,264 | $35,840 | $72,576 | $836 | $2,737 | $1,540 | $250 | $0 | $0 | $113,779 |
| P.10 | Heavy Equip. Operator 1: Crane, Dragline, Shovels | $32.87 | 150% | $49.36 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $6,458 | $250 | $0 | $0 | $145,115 |
| P.11 | Heavy Equip. Operator 2: Excavator, Loader, Dozers | $29.47 | 151% | $44.39 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $44.21 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $86,642 | $41,258 | $79,628 | $836 | $2,737 | $5,790 | $250 | $0 | $0 | $130,500 |
| P.12 | Heavy Equip. Operator 3: Rollers and compactors | $23.72 | 150% | $35.54 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 58 | 2.5 | Pelly | $0 | $0 | $0 | $0 | 1.5 | $35.58 | Yes | Resources (med.) | 1400 | 1766 | 80 | 88 | 3166 | $69,737 | $33,208 | $62,846 | $836 | $2,737 | $4,601 | $250 | $0 | $0 | $104,479 |
| P.13 | Heavy Equip. Mechanic | $32.87 | 150% | $49.36 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $6,458 | $250 | $0 | $0 | $145,115 |
| P.14 | Heavy Equip. Servicer | $29.47 | 151% | $44.39 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $44.21 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $86,642 | $41,258 | $79,628 | $836 | $2,737 | $5,790 | $250 | $0 | $0 | $130,500 |
| P.15 | Helicopter Pilot | $32.87 | 148% | $48.53 | 3 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | No | Resources (low) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $4,274 | $0 | $0 | $0 | $142,680 |
| P.16 | Labourers | $23.72 | 150% | $35.54 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 58 | 2.5 | Pelly | $0 | $0 | $0 | $0 | 1.5 | $35.58 | Yes | Resources (med.) | 1400 | 1766 | 80 | 88 | 3166 | $69,737 | $33,208 | $62,846 | $836 | $2,737 | $4,601 | $250 | $0 | $0 | $104,479 |
| P.17 | Linesperson (electric) | $32.87 | 150% | $49.36 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $6,458 | $250 | $0 | $0 | $145,115 |
| P.18 | Medic, First Aid Attendant | $23.72 | 157% | $37.32 | 1 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $35.58 | No | Resources (med.) | 1120 | 1512 | 80 | 88 | 2632 | $55,789 | $26,566 | $53,797 | $836 | $2,737 | $3,849 | $0 | $0 | $0 | $87,786 |
| P.19 | Office Manager | $39.90 | 155% | $61.85 | 2 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $59.85 | Yes | Resources (med.) | 1120 | 1512 | 80 | 88 | 2632 | $93,845 | $44,688 | $90,493 | $836 | $2,737 | $6,475 | $250 | $0 | $0 | $145,480 |
| P.20 | Owner's Project Manager | $39.90 | 155% | $61.85 | 2 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $59.85 | Yes | Resources (med.) | 1120 | 1512 | 80 | 88 | 2632 | $93,845 | $44,688 | $90,493 | $836 | $2,737 | $6,475 | $250 | $0 | $0 | $145,480 |
| P.21 | Mine Manager | $42.00 | 155% | $65.02 | 2 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $63.00 | Yes | Resources (med.) | 1120 | 1512 | 80 | 88 | 2632 | $98,784 | $47,040 | $95,256 | $836 | $2,737 | $6,816 | $250 | $0 | $0 | $152,936 |
| P.22 | Security Guard | $23.72 | 150% | $35.54 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 58 | 2.5 | Pelly | $0 | $0 | $0 | $0 | 1.5 | $35.58 | Yes | Resources (med.) | 1400 | 1766 | 80 | 88 | 3166 | $69,737 | $33,208 | $62,846 | $836 | $2,737 | $4,601 | $250 | $0 | $0 | $104,479 |
| P.23 | Site Caretaker | $26.14 | 151% | $39.52 | 3 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $39.21 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $76,852 | $36,596 | $70,630 | $836 | $2,737 | $5,136 | $250 | $0 | $0 | $116,186 |
| P.24 | Site Clerk / Administration | $29.47 | 156% | $46.11 | 3 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $44.21 | Yes | Resources (med.) | 1120 | 1512 | 80 | 88 | 2632 | $69,313 | $33,006 | $66,838 | $836 | $2,737 | $4,783 | $250 | $0 | $0 | $108,450 |
| P.25 | Site Supervisor | $39.90 | 155% | $61.85 | 2 | Yes | 2 in - 2 out | 28 | 12 | 7 | 2,352 | 112 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $59.85 | Yes | Resources (med.) | 1120 | 1512 | 80 | 88 | 2632 | $93,845 | $44,688 | $90,493 | $836 | $2,737 | $6,475 | $250 | $0 | $0 | $145,480 |
| P.26 | Surveyor | $32.87 | 150% | $49.36 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $0 | $0 | 1.5 | $49.31 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $6,458 | $250 | $0 | $0 | $145,115 |
| P.27 | Trades Labourer (carpenter, electrician, welder etc.) | $32.87 | 160% | $52.53 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 93 | 4 | Whitehorse | $0 | $0 | $50 | $100 | 1.5 | $49.31 | Yes | Resources (med.) | 1400 | 1801 | 80 | 88 | 3201 | $96,638 | $46,018 | $88,815 | $836 | $2,737 | $6,458 | $250 | $0 | $9,333 | $154,448 |
| P.28 | Truck Driver 1: 10 Ton GVW and up. | $29.47 | 149% | $43.84 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 58 | 2.5 | Pelly | $0 | $0 | $0 | $0 | 1.5 | $44.21 | Yes | Resources (med.) | 1400 | 1766 | 80 | 88 | 3166 | $86,642 | $41,258 | $78,081 | $836 | $2,737 | $5,716 | $250 | $0 | $0 | $128,879 |
| P.29 | Truck Driver 2: 3 - 10 Ton GVW | $26.14 | 149% | $39.03 | 1 | Yes | 3 in - 2 out | 35 | 12 | 7 | 2,940 | 58 | 2.5 | Pelly | $0 | $0 | $0 | $0 | 1.5 | $39.21 | Yes | Resources (med.) | 1400 | 1766 | 80 | 88 | 3166 | $76,852 | $36,596 | $69,258 | $836 | $2,737 | $5,070 | $250 | $0 | $0 | $114,748 |

**Notes:**
1 Basic Rate: Yukon Government Fair Wage Schedule - Effective Apr 1, 2016 (Accessed July 2016)
2 CostMine 2014 for an active BC mine site
3 Estimated from project experience
4 Consultants rates are reduced by 10% as this value is added back in later in the estimate (Contractor Profit = 10%)

# Worksheet 18 - Equipment Rate Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## EQUIPMENT RATES

**Adjustment Factors**

Equipment Rates used in estimate: 3rd-Party - BC Blue Book
Fuel Consumption Rates: 2 - Medium — Note: Medium consumption applied to most situations
On-site fuel cost per litre (diesel): $0.96 — Average On-site Cost

**BC Blue Book Cost Breakdown Assumptions**

BC Blue Book Source: 2017-18 — 1.00
Owner overhead rate: 10% — BC Roadbuilder Association (2000)
Profit rate: 10% — BC Roadbuilder Association (2000)

BC Govt Fuel Price Adjustment Factors:
Avg. BC diesel cost: $1.03 — Average BC diesel cost for the past 12 months
On-Road Equipment ($/hr): $1.35
Off-road equipment ($/hr): $3.15
Date: 8/1/2017
Source: http://www2.gov.bc.ca/gov/content/industry/construction-industry/transportation-infrastructure/hired-equipment-program/fuel-price-adjustment

| Equipment | | Rate Summary | | | | Operator Details | | | Weight | Fuel Consumption Details | | | | BC Blue Book Cost Breakdown | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equip Code | Model | Source Used in Estimate | Equipment Cost ($/hr) | Fuel Operating Cost ($/hr) | Total Equipment Rate ($/hr) | Number of Operators | Operator Type | Operator Rate ($/hr) | Shipping Weight (tonnes) | On-Road/ Off-Road | Low (liters/hr) | Medium (liters/hr) | High (liters/hr) | All-Found Rate ($/hr) | Operators Wage ($/hr) | Ownership/ Maintenance Cost ($/hr) | Fuel Operating Cost ($/hr) | Contractor Overhead Cost ($/hr) | Contractor Profit ($/hr) | Comments |
| | **Backhoe** | | | | | | | | | | | | | | | | | | | |
| E.01.1 | CAT430E (4x4) | 3rd Party | $11.58 | $11.66 | $23.24 | 1 | E. Operator 2 | $44.39 | 7.4 | Off | 8.1 | 12.15 | 21.95 | $91.65 | $48.50 | $11.58 | $15.66 | $7.57 | $8.33 | |
| | **Compactors** | | | | | | | | | | | | | | | | | | | |
| E.02.1 | CAT CP563 (Class 7 - 12-13.99 tons) | 3rd Party | $29.58 | $14.88 | $44.46 | 1 | Roller Operator | $35.54 | 11.5 | Off | 13 | 15.5 | 18.5 | $117.60 | $48.50 | $29.58 | $19.12 | $9.72 | $10.69 | |
| E.02.2 | Walk-behind vibrating (30 in) | 3rd Party | $9.46 | $2.25 | $11.71 | 0 | Roller Operator | $0.00 | n/a | n/a | 1.2 | 2.3 | 3.5 | $11.45 | $0.00 | $9.46 | $0.00 | $0.95 | $1.04 | Fuel rate estimated from a 22 in Wacker Neuson (3.5L/hr under 100%operation) |
| | **Dozers** | | | | | | | | | | | | | | | | | | | |
| E.03.1 | CAT D6R | 3rd Party | $105.36 | $23.28 | $128.64 | 1 | E. Operator 2 | $44.39 | 18.0 | Off | 18 | 24.25 | 30.5 | $220.20 | $48.50 | $105.36 | $28.13 | $18.20 | $20.02 | |
| E.03.2 | CAT D8R | 3rd Party | $128.31 | $35.28 | $163.59 | 1 | E. Operator 2 | $44.39 | 37.6 | Off | 27.25 | 36.75 | 46.25 | $263.55 | $48.50 | $128.31 | $41.00 | $21.78 | $23.96 | |
| E.03.3 | CAT D10T | 3rd Party | $194.68 | $67.01 | $261.69 | 1 | E. Operator 2 | $44.39 | 66.4 | Off | 51.45 | 69.8 | 88.6 | $385.05 | $48.50 | $194.68 | $75.04 | $31.82 | $35.00 | |
| E.03.4 | CAT D11R | 3rd Party | $206.55 | $96.00 | $302.55 | 1 | E. Operator 2 | $44.39 | 104.6 | Off | 71.7 | 100 | 126.25 | $437.05 | $48.50 | $206.55 | $106.15 | $36.12 | $39.73 | |
| | **Drills** | | | | | | | | | | | | | | | | | | | |
| E.04.1 | Air Rotary, 200 cfm compressor | 3rd Party | $161.91 | $24.00 | $185.91 | 2 | Driller / Blaster | $88.78 | n/a | Off | 20 | 25 | 30 | $348.25 | $97.00 | $161.91 | $28.90 | $28.78 | $31.66 | Med. Fuel consumption rate estimated based on DR10 drill (http://www.orbitdrilling.com.au/mineralexp.html) |
| E.04.2 | Air track production drill rig (900cfm) | 3rd Party | $62.77 | $48.00 | $110.77 | 2 | Driller / Blaster | $88.78 | 41.0 | Off | 33.35 | 50 | 66.5 | $259.45 | $97.00 | $62.77 | $54.65 | $21.44 | $23.59 | Med. Fuel consumption rate estimated from Cost Mine 2015 |
| | **Excavators** | | | | | | | | | | | | | | | | | | | |
| E.05.1 | CAT 330 | 3rd Party | $83.65 | $29.76 | $113.41 | 1 | E. Operator 2 | $44.39 | 35.1 | Off | 21.5 | 31 | 36.5 | $202.35 | $48.50 | $83.65 | $35.08 | $16.72 | $18.40 | |
| E.05.2 | CAT 385 | 3rd Party | $177.68 | $62.40 | $240.08 | 1 | E. Operator 2 | $44.39 | 83.0 | Off | 45.5 | 65 | 74.5 | $358.50 | $48.50 | $177.68 | $70.10 | $29.63 | $32.59 | |
| | **Graders** | | | | | | | | | | | | | | | | | | | |
| E.06.1 | CAT 140M (Class 6 - 200-248 FWHP) | 3rd Party | $78.57 | $15.60 | $94.17 | 1 | E. Operator 2 | $44.39 | 13.6 | Off | 10.35 | 16.25 | 24.2 | $177.82 | $48.50 | $78.57 | $19.89 | $14.70 | $16.17 | 10% grader attachment allowance added. |
| E.06.2 | CAT 16M (Class 7 - 250-300 FWHP) | 3rd Party | $83.88 | $21.79 | $105.67 | 1 | E. Operator 2 | $44.39 | 24.7 | Off | 14.7 | 22.7 | 37.25 | $192.28 | $48.50 | $83.88 | $26.53 | $15.89 | $17.48 | 10% grader attachment allowance added. |
| | **Haul Trucks** | | | | | | | | | | | | | | | | | | | |
| E.07.1 | Std Tandem Haul Truck (12 yd3) | 3rd Party | $13.20 | $11.52 | $24.72 | 1 | Truck Driver 1 | $43.84 | n/a | On | 8.04 | 12 | 15.96 | $91.25 | $48.50 | $13.20 | $13.71 | $7.54 | $8.30 | Fuel Consumption source: http://www.equipmentworld.com/owning-and-operating-costs-8/ (3.2 gal/hr for short hauls |
| E.07.2 | CAT 735 | 3rd Party | $89.43 | $25.87 | $115.31 | 1 | Truck Driver 1 | $43.84 | 29.9 | Off | 16.55 | 26.95 | 37.35 | $204.30 | $48.50 | $89.43 | $30.91 | $16.88 | $18.57 | |
| E.07.3 | CAT 769D | 3rd Party | $78.11 | $34.27 | $112.38 | 1 | Truck Driver 1 | $43.84 | 35.4 | Off | 25.5 | 35.7 | 45.9 | $201.50 | $48.50 | $78.11 | $39.92 | $16.65 | $18.32 | |
| E.07.4 | CAT 773G | 3rd Party | $142.14 | $48.77 | $190.91 | 1 | Truck Driver 1 | $43.84 | 45.0 | Off | 36.25 | 50.8 | 65.35 | $297.80 | $48.50 | $142.14 | $55.47 | $24.61 | $27.07 | |
| E.07.5 | CAT 777D | 3rd Party | $156.39 | $63.02 | $219.42 | 1 | Truck Driver 1 | $43.84 | 72.6 | Off | 46.85 | 65.65 | 84.4 | $333.55 | $48.50 | $156.39 | $70.77 | $27.57 | $30.32 | |
| | **Lifting** | | | | | | | | | | | | | | | | | | | |
| E.08.1 | Hydraulic Crane, 30Ton | 3rd Party | $81.38 | $6.00 | $87.38 | 1 | E. Operator 1 | $49.36 | 30.0 | Off | 4.19 | 6.25 | 8.31 | $168.75 | $48.50 | $81.38 | $9.59 | $13.95 | $15.34 | Med. Fuel consumption rate estimated from CostMine 2015 |
| | **Loaders** | | | | | | | | | | | | | | | | | | | |
| E.09.1 | CAT 950H | 3rd Party | $61.19 | $12.53 | $73.72 | 1 | E. Operator 2 | $44.39 | 18.3 | Off | 9.65 | 13.05 | 16.6 | $152.80 | $48.50 | $61.19 | $16.59 | $12.63 | $13.89 | |
| E.09.2 | CAT 990 | 3rd Party | $104.53 | $62.64 | $167.17 | 1 | E. Operator 2 | $44.39 | 77.8 | Off | 50 | 65.25 | 84.75 | $270.30 | $48.50 | $104.53 | $70.36 | $22.34 | $24.57 | |
| | **Support Vehicles** | | | | | | | | | | | | | | | | | | | |
| E.10.1 | Concrete Transit Mix Truck | 3rd Party | $29.05 | $10.85 | $39.90 | 1 | Labourer | $35.54 | n/a | On | 7.54 | 11.3 | 15.03 | $109.55 | $48.50 | $29.05 | $12.99 | $9.05 | $9.96 | Med. Fuel consumption from NRCA (http://www.nrmca.org/operations/documents/2012fleetsurveyfinal repot.pdf) |
| E.10.2 | Fuel Truck | 3rd Party | $3.86 | $9.25 | $13.11 | 1 | Equip. Servicer | $44.39 | n/a | On | 6.43 | 9.64 | 12.82 | $77.00 | $48.50 | $3.86 | $11.28 | $6.36 | $7.00 | Med. Fuel consumption from CostMine2015 (mobile field fuel/lube truck) |
| E.10.3 | Highway, Line Truck, with Aerial Platform | 3rd Party | $58.08 | $12.00 | $70.08 | 1 | Trade Labour | $52.53 | n/a | On | 8.34 | 12.5 | 16.63 | $146.18 | $48.50 | $58.08 | $14.23 | $12.08 | $13.29 | Med. Fuel consumption from CostMine2015 (Flatbed truck) |
| E.10.4 | Highway Service/Flatbed Truck (HIAB) 5 ton | 3rd Party | $20.79 | $12.00 | $32.79 | 1 | Equip. Servicer | $44.39 | n/a | On | 8.34 | 12.5 | 16.63 | $101.05 | $48.50 | $20.79 | $14.23 | $8.35 | $9.19 | Med. Fuel consumption from CostMine2015 (Flatbed truck) |
| E.10.5 | Lowbed Tractor/Trailer - 5 Axle (25 tonnes) | 3rd Party | $28.59 | $11.52 | $40.11 | 1 | Truck Driver 1 | $43.84 | n/a | Off | 8.00 | 12 | 15.96 | $112.05 | $48.50 | $28.59 | $15.51 | $9.26 | $10.19 | Fuel consumption estimated |
| E.10.6 | Lowbed Tractor Trailer - 6 Axle (33 tonnes) | 3rd Party | $34.64 | $14.40 | $49.04 | 1 | Truck Driver 1 | $43.84 | n/a | Off | 10.01 | 15 | 19.95 | $123.10 | $48.50 | $34.64 | $18.60 | $10.17 | $11.19 | Fuel consumption estimated |
| E.10.7 | Lowbed Tractor Trailer - 7 Axle (41 tonnes) | 3rd Party | $49.22 | $14.40 | $63.62 | 1 | Truck Driver 1 | $43.84 | n/a | Off | 10.01 | 15 | 19.95 | $140.75 | $48.50 | $49.22 | $18.60 | $11.63 | $12.80 | Fuel consumption estimated |
| E.10.8 | Lowbed Tractor Trailer - 8 Axle (48 tonnes) | 3rd Party | $51.78 | $14.40 | $66.18 | 1 | Truck Driver 1 | $43.84 | n/a | Off | 10.01 | 15 | 19.95 | $143.85 | $48.50 | $51.78 | $18.60 | $11.89 | $13.08 | Fuel consumption estimated |
| E.10.9 | Pick-up Truck (1.5T) 4x4 | 3rd Party | $7.55 | $4.80 | $12.35 | 0 | | $0.00 | n/a | On | 3 | 5 | 10 | $17.00 | $0.00 | $7.55 | $6.50 | $1.40 | $1.55 | Fuel consumption rate estimated |
| E.10.10 | Pilot Vehicle | 3rd Party | $8.36 | $4.80 | $13.16 | 1 | Labourer | $35.54 | n/a | On | 3 | 5 | 10 | $55.50 | $31.01 | $8.36 | $6.50 | $4.59 | $5.05 | Fuel consumption rate estimated; BCBlueBook operator rate reduced to obtain a bare rate to match BlueBook rate |
| E.10.12 | Water Truck (5,000 gal) | 3rd Party | $15.49 | $21.70 | $37.18 | 1 | Truck Driver 1 | $43.84 | n/a | Off | 15.07 | 22.6 | 30.06 | $109.40 | $48.50 | $15.49 | $26.43 | $9.04 | $9.95 | Med. Fuel consumption from CostMine2015 (5,000gel water truck) |

**Notes:**

1 Fuel consumption obtained from the Caterpillar Performance Handbook Version 42.
2 All-found BC Blue Book rate excludes the fuel adjustment factor
3 Equipment weights from Caterpillar Performance Handbook Version 35; values of n/a means the equipment would be driven to site/towed by an pick-up.

| | Misc. Equipment and Attachments | Unit | Equipment Rate ($/Unit) | Fuel Rate ($/Unit) | Total Equipment Rate ($/Unit) | Number of Operators | Operator Type | Operator Rate ($/hr) | Shipping Weight (tonnes) | Source |
|---|---|---|---|---|---|---|---|---|---|---|
| E.11.1 | ATV (4 wheel) | month | $1,483.80 | $20.00 | $1,503.80 | 0 | | $0.00 | 0.3 | BC Blue Book 2017-18; fuel rate estimated |
| E.11.2 | Boomlift: 60' articulating | hr | $25.00 | $2.00 | $27.00 | 0 | | $0.00 | 10.0 | United rental 2015; fuel rate estimated |
| E.11.3 | Soil auger (Truck mounted | hr | $27.00 | $0.00 | $27.00 | 0 | | $0.00 | n/a | Estimated |
| E.11.4 | Bus: Passenger Bus (24 person cap.) | month | $1,658.85 | $600.00 | $2,258.85 | 0 | | $0.00 | n/a | BC Blue Book 2017-18; fuel rate estimated |
| E.11.5 | Butt-fusion welding machine | hr | $38.20 | $9.55 | $47.75 | 0 | | $0.00 | n/a | RSMeans2016; fuel rate estimated |
| E.11.6 | Cleaning Equipment - High pressure washer | hr | $15.75 | $2.00 | $17.75 | 0 | | $0.00 | n/a | BC Blue Book 2017-18; fuel rate estimated, 2,000 gallons, includes 3 wands |
| E.11.7 | Crusher (200 Tons/hr) | hr | $170.00 | $35.00 | $205.00 | 1 | E. Operator 2 | $44.39 | 25.0 | RSMeans 2005 (17 03 9902) |
| E.11.8 | Demolition shears (excavator attach.) | hr | $150.00 | $0.00 | $150.00 | 0 | | $0.00 | 7.0 | Estimated; S390 (fits CAT 365-385) |
| E.11.9 | Demolition grapples (excavator attach.) | hr | $21.00 | $0.00 | $21.00 | 0 | | $0.00 | 7.0 | Estimated; G330 (fits CAT 345-365 |
| E.11.10 | Emergency Transport Vehicle | Month | $4,509.10 | $10.00 | $4,519.10 | 0 | | $0.00 | n/a | BC Blue Book 2017-18; fuel rate estimated |
| E.11.11 | Helicopter | hr | $1,500.00 | $100.00 | $1,600.00 | 1 | Trade Labour | $52.53 | n/a | Estimated from past project (2012) |
| E.11.12 | Hydraulic hammer (excavator attachment) | hr | $87.05 | $0.00 | $87.05 | 0 | | $0.00 | 4.0 | BC Blue Book 2017-18; 2,500 kg energy class |
| E.11.13 | Hydraulic plate tamper (excavator attach.) | hr | $13.45 | $0.00 | $13.45 | 0 | | $0.00 | 3.0 | BC Blue Book 2017-18; 454-680kg |
| E.11.14 | Hydroseed Truck | hr | $47.75 | $16.25 | $39.90 | 0 | | $0.00 | n/a | BC Blue Book 2017-18; 3,000gal water truck with highpressure spray nozzle |
| E.11.15 | Light towers | month | $1,405.85 | $272.16 | $1,678.01 | 0 | | $0.00 | 1.0 | BC Blue Book 2017-18; telescopic trailor mounted, multi-vaor light (3kV); (fuel assumes used average 5 hrs per day) |
| E.11.16 | Power mulcher, (20 ton/hr, 115 HP | hr | $25.00 | $24.33 | $49.33 | 0 | | $0.00 | n/a | RSMeans 2016 (015433202860) |
| E.11.17 | Pump: mud pump 6 in discharge | hr | $12.98 | $2.00 | $14.98 | 0 | | $0.00 | n/a | BC Blue Book 2017-18; fuel rate estimated |
| E.11.18 | Screener (finley 583) (~400tonnes/hr) | hr | $189.59 | $40.00 | $223.00 | 1 | E. Operator 2 | $44.39 | 75.0 | Nova Scotia Road Builder Association, 2012, fuel rate estimated |
| E.11.19 | Spreader (for reveg appliction) | hr | $8.90 | $0.00 | $8.90 | 0 | | $0.00 | n/a | BC Blue Book 2017-18; based on "hopper sander" for truck attachments |
| E.11.20 | Welding outfit (truck mounted) - 400 amps | hr | $27.10 | $0.00 | $27.10 | 0 | | $0.00 | n/a | BC Blue Book 2017-18 |
| E.11.21 | XRF rental | month | $1,272.00 | $0.00 | $1,272.00 | 0 | | $0.00 | n/a | Quote: Pine Environmental (2010) |

# Worksheet 19 - Material Rates and Indirect Cost Inputs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate

## MATERIAL RATES

**RS Means Adjustment Factors**

RSMeans Source: RSMeans Online (2016 QQ)

Notes:
1 All RSMeans 2017 material costs are in CAD and have been adjusted for location (Whitehorse).
2 As per note 1, a factor of 1.371 was applied to obtain a Yukon rate (compared to the US national average).
3 1.02 Inflation factor to convert from 2016 to 2018 dollars (obtained from Bank of Canada CPI calculator)

| Cost Code | Item | Unit Cost | Unit | Additional Details | Source |
|---|---|---|---|---|---|
| M.01 | Bitumen Geomembrane (BGM) Liner | $18.21 | m2 | | Quote: Coletanche 2014, plus 15% shipment to site |
| M.02 | Concrete: elevated slabs | $386.22 | m3 | Includes forms, grade 60 rebar, concrete, pla | RSMeans2016 (33053401900) |
| M.03 | Erosion control mats (jute mesh), 4' wide | $0.83 | m2 | | RSMeans2016 (312515160020), add 15% for shipment to site |
| M.04 | Fertilizer | $1.12 | kg | | Access (2014) Closure Plan |
| M.05 | Fertilizer tablets (for tree-planting) | $0.08 | | | Quote: Pickseed (Prince George), 2014; factor of 15% applied for shipment to site |
| M.06 | Formwork: curb forms, wood, 12" high, on grade, 1 use | $3.54 | m2 | Unit is m2 contact area | RSMeans2016 (31113652000) |
| M.07 | Geosynthetic Clay Liner | $10.56 | m2 | | Quote: Nilex Vancouver 15% added for shipment to site |
| M.08 | Geotextile | $2.16 | m2 | | Minto Quote: Layfield (2014) FOB Edmonton, 15% added for shipment to site |
| M.09 | HDPE liner (60mil) | $9.38 | m2 | | Minto Quote: Layfield (2014) FOB Edmonton, 15% added for shipment to site |
| M.10 | HDPE pipe: 100mm | $20.57 | m | Butt fusion joints, 40'length, SDR 21 | RSMeans2016 (33 11 13-350-100) |
| M.11 | HDPE pipe: 150mm | $57.38 | m | Butt fusion joints, 40'length, SDR 21 | RSMeans2016 (33 11 13-350-200) |
| M.12 | HDPE pipe: 300mm | $184.68 | m | Butt fusion joints, 40'length, SDR 21 | RSMeans2016 (33 11 13-350-500) |
| M.13 | Intake Structure: precast concrete panel wall | $37,000 | each | | Quote : Precon (2017) FOB Edmonton. Adjusted 15% for shipment |
| M.14 | Lab testing: Hydrocarbons | $102 | each | | Estimated |
| M.15 | Lab testing: SAL metals + pH (BC CSR package) | $133 | each | | Quote: CARO 2014 for BC CSR package, $30 allowance added for shipping |
| M.16 | Mulch (for hydroseeding) | $1.02 | kg | | Quote: Pickseed (Prince George), 2014; factor of 15% applied for shipment to site |
| M.17 | Rebar (#6 bar) | $3.37 | m | | RSMeans2016 (032111600400) , (#6 bar = 1.5 lbs per foot) |
| M.18 | Seed/Fertilizer Mix 1: Dry mix | $16.12 | kg | | Pickseed (2015) onsite cost |
| M.19 | Seed/Fertilizer Mix 2: Wet area mix | $17.85 | kg | | Access (2014) Closure Plan |
| M.20 | Signage: Open Pit Warning signs (incl. posts) | $199.26 | each | | Includes concrete, post and sign |
| M.21 | Signage: Large warning signs at entries (incl. posts) | $609.74 | each | | Assumed to be 3 times open pit signs. |
| M.22 | Silt Fencing (3ft high) | $0.92 | m | | RSMeans2016 (31251416100), 15% added for shipment to site |
| M.23 | Steel Beam: I-Beam W6x9 | $16.09 | m | | RSMeans2016 |
| M.24 | Steel decking (q-deck): | $45.35 | m2 | | RSMeans2016 (53133506700) |
| M.25 | Steel Pipe: 6" dia. | $115.16 | m | | RSMeans2016 (221316202200) |
| M.26 | Tackifier (for hydroseeding) | $3.69 | kg | | Quote: Pickseed (Prince George), 2014; factor of 15% applied for shipment to site |
| M.27 | Wetland planting | $1,159.23 | ha | | EPA, 1997. Costs for Wetland Creation and Restoration Projects in the Glaciated Northeast. Average cost adjusted up by 37% for location factor, 15% for shipping, 42% for inflation. |
| M.28 | Tree seedlings | $0.39 | stem | | Quote from a site in central BC in 2011; updated to 2016 dollars. |

## INDIRECT COSTS

| Cost Code | Category | Rate Used in Estimate | Unit | | Source/Comments |
|---|---|---|---|---|---|
| I.01 | Barge Operating Costs | $10,832 | month | | Based on Minto site costs ($36,800/month), assumes is required 20 hours per week (down from existing 70hrs per week) |
| I.01 | Bonding | 3.0% | % | of direct costs | Past Project (2014) |
| I.02 | Camp Operation Costs | $80 | $/day/person | includes catering and housekeeping | Estimated; Note: this rate is higher than the exisitng camp cost and is conservatively estimated to account for the smaller camp size during closure/post-closure. |
| I.03 | Camp power and heating costs | $3,570 | month | | Typical 2015 monthly cost between May and Oct 2015, and halved under assumption that only 1/2 of camp is required. |
| I.04 | Communications | $1,000 | month | | Estimated |
| I.05 | Contract Administration | 5% | % | Of Direct and other indirect costs | |
| I.06 | Contractor Profit | 10% | % | Of Direct and other indirect costs | |
| I.07 | Contingency | 12% | % | | |
| I.09 | Engineering, Design, and Construction Plans | 5% | % | | allowance |
| I.11 | Flight - Whitehorse-Minto Return | $3,000 | ea | | |
| I.13 | Helicopter trip Carmacks-Minto Return | $3,000 | ea | | Based on site costs, assumes 2 hrs helicoptor time. |
| I.15 | Freight | 0% | % | Included in material costs | |
| I.17 | Insurance | 1.5% | % | Of labour costs | |
| I.19 | Laboratory/Material Testing | $1,000 | month | | Estimated |
| I.21 | Misc. Admin Supplies | $500 | month | | Estimated |
| I.23 | Office Supplies | $1,000 | month | | Estimated |

# Worksheet 20 - Task Unit Rate Calculations

**Project: Minto Mine Closure Cost Estimate - RCP 2018-01**
**Project No.: 1CM002.045**
**Client: Minto Explorations Ltd.**
**Date: February 6, 2018**
**File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate**

**Rates / Productivity**

| Cost Code | Item | Unit | Total Unit Cost | Manhours per Unit (hrs/Unit) | Labor Cost Per Unit ($/Unit) | Equipment Cost Per Unit ($/Unit) | Fuel Cost Per Unit ($/Unit) | Material Cost Per Unit ($/Unit) | Productivity (unit/hr) | Productivity/Crew/Fleet Source (RSMeans line item) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Demolition/Equipment Removal** | | | | | | | | | | |
| C.1.01 | Concrete foundations: break in place | m2 | $14.24 | 0.081 | $2.39 | $9.37 | $2.48 | $0.00 | 37 | RSMeans (02 41 6.17-0400) |
| C.1.02 | Decontamination: Metal cleaning treatment, pressure washing | tonne | $3.82 | 0.072 | $2.55 | $1.13 | $0.14 | $0.00 | 13.94 | RSMeans (050110516215) |
| C.1.03 | Decontamination: Concrete cleaning treatment, pressure washing | m2 | $0.46 | 0.009 | $0.31 | $0.14 | $0.02 | $0.00 | 116.13 | RSMeans (050110516215) |
| C.1.04 | Decontamination: General pressure washing | hrs | $53.29 | 1.000 | $35.54 | $15.75 | $2.00 | $0.00 | 1.00 | n/a |
| C.1.05 | Demolition: Structural, steel | tonne | $242.28 | 2.000 | $69.36 | $139.08 | $33.84 | $0.00 | 5.0 | Assumes average 50ton/shift (see right) |
| C.1.06 | Demolition: Structural, concrete | m3 | $94.92 | 0.538 | $15.92 | $62.48 | $16.53 | $0.00 | 5.58 | Based on foundation demolition, assu |
| C.1.07 | Demolition: selective misc. demolition (wood) | m3 | $6.55 | 0.099 | $3.74 | $2.07 | $0.74 | $0.00 | 40.38 | RSMeans (24119180500) |
| C.1.08 | Demolition: Small wooden buildings (non selective demo) | m3 | $5.05 | 0.076 | $2.88 | $1.60 | $0.57 | $0.00 | 52.39 | RSMeans (24116130700) |
| C.1.09 | Disconnect services | hrs | $100.42 | 3.000 | $88.07 | $7.55 | $4.80 | $0.00 | 1.00 | n/a |
| C.1.10 | Electrical demolition: remove conduits (incl. fittings/hangers) | km | $3,831.94 | 68.957 | $2,639.96 | $940.09 | $251.90 | $0.00 | 0.20 | Based in RSMeans (337139130150_ |
| C.1.11 | Electrical demolition: remove powerpoles | each | $530.46 | 9.143 | $423.67 | $88.51 | $18.29 | $0.00 | 0.66 | Based in RSMeans (337116335140) |
| C.1.12 | Electrical demolition: remove transformers | each | $1,296.04 | 23.323 | $892.89 | $317.96 | $85.20 | $0.00 | 0.58 | Based in RSMeans (337323201200) |
| C.1.13 | Equipment removal: Small equip., dismantle, prep for transport | hrs | $268.71 | 4.000 | $168.00 | $86.19 | $14.53 | $0.00 | 1 | n/a |
| C.1.14 | Equipment removal: Small equip., dismantle, prep for transport | hrs | $457.98 | 6.000 | $269.89 | $167.56 | $20.53 | $0.00 | 1 | n/a |
| C.1.15 | HDPE Liner: cut and fold | m2 | $0.70 | 0.012 | $0.43 | $0.19 | $0.07 | $0.00 | 430 | Assumes can be removed 20 times q |
| C.1.16 | HDPE pipe demolition - 0.75 to 4 inches (19-100 mm) | m | $5.15 | 0.112 | $5.15 | $0.00 | $0.00 | $0.00 | 27 | RSMeans2005 (02 41 13.38-1600) |
| C.1.17 | HDPE pipe demolition - 6 to 8 inches (150-200 mm) | m | $7.21 | 0.157 | $7.21 | $0.00 | $0.00 | $0.00 | 19 | RSMeans2005 (02 41 13.38-1700) |
| C.1.18 | HDPE pipe demolition - 10 to 18 inches (250-450 mm) | m | $12.02 | 0.262 | $12.02 | $0.00 | $0.00 | $0.00 | 11 | RSMeans2005 (02 41 13.38-1800) |
| C.1.19 | HDPE pipe demolition - 20 to 36 inches (500-915 mm) | m | $18.04 | 0.394 | $18.04 | $0.00 | $0.00 | $0.00 | 8 | RSMeans2005 (02 41 13.38-1900) |
| C.1.20 | Modular Buildings: dismantle and load for transport | each | $1,748.04 | 19.500 | $850.98 | $730.60 | $166.46 | $0.00 | 0.33 | Assumes 1 every 3 hours |
| C.1.21 | Pipelines: flushing | each | $203.78 | 4.000 | $203.78 | $0.00 | $0.00 | $0.00 | 0.5 | Assumes 2hrs to flush 1 line |
| C.1.22 | Reagents: Load for transport off-site | hrs | $282.05 | 4.000 | $159.30 | $95.83 | $26.93 | $0.00 | 1.0 | n/a |
| C.1.23 | Reclaim pump systems: Dismantle and prep for transport | each | $1,284.65 | 26.400 | $1,205.96 | $49.89 | $28.80 | $0.00 | 0.1 | Assumed 6hr duration |
| C.1.24 | Tailing system pumps: Dismantle and prep for transport | each | $642.33 | 13.200 | $602.98 | $24.94 | $14.40 | $0.00 | 0.3 | RSMeans2005 (16010639) |
| **Earthworks** | | | | | | | | | | |
| C.2.01 | Bedding: Produce and stockpile | m3 | $3.51 | 0.020 | $0.96 | $2.11 | $0.44 | $0.00 | 148 | Based on avg 400tonne/hr screener |
| C.2.02 | Berm: Construct berm (locally sourced, no truck required) | m3 | $1.56 | 0.009 | $0.42 | $0.89 | $0.25 | $0.00 | 212 | Factored productivity of CAT 330 |
| C.2.03 | Clearing land: tree removal by dozer | m2 | $0.79 | 0.004 | $0.17 | $0.49 | $0.13 | $0.00 | 263 | RSMeans2005(31 13 13.20-0500) |
| C.2.04 | Compact soil with vibratory plate (Hand): 15 cm lifts | Cm3 | $6.62 | 0.097 | $2.58 | $3.01 | $1.03 | $0.00 | 30.96 | RSMeans2005 (17-03-0508) |
| C.2.05 | Compact soil with roller on flat ground: 15 cm lifts, 4 passes | m2 | $0.08 | 0.001 | $0.04 | $0.02 | $0.01 | $0.00 | 1210.54 | RSMeans2016 (312323235040) |
| C.2.06 | Compact soil with roller on slopes: 15 cm lifts, 4 passes (one way) | m2 | $0.20 | 0.003 | $0.11 | $0.06 | $0.03 | $0.00 | 484.22 | Based on flat ground, productivity adjusted by factor of 0.4 |
| C.2.07 | Compaction, placement of materials in landfill | m3 | $13.04 | 0.043 | $1.89 | $8.30 | $2.86 | $0.00 | 23.47 | RSMeans 241191880500 |
| C.2.08 | Earthwork repair/maintenance fleet (post-closure) | hrs | $476.08 | 3.000 | $132.06 | $262.52 | $81.50 | $0.00 | 1 | n/a |
| C.2.08 | Earthwork repair/maintenance fleet (perpetual maintenance) | hrs | $649.11 | 4.000 | $176.45 | $367.88 | $104.78 | $0.00 | 1 | n/a |
| C.2.09 | Erosion Control Mats (Jute mesh), Supply and install | m2 | $1.64 | 0.018 | $0.66 | $0.09 | $0.05 | $0.83 | 228 | RSMeans2016(312514160020) |
| C.2.10 | Mulch: tree chipping/mulch production | m3 | $11.18 | 0.113 | $4.50 | $4.87 | $1.82 | $0.00 | 35.5 | Based on 20ton/hr mulcher. See note |
| C.2.11 | Regrading - Rough grading to provide drainage (small areas) | m2 | $2.08 | 0.010 | $0.44 | $1.28 | $0.35 | $0.00 | 100 | Estimate |
| C.2.12 | Regrading - Rough grading to provide drainage - yards | m2 | $0.42 | 0.002 | $0.09 | $0.26 | $0.07 | $0.00 | 500 | Estimate |
| C.2.13 | Regrading - Waste Rock Dumps (D10) | hrs | $306.07 | 1.000 | $44.39 | $194.68 | $67.01 | $0.00 | 1 | n/a |
| C.2.14 | Rip-Rap (rounded, low quality): Screen and Stockpile | m3 | $7.32 | 0.000 | $1.78 | $4.24 | $1.30 | $0.00 | 50 | Based on 75% productivity of CAT 33 |
| C.2.15 | Rip-Rap (angular, high quality): Screen and Stockpile | m3 | $10.45 | 0.000 | $2.54 | $6.06 | $1.86 | $0.00 | 35 | Based on 50% productivity of CAT 33 |
| C.2.16 | Scarification: roads, yards, etc. | m2 | $0.12 | 0.000 | $0.03 | $0.07 | $0.02 | $0.00 | 1277 | RSMeans2016(32 91 13-2620 |
| C.2.17 | Silt fencing: Supply, Install, and remove | m | $6.75 | 0.040 | $3.23 | $1.93 | $0.68 | $0.92 | 50 | RSMeans2016 (312514131100) |
| C.2.18 | Surface preparation for liner | m2 | $1.31 | 0.034 | $1.31 | $0.00 | $0.00 | $0.00 | 73.125 | RSMeans2013 (31 22 16.10-1150) |
| C.2.19 | Underground plug placement with small dozer | hrs | $173.02 | 0.000 | $44.39 | $105.36 | $23.28 | $0.00 | 1 | n/a |
| **Environmental Monitoring/Investigations** | | | | | | | | | | |
| C.3.01 | Contaminated soil investigation test pits | ea | $293.25 | 0.500 | $22.24 | $2.89 | $2.92 | $265.20 | 4 | 4 per hour |
| C.3.02 | Contaminated soil confirmation testing | ea | $22.01 | 0.167 | $7.43 | $1.33 | $0.00 | $13.26 | 6 | 6 per hour |
| C.3.03 | HC soil test pits | ea | $232.05 | 0.500 | $22.24 | $2.89 | $2.92 | $204.00 | 4 | 4 per hour |
| C.3.04 | Aerate soils in landfarm | event | $2,255.90 | 22.500 | $999.20 | $923.10 | $333.60 | $0.00 | 0.1 | Assumed 10 hours per event (incl. mo |
| C.3.05 | Landfarm confirmation testing | yr | $2,121.63 | 16.000 | $711.69 | $92.63 | $93.31 | $1,224.00 | 0.125 | Assumed 8 hours for sampling |
| **Groundwater / Piping** | | | | | | | | | | |
| C.4.01 | HDPE pipe: 100mm; supplied and installed | m | $40.12 | 0.328 | $14.26 | $4.50 | $0.79 | $20.57 | 15.2 | RSMeans2016 (33 11 13-350-100) |
| C.4.02 | HDPE pipe: 150mm; supplied and installed | m | $77.95 | 0.345 | $15.01 | $4.73 | $0.83 | $57.38 | 14.5 | RSMeans2016 (33 11 13-350-200) |
| C.4.05 | HDPE pipe: 300mm, perforated | m | $214.75 | 0.505 | $21.94 | $6.92 | $1.21 | $184.68 | 9.9 | RSMeans2016 (33 11 13-350-500) |
| C.4.11 | Pump water: small 2" centrifugal pump (100GPM) (small head) | m3 | $0.35 | 0.002 | $0.08 | $0.23 | $0.05 | $0.00 | 22 | 100 gallons per minute |
| C.4.12 | Pump water: large 6" mud pump | m3 | $0.07 | 0.000 | $0.01 | $0.05 | $0.01 | $0.00 | 273 | 1200 gallons per minute |
| C.4.13 | Pump water: operate large 6" mud pump | hr | $18.53 | 0.100 | $3.55 | $12.98 | $2.00 | $0.00 | 1 | n/a |
| C.4.14 | Pump water: Set-up pumps hoses, etc. | hr | $147.76 | 4.000 | $120.43 | $20.53 | $6.80 | $0.00 | 1 | n/a |

**Equipment Fleet (Including Operators)**

| Cost Code | Excavators: CAT 330 | Excavators: CAT 385 | Excavators: CAT430E (4x4) | Haul Trucks: Std Tandem Haul Truck (12 | Haul Trucks: CAT 735 | Loader: CAT 950H | Dozers: CAT D6R | Dozers: CAT D8R | Dozers: CAT D10T | Compactor: CAT CP563 (Class 7 - 12- | Compactor: Walk-behind vibrating (30 in) | Grader: CAT 140M (Class 6 - 200- | Grader: CAT 16M (Class 7 - 250- | Support: Hydraulic Crane, 30Ton | Support: Concrete Transit Mix Truck | Support: Highway, Line Truck, with Aerial Platform | Support: Highway Service/Flatbed Truck (HIAB) 5 | Support: Lowbed Tractor Trailer - 6 Axle (33 tonnes) | Support: Pick-up Truck (1.5T) 4x4 | Support: Demolition shears (excavator | Support: Demolition grapples (excavator | Support: Hydraulic hammer (excavator | Other: Equip Cost ($/hr) | Other: Fuel Cost ($/hr) | Other: Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C.1.01 | 1.0 | 1.0 | | | | | | | | | | | | | | | | | | | | 1.0 | | | |
| C.1.02 | | | | | | | | | | | | | | | | | | | | | | | $15.75 | $2.00 | Cleaning Equipment - High pressure washer |
| C.1.03 | | | | | | | | | | | | | | | | | | | | | | | $15.75 | $2.00 | Cleaning Equipment - High pressure washer |
| C.1.04 | | | | | | | | | | | | | | | | | | | | | | | $15.75 | $2.00 | Cleaning Equipment - High pressure washer |
| C.1.05 | | 2.0 | | | 1.0 | 1.0 | | | | | | | | 1.0 | | | | | | | 1.0 | 1.0 | | | |
| C.1.06 | 1.0 | 1.0 | | | | | | | | | | | | | | | | | | | | 1.0 | | | |
| C.1.07 | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.08 | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.09 | | | | | | | | | | | | | | | | | | | 1.0 | | | | | | |
| C.1.10 | | | | | | | 1.0 | | | | | | | 0.4 | | 0.2 | 1.0 | | 2.0 | | | | | | |
| C.1.11 | | | | | | | | | | | | | | | | 1.0 | | | | | | | | | |
| C.1.12 | | | | | | | 1.0 | | | | | | | 0.4 | | 0.2 | 1.0 | | 2.0 | | | | | | |
| C.1.13 | | | | | | 1.0 | | | | | | | | | | | | | | | | | $25.00 | $2.00 | Boomlift |
| C.1.14 | | | | | | 1.0 | | | | | | | | 1.0 | | | | | | | | | $25.00 | $2.00 | Boomlift |
| C.1.15 | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.16 | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.17 | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.18 | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.19 | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.20 | 1.0 | | | | | 1.0 | | | | | | | | 1.0 | | | | 0.5 | | | | | | | |
| C.1.21 | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.1.22 | | | | | | 1.0 | | | | | | | | | | | | 1.0 | | | | | | | |
| C.1.23 | | | | | | | | | | | | | | | | | 0.3 | | | | | | | | |
| C.1.24 | | | | | | | | | | | | | | | | | 0.3 | | | | | | | | |
| C.2.01 | | | | | | 2.0 | | | | | | | | | | | | | | | | | $189.59 | $40.00 | Screen Plant |
| C.2.02 | 1.0 | | | | | | 1.0 | | | | | | | | | | | | | | | | | | |
| C.2.03 | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | |
| C.2.04 | 1.0 | | | | | | | | | | 1.0 | | | | | | | | | | | | | | |
| C.2.05 | | | | | | | | | | 1.0 | | | | | | | | | | | | | | | |
| C.2.06 | | | | | | | | | | 1.0 | | | | | | | | | | | | | | | |
| C.2.07 | | | | | | | | | 1.0 | | | | | | | | | | | | | | | | |
| C.2.08 | 1.0 | | | | 2.0 | | | | | | | | | | | | | | | | | | | | |
| C.2.08 | 1.0 | | | | 2.0 | | 1.0 | | | | | | | | | | | | | | | | | | |
| C.2.09 | | | | | | | | | | | | | | | | | 1.0 | | | | | | | | |
| C.2.10 | 0.5 | | | | 0.5 | 1.0 | | | | | | | | | | | | | | | | | $25.00 | $24.33 | Power Mulcher |
| C.2.11 | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | |
| C.2.12 | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | |
| C.2.13 | | | | | | | | | 1.0 | | | | | | | | | | | | | | | | |
| C.2.14 | 1.0 | | | | | | | 1.0 | | | | | | | | | | | | | | | | | |
| C.2.15 | 1.0 | | | | | | | 1.0 | | | | | | | | | | | | | | | | | |
| C.2.16 | | | | | | | | | | | | | 1.0 | | | | | | | | | | | | |
| C.2.17 | | | 1.0 | | | | | | | | | | 1.0 | | | | | | | | | | | | |
| C.2.18 | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.2.19 | | | | | | | 1.0 | | | | | | | | | | | | | | | | | | |
| C.3.01 | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | |
| C.3.02 | | | | | | | | | | | | | | | | | | | | | | | $7.95 | | XRF rental |
| C.3.03 | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | |
| C.3.04 | 1.0 | | | | | | | | | | | | | | | | | 0.3 | | | | | | | |
| C.3.05 | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | |
| C.4.01 | | | | | | | | | | | | | | | | | 1.0 | | | | | | $47.75 | | Butt fusion machine |
| C.4.02 | | | | | | | | | | | | | | | | | 1.0 | | | | | | $47.75 | | Butt fusion machine |
| C.4.05 | | | | | | | | | | | | | | | | | 1.0 | | | | | | $47.75 | | Butt fusion machine |
| C.4.11 | | | | | | | | | | | | | | | | | | | | | | | $5.00 | $1.00 | Small 2" pump |
| C.4.12 | | | | | | | | | | | | | | | | | | | | | | | $12.98 | $2.00 | 6" mud Pump |
| C.4.13 | | | | | | | | | | | | | | | | | | | | | | | $12.98 | $2.00 | 6" mud Pump |
| C.4.14 | | | | | | | | | | | | | | | | | | | 1.0 | | | | $12.98 | $2.00 | 6" mud Pump |

**Labour / Material Details**

| Cost Code | Environmental Monitor | Foreman | Heavy Equip. Mechanic | Heavy Equip. Servicer | Labourers | Trades Labourer (carpenter | Material Cost Code | Material Item | Unit Rate | Unit | Multiplier (unit/unit) | Other Comments/Details |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C.1.01 | | | | | | | | | | | | Crew B13L |
| C.1.02 | | | | | 1.0 | | | | | | | Based on RSMeans productivity of 15,000ft2/day, assumes avg. thickness of 1cm |
| C.1.03 | | | | | 1.0 | | | | | | | |
| C.1.04 | | | | | 1.0 | | | | | | | |
| C.1.05 | | 1.0 | | | 2.0 | | | | | | | based on an average productivity for a XS4000 demolition shear (http://www.terrafirmaequipment.com/images/stories/virtuemart/product/series-ds-&-xs-shears.pdf) |
| C.1.06 | | | | | | | | | | | | Crew B13L |
| C.1.07 | | | | | 3.0 | | | | | | | Crew B3. (loader sub'ed for an excavator) |
| C.1.08 | | | | | 3.0 | | | | | | | Crew B3. small wood buildings (loader sub'ed for an excavator) |
| C.1.09 | | | | | 1.0 | 1.0 | | | | | | |
| C.1.10 | | 1.0 | | | 4.0 | 4.0 | | | | | | Based on RSMeans for conduit installation. Assumes 3 wires, dismantling is 50% more productive than installation |
| C.1.11 | | 1.0 | | | 2.0 | 2.0 | | | | | | Based on RSMeans for 60' pole installation. Assumes dismantling is 50% more productive than installation |
| C.1.12 | | 1.0 | | | 4.0 | 4.0 | | | | | | Based on RSMeans for transformer installation. Assumes dismantling is 50% more productive than installation |
| C.1.13 | | | | | 2.0 | 1.0 | | | | | | |
| C.1.14 | | | | | 2.0 | 2.0 | | | | | | |
| C.1.15 | | | | | 4.0 | | | | | | | |
| C.1.16 | | 1.0 | | | 1.0 | 1.0 | | | | | | |
| C.1.17 | | 1.0 | | | 1.0 | 1.0 | | | | | | |
| C.1.18 | | 1.0 | | | 1.0 | 1.0 | | | | | | |
| C.1.19 | | 1.0 | | | 1.0 | 1.0 | | | | | | |
| C.1.20 | | | | | 2.0 | 1.0 | | | | | | |
| C.1.21 | | 1.0 | | | | 1.0 | | | | | | No real basis to task, but cost is expected to be small and insignificant |
| C.1.22 | | | | | 2.0 | | | | | | | No real basis to task, but cost is expected to be small and insignificant |
| C.1.23 | | 1.0 | | | 1.0 | 1.0 | | | | | | RSMEANS description: Remove pump to 200HP |
| C.1.24 | | 1.0 | | | 1.0 | 1.0 | | | | | | RSMEANS description: Remove pump to 200HP |
| C.2.01 | | | | | | 1.0 | | | | | | Assumes avg. material density of 1,800 km/m3, 50min/hr, and 20% wastage |
| C.2.02 | | | | | | | | | | | | Berm shaped by excavator, dozer used to push suitable material to excavator |
| C.2.03 | | | | | | | | | | | | |
| C.2.04 | | | | | 1.0 | | | | | | | |
| C.2.05 | | | | | 0.5 | | | | | | | RSMeans crew: B-10Y |
| C.2.06 | | | | | 0.5 | | | | | | | RSMeans crew: B-10Y |
| C.2.07 | | | | | | | | | | | | |
| C.2.08 | | | | | | | | | | | | |
| C.2.08 | | | | | | | | | | | | |
| C.2.09 | | | | | 3.0 | | M.03 | Erosion control mats (jute me | $0.83 | m2 | 1.0 | |
| C.2.10 | | | | | 2.0 | | | | | | | Applied factors of .833 for job efficiency, and .75 for equipment availability/operator skill. |
| C.2.11 | | | | | | | | | | | | |
| C.2.12 | | | | | | | | | | | | |
| C.2.13 | | | | | | | | | | | | Check that the dozer model matches that used on resloping worksheet |
| C.2.14 | | | | | | | | | | | | |
| C.2.15 | | | | | | | | | | | | |
| C.2.16 | | | | | | | | | | | | |
| C.2.17 | | | | | 2.0 | | M.22 | Silt Fencing (3ft high) | $0.92 | m | 1.0 | |
| C.2.18 | | 0.5 | | | 2.0 | | | | | | | RSMeans = Fine/finish grading, hand grading for slab on grade |
| C.2.19 | | | | | | | | | | | | |
| C.3.01 | 1.0 | | | | | | M.15 | Lab testing: SAL metals + pH | $132.60 | each | 2.0 | |
| C.3.02 | 1.0 | | | | | | M.15 | Lab testing: SAL metals + pH | $132.60 | each | 0.1 | Assumes on-site testing using XRF, and 1 out of every 10 samples submitted for laboratory analysis |
| C.3.03 | 1.0 | | | | | | M.14 | Lab testing: Hydrocarbons | $102.00 | each | 2.0 | |
| C.3.04 | 1.0 | | | | | | | | | | | |
| C.3.05 | 1.0 | | | | | | M.14 | Lab testing: Hydrocarbons | $102.00 | each | 12.0 | Costs exclude reporting |
| C.4.01 | | 1.0 | | | 2.0 | 1.0 | M.10 | HDPE pipe: 100mm | $20.57 | m | 1 | Crew B-22A |
| C.4.02 | | 1.0 | | | 2.0 | 1.0 | M.11 | HDPE pipe: 150mm | $57.38 | m | 1.0 | Crew B-22A |
| C.4.05 | | 1.0 | | | 2.0 | 1.0 | M.12 | HDPE pipe: 300mm | $184.68 | m | 1.0 | Crew B-22A |
| C.4.11 | | | | | 0.1 | | | | | | | |
| C.4.12 | | | | | 0.1 | | | | | | | |
| C.4.13 | | | | | 0.1 | | | | | | | |
| C.4.14 | | 1.0 | | | 2.0 | | | | | | | Estimated crew |

Equipment Fleet (Including Operators)

| | | | Rates | | | | | | Productivity | | Excavators | | | Haul Trucks | | Loader | Dozers | | | Compactor | | Grader | | Support Vehicles/Equipment | | | | | | | | | Other | | | Labour | | | | | | Material Details | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost Code | Item | Unit | Total Unit Cost | Manhours per Unit (hrs/Unit) | Labor Cost Per Unit ($/Unit) | Equipment Cost Per Unit ($/Unit) | Fuel Cost Per Unit ($/Unit) | Material Cost Per Unit ($/Unit) | Productivity (unit/hr) | Productivity/Crew/Fleet Source (RSMeans line item) | CAT 330 | CAT 385 | CAT430E (4x4) | Std Tandem Haul Truck (12 | CAT 735 | CAT 950H | CAT D6R | CAT D8R | CAT D10T | CAT CP563 (Class 7 - 12- | Walk-behind vibrating (30 in) | CAT 140M (Class 6 - 200- | CAT 16M (Class 7 - 250- | Hydraulic Crane, 30Ton | Concrete Transit Mix Truck | Highway, Line Truck, with Aerial Platform | Highway Service/Flatbed Truck (HIAB) 5 | Lowbed Tractor Trailer - 6 Axle (33 tonnes) | Pick-up Truck (1.5T) 4x4 | Demolition shears (excavator | Demolition grapples (excavator | Hydraulic hammer (excavator | Equip Cost ($/hr) | Fuel Cost ($/hr) | Description | Environmental Monitor | Foreman | Heavy Equip. Mechanic | Heavy Equip. Servicer | Labourers | Trades Labourer (carpenter | Cost Code | Item | Unit Rate | Unit | Multiplier (unit/unit) | Other Comments/Details |
| **Materials** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.5.01 | BGM Liner: Supplied and Installed | m2 | $21.22 | 0.047 | $1.93 | $0.79 | $0.28 | $18.21 | 105.5 | SRK measured productivity (2015) | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3.0 | 1.0 | M.01 | Bitumen Geomembrane (BG | $18.21 | m2 | 1.0 | Productivity measured by SRK on a 2015 cover installation project |
| C.5.07 | Geotextile: Supply and Install (large areas, no seaming) | m2 | $2.82 | 0.014 | $0.55 | $0.05 | $0.06 | $2.16 | 211 | Assumed 2x value below (assumes no seaming | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 2.0 | | M.08 | Geotextile | $2.16 | m2 | 1.0 | |
| C.5.08 | Geotextile: Supply and Install (channels) | m2 | $3.47 | 0.028 | $1.09 | $0.11 | $0.11 | $2.16 | 105.5 | Productivity adjusted to match installed quote ($4 | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 2.0 | | M.08 | Geotextile | $2.16 | m2 | 1.0 | |
| C.5.09 | Geosynthetic Clay Liner: Supplied & Installed | m2 | $12.07 | 0.033 | $1.36 | $0.08 | $0.08 | $10.56 | 150 | Estimated from a 2014 quote for a cover installati | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 3.0 | 1.0 | M.07 | Geosynthetic Clay Liner | $10.56 | m2 | 1.0 | |
| C.5.10 | HDPE liner (60mil): Supplied & Installed (large areas) | m2 | $11.53 | 0.047 | $1.93 | $0.11 | $0.11 | $9.38 | 105.5 | Productivity adjusted to match BGM | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 3.0 | 1.0 | M.09 | HDPE liner (60mil) | $9.38 | m2 | 1.0 | |
| C.5.11 | HDPE liner: Supplied & Installed (channels) | m2 | $14.66 | 0.116 | $4.74 | $0.27 | $0.27 | $9.38 | 43 | RSMeans2016(33-47-13.53-1100) | | | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | 3.0 | 1.0 | M.09 | HDPE liner (60mil) | $9.38 | m2 | 1.0 | |
| C.5.12 | Intake structure: Supply and Install (precast concrete) | each | $47,172.29 | 140.00 | $5,946 | $3,583 | $644 | $37,000 | 0.05 | SRK measured productivity (2011) (2 days) | | | 1.0 | | | 1.0 | | | | | | | | 1.0 | | | | | | | | | $25.00 | $2.00 | Boomlift | | | | | 3.0 | 1.0 | M.13 | Intake Structure: precast con | $37,000 | each | 1.0 | Two days installation |
| C.5.13 | Signage: Open Pit warning signs | each | $261.00 | 0.928 | $40.27 | $15.90 | $5.57 | $199.26 | 4.3 | RSMeans2016(32-31-13.30-6600) | | | | | | | | | | | | | | | | | 2.0 | | | | | | $27.00 | | Auger attachment | | 1.0 | | | 1.0 | | M.20 | Signage: Open Pit Warning s | $199.26 | each | 1.0 | 8 foot galvanized steel post set in concrete with a 18"x24" reflective warning sign |
| C.5.14 | Signage: Large signs at main entrance | each | $671.48 | 0.928 | $40.27 | $15.90 | $5.57 | $609.74 | 4.3 | RSMeans2016(32-31-13.30-6600) | | | | | | | | | | | | | | | | | 2.0 | | | | | | $27.00 | | Auger attachment | | 1.0 | | | 1.0 | | M.21 | Signage: Large warning sign: | $609.74 | each | 1.0 | 8 foot galvanized steel post set in concrete with a 18"x24" reflective warning sign |
| **Revegetation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.6.01 | Seeding/Fertilizing: Tractor Application, Dry seed mix | ha | $2,669.89 | 33.126 | $1,029.50 | $401.72 | $232.94 | $1,005.72 | 0.060375 | RSMeans2016 (32 92 19-14-0100) | | | 1.0 | | | | | | | | | | | | | | | | 0.5 | | | | $8.90 | | Spreader | | | | | 0.5 | | n/a | Seed Mix #1 | $1,005.72 | ha | 1.0 | See 'SeedMix' worksheet for seed mix details and application rates |
| C.6.02 | Seeding/Fertilizing: Tractor Application, Wet seed mix | ha | $2,669.89 | 33.126 | $1,029.50 | $401.72 | $232.94 | $1,005.72 | 0.060375 | RSMeans2016 (32 92 19-14-0100) | | | 1.0 | | | | | | | | | | | | | | | | 0.5 | | | | $8.90 | | Spreader | | | | | 0.5 | | n/a | Seed Mix #2 | $1,005.72 | ha | 1.0 | See 'SeedMix' worksheet for seed mix details and application rates |
| C.6.03 | Seeding/Fertilizing: Hydroseeding Application, Dry seed mix | ha | $4,841.11 | 32.292 | $1,242.82 | $653.23 | $129.17 | $2,815.89 | 0.0929 | RSMeans2016 (32 92 19.14-0200) | | | | | | | | | | | | | | | | | 1.0 | | | | | | $39.90 | | Water truck w/ nozzle | | | | | 2.0 | | n/a | Seed Mix #3 | $2,815.89 | ha | 1.0 | See 'SeedMix' worksheet for seed mix details and application rates |
| C.6.04 | Seeding/Fertilizing: Hydroseeding Application, Wet Area mix | ha | $4,841.11 | 32.292 | $1,242.82 | $653.23 | $129.17 | $2,815.89 | 0.0929 | RSMeans2016 (32 92 19.14-0200) | | | | | | | | | | | | | | | | | 1.0 | | | | | | $39.90 | | Water truck w/ nozzle | | | | | 2.0 | | n/a | Seed Mix #4 | $2,815.89 | ha | 1.0 | See 'SeedMix' worksheet for seed mix details and application rates |
| C.6.05 | Wetland planting: by hand | ha | $3,089.53 | 43.750 | $1,443.27 | $307.03 | $180.00 | $1,159.23 | 0.08 | Assume 50% productivity as tree planting | | | | | | | | | | | | | | | | | 1.0 | | 0.5 | | | | | | | | | | | 2.0 | | M.27 | Wetland planting | $1,159.23 | ha | 1.0 | |
| C.6.06 | Tree planting (1,000 stems/ha) | ha | $2,343.03 | 51.250 | $1,832.33 | $25.98 | $15.00 | $469.71 | 0.16 | 8 planters, 8hrs/day. WorkSafeBC: avg. tree planter plants 1,600 stems/day | | | | | | | | | | | | | | | | | 0.2 | | | | | | | | | | | | | 8.0 | | n/a | Tree planting #1 | $469.71 | ha | 1.0 | See 'SeedMix' worksheet for seed mix details and application rates<br>A pickup truck and 0.2 time for support flatbed truck added to move materials around site |
| **Transportation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.7.01 | Misc. On-site Mobilization/Demobilization | hr | $250.67 | 2.000 | $88.22 | $118.29 | $44.16 | $0.00 | 1.0000 | n/a | 1.0 | | | | | | | | | | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | | | |
| C.7.02 | Off-site disposal to Whitehorse in 6-Axle Semi-Trailer (by weight) | tonne | $38.41 | 0.400 | $17.56 | $15.18 | $5.67 | $0.00 | 2.8571 | Assumes 80% capacity/7 hr travel/offload time | | | | | | 0.1 | | | | | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | | | |
| C.7.03 | Off-site Debris disposal to Whitehorse in 6-Axle Semi-Trailer (by volume) | m3 | $25.67 | 0.267 | $11.74 | $10.15 | $3.79 | $0.00 | 4.2745 | Assumes 80% capacity/7 hr travel/offload time | | | | | | 0.1 | | | | | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | | | |
| C.7.04 | Off-site disposal to Whitehorse in 6-Axle Semi-Trailer (by trip) | trip | $768.21 | 8.000 | $351.24 | $303.64 | $113.33 | $0.00 | 0.1429 | Assumes 7 hr travel/offload time | | | | | | 0.1 | | | | | | | | | | | | 1.0 | | | | | | | | | | | | | | | | | | | |
| C.7.05 | Off-site disposal to Whitehorse in 8-Axle Semi-Trailer (by weight) | tonne | $23.23 | 0.208 | $9.25 | $11.03 | $2.95 | $0.00 | 5.4857 | Assumes 80% capacity/7 hr travel/offload time | | | | | | 0.1 | | | | | | | | | | | | | | | | | $51.78 | $14.40 | 8 axle lowboy trailer | | | | 1.0 | | | | | | | | |
| C.7.06 | Off-site Debris disposal to Whitehorse in 8-Axle Semi-Trailer (by volume) | m3 | $15.53 | 0.139 | $6.18 | $7.37 | $1.97 | $0.00 | 8.2070 | Assumes 80% capacity/7 hr travel/offload time | | | | | | 0.1 | | | | | | | | | | | | | | | | | $51.78 | $14.40 | 8 axle lowboy trailer | | | | 1.0 | | | | | | | | |
| C.7.07 | Off-site disposal to Whitehorse in 8-Axle Semi-Trailer (by trip) | trip | $892.11 | 8.000 | $355.10 | $423.68 | $113.33 | $0.00 | 0.1429 | Assumes 7 hr travel/offload time | | | | | | 0.1 | | | | | | | | | | | | | | | | | $51.78 | $14.40 | 8 axle lowboy trailer | | | | 1.0 | | | | | | | | |
| **Underground Opening Seals** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.8.01 | Excavate to competent soils around perimeter and clean (pressure wash) | m3 | $104.49 | 2.000 | $84.00 | $13.66 | $6.83 | $0.00 | 2 | Assumed | | | 1.0 | | | | | | | | | | | | | | | | | | | | $15.75 | $2.00 | quipment - High pressure washer | | | | | 2.0 | 1.0 | | | | | | |
| C.8.02 | Structural I-Beams: supply and install | m | $88.27 | 1.225 | $50.19 | $15.95 | $6.05 | $16.09 | 5.7 | RSMeans 51223750100 (see notes) | 1.0 | | | | | | | | | | | | | | | | | | 1.0 | | | | | | | | 1.0 | | | 1.0 | 3.0 | M.23 | Steel Beam: I-Beam W6x9 | $16.09 | m | 1.0 | Productivity was reduced by 75% to account for dangerous conditions, and small job |
| C.8.03 | Formwork: concrete ringwall | m2 | $312.97 | 6.408 | $309.43 | $0.00 | $0.00 | $3.54 | 0.6 | RSMeans 31113652000 (see notes) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.0 | 3.0 | M.06 | Formwork: curb forms, wood | $3.54 | m2 | 1.0 | Productivity was reduced by 75% to account for dangerous conditions, and small job |
| C.8.04 | Steel decking (q-deck): supply and install | m2 | $87.87 | 0.574 | $29.08 | $10.60 | $2.85 | $45.35 | 10.5 | RSMeans 53133506700 | 1.0 | | | | | | | | | | | | | | | | | | | | | | $27.10 | $0.00 | utfit (truck mounted) - 400 an | | 1.0 | | | | 4.0 | M.24 | Steel decking (q-deck): | $45.35 | m2 | 1.0 | Productivity was reduced by 75% to account for dangerous conditions, and small job |
| C.8.05 | Rebar: supplied and installed | m | $4.64 | 0.024 | $1.27 | $0.00 | $0.00 | $3.37 | 165 | RSMeans 32111600400 (see notes) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4.0 | M.17 | Rebar (#6 bar) | $3.37 | m | 1.0 | #6 rebar assumed (1.5 lbs per ft.) |
| C.8.06 | Concrete: Supply and install elevated slab (incl. formwork, rebar) | m3 | $729.58 | 7.076 | $329.23 | $10.63 | $3.50 | $386.22 | 3.6744 | RSMeans 33053401900 | | | | | | | | | | | | | | | 1.0 | | | | | | | | $10.00 | $2.00 | Gas Eng. Vibrator | | 1.0 | | | 8.0 | 16.0 | M.02 | Concrete: elevated slabs | $386.22 | m3 | 1.0 | |
| C.8.07 | Vent raise: supply and install | ea | $478.39 | 0.500 | $17.77 | $0.00 | $0.00 | $460.62 | 2 | assumed | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.0 | | M.25 | Steel Pipe: 6" dia. | $115.16 | m | 4.0 | |

# Worksheet 21 - Relocation Unit Rates

**Project: Minto Mine Closure Cost Estimate - RCP 2018-01**
**Project No.: 1CM002.045**
**Client: Minto Explorations Ltd.**
**Date: February 6, 2018**
**File Location: \\van-svr0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate**

| | | | | | | Unit Rate Summary | | | | | | | | Fleet | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost Code | Source | Destination | Activities | Material | Costed Volume Unit | Total Unit Rate ($/m$^3$) | Manhours (hrs/m$^3$) | Labor Rate ($/m$^3$) | Equipment Rate ($/m$^3$) | Fuel Rate ($/m$^3$) | Productivity (m$^3$/hr) | Total Dist. (1-way) (km) | Avg. Grade (%) | Excavator | Truck Fleet | Max. # of Trucks | # of Dozers | Dozer Size | Compaction? |
| R.001 | Misc. 1km flat haul w/ Articulated Trucks | | Load, haul, dump, spread | Earth, moist | CCM | $5.31 | 0.03 | $1.39 | $3.03 | $0.90 | 159 | 1.0 | 0.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.002 | Misc. 1km flat haul w/ Articulated Trucks w/ compaction | | Load, haul, dump, spread, compact | Earth, moist | CCM | $5.82 | 0.04 | $1.61 | $3.21 | $0.99 | 159 | 1.0 | 0.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | Yes |
| R.003 | Misc. 1km flat haul w/ Large Fleet | | Load, haul, dump, spread | Earth, moist | CCM | $2.78 | 0.01 | $0.51 | $1.70 | $0.57 | 516 | 1.0 | 0.0% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.004 | Misc. 1km flat haul w/ Large Fleet | | Load, haul, dump, spread | Earth, moist | CCM | $2.78 | 0.01 | $0.51 | $1.70 | $0.57 | 516 | 1.0 | 0.0% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.005 | Airport Laydown | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $6.37 | 0.04 | $1.76 | $3.53 | $1.08 | 100 | 2.4 | 3.2% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.006 | Airstrip Area | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $5.35 | 0.03 | $1.48 | $2.95 | $0.92 | 89 | 1.0 | 0.0% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.007 | Camp Area | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $7.20 | 0.05 | $1.99 | $3.99 | $1.22 | 88 | 3.1 | 2.7% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.008 | Dyno Compound | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $8.39 | 0.05 | $2.32 | $4.65 | $1.42 | 76 | 5.5 | -0.5% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.009 | Fuel Farm Area | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $8.37 | 0.05 | $2.32 | $4.64 | $1.41 | 76 | 3.6 | 2.3% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.010 | Fuel Farm Area | Landfarm | Load, haul, dump | Earth, moist | CCM | $7.84 | 0.05 | $2.17 | $4.36 | $1.31 | 122 | 3.6 | 2.3% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.011 | IROD Laydown | SWD-High Grade Waste | Load, haul, dump, spread, compact | Sand, dry | CCM | $3.14 | 0.01 | $0.63 | $1.89 | $0.63 | 547 | 1.6 | -0.8% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | Yes |
| R.012 | Main Pit (SAT) | Main Pit (SAT) | Load, haul, dump | Waste Rock (Minto | CCM | $3.13 | 0.02 | $0.75 | $1.86 | $0.51 | 409 | 0.4 | 0.0% | CAT 385 | CAT 735 | 3 | 3 | CAT D6R | No |
| R.013 | Main Pit Dump | Main Pit Dump Buttress | Load, haul, dump | Waste Rock (Minto | CCM | $3.08 | 0.01 | $0.58 | $1.89 | $0.61 | 456 | 1.0 | -5.0% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.014 | Main Pit Dump | Main Pit Tailings Cover | Load, haul, dump, spread | Waste Rock (Minto | CCM | $5.05 | 0.03 | $1.38 | $2.86 | $0.82 | 160 | 1.5 | -5.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D6R | No |
| R.015 | Main Waste Dump Extension | Main Pit Access Point | Load, haul, dump, place | Rip-rap (Minto) | CCM | $4.77 | 0.03 | $1.25 | $2.71 | $0.81 | 177 | 1.8 | -6.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.016 | Main Waste Dump Extension | Area 2 Pit Access point | Load, haul, dump, place | Rip-rap (Minto) | CCM | $4.57 | 0.03 | $1.19 | $2.60 | $0.77 | 184 | 1.6 | -6.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.017 | Main Waste Dump Extension | Area 118 Pit Access Point | Load, haul, dump, place | Rip-rap (Minto) | CCM | $6.45 | 0.04 | $1.70 | $3.66 | $1.08 | 156 | 3.2 | -1.4% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.018 | Main Waste Dump Extension | W15/Main Pit Channel | Load, haul, dump | Rip-rap (Minto) | CCM | $4.47 | 0.03 | $1.17 | $2.55 | $0.76 | 189 | 1.2 | -10.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.019 | Main Waste Dump Extension | W15/Main Pit Channel | Load, haul, dump, place | Sand & gravel, dry | CCM | $6.51 | 0.04 | $1.64 | $3.77 | $1.10 | 162 | 1.2 | -10.0% | CAT 330 | CAT 735 | 5 | 2 | CAT D8R | No |
| R.020 | Main Waste Dump Extension | Ditch B1 (W35 to Mill area) | Load, haul, dump | Rip-rap (Minto) | CCM | $5.03 | 0.03 | $1.32 | $2.87 | $0.85 | 168 | 2.0 | -4.8% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.021 | Main Waste Dump Extension | Ditch B1 (W35 to Mill area) | Load, haul, dump, place | Sand & gravel, dry | CCM | $7.41 | 0.04 | $1.86 | $4.29 | $1.25 | 142 | 2.0 | -4.8% | CAT 330 | CAT 735 | 5 | 2 | CAT D8R | No |
| R.022 | Main Waste Dump Extension | Mill Area | Load, haul, dump | Rip-rap (Minto) | CCM | $5.85 | 0.04 | $1.54 | $3.33 | $0.98 | 171 | 2.1 | -5.3% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.023 | Main Waste Dump Extension | Mill Area | Load, haul, dump, place | Sand & gravel, dry | CCM | $8.50 | 0.05 | $2.17 | $4.90 | $1.43 | 142 | 2.1 | -5.3% | CAT 330 | CAT 735 | 5 | 2 | CAT D8R | No |
| R.024 | Main Waste Dump Extension | Minto North | Load, haul, dump | Rip-rap (Minto) | CCM | $4.14 | 0.02 | $1.08 | $2.36 | $0.70 | 204 | 1.1 | -5.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.025 | Main Waste Dump Extension | MVFE2 (by access road) | Load, haul, dump | Rip-rap (Minto) | CCM | $6.87 | 0.04 | $1.81 | $3.91 | $1.16 | 146 | 2.5 | -4.9% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.026 | Main Waste Dump Extension | MVFE2 (by access road) | Load, haul, dump, place | Sand & gravel, dry | CCM | $9.11 | 0.05 | $2.34 | $5.24 | $1.53 | 150 | 2.5 | -4.9% | CAT 330 | CAT 735 | 5 | 2 | CAT D8R | No |
| R.027 | Main Waste Dump Extension | MVFE2 Toe area | Load, haul, dump | Rip-rap (Minto) | CCM | $7.00 | 0.04 | $1.86 | $3.97 | $1.17 | 166 | 2.9 | -5.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.028 | Main Waste Dump Extension | MVFE2 Toe area | Load, haul, dump, place | Sand & gravel, dry | CCM | $10.05 | 0.06 | $2.59 | $5.78 | $1.69 | 136 | 2.9 | -5.0% | CAT 330 | CAT 735 | 5 | 2 | CAT D8R | No |
| R.029 | Main Waste Dump Extension | Main Waste Dump | Load, haul, dump | Rip-rap (Minto) | CCM | $4.24 | 0.02 | $1.09 | $2.42 | $0.72 | 161 | 0.4 | -6.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.030 | Main Waste Dump Extension | Main Waste Dump | Load, haul, dump | Sand & gravel, dry | CCM | $4.83 | 0.03 | $1.25 | $2.76 | $0.82 | 142 | 0.4 | -6.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.031 | Main Waste Dump Extension | Southwest Dump | Load, haul, dump | Rip-rap (Minto) | CCM | $5.54 | 0.03 | $1.45 | $3.15 | $0.94 | 152 | 2.0 | -3.5% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.032 | Main Waste Dump Extension | Southwest Dump | Load, haul, dump | Sand & gravel, dry | CCM | $5.87 | 0.04 | $1.55 | $3.34 | $0.99 | 171 | 2.0 | -3.5% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.033 | Main Waste Dump Extension | Reclamation OVB Dump | Load, haul, dump | Rip-rap (Minto) | CCM | $5.30 | 0.03 | $1.39 | $3.02 | $0.90 | 159 | 1.3 | 1.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.034 | Main Waste Dump Extension | Reclamation OVB Dump | Load, haul, dump, place | Sand & gravel, dry | CCM | $6.29 | 0.04 | $1.64 | $3.58 | $1.06 | 134 | 1.3 | 1.0% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.035 | Main Waste Dump Extension | Tailings Diversion Ditch | Load, haul, dump | Rip-rap (Minto) | CCM | $7.79 | 0.05 | $2.07 | $4.42 | $1.30 | 149 | 3.3 | -4.8% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.036 | MWD Low Grade Stockpile | Main Pit | Load, haul, dump, spread | Waste Rock (Minto | CCM | $3.02 | 0.01 | $0.56 | $1.84 | $0.62 | 474 | 1.9 | -5.4% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.037 | Mill Area | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $6.77 | 0.04 | $1.87 | $3.75 | $1.14 | 94 | 3.0 | 3.1% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.038 | Mill Area | Landfarm | Load, haul, dump | Waste Rock (Minto | CCM | $5.70 | 0.04 | $1.58 | $3.17 | $0.96 | 139 | 3.0 | 3.1% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.039 | Mill Area | Minto South Portal | Load, haul, dump | Waste Rock (Minto | CCM | $5.84 | 0.03 | $1.53 | $3.33 | $0.99 | 144 | 1.6 | 3.8% | CAT 330 | CAT 735 | 5 | 1 | CAT D8R | No |
| R.040 | Mill Pond | Main Pit | Load, haul, dump | Sand, wet | CCM | $3.30 | 0.02 | $0.91 | $1.82 | $0.56 | 144 | 0.4 | 5.0% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.041 | Minto North | MVFE Stage 2 | Load, haul, dump, spread | Waste Rock (Minto | CCM | $5.15 | 0.02 | $0.97 | $3.15 | $1.04 | 364 | 4.1 | -3.1% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.042 | Minto North Portal | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $8.18 | 0.05 | $2.27 | $4.53 | $1.38 | 78 | 5.7 | 0.2% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.043 | Minto South Portal | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $7.18 | 0.05 | $1.99 | $3.98 | $1.21 | 88 | 3.2 | 0.3% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.044 | Ore Stockpile Area (Mill) | Main Pit | Load, haul, dump, spread | Waste Rock (Minto | CCM | $2.82 | 0.01 | $0.52 | $1.72 | $0.57 | 425 | 1.1 | 1.5% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.045 | Pelly Laydown | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $7.33 | 0.05 | $2.03 | $4.06 | $1.24 | 87 | 4.3 | -0.7% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| R.046 | Reclamation Ovb. Dump | Camp Area | Load, haul, dump, spread | Earth, moist | CCM | $4.50 | 0.02 | $0.85 | $2.75 | $0.91 | 416 | 2.9 | -4.3% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.047 | Reclamation Ovb. Dump | Camp Area | Load, haul, dump | Earth, moist | CCM | $4.00 | 0.02 | $0.74 | $2.44 | $0.82 | 416 | 2.9 | -4.3% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.048 | Reclamation Ovb. Dump | DSTSF | Load, haul, dump, spread | Earth, moist | CCM | $4.55 | 0.02 | $0.86 | $2.78 | $0.91 | 412 | 3.1 | -4.2% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.049 | Reclamation Ovb. Dump | Fuel Storage Area | Load, haul, dump, spread | Earth, moist | CCM | $4.56 | 0.02 | $0.86 | $2.79 | $0.92 | 411 | 2.7 | -3.7% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.050 | Reclamation Ovb. Dump | Main Dump | Load, haul, dump, spread | Earth, moist | CCM | $4.37 | 0.02 | $0.82 | $2.67 | $0.88 | 429 | 1.5 | 2.0% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.051 | Reclamation Ovb. Dump | Main Dump | Load, haul, dump | Earth, moist | CCM | $3.89 | 0.02 | $0.72 | $2.37 | $0.80 | 429 | 1.5 | 2.0% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.052 | Reclamation Ovb. Dump | Main Pit | Load, haul, dump, spread | Earth, moist | CCM | $4.18 | 0.02 | $0.79 | $2.55 | $0.84 | 448 | 2.6 | -4.8% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.053 | Reclamation Ovb. Dump | Main Pit Dump | Load, haul, dump, spread | Earth, moist | CCM | $3.79 | 0.02 | $0.71 | $2.32 | $0.76 | 433 | 1.7 | -5.5% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.054 | Reclamation Ovb. Dump | Main Pit Dump | Load, haul, dump | Earth, moist | CCM | $3.31 | 0.01 | $0.61 | $2.02 | $0.68 | 433 | 1.7 | -5.5% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.055 | Reclamation Ovb. Dump | Mill Area | Load, haul, dump, spread | Earth, moist | CCM | $4.25 | 0.02 | $0.80 | $2.60 | $0.86 | 441 | 2.7 | -4.8% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.056 | Reclamation Ovb. Dump | MVFE Stage 1 and 2 | Load, haul, dump, spread | Earth, moist | CCM | $4.77 | 0.02 | $0.90 | $2.91 | $0.96 | 393 | 3.4 | -3.8% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.057 | Reclamation Ovb. Dump | MVFE Stage 1 and 2 | Load, haul, dump | Earth, moist | CCM | $4.24 | 0.02 | $0.78 | $2.59 | $0.87 | 393 | 3.4 | -3.8% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.058 | Reclamation Ovb. Dump | Pelly Laydown | Load, haul, dump, spread | Earth, moist | CCM | $3.45 | 0.01 | $0.65 | $2.11 | $0.69 | 475 | 1.4 | -4.5% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.059 | Reclamation Ovb. Dump | Southwest Dump | Load, haul, dump, spread | Earth, moist | CCM | $4.08 | 0.02 | $0.77 | $2.49 | $0.82 | 402 | 1.7 | 0.2% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.060 | Reclamation Ovb. Dump | SWD-High Grade Waste | Load, haul, dump, spread | Earth, moist | CCM | $3.87 | 0.02 | $0.73 | $2.37 | $0.78 | 423 | 1.9 | -0.8% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.061 | Reclamation Ovb. Dump | SWD-High Grade Waste | Load, haul, dump | Earth, moist | CCM | $3.30 | 0.01 | $0.61 | $2.02 | $0.68 | 433 | 2.0 | -1.0% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R.062 | Reclamation Ovb. Dump | Ridgetop Pit | Load, haul, dump, spread | Earth, moist | CCM | $6.61 | 0.03 | $1.24 | $4.04 | $1.33 | 283 | 4.6 | 1.5% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.063 | Reclamation Ovb. Dump | Ridgetop Waste Dump | Load, haul, dump, spread | Earth, moist | CCM | $6.27 | 0.03 | $1.18 | $3.83 | $1.26 | 299 | 4.0 | 1.7% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.064 | Reclamation Ovb. Dump | Ridgetop Waste Dump | Load, haul, dump | Earth, moist | CCM | $5.57 | 0.02 | $1.03 | $3.40 | $1.14 | 299 | 4.0 | 1.7% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.065 | Reclamation Ovb. Dump | W15 Sump Area | Load, haul, dump, spread | Earth, moist | CCM | $3.56 | 0.02 | $0.67 | $2.18 | $0.71 | 460 | 1.5 | -4.8% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.066 | Reclamation Ovb. Dump | Tailings Diversion Ditch | Load, haul, dump, spread | Earth, moist | CCM | $5.23 | 0.02 | $0.98 | $3.20 | $1.05 | 358 | 4.1 | -3.2% | CAT 385 | CAT 773G | 5 | 2 | CAT D8R | No |
| R.067 | Reclamation Ovb. Dump | Tailings Diversion Ditch | Load, haul, dump | Earth, moist | CCM | $4.65 | 0.02 | $0.86 | $2.84 | $0.95 | 358 | 4.1 | -3.2% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.068 | Ridgetop Waste Dump | Ridgetop Pit | Load, haul, dump | Waste Rock (Minto | CCM | $3.12 | 0.01 | $0.58 | $1.90 | $0.64 | 459 | 2.0 | -4.4% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.069 | SWD-High Grade Waste | Main Pit | Load, haul, dump, spread | Waste Rock (Minto | CCM | $3.59 | 0.02 | $0.66 | $2.19 | $0.73 | 399 | 2.8 | -3.7% | CAT 385 | CAT 773G | 5 | 1 | CAT D8R | No |
| R.070 | W15 Sump | Solid Waste Landfill | Load, haul, dump | Demo Debris | LCM | $6.86 | 0.04 | $1.90 | $3.80 | $1.16 | 93 | 3.7 | 1.1% | CAT 330 | CAT 735 | 5 | 0 | CAT D8R | No |
| | Note: Leave this row blank - Insert new rows above this one | | | | | | | | | | | | | | | | | | |

## EXCAVATION UNIT RATES (NO HAULING)

| | | | | Unit Rate Summary | | | | | | Inputs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost Code | Description | Material | Costed Volume Unit | Total Unit Rate ($/m$^3$) | Manhours (hrs/m$^3$) | Labor Rate ($/m$^3$) | Equipment Rate ($/m$^3$) | Fuel Rate ($/m$^3$) | Productivity (m$^3$/hr) | Excavator | # of Dozers | Dozer Size | Job Condition | Source, Comments/Notes |
| R.901 | Culvert removal, large excavator | Waste Rock (Minto | BCM | $0.93 | 0.00 | $0.15 | $0.58 | $0.20 | 305 | CAT 385 | 0 | CAT D8R | Avg. (Typical | |
| R.902 | Channel excavation, small excavator, dozer used to spoil locally | Earth, moist | BCM | $2.88 | 0.02 | $0.77 | $1.64 | $0.46 | 115 | CAT 330 | 1 | CAT D6R | Below Avg. | Below average conditions used to account for channel shaping |
| R.903 | Channel excavation in steep areas, small excavator, dozer used to spoil locally | Earth, moist | BCM | $3.26 | 0.02 | $0.88 | $1.86 | $0.52 | 101 | CAT 330 | 1 | CAT D6R | Severe | Severe conditions used to account for channel shaping, difficult access |
| R.904 | Channel rip-rap placement | Rip-rap (Minto) | CCM | $1.72 | 0.01 | $0.48 | $0.91 | $0.32 | 92 | CAT 330 | 0 | CAT D6R | Below Avg. | Below average conditions used to account for channel shaping/placement |
| R.905 | Channel rip-rap placement in difficult access areas | Rip-rap (Minto) | CCM | $4.08 | 0.02 | $1.10 | $2.33 | $0.65 | 81 | CAT 330 | 1 | CAT D6R | Severe | Severe conditions used to account for channel shaping/placement, dozer added to help |
| Note: Leave this row blank - Insert new rows above this one. | | | | | | | | | | | | | | |

**Notes:**

# Worksheet 22 - Area Calculations for Covers and Revegetation

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans)** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\!040_AutoCAD\1CM002-45_ClosureQuantities.dwg

## A: Existing Yards, Waste Rock Dumps

| | Areas | | | | | | Reveg Prescription | | | | | | Calculated Quantities | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility | Total 2D Area (pre-regrade) (m2) | 2D Slope Area (from 'Regrade' worksheet) ($m^2$) | 3D Slope Area (from 'Regrade' worksheet) ($m^2$) | Footprint Area increase due to regrading (from 'Regrade' worksheet) ($m^2$) | 3D slope Area override ($m^2$) | Flat Area (post-regrade) override ($m^2$) | Flat Area Cover Thickness (m) | Slope Area Cover Thickness (m) | Flat Area Scarified/ Ripped? | Slopes Scarified/ Ripped? | Percentage of flat areas seeded/fertilized | Percentage of sloped Areas seeded/fertilized? | Estimated Flat Area (post-regrade) | 3D Sloped Area ($m^2$) | Scarified flat areas ($m^2$) | Scarified sloped areas ($m^2$) | Cover Volume in Flat Areas ($m^3$) | Cover Volume - Sloped Areas ($m^3$) | Revegetated Area (ha) | Comments/Notes |
| Airport Laydown | 21,277 | | | | | | | | Yes | | 100% | | 21,277 | 0 | 21,277 | 0 | 0 | 0 | 2.13 | |
| Airstrip | 64,378 | | | | | | | | Yes | | 100% | | 64,378 | 0 | 64,378 | 0 | 0 | 0 | 6.44 | |
| Area 118 Backfill Dump | 41,899 | | | 0 | | | 0 | 0 | Yes | Yes | 100% | 100% | 41,899 | 0 | 41,899 | 0 | 0 | 0 | 4.19 | |
| Camp | 33,525 | 17,739 | 18,699 | 4,840 | | | 0.5 | 0.5 | Yes | Yes | 100% | 100% | 20,626 | 18,699 | 20,626 | 18,699 | 10,313 | 9,349 | 3.93 | |
| Crusher Area | 26,964 | | | 0 | 0 | 26,964 | 0.5 | | Yes | Yes | 100% | 100% | 26,964 | 0 | 26,964 | 0 | 13,482 | 0 | 2.70 | |
| DSTSF WR Shell | 50,237 | 51,376 | 52,957 | | | 0 | 0.5 | 0.5 | Yes | No | 100% | 100% | 0 | 52,957 | 0 | 0 | 0 | 26,479 | 5.30 | |
| DSTSF Tailings Surface | 191,561 | 10,000 | 10,308 | | | 48,000 | 0.5 | 0.5 | No | No | 100% | 100% | 48,000 | 10,308 | 0 | 0 | 24,000 | 5,154 | 19.16 | Assumes areas covered in residuum only require covers. Note: Reveg area formula has been adjusted compared to the other rows so that the entire DSTSF area is included in the reveg area calculation. |
| Explosive Plant & Storage Areas | 55,113 | | | | | | 0 | 0 | Yes | No | 100% | 100% | 55,113 | 0 | 55,113 | 0 | 0 | 0 | 5.51 | Roads between laydown/storage areas included in 'Roads' worksheet |
| Fuel Storage Area | 8,400 | | | | | | 0.5 | 0 | No | No | 100% | 0% | 8,400 | 0 | 0 | 0 | 4,200 | 0 | 0.84 | |
| Ice Rich Overburden Dump | 27,583 | | | | 0 | | 0 | 0 | No | No | 100% | 100% | 27,583 | 0 | 0 | 0 | 0 | 0 | 2.76 | |
| IROD Laydown | 23,055 | 4,949 | 5,147 | 0 | | | 0 | 0 | Yes | No | 100% | 100% | 18,106 | 5,147 | 18,106 | 0 | 0 | 0 | 2.33 | Roads between laydown/storage areas included in 'Roads' worksheet |
| Main Waste Dump Ext. (includes Main Dump) | 496,414 | 280,341 | 295,506 | 9,053 | | | 0.5 | 0.5 | No | No | 100% | 100% | 225,126 | 295,506 | 0 | 0 | 112,563 | 147,753 | 52.06 | |
| Main Waste Dump Wrap | 98,046 | 81,600 | 84,895 | 0 | | | 0.5 | 0.5 | No | No | 100% | 100% | 16,446 | 84,895 | 0 | 0 | 8,223 | 42,447 | 10.13 | |
| Main Pit Dump (inc. rev.5-6) | 236,535 | 159,480 | 168,106 | 13,485 | | | 0.5 | 0.5 | No | No | 100% | 100% | 90,540 | 168,106 | 0 | 0 | 45,270 | 84,053 | 25.86 | |
| Mill Area | 42,365 | | | | | | 0.5 | 0.5 | Yes | Yes | 100% | 100% | 42,365 | 0 | 42,365 | 0 | 21,182 | 0 | 4.24 | |
| Mill Valley Fill Extension (1 and 2) | 171,634 | | | | 59,852 | 114,853 | 0.5 | 0.5 | No | No | 100% | 100% | 114,853 | 59,852 | 0 | 0 | 57,427 | 29,926 | 17.47 | |
| Minto South Portal | 105,446 | 45,406 | 47,862 | 2,725 | | | 0 | 0 | Yes | No | 100% | 100% | 62,765 | 47,862 | 62,765 | 0 | 0 | 0 | 11.06 | |
| Ore Stockpile Area | 139,307 | | | | 0 | | 0.5 | | Yes | No | 100% | 100% | 139,307 | 0 | 139,307 | 0 | 69,653 | 0 | 13.93 | |
| Pelly Laydown | 51,710 | | | | | | 0.5 | 0.5 | Yes | No | 100% | 100% | 51,710 | 0 | 51,710 | 0 | 25,855 | 0 | 5.17 | |
| Reclamation OVB Dump | 297,857 | | | | 0 | 297,857 | | | No | No | 100% | 100% | 297,857 | 0 | 0 | 0 | 0 | 0 | 29.79 | |
| Ridgetop Exploration Area | 34,778 | | | | 0 | | | | Yes | No | 100% | 100% | 34,778 | 0 | 34,778 | 0 | 0 | 0 | 3.48 | Assumes 50% of area scarified/reveged. |
| Ridgetop Waste Dump | 286,836 | 271,319 | 285,996 | 28,609 | | | 0.5 | 0.5 | No | No | 100% | 100% | 44,126 | 285,996 | 0 | 0 | 22,063 | 142,998 | 33.01 | |
| Ridgetop South Backfill Dump | 30,662 | 28,172 | 29,696 | 6,001 | | | 0 | 0 | No | No | 100% | 100% | 8,491 | 29,696 | 0 | 0 | 0 | 0 | 3.82 | |
| Southwest Dump | 627,621 | | | | 0 | | 0.5 | 0.5 | No | No | 100% | 100% | 627,621 | 0 | 0 | 0 | 313,810 | 0 | 62.76 | Excludes High Grade Waste Stockpile |
| SWD - High Grade Waste (In-place) | 31,165 | 40,679 | 41,485 | 15,430 | | | 1 | 1 | No | No | 100% | 100% | 5,915 | 41,485 | 0 | 0 | 5,915 | 41,485 | 4.74 | |
| SWD - High Grade Waste (removed) | 31,165 | | | | | | 0.5 | 0.5 | No | No | 100% | 100% | 31,165 | 0 | 0 | 0 | 15,583 | 0 | 3.12 | |
| Tailings Diversion Ditch | 72,143 | 34,246 | 36,099 | 12,467 | | | 0.5 | 0.5 | No | No | 100% | 100% | 50,364 | 36,099 | 0 | 0 | 25,182 | 18,049 | 8.65 | |
| WSP Dam Breach | 13,950 | | | | 13,950 | 0 | 0.5 | 0.5 | No | No | 100% | 100% | 0 | 13,950 | 0 | 0 | 0 | 6,975 | 1.40 | Cover volume is an allowance: it is unlikely it will be to be placed over a large portion of the dam footpri due to slopes steeper than 2H:1V |
| W15 Sump Area | 12,306 | 4,235 | 4,465 | 1,413 | | | 0.5 | 0.5 | Yes | No | 100% | 100% | 9,484 | 4,465 | 9,484 | 0 | 4,742 | 2,232 | 1.39 | |
| **TOTAL** | | | | | | | | | | | | | | | | | **779,463** | **556,901** | **347** | |

**Notes:**

## B: Future Yards, Waste Rock Dumps

| | Areas | | | | | | Reveg Prescription | | | | | | Calculated Quantities | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility | Total 2D Area (pre-regrade) ($m^2$) | 2D Slope Area (from 'Regrade' worksheet) ($m^2$) | 3D Slope Area (from 'Regrade' worksheet) ($m^2$) | Footprint Area increase due to regrading (from 'Regrade' worksheet) ($m^2$) | 3D slope Area override ($m^2$) | Flat Area (post-regrade) override ($m^2$) | Flat Area Cover Thickness (m) | Slope Area Cover Thickness (m) | Flat Area Scarified/ Ripped? | Slopes Scarified/ Ripped? | Percentage of flat areas seeded/fertilized | Percentage of sloped Areas seeded/fertilized? | Estimated Flat Area (post-regrade) | 3D Sloped Area ($m^2$) | Scarified flat areas ($m^2$) | Scarified sloped areas ($m^2$) | Cover Volume Flat Areas ($m^2$) | Cover Volume - Sloped Areas ($m^3$) | Revegetated Area (ha) | Comments/Notes |
| Area 118 Backfill Dump | 68,438 | 18,405 | 19,401 | 0 | | | 0 | 0 | Yes | Yes | 100% | 100% | 50,033 | 19,401 | 50,033 | 19,401 | 0 | 0 | 6.94 | |

## C: Complex Covers

| | Inputs | | | | | | | Calculated Quantities | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility | Flat Area ($m^2$) | 3D Slope Area (from 'Regrade' worksheet) ($m^2$) | Bedding Layer Thickness (m) | Liner (Y/N) | Geotextile Layers | Protection Layer Thickness (m) | Growth Medium Cover Thickness (m) | Liner Area ($m^2$) | Geotextile Area ($m^2$) | Bedding Volume - Flat Areas ($m^3$) | Bedding Volume - Sloped Areas ($m^3$) | Total Bedding Volume ($m^3$) | Protection Layer Volume - Flat Areas ($m^3$) | Protection Layer Volume - Sloped Areas ($m^3$) | Total Protection Layer Volume ($m^3$) | Growth Medium Volume - Flat Areas ($m^3$) | Growth Medium Volume - Sloped Areas ($m^3$) | Total Growth Medium Volume ($m^3$) | Revegetated Area (ha) | Comments/Notes |
| Main Pit Tailings | 17,750 | | | No | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 17,750 | 0 | 17,750 | 8,875 | 0 | 8,875 | 1.78 | Protection layer = waste rock |
| Ridgetop Tailings | 62,477 | | | No | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 62,477 | 0 | 62,477 | 31,239 | 0 | 31,239 | 6.25 | |

# Worksheet 23 - Demolition Quantity Calculations

**Project:** Minto Mine Closure Cost Estimate
**Project No.:** 1CM002.P04
**Client:** Minto Explorations Ltd.
**Date of Submission:** August 2016
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**TOTAL DEMOLITION/SOLID WASTE VOLUME FOR SOLID WASTE LANDFILL 12,920 LCM**

## A: Building Demolition

| | | | | Exterior Building Dimensions | | | | | Sub-component Measurements | | | | | | | Disposal | Steel Quantity Calcs | | | Concrete Quantity Calcs | | Wood/Misc. Qnty Calcs. | | Off-site Transport | | On-site Disposal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Area | Sub Area | Sub-component/ Building/ Section | Building Demolition Type | Length (m) | Width (m) | Height (m) | Modular Building Loads | Material | Wall thickness (m)[1] | # of Exterior Steel Columns | Avg. Ext. Column X-Section Area (m2) | # of Steel Trusses | Average Truss x section area (m2) | Disposal Location | Wall mass (tonnes) | Column and Truss Mass (tonnes) | Total Mass (tonnes) | In-Place Concrete Volume (m3) | Concrete Debris Volume (LCM) | In-Place Demo Volume (m3) | Debris Volume (LCM) | Modular Building Truckloads (Offsite) | Off-site Debris Trips | On-site Demolition Debris Volume (LCM) | Comments/Notes |
| **Airport Laydown** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Airport Laydown | Mechanics Shop | Entire building | Steel Building - Small | 24.00 | 25.00 | 6.00 | | Steel | 0.01 | | | | | On-site | 95.6 | 0.0 | 95.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 137 | AutoCAD/Photos |
| 2 | | Covered Storage | | Wooden Building - Large | 70.00 | 4.00 | 2.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 560.0 | 184.8 | 0.0 | 0.0 | 185 | Photos |
| **SUBTOTAL - Airport Laydown** | | | | | | | | | | | | | | | | | | **96** | | **0** | **560** | | **0** | **0** | **321** | |
| **Airstrip Area** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Airstrip | Exploration Camp | Camp tents (11) | Wooden Building - Small | 44.00 | 4.00 | 2.50 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 440.0 | 145.2 | 0.0 | 0.0 | 145 | AutoCAD/Photos (lengths summed to account for 11 structures |
| 2 | | | Exploration core shed 1 | Wooden Building - Small | 7.50 | 4.50 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 101.3 | 33.4 | 0.0 | 0.0 | 33 | AutoCAD/Photos |
| 3 | | | Exploration core shed 2 | Wooden Building - Small | 10.00 | 4.50 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 135.0 | 44.6 | 0.0 | 0.0 | 45 | AutoCAD/Photos |
| 4 | | | Core Logging Shack | Wooden Building - Small | 25.00 | 6.30 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 472.5 | 155.9 | 0.0 | 0.0 | 156 | AutoCAD/Photos |
| **SUBTOTAL - Airstrip** | | | | | | | | | | | | | | | | | | **0** | | **0** | **1149** | | **0** | **0** | **379** | |
| **Camp Area** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Offices | Safety Building | Prefab Bldg. Shell | Steel Building - Small | 17.00 | 18.00 | 6.00 | | Steel | 0.03 | | | | | On-site | 175.3 | 0.0 | 175.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 250 | AutoCAD/Photos |
| 2 | | Mine Offices | Entire building | Wooden Building - Small | 50.00 | 10.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1500.0 | 495.0 | 0.0 | 0.0 | 495 | AutoCAD/Photos |
| 3 | Old Camp Complex | Capstone Building | Entire building | Wooden Building - Small | 56.00 | 9.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1512.0 | 499.0 | 0.0 | 0.0 | 499 | AutoCAD/Photos |
| 4 | | Building betw Capstone & Sherwood | | Wooden Building - Small | 19.00 | 7.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 399.0 | 131.7 | 0.0 | 0.0 | 132 | AutoCAD/Photos |
| 5 | | Sherwood Building | | Wooden Building - Small | 110.00 | 7.50 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2475.0 | 816.8 | 0.0 | 0.0 | 817 | AutoCAD/Photos |
| 6 | | Minto Building | | Wooden Building - Small | 70.00 | 7.50 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1575.0 | 519.8 | 0.0 | 0.0 | 520 | AutoCAD/Photos |
| 7 | | Dining Hall/Dry | | Wooden Building - Small | 64.00 | 9.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1728.0 | 570.2 | 0.0 | 0.0 | 570 | AutoCAD/Photos |
| 8 | | Gym/Muster | | Wooden Building - Small | 16.00 | 8.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 384.0 | 126.7 | 0.0 | 0.0 | 127 | AutoCAD/Photos |
| 9 | | Site Services/IT Offices | | Wooden Building - Small | 28.00 | 9.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 756.0 | 249.5 | 0.0 | 0.0 | 249 | AutoCAD/Photos |
| 10 | North End of Camp | Trailer betw/Minto and Selkirk Tower | | Wooden Building - Small | 30.00 | 7.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 630.0 | 207.9 | 0.0 | 0.0 | 208 | AutoCAD/Photos |
| 11 | | Selkirk Towers | | Modular Buildings - Dismantle/Prep | | | | 87 | | | | | | | Off-site | | | | | | | | 87.0 | | | Photos |
| 12 | Other | Misc. Seacans | | Modular Buildings - Dismantle/Prep | | | | 5 | | | | | | | Off-site | | | | | | | | 5.0 | | | Photos |
| **SUBTOTAL - Camp Area** | | | | | | | | | | | | | | | | | | **175** | | **0** | **10959** | | **92** | **0** | **3867** | |
| **Explosive Plant and Storage Areas** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Explosive Plant | Dyno Compound | Dyno Garage | Steel Building - Small | 15.00 | 15.00 | 6.00 | | Steel | 0.01 | | | | | On-site | 47.1 | 0.0 | 47.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 67 | AutoCAD/Photos |
| 2 | | Dyno office | | Modular Buildings - Dismantle/Prep | | | | 1 | | | | | | | Off-site | | | | | | | | 1.0 | | | Photos |
| **SUBTOTAL - Explosive Plant and Storage Areas** | | | | | | | | | | | | | | | | | | **47** | | **0** | **0** | | **1** | **0** | **67** | |
| **Fuel Farm Area** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Fuel Farm Area | Generators | Sheds | Wooden Building - Small | 5.00 | 5.00 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 75.0 | 24.8 | 0.0 | 0.0 | 25 | AutoCAD/Photos |
| **SUBTOTAL - Fuel Farm Area** | | | | | | | | | | | | | | | | | | **0** | | **0** | **75** | | **0** | **0** | **25** | |
| **Mill Area Complex** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Mill Complex | Process Building | Prefab Bldg. Shell | Steel Building - Large | 59.76 | 21.34 | 15.24 | | Steel | 0.03 | 20 | 0.0055914 | 10 | 0.0223656 | On-site | 905.1 | 52.1 | 957.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1367 | Drawings: 16-10-001 and 105 |
| 2 | | Concentrator Storage | Bayline 1 | Steel Building - Large | 30.49 | 6.71 | 9.15 | | Steel | 0.03 | | | | | On-site | 213.7 | 0.0 | 213.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 305 | Drawing 34-14-004 |
| 3 | | Tailings filter building | Prefab Bldg. Shell | Steel Building - Large | 36.5854 | 20 | 15.24 | | Steel | 0.03 | | | | | On-site | 593.3 | 0.0 | 593.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 848 | Drawings 35-10-106 and 35-10-104 |
| 4 | | Mill Building | Phase 2 shell | Steel Building - Large | 24.3902 | 14.4817 | 13.72 | | Steel | 0.03 | 5 | 0.0055914 | 10 | 0.0223656 | On-site | 342.9 | 29.2 | 372.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 531 | Drawings: 16-10-001 and 105 |
| 5 | | Mill Warehouse | Shell | Steel Building - Large | 30.4878 | 24.3902 | 7.32 | | Steel | 0.03 | | | | | On-site | 373.5 | 0.0 | 373.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 534 | |
| 6 | | Assay Lab | Entire building | Wooden Building - Small | 17 | 10 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 510.0 | 168.3 | 0.0 | 0.0 | 168 | |
| 7 | | Mechanics Shop | Shell | Steel Building - Small | 14 | 20 | 5.00 | | Steel | 0.03 | | | | | On-site | 149.7 | 0.0 | 149.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 214 | AutoCAD/Photos |
| 8 | | Electricians shop | Entire building | Wooden Building - Small | 15 | 10 | 3.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 450.0 | 148.5 | 0.0 | 0.0 | 149 | AutoCAD/Photos |
| **SUBTOTAL - Mill Area Complex** | | | | | | | | | | | | | | | | | | **2660** | | **0** | **960** | | **0** | **0** | **4116** | |
| **Mill Valley Fill Laydown** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Reagent Storage Area | | Tent | Wooden Building - Small | 25.00 | 18.00 | 4.00 | | Wood/Mixed | 0.01 | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1800.0 | 594.0 | 0.0 | 0.0 | 594 | height negatively adjusted to reduce demo vol. |
| **SUBTOTAL - Mill Valley Fill Laydown** | | | | | | | | | | | | | | | | | | **0** | | **0** | **1800** | | **0** | **0** | **594** | |
| **Pelly Laydown** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Pelly Laydown | Pelly office | 3 modular trailers | Modular Buildings - Dismantle/Prep | | | | 3 | | | | | | | Off-site | | | | | | | | 3.0 | | | AutoCAD/Photos |
| 2 | | Pelly workshop | Wooden building | Wooden Building - Large | 12.00 | 21.00 | 6.00 | | Wood/Mixed Debris | | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1512.0 | 499.0 | 0.0 | 0.0 | 499 | AutoCAD/Photos |
| 3 | | | prefab building shell | Steel Building - Small | 15.00 | 30.00 | 6.00 | | Steel | 0.01 | | | | | On-site | 79.7 | 0.0 | 79.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 114 | AutoCAD/Photos |
| 4 | | Pelly warehouse | Weatherhaven | Wooden Building - Small | 40.00 | 25.00 | 4.00 | | Wood/Mixed | 0.03 | | | | | On-site | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4000.0 | 1320.0 | 0.0 | 0.0 | 1320 | AutoCAD/Photos |
| 5 | W15 Sump Area | W15 Laydown | 4 propane tanks | Modular Buildings - Dismantle/Prep | | | | 4 | | | | | | | Off-site | | | | | | | | 4.0 | | | AutoCAD/Photos |
| **SUBTOTAL - Pelly Laydown** | | | | | | | | | | | | | | | | | | **80** | | **0** | **5512** | | **7** | **0** | **1933** | |
| **Water Treatment Plant** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Plant | | Prefab Bldg. Shell | Steel Building - Large | 46.04 | 18.29 | 9.15 | | Steel | 0.01 | | | | | Off-site | 162.5 | 0.0 | 162.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.4 | 0 | |
| **SUBTOTAL - Water Treatment Plant** | | | | | | | | | | | | | | | | | | **163** | | **0** | **0** | | **0** | **3** | **0** | |

**Notes:**
1. Internal steel structure/demo debris accounted for in part C
2. Steel wall thickness adjusted to account for airspace, insulation, HVAC debris, etc.
3. Wall areas includes the roof
4. Building debris volume for wooden structures based on FEMA "Debris Estimating Field Guide" FEMA publication No. 329.

## B: Concrete Foundations

| | | | | Disposal | Exterior Building | | Foundation Dimensions | | | | | Calculations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Area | Sub Area | Sub-component/ Building/ Section | Disposal Location | Length (m) | Width (m) | Slab Thickness (m) | Wall Thickness (m) | Wall Height (m) | Requires washing/de contaminati on? | In-place Concrete Vol. User Override (m3) | In-Place Concrete Volume (m3) | Concrete Debris Volume (m3) | Total Mass (tonnes) | Washing Area (m2) | On-site Demolition Debris Volume (LCM) | Comments/Notes |
| **Camp Area** | | | | | | | | | | | | | | | | | |
| 1 | Offices | Safety Building | Concrete foundation | Bury-in-place | 17 | 18 | 0.15 | 0.25 | 0.3 | No | | 51.2 | 86.1 | 122.8 | 0.0 | 0.0 | |
| **SUBTOTAL - Camp Area** | | | | | | | | | | | | **51** | **86** | **123** | **0** | **0** | |
| **Mill Area Complex** | | | | | | | | | | | | | | | | | |
| 1 | Mill Complex | Crusher and Ore Storage | Concrete - Ore Dump | Bury-in-place | 12 | 6 | 0.3 | 0.305 | 1 | No | | 32.6 | 54.9 | 78.2 | 0.0 | 0.0 | |
| 2 | | Mill Building | phase 1 portion | Bury-in-place | 59.7561 | 21.3415 | 0.203 | 0.254 | 0.3 | Yes | | 271.6 | 457.4 | 651.8 | 1275.3 | 0.0 | Dwg. 16-10-022 and 16--10-001 |
| 3 | | Mill Building | Phase 2 portion | Bury-in-place | 24.3902 | 14.4817 | 0.203 | 0.254 | 0.3 | Yes | | 77.6 | 130.7 | 186.3 | 353.2 | 0.0 | Dwg. 16-10-022 and 16--10-001 |
| 4 | | Mill Building | Compressor/generator area | Bury-in-place | 12.1951 | 10.061 | 0.203 | 0.254 | 0.3 | Yes | | 28.3 | 47.7 | 67.9 | 122.7 | 0.0 | Dwg. 16-10-022 and 16--10-001 |
| 5 | | Concentrate Storage | Concrete foundation | Bury-in-place | 73.7805 | 30.4878 | 0.3 | 0.45 | 2.21037 | Yes | | 882.2 | 1485.9 | 2117.4 | 2249.4 | 0.0 | Dwg. 34-15-001 |
| 6 | | Tailings Filter Building | Concrete foundation | Bury-in-place | 36.5854 | 20 | 0.3 | 0.305 | 0.3 | Yes | | 229.9 | 387.1 | 551.7 | 731.7 | 0.0 | Dwg 35-10-022 and 35-10-101 |
| 7 | | Mill Warehouse | Concrete foundation | Bury-in-place | 30.4878 | 24.3902 | 0 | 0.305 | 0.3 | No | | 10.0 | 16.9 | 24.1 | 0.0 | 0.0 | Dwg. 131-20020-00-C-2001 and 2002 |
| **SUBTOTAL - Mill Area Complex** | | | | | | | | | | | | **1532** | **2581** | **3677** | **4732** | **0** | |
| **Mill Valley Fill Laydown** | | | | | | | | | | | | | | | | | |
| 1 | Reagent storage area | Strip footings | | Bury-in-place | 25 | 18 | 0 | 0.3 | 0.3 | No | | 7.7 | 13.0 | 18.6 | 0.0 | 0.0 | AutoCAD/Photos |
| **SUBTOTAL - Mill Valley Fill Laydown** | | | | | | | | | | | | **8** | **13** | **19** | **0** | **0** | |
| **Pelly Laydown** | | | | | | | | | | | | | | | | | |
| 1 | Pelly Laydown | Washpad | | Bury-in-place | 15 | 5 | 0.3 | 0 | 0 | No | | 22.5 | 37.9 | 54.0 | 0.0 | 0.0 | Photos |
| **SUBTOTAL - Pelly Laydown** | | | | | | | | | | | | **23** | **38** | **54** | **0** | **0** | |
| **Water Treatment Plant** | | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Plant | No foundation present | | | | | | | | | | | | | | | |
| **SUBTOTAL - Water Treatment Plant** | | | | | | | | | | | | **0** | **0** | **0** | **0** | **0** | |

**Notes:**
1. Regrading of the areas are included in the elsewhere in the estimate.

## C: Other Demolition

| | | | | Dimensions | | | | | | | | | Disposal | Demolition Quantities (Manual Calcs) | | | | Transport | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Area | Sub Area | Sub-component/ Building/ Section | Material | Quantity | Length (m) | Width (m) | Area ($m^2$) | Height/ Thickness (m) | Diameter (m) | Volume ($m^3$) | Air Factor | Disposal Location | Steel (tonnes) | Concrete In-place volume (m3) | Concrete Debris Volume (LCM) | Misc. Demolition Volume (m3) | Total Mass (tonnes) | Off-site Demolition Debris Trips | On-site Demolition Debris Volume (LCM) | Comments/Notes |
| **Airstrip Area** | | | | | | | | | | | | | | | | | | | | | |
| 1 | Airstrip area | Exploration camp | misc. debris | Wood/Mixed Debris | | | | | | | 50 | 1 | On-site | | | | 50.0 | 35.0 | 0.0 | 50.0 | Allowance based on photos |
| 2 | | Waste Storage Areas | misc. debris | Wood/Mixed Debris | | | | | | | 100 | 1 | On-site | | | | 100.0 | 70.0 | 0.0 | 100.0 | Allowance based on photos |
| 3 | | | Special waste pole barn | Wood/Mixed Debris | | 55 | 5 | | 2.5 | | 687.5 | 0.33 | On-site | | | | 226.9 | 158.8 | 0.0 | 226.9 | |
| 4 | | | | Wood/Mixed Debris | | 32 | 2 | | 2.5 | | 160 | 0.33 | On-site | | | | 52.8 | 37.0 | 0.0 | 52.8 | |
| 5 | | Storage East of strip | misc. debris | Wood/Mixed Debris | | | | | | | 100 | 1 | On-site | | | | 100.0 | 70.0 | 0.0 | 100.0 | Allowance based on photos |
| **SUBTOTAL - Airstrip Area** | | | | | | | | | | | | | | **0** | **0** | **0** | **530** | **371** | **0** | **530** | |
| **Camp Area** | | | | | | | | | | | | | | | | | | | | | |
| 1 | Camp area | Utilidors | Mill to Camp | Wood/Mixed Debris | | 229 | 1 | | 1 | | 229 | 0.5 | On-site | | | | 114.5 | 80.2 | 0.0 | 114.5 | |
| 2 | | | East side of camp | Wood/Mixed Debris | | 181 | 1 | | 1 | | 181 | 0.5 | On-site | | | | 90.5 | 63.4 | 0.0 | 90.5 | |
| 3 | | Covered walkways | Camp to Selkirk towers | Wood/Mixed Debris | | 55 | 2 | | 2.5 | | 275 | 0.33 | On-site | | | | 90.8 | 63.5 | 0.0 | 90.8 | |
| 4 | | | Misc. walkway/corridor allowa | Wood/Mixed Debris | | 100 | 2 | | 2.5 | | 500 | 0.33 | On-site | | | | 165.0 | 115.5 | 0.0 | 165.0 | |
| 5 | | Smokers area | Building | Wood/Mixed Debris | | 2.5 | 2.5 | | 2.5 | | 15.625 | 0.33 | On-site | | | | 5.2 | 3.6 | 0.0 | 5.2 | |
| **SUBTOTAL - Camp Area** | | | | | | | | | | | | | | **0** | **0** | **0** | **466** | **326** | **0** | **466** | |
| **Fuel Farm Area** | | | | | | | | | | | | | | | | | | | | | |
| 1 | Fuel Farm Area | Generators | Generator wooden support st | Wood/Mixed Debris | 8 | 6 | 3 | | 1 | | 18 | 0.33 | On-site | | | | 5.9 | 10.0 | 0.0 | 14.3 | AutoCAD/Photos |
| | | | Misc. piping/electrical conduit | Wood/Mixed Debris | | | | | | | | | On-site | | | | 15.0 | 25.3 | 0.0 | 36.1 | Allowance |
| **SUBTOTAL - Fuel Farm Area** | | | | | | | | | | | | | | **0** | **0** | **0** | **21** | **35** | **0** | **50** | |
| **Mill Area Complex** | | | | | | | | | | | | | | | | | | | | | |
| 1 | Crushing & Ore Storage Re | Reclaim Tunnel | Feeder floor, stairs, ladders | Steel | | | | | | | | | On-site | 7 | | | | 6.8 | 0.0 | 9.7 | Source Hatch: FS (2006) |
| 2 | | | Grating feeder floor | Steel | 1 | | | 42 | 0.01 | | | | On-site | 3 | | | | 3.4 | 0.0 | 4.8 | Source Hatch: FS (2006) |
| 3 | | | Mechanical (liners, conveyor | Steel | | | | | | | | | On-site | 28 | | | | 28.2 | 0.0 | 40.3 | Source Hatch: FS (2006) |
| 4 | | Ore Dump | Concrete components | Concrete | 1 | | | | | | 44.5 | | Bury-in-place | | 44.5 | 75 | | 0.0 | 0.0 | 0.0 | Source Hatch: FS (2006) |
| 5 | | Reclaim area | Concrete components | Concrete | 1 | | | | | | 329 | | Bury-in-place | | 329.0 | 554 | | 0.0 | 0.0 | 0.0 | Source Hatch: FS (2006) |
| 6 | Mill Area | Mill Building | Process building elevated sla | Concrete | | | | | | | | | Bury-in-place | | 96.9 | 163 | | 0.0 | 0.0 | 0.0 | Source Hatch: FS (2006) |
| 7 | | | Structural steel platforms | Steel | | | | | | | | | On-site | 108 | | | | 108.0 | 0.0 | 154.3 | Source Hatch: FS (2006) |
| 8 | | | Grating | Steel | | | | 527.9 | 0.01 | | | | On-site | 42 | | | | 42.5 | 0.0 | 60.7 | Source Hatch: FS (2006) |
| 9 | | | Q-deck | Steel | | | | 690.3 | 0.001 | | | | On-site | 6 | | | | 5.6 | 0.0 | 7.9 | Source Hatch: FS (2006) |
| 10 | | | Partition walls | Wood/Mixed Debris | | | | 130 | 0.15 | | | 0.5 | On-site | | | | 9.8 | 16.4 | 0.0 | 23.5 | Source Hatch: FS (2006) |
| 11 | | | Concrete separation walls | Concrete | | | | 408 | 0.15 | | | 1.3 | On-site | | 61.2 | 79.6 | | 113.4 | 0.0 | 162.0 | Source Hatch: FS (2006) |
| 12 | | Concentrate storage area | Coverall structure | Wood/Mixed Debris | | | | 2044 | 0.005 | | 10.21925 | 10 | On-site | | | | 102.2 | 172.1 | 0.0 | 245.9 | Source Hatch: FS (2006) |
| 13 | | | Metal trusses | Steel | 12 | 39.6341 | | | | 0.3 | 33.6 | 2 | On-site | | | | 67.2 | 113.2 | 0.0 | 161.8 | Estimated based on dwg and photo |
| 14 | | Grinding circuit | Misc. grinding ancillary equip | Steel | 1 | | | | | | | | On-site | 0.7 | | | | 0.7 | 0.0 | 1.0 | Source Hatch: FS (2006) |
| 15 | | | Process water tank | Steel | 1 | | | | | | | | On-site | 14.0 | | | | 14.0 | 0.0 | 20.0 | Source Hatch: FS (2006) |
| 16 | | | Fresh water tank | Steel | 1 | | | | | | | | On-site | 4.0 | | | | 4.0 | 0.0 | 5.7 | Source Hatch: FS (2006) |
| 17 | | Flotation circuit | Misc. mechanical equip. stee | Steel | | | | | | | | | On-site | 3.0 | | | | 3.0 | 0.0 | 4.3 | Source Hatch: FS (2006) (mostly pump frames |
| 18 | | Concentrate dewatering | Concentrate Thickener | Steel | 1 | | | 70.08312 | 2.13414634 | 6.097561 | 2.102494 | | On-site | 16.9 | | | | 16.9 | 0.0 | 24.2 | Source Hatch: FS (2006) |
| 19 | | | Misc. mechanical equip. stee | Steel | | | | | | | | | On-site | 5.2 | | | | 5.2 | 0.0 | 7.4 | Source Hatch: FS (2006) |
| 20 | | Tailings Filter building | Concrete components | Concrete | 1 | | | | | | 313 | | Bury-in-place | | 44.5 | 75 | | 0.0 | 0.0 | 0.0 | Source Hatch: FS (2006) |
| 21 | | | Filter support steel and platfo | Steel | | | | | | | | | On-site | 102.0 | | | | 102.0 | 0.0 | 145.7 | Source Hatch: FS (2006) |
| 22 | | | Q-deck | Steel | | | | 28 | 0.01 | | | | On-site | 2 | | | | 2.3 | 0.0 | 3.2 | Source Hatch: FS (2006) |
| 23 | | | Concrete separation walls | Concrete | | | | 112 | 0.15 | | | 1.3 | On-site | | 16.8 | 21.8 | | 31.1 | 0.0 | 44.5 | Source Hatch: FS (2006) |
| 24 | | | Architectural walls | Wood/Mixed Debris | | | | 100 | 0.1 | | | 0.5 | On-site | | | | 5.0 | 8.4 | 0.0 | 12.0 | Source Hatch: FS (2006) |
| 25 | | | Tanks & misc. mechanical eq | Steel | | | | | | | | | On-site | 36 | | | | 36.1 | 0.0 | 51.5 | Source Hatch: FS (2006) |
| 26 | | | Thickener | Steel | | | | 205.8692 | 4.88 | 9.15 | 6.176075 | | On-site | 49.7 | | | | 49.7 | 0.0 | 71.0 | |
| 27 | | Reagents | Tanks & misc. mechanical eq | Steel | | | | | | | | | On-site | 1 | | | | 1.5 | 0.0 | 2.1 | Source Hatch: FS (2006) |
| 28 | | Mill building - phase 2 | Interior retaining wall | Concrete | | | | | | | | | Bury-in-place | | 8.8 | 15 | | 0.0 | 0.0 | 0.0 | Source Hatch: FS (2006) |
| 29 | | | Structural steel platforms | Steel | | | | | | | | | On-site | 37.1 | | | | 37.1 | 0.0 | 53.0 | Source Hatch: FS (2006) |
| 30 | | | Grating | Steel | | | | 696.8 | 0.01 | | | | On-site | 56 | | | | 56.1 | 0.0 | 80.1 | Source Hatch: FS (2006) |
| 31 | | | Misc. mechanical equip. stee | Steel | | | | | | | | | On-site | 1 | | | | 1.0 | 0.0 | 1.4 | Source Hatch: FS (2006) |
| 32 | | | Misc. mechanical equip. stee | Steel | | | | | | | | | On-site | 2 | | | | 2.4 | 0.0 | 3.4 | Source Hatch: FS (2006) |
| 33 | | Electricians shop | Entire building | Wood/Mixed Debris | 1 | 12 | 10 | | 1.5 | | 180 | 0.33 | On-site | | | | 59.4 | 100.0 | 0.0 | 142.9 | |
| **SUBTOTAL - Mill Area Complex** | | | | | | | | | | | | | | **526** | **602** | **983** | **244** | **1081** | **0** | **1544** | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Minto South Portal** | | | | | | | | | | | | | | | | | | | | |
| 1 | Minto South Portal | Pad A | Misc. small storage areas/co | Wood/Mixed Debris | 3 | 6 | 3 | | 2 | | 36 | 0.33 | On-site | | | | 35.6 | 24.9 | 0.0 | 35.6 | Allowance based on photos |
| 2 | | Pad B | Green tents | Wood/Mixed Debris | 2 | 18 | 12 | | 5 | | 1080 | 0.025 | On-site | | | | 54.0 | 37.8 | 0.0 | 54.0 | AutoCAD/Photos |
| 3 | | | Culverts/Debris | Wood/Mixed Debris | 1 | 10 | 16 | | 1.5 | | 240 | 0.33 | On-site | | | | 79.2 | 55.4 | 0.0 | 79.2 | Allowance based on photos |
| 4 | | Pad C | Culverts/Debris | Wood/Mixed Debris | 1 | 37 | 12 | | 2 | | 888 | 0.33 | On-site | | | | 293.0 | 205.1 | 0.0 | 293.0 | Allowance based on photos |
| | | | | | | | | | | | | | | | | | | | | | |
| **SUBTOTAL - Pelly Laydown** | | | | | | | | | | | | | | **0** | **0** | **0** | **462** | **323** | **0** | **462** | |
| **Pelly Laydown** | | | | | | | | | | | | | | | | | | | | | |
| 1 | Pelly Laydown | Misc. small storage areas/covers | | Wood/Mixed Debris | 1 | 27 | 12 | | 1.5 | | 486 | 0.33 | On-site | | | | 160.4 | 112.3 | 0.0 | 160.4 | Est. Allowance based on photos/AutoCAD |
| | | | | | | | | | | | | | | | | | | | | | |
| **SUBTOTAL - Pelly Laydown** | | | | | | | | | | | | | | **0** | **0** | **0** | **160** | **112** | **0** | **160** | |
| **Water Treatment Plant** | | | | | | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Plant | | Misc. wooden walkways etc. | Wood/Mixed Debris | 1 | | | | | | | | | | | | 15.0 | 10.5 | | | Estimated based on site photos. |
| **SUBTOTAL - Water Treatment Plant** | | | | | | | | | | | | | | **0** | **0** | **0** | **15** | **11** | **0** | **0** | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |

**Notes:**
1. Where noted, demolition quantities were taken directly from the Hatch 2006 feasibility study.

## D: Equipment and Material Removal

| | | | | Dimensions/Measurements | | | | | | | | | Disassembly/Disposal Details | | | | | Calculated Quantities | | | Transport | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Area | Sub Area | Sub-component/ Building/ Section | Quantity | Length (m) | Width (m) | Height (m) | Diameter (m) | Volume (m3) | Surface Area (m2) | Volume (m3) | Mass of Item (tonnes) | Disposal Location | Requires washing/de contaminati on? | Crew Size | OVERRIDE - Time to dismantle (hrs) | OVERRIDE - Off-site number of trips | Small Disassembly Crew Time (hrs) | Large Disassembl y Crew Time (hrs) | Decontamination Time (hrs) | Off-site Removal Trips | On-site Demolition Debris Volume (LCM) | Comments/Notes |
| **Airport Laydown** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Airport Laydown | Tires | | | 30 | 3 | 2 | | | | 180.00 | 90.0 | Off-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 1.9 | 0.0 | |
| | | Seacans | | 1 | 16.0 | | | | | | | | Off-site | No | Small | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | Assumed to be filled other materials and removed. |
| | | Propane tank | | 1 | | | | | | | | | Off-site | No | Small | 2 | 1.00 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | |
| | | Misc. equipment | | 1 | | | | | | | | 50.0 | On-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 0.0 | 71.4 | Allowance based on photos |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Airport Laydown** | | | | | | | | | | | | | | | | | | **2** | **0** | **0** | **3** | **71** | |
| **Airstrip Area** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Airstrip area | Meteorological station | | 1 | | | | | | | | 0.3 | Off-site | No | Small | 3 | | 3.0 | 0.0 | 0.0 | 0.01 | 0.0 | |
| | | Land treatment facility | Waste Oil tanker | 1 | | | | | | | | 40.0 | Off-site | Yes | Small | 2 | 1 | 2.0 | 0.0 | 2.9 | 1.0 | 0.0 | Mass of item bumped up to increase the decont. Time |
| | | Incinerators | Primary incinerator | 1 | | | | | | | | 1.0 | Off-site | No | Small | 1 | | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | mass assumed |
| | | | Secondary incinerator | 1 | | | | | | | | 1.0 | Off-site | No | Small | 1 | | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | mass assumed |
| | | Special waste pole barn | Poles | 1 | 30 | 5 | 1.5 | | 225 | | | 157.5 | Off-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 | Dimensions/mass assumed based on aerial photos/size of facility |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Airstrip Area** | | | | | | | | | | | | | | | | | | **7** | **0** | **3** | **4** | **0** | |
| **Camp Area** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Camp Area | Offices | Safety equipment | 1 | | | | | | | | | Off-site | No | Small | 8 | 0.25 | 8.0 | 0.0 | 0.0 | 0.3 | 0.0 | |
| | | | Computer/office equipment | 1 | | | | | | | | | Off-site | No | Small | 16 | 0.25 | 16.0 | 0.0 | 0.0 | 0.3 | 0.0 | |
| | | | communication equip. | 1 | | | | | | | | | Off-site | No | Small | 16 | 0.25 | 16.0 | 0.0 | 0.0 | 0.3 | 0.0 | |
| | | Camp | kitchen equipment/freezers, e | 1 | | | | | | | | | Off-site | No | Small | 8 | 0.25 | 8.0 | 0.0 | 0.0 | 0.3 | 0.0 | |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Camp Area** | | | | | | | | | | | | | | | | | | **48** | **0** | **0** | **1** | **0** | |
| **Explosives Plant and Storage Areas** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Explosives Plant/Fueling ar | Dyno compound | Fuel tank | 1 | | | | | | | | | Off-site | No | Small | 2 | 1 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | Photos |
| 2 | | | Misc. tanks/debris etc. | | | | | | | | | 25.0 | On-site | No | Small | | | 33.3 | 0.0 | 0.0 | 0.0 | 35.7 | Allowance based on photos |
| 3 | | | Vertical tank | 1 | | | | | | | | | Off-site | No | Small | 2 | 1 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | Photos |
| 4 | | | Explosive Storage | 3 | 12 | 4 | 2 | | 96 | | | | Off-site | No | Small | 0 | 3 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Explosives Plant and Storage Areas** | | | | | | | | | | | | | | | | | | **37** | **0** | **0.0** | **5** | **36** | |
| **Fuel Farm Area** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Fuel Farm Area | Generators | Generators | 8 | 5 | 3 | 2.5 | | 37.5 | | | | Off-site | No | Small | 16 | 2 | 16.0 | 0.0 | 0.0 | 2.0 | 0.0 | |
| 2 | | Fueling Area | Northern Steel fuel tanks | 4 | | | | | | | | | Off-site | No | Small | 4 | 4 | 4.0 | 0.0 | 0.0 | 4.0 | 0.0 | |
| 3 | | | Misc. fuel lines/power/piping | | | | | | | | | 2.0 | On-site | Yes | Small | 4 | | 4.0 | 0.0 | 0.1 | 0.0 | 2.9 | Allowance/photos |
| 4 | | | Diesel tank in NE corner of fa | 1 | | | 6 | 3.5 | | | | | Off-site | No | Large | 4 | 1.00 | 0.0 | 4.0 | 0.0 | 1.0 | 0.0 | |
| 5 | | | Large tanks | 2 | | | 12.00 | 14.5 | | 876.89705 | 9 | 141.2 | On-site | Yes | Large | | | 0.0 | 188.2 | 10.1 | 0.0 | 201.7 | |
| **SUBTOTAL - Fuel Farm Area** | | | | | | | | | | | | | | | | | | **24** | **192** | **10.3** | **7** | **205** | |
| **Mill Area Complex** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Crushing & Ore Storage Re | Mobile Crusher/Feeder | | 1 | | | | | | | | | Off-site | Yes | Small | 10 | 1 | 10.0 | 0.0 | 1.0 | 1.0 | 0.0 | Assume 1 day to prep for transport |
| 2 | | Reclaim apron feeder | | | 7.3 | 0.91 | 2.44 | | | | | | Off-site | Yes | Small | 2 | 1 | 2.0 | 0.0 | 1.0 | 1.0 | 0.0 | Dimensions form dwg. 1216002-R1 |
| 3 | | Slewing-Stockpile feed conv | Conveyor 36"x107 feet 40 h | 1 | 51.8 | 1.0 | 4.39 | | 227 | | | | Off-site | Yes | Large | 30 | 4.2 | 0.0 | 30.0 | 1.0 | 4.2 | 0.0 | Dimensions form dwg. 1216001-R1 |
| 4 | | SAG Mill Feed | Weightometer | 1 | 3 | 1 | 0.6 | | 2 | | | | Off-site | Yes | Small | 2 | 0.19 | 2.0 | 0.0 | 1.0 | 0.2 | 0.0 | Dimensions assumed |
| 5 | | SAG Mill Feed | Conveyor, 36" x 130 feet | 1 | 39.6 | 1.0 | 4.39 | | 174 | | | | Off-site | Yes | Large | 30 | 3.5 | 0.0 | 30.0 | 1.0 | 3.5 | 0.0 | Dimensions form Hatch 2006 |
| 6 | Mill Building - Phase 1 | Mechanical | Small pumps (fire water) | 3 | | | | | | | | | Off-site | Yes | Small | 1 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.0 | Hatch (2006) |
| 7 | | Mechanical | Fire water tank | | | | | | | | | 14.0 | On-site | No | Small | | | 18.7 | 0.0 | 0.0 | 0.0 | 20.0 | Hatch (2006) |
| 8 | | Mechanical | O/H Crane | 1 | | | | | | | | | Off-site | Yes | Large | 1 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | Hatch (2006) |
| 9 | | Mechanical | Dust collector (20HP) | 1 | | | | | | | | | Off-site | Yes | Small | 1 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.0 | Hatch (2006) |
| 10 | Grinding Circuit - Phase 1 | SAG Mill | Sag Mill | 1 | | | | 5.030488 | | | | 50.0 | Off-site | Yes | Large | | 3.0 | 0.0 | 66.7 | 3.6 | 3.0 | 0.0 | Scaled from previous project based on diameter |
| 11 | | Ball Mill Phase 1 | 10.5' x 12' | 1 | 3.2 | 3.7 | | | | | | 60.0 | Off-site | Yes | Large | | 2.0 | 0.0 | 80.0 | 4.3 | 2.0 | 0.0 | Scaled from previous project based on diameter |
| 12 | | Grinding ancillary equip. | Pump box | 1 | | | | | | | | 2.0 | Off-site | Yes | Small | | | 2.7 | 0.0 | 0.1 | 0.0 | 0.0 | |
| 13 | | | Rubber lining - 6.5'x6.5'x10' | 1 | | | | | | 27 | | 0.2 | On-site | Yes | Small | | | 0.3 | 0.0 | 0.0 | 0.0 | 0.3 | |
| 14 | | | Discharge chutes | 2 | | | | | | | | 2.6 | On-site | Yes | Small | | | 3.5 | 0.0 | 0.2 | 0.0 | 3.7 | |
| 15 | | | Cyclo-pac 3x15" dia. | 1 | 3.0 | 4.6 | 3.05 | | 42.51 | | | 8.6 | Off-site | Yes | Large | | | 0.0 | 11.4 | 0.6 | 0.2 | 0.0 | pick-up truck factor applied' |
| 16 | | | Cyclone feed pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 17 | | | Sump pump #1 | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 18 | | | Pump 8"x6' process water pu | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 19 | | | Pump 1" x 1.5" fresh water pu | 2 | | | | | | | | 2.0 | Off-site | No | Small | 2 | | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 20 | Flotation Circuit - Phase 1 | Flotation mechanical equip. | Reclaim/conc feed pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 21 | | | Flotation Area 1 sump pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 22 | | | Floatation cells 15m3 | 5 | | | 3.00 | 2.523133 | 15.00 | 23.779971 | 0 | 9.6 | On-site | Yes | Large | | | 0.0 | 12.8 | 0.7 | 0.0 | 13.7 | Assumed dimensions and steel thickness |
| 23 | | | Flotation cells (2.8m3) | 6 | | | 2.00 | 1.335118 | 2.80 | 8.3887937 | 0 | 4.1 | On-site | Yes | Small | | | 5.4 | 0.0 | 0.3 | 0.0 | 5.8 | |
| 24 | | | Rougher concentrate pump 1 | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 25 | | | Concentrate thickener feed p | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 26 | | | Flotation blowers | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 27 | | | Hoist | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 28 | Concentrate Dewatering | Mechanical equip. | Filter, 30m2 40 hp | 1 | 4.6 | 3.7 | 4.57 | | | | 77 | 15.4 | Off-site | Yes | Large | 16 | | 0.0 | 16.0 | 1.1 | 0.3 | 0.0 | pick-up truck factor applied' |
| 29 | | | Concentrate discharge conve | 1 | 50.0 | 0.6 | 2.44 | | | | | | Off-site | Yes | Large | 16 | 2.1 | 0.0 | 16.0 | 1.0 | 2.1 | 0.0 | |
| 30 | | | Concentrate thickener OF pu | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 31 | | | Concentrate filter feed pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 32 | | | Sump pump, 2" vert 5HP | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 33 | | | Truck scale | 1 | | | | | | | | | Off-site | Yes | Large | 4 | 1.0 | 0.0 | 4.0 | 1.0 | 1.0 | 0.0 | |
| 34 | Tailings Filter Building | Mechanical equip. | Tailings pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 35 | | | Process water tank feed pum | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 36 | | | Tailings U/F Pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 37 | | | Belt filter feed pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 38 | | | Belt filter | 2 | 11.0 | 3.0 | 6.10 | | | | | | Off-site | Yes | Large | 16 | 2.0 | 0.0 | 16.0 | 1.0 | 2.0 | 0.0 | |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | | | Concentrate discharge conve | 1 | 50.0 | 1.0 | 2.44 | | | | | | Off-site | Yes | Large | 16 | 2.1 | 0.0 | 16.0 | 1.0 | 2.1 | 0.0 | |
| 40 | | | Concentrate stockpile feed co | 1 | 50.0 | 1.0 | 2.44 | | | | | | Off-site | Yes | Large | 16 | 2.1 | 0.0 | 16.0 | 1.0 | 2.1 | 0.0 | |
| 41 | | | Haul truck freed conveyor | 1 | 92.3 | 1.0 | 2.44 | | | | | | Off-site | Yes | Large | 16 | 3.4 | 0.0 | 16.0 | 1.0 | 3.4 | 0.0 | |
| 42 | | | Fresh water pumps | 2 | | | | | | | | 2.0 | Off-site | No | Small | 2 | | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 43 | | | Wash water pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 44 | | | Vacuum pump #1 | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 45 | | | Tailings filtrate pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 46 | | | Filter area sump pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 47 | | | Tailings area sump pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 48 | | | Belt filter compressors | 2 | 3.0 | 3.0 | 2.44 | | 22.67 | | | 9.1 | Off-site | Yes | Large | | | 0.0 | 12.2 | 0.7 | 0.2 | 0.0 | |
| 49 | | | Tailings Area Boiler | 1 | 4.6 | 1.5 | 1.22 | | 8.50 | | | 1.7 | Off-site | Yes | Small | | | 2.3 | 0.0 | 0.1 | 0.0 | 0.0 | |
| 50 | | | Boiler feed pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 51 | | | Boiler blower | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 52 | | | Boiler fuel pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 53 | | | Water collection pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 54 | Reagents | Mechanical equip. | Metering pumps | 11 | | | | | | | | 11.0 | Off-site | Yes | Small | 11 | | 11.0 | 0.0 | 0.8 | 0.2 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 55 | | | Pax transfer pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 56 | | | Thickener flocculent unit | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 57 | Mill Services | Mechanical equip. | Reclaim water pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 58 | | | Mill water Pump | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 59 | | | Mill water Booster Pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 60 | | | Plant air compressors | 2 | 1.8 | 0.9 | 0.91 | | 1.53 | | | 2.0 | Off-site | Yes | Small | 2 | 0.1 | 2.0 | 0.0 | 0.1 | 0.1 | 0.0 | |
| 61 | First fills | Grinding balls | Ball Mill and SAG Mill | | | | | | | | | 184.5 | On-site | No | Small | | | 246.0 | 0.0 | 0.0 | 0.0 | 263.6 | |
| 62 | Mill Building - Phase 2 | Mechanical equip. | O/H Crane Ball Mill area | | 22.9 | | | | | 0.0055914 | | 1.5 | Off-site | Yes | Large | | | 0.0 | 2.0 | 0.1 | 0.0 | 0.0 | Assumed I-beam dimensions for crane rail, plus 0.5 tonnes for crane |
| 63 | Grinding Circuit - Phase 2 | Mechanical Grinding | Grinding area sump pump#2 | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 64 | | | Cyclo-pac 2x26' dia. | 1 | 3.0 | 4.6 | 3.05 | | 42.51 | | | 8.6 | Off-site | Yes | Large | | | 0.0 | 11.4 | 0.6 | 0.2 | 0.0 | pick-up truck factor applied' |
| 65 | | Grinding ancillary equip. | No. 2 floatation feed sampler | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 66 | | | Pump box | 1 | | | | | | | | 2.0 | Off-site | Yes | Small | | | 2.7 | 0.0 | 0.1 | 0.0 | 0.0 | |
| 67 | | | SAG discharge pump | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 68 | | | VFD cyclone feed pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 69 | Flotation Circuit - Phase 2 | Mechanical equip. | Floatation feed pumps | 2 | | | | | | | | 2.0 | Off-site | Yes | Small | 2 | | 2.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 70 | | | Floatation cells 15m3 | 5 | | | 3.00 | 2.523133 | 15.00 | 23.779971 | 0 | 9.6 | On-site | Yes | Large | | | 0.0 | 12.8 | 0.7 | 0.0 | 13.7 | Assumed dimensions and steel thickness |
| 71 | | | Pump box | 1 | | | | | | | | 2.0 | Off-site | Yes | Small | | | 2.7 | 0.0 | 0.1 | 0.0 | 0.0 | |
| 72 | | | Sump pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 73 | | | Recleaner tails pump | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 74 | | | Rougher concentrate pump 2 | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 75 | | | Floatation cells 100 cu. Ft | 4 | | | 2.00 | 1.335118 | 2.80 | 8.3887937 | 0 | 2.7 | On-site | Yes | Small | | | 3.6 | 0.0 | 0.2 | 0.0 | 3.9 | |
| 76 | Tailings Deposal - phase 2 | Mechanical equip. | Belt filter #3 (90m2 x 3m) | 1 | 18.3 | 3.0 | 6.10 | | 334.62 | | | 67.3 | Off-site | Yes | Large | | 3.0 | 0.0 | 89.8 | 4.8 | 3.0 | 0.0 | dwg. 35-10-105; 'pick-up truck factor applied) |
| 77 | | | Fresh water pumps | 1 | | | | | | | | 1.0 | Off-site | No | Small | 1 | | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 78 | | | Wash water pumps | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 79 | | | Vacuum pump #3 | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 80 | | | Tailings filtrate pumps | 1 | | | | | | | | 1.0 | Off-site | Yes | Small | 1 | | 1.0 | 0.0 | 0.1 | 0.0 | 0.0 | assumed 1 hr for dismantling, 1 tonne each |
| 81 | | | Belt filter compressor | 1 | 3.0 | 3.0 | 2.44 | | 22.67 | | | 4.6 | Off-site | Yes | Large | | | 0.0 | 6.1 | 0.3 | 0.1 | 0.0 | pick-up truck factor applied' |
| **SUBTOTAL - Mill Area Complex** | | | | | | | | | | | | | | | | | | **379** | **466** | **38** | **33** | **325** | |
| **Mill Valley Fill Laydown** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | MVF Laydown Area | Grinding media | | | | | | | | | | | On-site | No | Small | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 2 | | Steel rack | misc. | | 76.0 | 2.00 | 1.00 | | 152 | | | 106.4 | On-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 0.0 | 152.0 | |
| 3 | | Tire racks | Tires | | 150.0 | 3.0 | 1.50 | | 675 | | | 472.5 | Off-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 9.8 | 0.0 | |
| 4 | | Site Services | | | 100 | 2 | 1 | | 200 | | | 140.0 | On-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 0.0 | 200.0 | |
| 5 | | Mill Elect | | | 40 | 2 | 2.5 | | 200 | | | 140.0 | On-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 0.0 | 200.0 | |
| 6 | | Misc. | | | 50 | 2 | 1 | | 100 | | | 70.0 | On-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Mill Valley Fill Laydown** | | | | | | | | | | | | | | | | | | **0** | **0** | **0** | **10** | **652** | |
| **Minto South Portal** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Minto South Portal | Pad A | Fuel tank | 1 | | | | | | | | | Off-site | No | Small | 2 | 1 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | |
| | | Pad C | Propane Fuel tanks | 2 | | | | | | | | | Off-site | No | Small | 4 | 2 | 4.0 | 0.0 | 0.0 | 2.0 | 0.0 | |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Minto South Portal** | | | | | | | | | | | | | | | | | | **6** | **0** | **0** | **3** | **0** | |
| **Pelly Laydown** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Pelly Laydown | Tires | | | 30 | 3 | 2 | | | | 180.00 | 90.0 | Off-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 1.9 | 0.0 | |
| | | Seacans/trailers | | 7 | 16.0 | | | | | | | | Off-site | No | Small | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | Assumed to be filled other materials and removed. |
| | | Misc. equipment | | 1 | | | | | | | | 50.0 | On-site | No | Small | 0 | | 0.0 | 0.0 | 0.0 | 0.0 | 71.4 | Allowance based on photos |
| | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| **SUBTOTAL - Pelly Laydown** | | | | | | | | | | | | | | | | | | **0** | **0** | **0** | **2** | **71** | |
| **Vent Raises - Area 118** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Area 118 | Air Heater | All components | 1 | | | | | | | | 44.6 | Off-site | No | Small | 20 | 1 | 20.0 | 0.0 | 0.0 | 1.0 | 0.0 | Dwg. 9057-MGD; Mass of equipment listed on drawings. |
| 2 | | | | | | | | | | | | | | | | | | | | | | | |
| **SUBTOTAL - Vent Raises - Area 118** | | | | | | | | | | | | | | | | | | **20** | **0** | **0** | **1** | **0** | |
| **Water Treatment Plant** | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Water Treatment Plant | WTP building | Actiflo clarifier | 1 | 6.85976 | 2.7439 | 3.04878 | | 57.39 | | | 11.5 | Off-site | No | Large | | 1 | 0.0 | 15.4 | 0.0 | 1.0 | 0.0 | Dwg. MIN-000-GA-01 and-02; pick-up truck factor applied |
| 2 | | | BQE skid #1 | 1 | 9.1 | 2.62 | 1.52 | | 36.56 | | | 1.5 | Off-site | No | Small | | 1 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | Dwg. MIN-000-GA-01 and-02 |
| 3 | | | BQE Skid #2 | 1 | 4.6 | 2.13 | 2.22 | | 22.05 | | | 1.5 | Off-site | No | Small | | 0.5 | 2.0 | 0.0 | 0.0 | 0.5 | 0.0 | Dwg. MIN-000-GA-01 and-02 |
| 4 | | | BQE Skid #3 | 1 | 5.9 | 3.57 | 2.44 | | 51.75 | | | 10.4 | Off-site | No | Large | | 1 | 0.0 | 13.9 | 0.0 | 1.0 | 0.0 | Dwg. MIN-000-GA-01 and-02 |
| 5 | | | BQE Skid #4 | 1 | 8.2 | 3.05 | 0.91 | | 22.95 | | | 1.0 | Off-site | No | Small | | 0.5 | 1.3 | 0.0 | 0.0 | 0.5 | 0.0 | Dwg. MIN-000-GA-01 and-02 |
| 6 | | | RO Skids | 2 | 7.8 | 1.83 | 1.50 | | 21.33 | | | 8.6 | Off-site | No | Small | | 0.5 | 11.4 | 0.0 | 0.0 | 0.5 | 0.0 | Dwg. MIN-000-GA-01 and-02 |
| **SUBTOTAL - Water Treatment Plant** | | | | | | | | | | | | | | | | | | **17** | **29** | **0** | **5** | **0** | |

**Notes:**
1. Assumes steel material
2. See disassembly crew details below
3. Time to dismantle includes time to prepare for transport
4. Where noted, demolition quantities were taken directly from the Hatch 2006 feasibility study.
5. HVAC equipment (fans, ducts, heater, etc.) assumed to be part of demo debris and considered as part of the wall thickness in Part A.
6. 'pick-p truck factor' = 20 m3 bulk volume ~ 4 tonnes

# Worksheet 24 - Mobilization-Demobilization Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## A: Equipment Mobilization - Year 0

**Equipment**

| | | Equipment Input | | | | Breakdown and Assembly Time (each) | | | Transport Time (each) | | | | | | Calculations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equip. Code | Equipment | Qnty | Shipping Weight (tonne) | Transport Vehicle 1 (axles) | Transport Vehicle #2 (axles) | Breakdown Time (hrs) | Assembly Time (hrs) | Mechanic Workforce Size | Shipping Origin | Shipping Distance (km) | Average Speed to Barge (km/hr) | Average Speed from Barge to Site (km/hr) | Loading and Off-Loading Time (hrs) | # of Pilot Vehicles required per equip. | Meals/Hotel Allowance ($) | Total Mechanic Hourly Rate ($/hr) | Breakdown-Assembly Cost Per Equip. | Travel Time to Barge (hrs) | Travel Time Barge to Site (hrs) | Total Travel Time (1-way) (hrs) | Equipment Rate | Transport Vehicle 1 Hourly Rate | Transport Vehicle 2 Hourly Rate | Total Transport Cost per Equip. | Total cost Per Equip. | TOTAL COST | Comments/Notes |
| E.03.1 | CAT D6R | 1 | 18 | 5 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $105.36 | $83.95 | $0.00 | $1,909.14 | $3,573 | $3,573 | |
| E.03.2 | CAT D8R | 2 | 38 | 8 | 0 | 4 | 8 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $50 | $207.96 | $2,496 | 4 | 1.1 | 5 | $128.31 | $110.02 | $0.00 | $3,308.87 | $5,804 | $11,609 | |
| E.03.3 | CAT D10T | 2 | 66 | 8 | 5 | 4 | 8 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $2,496 | 4 | 1.1 | 5 | $194.68 | $110.02 | $83.95 | $4,897.18 | $7,393 | $14,785 | |
| E.05.1 | CAT 330 | 3 | 35 | 7 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $83.65 | $107.46 | $0.00 | $2,032.04 | $3,696 | $11,087 | |
| E.05.2 | CAT 385 | 1 | 83 | 8 | 8 | 8 | 16 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $4,991 | 4 | 1.1 | 5 | $177.68 | $110.02 | $110.02 | $5,087.52 | $10,079 | $10,079 | |
| E.06.2 | CAT 16M (Class 7 - 250-300 FWHP) | 1 | 25 | 6 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $83.88 | $92.87 | $0.00 | $1,854.60 | $3,518 | $3,518 | |
| E.07.2 | CAT 735 | 5 | 30 | 6 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $89.43 | $92.87 | $0.00 | $1,897.06 | $3,561 | $17,804 | |
| E.07.4 | CAT 773G | 5 | 45 | 8 | 5 | 4 | 12 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $3,327 | 4 | 1.1 | 5 | $142.14 | $110.02 | $83.95 | $4,495.72 | $7,823 | $39,116 | |
| E.08.1 | Hydraulic Crane, 30Ton | 1 | 30 | 7 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $1,664 | 4 | 1.1 | 5 | $81.38 | $107.46 | $0.00 | $2,968.77 | $4,632 | $4,632 | |
| E.09.1 | CAT 950H | 1 | 18 | 5 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $100 | $207.96 | $1,664 | 4 | 1.1 | 5 | $61.19 | $83.95 | $0.00 | $1,621.64 | $3,285 | $3,285 | |
| E.09.2 | CAT 990 | 1 | 78 | 8 | 8 | 8 | 16 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $4,991 | 4 | 1.1 | 5 | $104.53 | $110.02 | $110.02 | $4,528.55 | $9,520 | $9,520 | |
| E.10.2 | Fuel Truck | 1 | n/a | 0 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 60 | 3 | 0 | $100 | $0.00 | $0 | 4 | 0.8 | 4 | $3.86 | $44.84 | $0.00 | $672.09 | $672 | $672 | |
| E.10.4 | Highway Service/Flatbed Truck (HIAB) 5 ton | 1 | n/a | 0 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 60 | 3 | 0 | $100 | $0.00 | $0 | 4 | 0.8 | 4 | $20.79 | $44.84 | $0.00 | $796.02 | $796 | $796 | |
| E.10.12 | Water Truck (5,000 gal) | 1 | n/a | 0 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 60 | 3 | 0 | $100 | $0.00 | $0 | 4 | 0.8 | 4 | $15.49 | $44.84 | $0.00 | $757.21 | $757 | $757 | |
| E.11.2 | Boomlift: 60' articulating | 1 | 10 | 2 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 60 | 3 | 0 | $100 | $0.00 | $0 | 4 | 0.8 | 4 | $25.00 | $36.07 | $0.00 | $724.81 | $725 | $725 | |
| E.11.4 | Bus: Passenger Bus (24 person cap.) | 1 | n/a | 0 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 50 | 3 | 0 | $100 | $0.00 | $0 | 4 | 0.9 | 4 | $75.30 | $43.84 | $0.00 | $1,198.31 | $1,198 | $1,198 | |
| E.11.7 | Crusher (200 Tons/hr) | 1 | 25 | 8 | 8 | 8 | 16 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $4,991 | 4 | 1.1 | 5 | $170.00 | $110.02 | $110.02 | $5,028.82 | $10,020 | $10,020 | |
| E.11.10 | Emergency Transport Vehicle | 1 | n/a | 0 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 60 | 0 | 0 | $0 | $0.00 | $0 | 4 | 0.8 | 4 | $150.30 | $43.84 | $0.00 | $1,028.06 | $1,028 | $1,028 | |
| E.11.18 | Screener (finley 583) (~400tonnes/hr) | 1 | 75 | 8 | 8 | 8 | 16 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 2 | $100 | $207.96 | $4,991 | 4 | 1.1 | 5 | $189.59 | $110.02 | $110.02 | $5,178.50 | $10,170 | $10,170 | |
| n/a | Misc. Equipment/Supplies | 4 | #N/A | 8 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 40 | 3 | 0 | $100 | $0.00 | $0 | 4 | 1.0 | 5 | $0.00 | $110.02 | $0.00 | $1,452.78 | $1,453 | $5,811 | |
| **TOTAL - Equipment Mobilization Costs** | | | | | | | | | | | | | | | | | | | | | | | | | | **$162,039** | |

**Notes:**
1. See Transport vehicle details below for number capacity.
2. Loading and off-loading time is a total (ie. Include both loading and unloading).
3. Calculations include costs for transport vehicles to return to shipping origin.
4. Mob costs for materials are included in the material rates.

## B: Equipment Demobilization - End of Post-Closure 2

1. Demobilization assumed to consist of the same equipment assumed in the Year 0 mobilization, EXCEPT for a reduced fleet that is assumed to remain for post closure maintenance/repairs activities.

| Equip. Code | Equipment to remain during post closure | Qnty | TOTAL MOB COST (from Part A) |
|---|---|---|---|
| E.03.1 | CAT D6R | 1 | $3,573 |
| E.05.1 | CAT 330 | 1 | $3,696 |
| E.07.2 | CAT 735 | 2 | $3,561 |
| E.09.1 | CAT 950H | 1 | $3,285 |
| E.06.2 | CAT 16M (Class 7 - 250-300 FWHP) | 1 | $3,518 |
| **TOTAL:** | | | **$17,633** |

TOTAL Equipment Demobilization Cost at end of Active Closure: **$144,406**

## C: Equipment Mobilization - Perpetual Care Year

**Equipment**

| | | Equipment Input | | | | Breakdown and Assembly Time (each) | | | Transport Time (each) | | | | | | Calculations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equip. Code | Equipment | Qnty | Shipping Weight (kg) | Transport Vehicle 1 (axles) | Transport Vehicle #2 (axles) | Breakdown Time (hrs) | Assembly Time (hrs) | Mechanic Workforce Size | Shipping Origin | Shipping Distance (km) | Average Speed to Barge (km/hr) | Average Speed from Barge to Site (km/hr) | Loading and Off-Loading Time (hrs) | # of Pilot Vehicles required per equip. | Meals/Hotel Allowance ($) | Total Mechanic Hourly Rate ($/hr) | Breakdown-Assembly Cost Per Equip. | Travel Time to Barge (hrs) | Travel Time Barge to Site (hrs) | Total Travel Time (1-way) (hrs) | Equipment Rate | Transport Vehicle 1 Hourly Rate | Transport Vehicle 2 Hourly Rate | Total Transport Cost per Equip. | Total cost Per Equip. | TOTAL COST | Comments/Notes |
| E.03.1 | CAT D6R | 1 | 18 | 5 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $105.36 | $83.95 | $0.00 | $1,909.14 | $3,573 | $3,573 | |
| E.05.1 | CAT 330 | 1 | 35 | 7 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $83.65 | $107.46 | $0.00 | $2,032.04 | $3,696 | $3,696 | |
| E.07.2 | CAT 735 | 2 | 30 | 6 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $89.43 | $92.87 | $0.00 | $1,897.06 | $3,561 | $7,122 | |
| E.09.1 | CAT 950H | 1 | 18 | 5 | 0 | 4 | 4 | 3 | Whitehorse | 283 | 80 | 35 | 3 | 0 | $50 | $207.96 | $1,664 | 4 | 1.1 | 5 | $61.19 | $83.95 | $0.00 | $1,571.64 | $3,235 | $3,235 | |
| E.10.4 | Highway Service/Flatbed Truck (HIAB) 5 ton | 1 | n/a | 0 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 60 | 0 | 0 | $50 | $0.00 | $0 | 4 | 0.8 | 4 | $20.79 | $44.84 | $0.00 | $527.19 | $527 | $527 | |
| n/a | **MISC. Equipment** | 1 | #N/A | 8 | 0 | 0 | 0 | 0 | Whitehorse | 283 | 80 | 40 | 3 | 0 | $50 | $0.00 | $0 | 4 | 1.0 | 5 | $0.00 | $110.02 | $0.00 | $1,402.78 | $1,403 | $1,403 | Fuel tanks, etc. |
| **TOTAL - Equipment Mobilization Costs** | | | | | | | | | | | | | | | | | | | | | | | | | | $19,555 | |

**Notes:**
1. See Transport vehicle details below for number capacity.
2. Loading and off-loading time is a total (i.e.. Include both loading and unloading).
3. Calculations include costs for transport vehicles to return to shipping origin.

# Worksheet 25 - Monitoring Costs

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Subr** February 6, 2018
**File Locatior** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## Summary of Monitoring Costs Per Event

| | | Annual Cost Per Phase | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual | n/a | Comments/Notes |
| 1 | Water Quality Monitoring | $115,295 | $130,437 | $51,987 | $27,220 | $27,664 | $0 | |
| 2 | Sediment Monitoring | $3,388 | $3,388 | $3,388 | $3,388 | $3,388 | $0 | Assumes samples collected during water quality sampling. |
| 3 | Biological Monitoring | $12,294 | $12,294 | $12,294 | $12,294 | $12,294 | $0 | |
| 4 | Geotechnical Monitoring | $12,409 | $12,409 | $12,409 | $23,216 | $23,216 | $0 | |
| 5 | Revegetation Monitoring | $0 | $10,530 | $10,530 | $10,530 | $10,530 | $0 | |
| 6 | Annual Inspection Reporting | $2,372 | $2,372 | $2,372 | $23,900 | $23,900 | $0 | |

## Monitoring Schedule and Total Cost Summary

**1. Year 0 and Peak Scenario**

| | | # of Years | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual | TOTAL COST | Comments/Notes |
| 1 | Water Quality Monitoring | 2 | 3 | 5 | 10 | 9 | $1,403,014 | |
| 2 | Sediment Monitoring | 2 | 3 | 3 | 2 | 9 | $64,372 | |
| 3 | Biological Monitoring | 2 | 3 | 3 | 2 | 9 | $233,587 | |
| 4 | Geotechnical Monitoring | 2 | 3 | 5 | 2 | 9 | $379,471 | |
| 5 | Revegetation Monitoring | 0 | 3 | 5 | 2 | 9 | $200,071 | |
| 6 | Annual Inspection Reporting | 2 | 3 | 5 | 2 | 9 | $286,620 | |

**2. EOM Scenario**

| | | # of Years | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 - Interim | 2 - Active | 3 - PC 1 | 4 - PC 2 | 5 - Perpetual | TOTAL COST | Comments/Notes |
| 1 | Water Quality Monitoring | 0 | 3 | 5 | 10 | 9 | $1,172,423 | |
| 2 | Sediment Monitoring | 0 | 3 | 3 | 2 | 9 | $57,596 | |
| 3 | Biological Monitoring | 0 | 3 | 3 | 2 | 9 | $208,999 | |
| 4 | Geotechnical Monitoring | 0 | 3 | 5 | 2 | 9 | $354,653 | |
| 5 | Revegetation Monitoring | 0 | 3 | 5 | 2 | 9 | $200,071 | |
| 6 | Annual Inspection Reporting | 0 | 3 | 5 | 2 | 9 | $281,876 | |

**NOTES:**
1. These tables are used as a check to the NPV calculation spreadsheets.

## Phase 1 - Annual Monitoring Costs - Prior to Closure

| | | | | | | Unit Rates | | | Activity Totals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Crew/ Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Material Cost | Labour Cost | Equipment Cost | Cost | Sub-Totals | Source / Comments |
| M1.1 | **Water Quality Monitoring** | | | | | | | | | | | | **$115,295** | |
| M1.1.1 | | Collect water quality sampling (by onsite staff) | 2 | ea | 144 | | $45 | $12 | | $12,837 | $1,778 | $14,615 | | |
| M1.1.2 | | Complete lab testing | 640 | yr | | $150 | | | $96,000 | | | $96,000 | | test unit rate based on actual site costs. |
| M1.1.3 | | Reporting | 1 | ea | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M1.2 | **Sediment Monitoring** | | | | | | | | | | | | **$3,388** | |
| M1.2.1 | | Collect data/samples | 2 | ea | 0 | | $45 | $12 | | $0.00 | $0.00 | $0 | | |
| M1.2.2 | | Laboratory Analysis | 2 | ea | | $290 | | | $580 | | | $580 | | Test unit rate based on actual costs. (Total metals + contaminates) |
| M1.2.3 | | Reporting | 1 | ls | 24 | | $117 | | | $2,808 | | $2,808 | | |
| M1.3 | **Biological Monitoring** | | | | | | | | | | | | **$12,294** | |
| M1.3.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M1.3.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M1.3.3 | | Collect data/samples | 2 | ls | 8 | | $117 | | | $1,872 | | $1,872 | | |
| M1.3.4 | | Laboratory Analysis | 10 | ea | | $270 | | | $2,700 | | | $2,700 | | Biological test actual costs range from $180 to $270 depending on test type |
| M1.3.5 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M1.4 | **Geotechnical Monitoring** | | | | | | | | | | | | **$12,409** | |
| M1.4.1.1 | Annual Geotech Inspection | Consultant travel - Whitehorse to/from site | 1 | ls | 8.1 | $50 | $117 | | $50 | $946 | | $996 | | |
| M1.4.1.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M1.4.1.3 | | Site Inspection | 1 | ls | 12 | | $117 | | | $1,404 | | $1,404 | | |
| M1.4.1.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M1.4.2.1 | Instrumentation Monitoring | Collect data, plot and review trends | 1 | ls | 96 | | $45 | | | $4,279 | | $4,279 | | |
| M1.5 | **Annual Reclamation Reports** | | | | | | | | | | | | **$2,372** | |
| M1.5.1 | | Reporting | 1 | ls | 16 | $500 | $117 | | $500 | $1,872 | | $2,372 | | |
| **TOTAL** | | | | | | | | | | | | **$145,758** | **$145,758** | |

**NOTES:**
1. Assumes water quality sampling completed by site personnel; Number of test obtained from Table 2-2 in EMSRP
2. Assumes sediment samples collected during water quality sampling.
3. Assumes biological sampling completed by consultants based in Whitehorse, and sampling takes place while barge in place.
4. Assumes geotechnical instrumentation readings collected and plotted by on-site staff.
5. Assumes annual reclamation report compiled by on-site staff whose salary is included in indirect costs; cost included here is for additional consultant review.

## Phase 2 - Annual Monitoring Costs - Active Closure

| | | | | | | Unit Rates | | | Activity Totals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Crew/ Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Material Cost | Labour Cost | Equipment Cost | Cost | Sub-Totals | Source / Comments |
| M2.1 | **Water Quality Monitoring** | | | | | | | | | | | | **$130,437** | |
| M2.1.1 | Sampling during camp ops. | Collect water quality sampling (by onsite staff) | 2 | ea | 42 | | $45 | $12 | | $3,744 | $1,037.37 | $4,781 | | |
| M2.2.1 | Winter sampling | Helicopter time (5 months) | 5 | ea | 2.25 | | $49 | $1,600 | | $546 | $18,000 | $18,546 | | Helicopter cost based on onsite costs |
| M2.2.2 | | Consultant time incl. travel | 5 | ea | 8 | | $117 | | | $4,680 | | $4,680 | | 1 consultant |
| M2.2.3 | | Car Rental (inc. fuel) | 5 | days | | | | $350 | | | $1,750 | $1,750 | | |
| M2.3.1 | Lab testing | Complete lab testing | 640 | ea | | $150 | | | $96,000 | | | $96,000 | | |
| M2.3.2 | | Reporting | 1 | ea | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M2.2 | **Sediment Monitoring** | | | | | | | | | | | | **$3,388** | |
| M2.2.1 | | Collect data/samples | 2 | ea | 0 | | $45 | $12 | | $0 | $0 | $0 | | |
| M2.2.2 | | Laboratory Analysis | 2 | ea | | $290 | | | $580 | | | $580 | | |
| M2.2.3 | | Reporting | 1 | ls | 24 | | $117 | | | $2,808 | | $2,808 | | |
| M2.3 | **Biological Monitoring** | | | | | | | | | | | | **$12,294** | |
| M2.3.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M2.3.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M2.3.3 | | Collect data/samples | 2 | ls | 8 | | $117 | | | $1,872 | | $1,872 | | |
| M2.3.4 | | Laboratory Analysis | 10 | ea | | $270 | | | $2,700 | | | $2,700 | | |
| M2.3.5 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M2.4 | **Geotechnical Monitoring** | | | | | | | | | | | | **$12,409** | |
| M2.4.1.1 | Annual Geotech Inspection | Consultant travel - Whitehorse to/from site | 1 | ls | 8.1 | $50 | $117 | | $50 | $946 | | $996 | | |
| M2.4.1.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M2.4.1.3 | | Site Inspection | 1 | ls | 12 | | $117 | | | $1,404 | | $1,404 | | |
| M2.4.1.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M2.4.2.1 | Instrumentation Monitoring | Collect data, plot and review trends | 1 | ls | 96 | | $45 | | | $4,279 | | $4,279 | | |
| M2.5 | **Reclamation Monitoring** | | | | | | | | | | | | **$10,530** | |
| M2.5.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M2.5.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M2.5.3 | | Inspect vegetation | 2 | ls | 12 | | $117 | | | $2,808 | | $2,808 | | |
| M2.5.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M2.6 | **Annual Reclamation Reports** | | | | | | | | | | | | **$2,372** | |
| M2.6.1 | | Reporting | 1 | ls | 16 | $500 | $117 | | $500 | $1,872 | | $2,372 | | |
| **TOTAL** | | | | | | | | | | | | **$171,431** | **$171,431** | |

**NOTES:**
1. Assumes water quality sampling completed by site personnel when camp in operation, and by helicopter during the winter months
2. Assumes sediment samples collected during water quality sampling.
3. Assumes biological sampling completed by consultants based in Whitehorse, and sampling takes place while barge in place.
4. Assumes geotechnical instrumentation readings collected and plotted by on-site staff.
5. Assumes annual reclamation report compiled by on-site staff whose salary is included in indirect costs; cost included here is for additional consultant review.

## Phase 3 - Annual Monitoring Costs - Post-Closure 1

| | | | | | | Unit Rates | | | Activity Totals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Crew/ Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Material Cost | Labour Cost | Equipment Cost | Cost | Sub-Totals | Source / Comments |
| M3.1 | **Water Quality Monitoring** | | | | | | | | | | | | **$51,987** | |
| M3.1.1.1 | Sampling during camp ops. | Collect water quality samples | 2 | ea | 42 | | $45 | $12 | | $3,744 | $1,037 | $4,781 | | |
| M3.1.2.1 | Winter sampling | Helicopter time (5 months) | 5 | ea | 2.25 | | $49 | $1,600 | | $546 | $18,000 | $18,546 | | Helicopter cost based on onsite costs |
| M3.1.2.2 | | Consultant time incl. travel | 5 | ea | 8 | | $117 | | | $4,680 | | $4,680 | | 1 consultant |
| M3.1.2.3 | | Car Rental (inc. fuel) | 5 | days | | | | $350 | | | $1,750 | $1,750 | | |
| M3.1.3.1 | Lab testing | Complete lab testing | 117 | ea | | $150 | | | $17,550 | | | $17,550 | | |
| M3.1.3.2 | | Reporting | 1 | ea | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M3.2 | **Sediment Monitoring (Bi - Annual)** | | | | | | | | | | | | **$3,388** | |
| M3.2.1 | | Collect data/samples | 2 | ea | 0 | | $45 | $12 | | $0.00 | $0.00 | $0 | | Samples collected during water sampling |
| M3.2.2 | | Laboratory Analysis | 2 | ea | | $290 | | | $580 | | | $580 | | |
| M3.2.3 | | Reporting | 1 | ls | 24 | | $117 | | | $2,808 | | $2,808 | | |
| M3.3 | **Biological Monitoring (Bi-Annual)** | | | | | | | | | | | | **$12,294** | |
| M3.3.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M3.3.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M3.3.3 | | Collect data/samples | 2 | ls | 8 | | $117 | | | $1,872 | | $1,872 | | |
| M3.3.4 | | Laboratory Analysis | 10 | ea | | $270 | | | $2,700 | | | $2,700 | | |
| M3.3.5 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M3.4 | **Geotechnical Monitoring** | | | | | | | | | | | | **$12,409** | |
| M3.4.1.1 | Annual Geotech Inspection | Consultant travel - Whitehorse to/from site | 1 | ls | 8.1 | $50 | $117 | | $50 | $946 | | $996 | | |
| M3.4.1.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M3.4.1.3 | | Site Inspection | 1 | ls | 12 | | $117 | | | $1,404 | | $1,404 | | |
| M3.4.1.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M3.4.2.1 | Instrumentation Monitoring | Collect data, plot and review trends | 1 | ls | 96 | | $45 | | | $4,279 | | $4,279 | | |
| M3.5 | **Reclamation Monitoring** | | | | | | | | | | | | **$10,530** | |
| M3.5.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M3.5.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M3.5.3 | | Inspect vegetation | 2 | ls | 12 | | $117 | | | $2,808 | | $2,808 | | |
| M3.5.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M3.6 | **Annual Reclamation Reports** | | | | | | | | | | | | **$2,372** | |
| M3.6.1 | | Reporting | 1 | ls | 16 | $500 | $117 | | $500 | $1,872 | | $2,372 | | |
| **TOTAL** | | | | | | | | | | | | **$92,981** | **$92,981** | |

**NOTES:**
1. Assumes water quality sampling completed by site personnel when camp in operation, and by helicopter during the winter months
2. Assumes sediment samples collected during water quality sampling.
3. Assumes biological sampling completed by consultants based in Whitehorse, and sampling takes place while barge in place.
4. Assumes geotechnical instrumentation readings collected and plotted by on-site staff.
5. Assumes annual reclamation report compiled by on-site staff whose salary is included in indirect costs; cost included here is for additional consultant review.

## Phase 4 - Annual Monitoring Costs - Post-Closure 2

| | | | | | | Unit Rates | | | Activity Totals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Crew/ Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Material Cost | Labour Cost | Equipment Cost | Cost | Sub-Totals | Source / Comments |
| M4.1 | **Water Quality Monitoring** | | | | | | | | | | | | **$27,220** | |
| M4.1.1 | | Helicopter time (3 rounds) | 3 | ea | 2.25 | | $49 | $1,600 | | $328 | $10,800 | $11,128 | | Helicopter cost based on onsite costs |
| M4.1.2 | | Consultant time incl. travel | 3 | ea | 12 | | $117 | | | $4,212 | | $4,212 | | 1 consultant |
| M4.1.3 | | Car Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M4.1.4 | | Complete lab testing | 41 | ea | | $150 | | | $6,150 | | | $6,150 | | |
| M4.1.5 | | Reporting | 1 | ea | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M4.2 | **Sediment Monitoring (Bi - Annual)** | | | | | | | | | | | | **$3,388** | |
| M4.2.1 | | Collect data/samples | 2 | ea | 0 | | $45 | $12 | | $0.00 | $0.00 | $0 | | Samples collected during water sampling |
| M4.2.2 | | Laboratory Analysis | 2 | ea | | $290 | | | $580 | | | $580 | | |
| M4.2.3 | | Reporting | 1 | ls | 24 | | $117 | | | $2,808 | | $2,808 | | |
| M4.3 | **Biological Monitoring (Bi-Annual)** | | | | | | | | | | | | **$12,294** | |
| M4.3.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M4.3.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M4.3.3 | | Collect data/samples | 2 | ls | 8 | | $117 | | $0 | $1,872 | | $1,872 | | |
| M4.3.4 | | Laboratory Analysis | 10 | ea | | $270 | | | $2,700 | | | $2,700 | | |
| M4.3.5 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M4.4 | **Geotechnical Monitoring** | | | | | | | | | | | | **$23,216** | |
| M4.4.1 | Annual Geotech Inspection | Consultant travel/on-site time | 2 | ea | 16.0 | $50 | $117 | | $100 | $3,744 | | $3,844 | | |
| M4.4.2 | | Car Rental (2 days) | 2 | days | | | | $350 | | | $700 | $700 | | |
| M4.4.3 | | Helicopter time | 1 | ea | 5 | | $49 | $1,600 | | $243 | $8,000 | $8,243 | | |
| M4.4.4 | | Instrumentation review | 1 | ls | 24 | | $45 | | | $1,070 | | $1,070 | | |
| M4.4.5 | | Reporting/Maintenance Planning | 1 | ls | 80 | | $117 | | | $9,360 | | $9,360 | | |
| M4.5 | **Reclamation Monitoring** | | | | | | | | | | | | **$10,530** | |
| M4.5.1 | | Consultant travel - Whitehorse to site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M4.5.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M4.5.3 | | Inspect vegetation | 2 | ls | 12 | | $117 | | $0 | $2,808 | | $2,808 | | |
| M4.5.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M4.6 | **Annual Reclamation Reports** | | | | | | | | | | | | **$23,900** | |
| M4.6.1 | | Reporting | 1 | ls | 200 | $500 | $117 | | $500 | $23,400 | | $23,900 | | Includes as-built reporting |
| **TOTAL** | | | | | | | | | | | | **$100,548** | **$100,548** | |

**NOTES:**
1. Water quality sampling assumes 2 rounds of sampling completed by helicopter from Carmacks, and one round when the barge is in place.
2. Assumes sediment samples collected during water quality sampling.
3. Assumes biological sampling completed by consultants based in Whitehorse, and sampling takes place while barge in place.
4. Geotechnical inspection assumed to be completed by helicopter. Two consultants assumed to be present to also collect geotech data. The inspection is also used to determine the site maintenance required for the year.
5. Assumes annual reclamation report compiled by outside consultants.

## Phase 5 - Annual Monitoring Costs - Perpetual Maintenance Year

| | | | | | | Unit Rates | | | Activity Totals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBS | Facility/Area | Task | Crew/ Qnty | Unit | Hours | Material Cost ($/unit) | Labour Rate ($/hr) | Equipment Rate ($/hr) | Material Cost | Labour Cost | Equipment Cost | Cost | Sub-Totals | Source / Comments |
| M5.1 | **Water Quality Monitoring** | | | | | | | | | | | | **$27,664** | |
| M5.1.1 | | Helicopter time (3 rounds) | 3 | ea | 2.25 | | $49 | $1,600 | | $328 | $10,800 | $11,128 | | Helicopter cost based on onsite costs |
| M5.1.2 | | Consultant time incl. travel | 3 | ea | 12 | | $117 | $12 | | $4,212 | $445 | $4,657 | | 1 consultant |
| M5.1.3 | | Car Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M5.1.4 | | Complete lab testing | 41 | ea | | $150 | | | $6,150 | | | $6,150 | | |
| M5.1.5 | | Reporting | 1 | ea | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M5.2 | **Sediment Monitoring** | | | | | | | | | | | | **$3,388** | |
| M5.2.1 | | Collect data/samples | 2 | ea | 0 | | $45 | $12 | | $0.00 | $0.00 | $0 | | Collected during water sampling |
| M5.2.2 | | Laboratory Analysis | 2 | ea | | $290 | | | $580 | | | $580 | | |
| M5.2.3 | | Reporting | 1 | ls | 24 | | $117 | | | $2,808 | | $2,808 | | |
| M5.3 | **Biological Monitoring** | | | | | | | | | | | | **$12,294** | |
| M5.3.1 | | Consultant travel - Whitehorse to/from site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M5.3.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M5.3.3 | | Collect data/samples | 2 | ls | 8 | | $117 | | | $1,872 | | $1,872 | | |
| M5.3.4 | | Laboratory Analysis | 10 | ea | | $270 | | | $2,700 | | | $2,700 | | |
| M5.3.5 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M5.4 | **Geotechnical Monitoring** | | | | | | | | | | | | **$23,216** | |
| M5.4.1 | Annual Geotech Inspection | Consultant travel/on-site time | 2 | ea | 16.0 | $50 | $117 | | $100 | $3,744 | | $3,844 | | |
| M5.4.2 | | Car Rental (2 days) | 2 | days | | | | $350 | | | $700 | $700 | | |
| M5.4.3 | | Helicopter time | 1 | ea | 5 | | $49 | $1,600 | | $243 | $8,000 | $8,243 | | |
| M5.4.4 | | Instrumentation review | 1 | ls | 24 | | $45 | | | $1,070 | | $1,070 | | |
| M5.4.5 | | Reporting/Maintenance Planning | 1 | ls | 80 | | $117 | | | $9,360 | | $9,360 | | |
| M5.5 | **Reclamation Monitoring** | | | | | | | | | | | | **$10,530** | |
| M5.5.1 | | Consultant travel - Whitehorse to site | 2 | ls | 8.1 | $50 | $117 | | $100 | $1,892 | | $1,992 | | |
| M5.5.2 | | Truck Rental (inc. fuel) | 3 | days | | | | $350 | | | $1,050 | $1,050 | | |
| M5.5.3 | | Inspect vegetation | 2 | ls | 12 | | $117 | | | $2,808 | | $2,808 | | |
| M5.5.4 | | Reporting | 1 | ls | 40 | | $117 | | | $4,680 | | $4,680 | | |
| M5.6 | **Annual Reclamation Reports** | | | | | | | | | | | | **$23,900** | |
| M5.6.1 | | Reporting | 1 | ls | 200 | $500 | $117 | | $500 | $23,400 | | $23,900 | | Includes Asbuilt reporting |
| **TOTAL** | | | | | | | | | | | | **$100,993** | **$100,993** | |

**NOTES:**
1. Water quality sampling assumes 2 rounds of sampling completed by helicopter from Carmacks, and one round when the barge is in place.
2. Assumes sediment samples collected during water quality sampling.
3. Assumes biological sampling completed by consultants based in Whitehorse, and sampling takes place while barge in place.
4. Geotechnical inspection assumed to be completed by helicopter. Two consultants assumed to be present to also collect geotech data. The inspection is also used to determine the site maintenance required for the year.
5. Assumes annual reclamation report compiled by outside consultants and includes additional hours for asbuilt reporting

# Worksheet 26 - Ore Stockpiles and Misc. Volume Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\!040_AutoCAD\1CM002-45_ClosureQuantities.dwg

## A: Ore Stockpile Excavation

| | | Inputs | | | | Calculated Quantities | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Description | Volume of Ore Remaining ($m^3$) | Ore Pad Area ($m^2$) | Ore Pad Excavation depth (m) | Confirmation Test Grid Spacing (m) | Ore Relocation Volume ($m^3$) | Ore Pad Excavation Volume ($m^3$) | Confirmation Tests Required | Comments/Notes |
| **Year 0 Scenario** | | | | | | | | | |
| Mill Area | North Stockpile | 70,673 | 13,760 | 0.5 | 10 | 70,673 | 6,880 | 138 | |
| | West Stockpile | 1,657 | 38,670 | 0.5 | 10 | 1,657 | 19,335 | 387 | |
| | East Stockpile | 0 | 31,190 | 0.5 | 10 | 0 | 15,595 | 312 | |
| | South Stockpile | 123,698 | 41,571 | 0.5 | 10 | 123,698 | 20,786 | 416 | |
| | Nuway Stockpiles | 9,463 | 4,145 | 0.5 | 10 | 9,463 | 2,073 | 41 | |
| | Crusher Stockpile | 0 | 12,678 | 0.5 | 10 | 0 | 6,339 | 127 | |
| **Mill Area** | **TOTAL** | | | | | 205,490 | 71,007 | 1,421 | |
| Main Waste Dump | Low Grade Ore Stockpiles | 15,490 | 62,631 | 0.5 | 10 | 15,490 | 31,316 | 626 | "Top of the World Stockpile" |
| **Main Waste Dump** | **TOTAL** | | | | | 15,490 | 31,316 | 626 | |
| SWD | High grade waste | 45,711 | | | | 45,711 | | | |
| **South West Dump** | **TOTAL** | | | | | 45,711 | 0 | 0 | |
| **Peak Liability Scenario** | | | | | | | | | |
| Mill Area | North Stockpile | 0 | 13,760 | 0.5 | 10 | 0 | 6,880 | 138 | |
| | West Stockpile | 0 | 38,670 | 0.5 | 10 | 0 | 19,335 | 387 | |
| | East Stockpile | 0 | 31,190 | 0.5 | 10 | 0 | 15,595 | 312 | |
| | South Stockpile | 884,785 | 41,571 | 0.5 | 10 | 884,785 | 20,786 | 416 | All mill area ore was allocated to this stockpile. |
| | Crushed Ore Stockpiles | 0 | 4,145 | 0.5 | 10 | 0 | 2,073 | 41 | |
| | Crusher Stockpile | 0 | 12,678 | 0.5 | 10 | 0 | 6,339 | 127 | |
| **Mill Area** | **TOTAL** | | | | | 884,785 | 71,007 | 1,421 | |
| Main Waste Dump | Low Grade Ore Stockpiles | 15,490 | 62,631 | 0.5 | 10 | 15,490 | 31,316 | 626 | |
| **Main Waste Dump** | **TOTAL** | | | | | 15,490 | 31,316 | 626 | |
| SWD | High grade waste | 44,730 | | | | 44,730 | | | Based of HGW covered as per SWD perscription |
| **South West Dump** | **TOTAL** | | | | | 44,730 | 0 | 0 | |

**Notes:**
1. Year 0 stockpile tonnes provided by Minto in January 2018. Stockpile density = 2 tonnes/m3
2. Peak ore stockpile volume occurs in 2019 and is estiamted based on the closure plan production profile. For the EOM scenario, the stockpile volumes are 0.
3. Covers and revegetation of the ore stockpiles included in the "Areas" worksheet.

## B: Misc. Volumes

| | | Inputs | | | | Calculated Quantities | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Description | Length (m) | Width (m) | Area (m2) | Average Thickness (m) | Volume (Cm3) | Volume (Lm3) | | Comments/Notes |
| DSTSF | Fill at south side of DSTSF to cover tailings and provide drainage to the east. | 404 | 25 | | 3 | 30,300 | | | Material assumed to be sourced from the Tailings Diversion Ditch road |
| DSTSF | Unsuitable existing cover material to be removed. | | | 69,467 | 0.75 | 52,100 | | | Area based on 2014 aerial photo |
| Main Pit/SAT | SAT in the Main Pit to be relocated to below 786 m elevation | | | | | 1,040,000 | | | Volume provided by Minto Dec. 2015, and includes a projection of the SAT volume to be placed from Minto North |
| Main Pit/SAT | Allowance for backfill to stabilize MPD/Main Pit South Wall following removal of SAT | | | | | 245,000 | | | Buttress volume from E. Ketilison from AutoCAD |
| Main Pit | Est. Tailings near outlet above long term water table elevation of 786. | | | 2,311 | 1.50 | 3,467 | | | Area estimated from 2014 site aerial photographs and June 2016 site photography |
| Southwest Wetlands | 3 Berms acrros valley | 300 | 5 | | 2.00 | 3,000 | | | Assumed width, thickness. Length estimated from 2014 orthophoto. |
| Ridgetop North | Waste Rock Volume | | | | | | 3,416,000 | 0.84 | From WROMP June 2014 |
| Ridgetop South | Waste rock volume | | | | | | 637,000 | 0.16 | From WROMP June 2014 |

**Notes:**

# Worksheet 27 - Open Pit Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans):** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\!040_AutoCAD\1CM002-45_ClosureQuantities.dwg
**Layer:** ~Pits

## Open Pit Quantity Calculations

| | | Safety Berms | | | | | | | Boulder Fence | | Warning Signs | | | Quantity Calculations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pit | Scenario | Berm Placement Length (m) | % Open Space in Berm | Length of berm requiring land clearing (m) | Land clearing width (m) | Berm Height (m) | Berm Side-Slope Angle (H:1V) | Berm Crest Width (m) | Fence Length (m) | Boulder Spacing (m) | Warning Sign Perimeter Length (m) | Sign Spacing (m) | User Override - Number of Signs | Berm Volume ($m^3$/m) | Berm Volume ($m^3$) | Land Clearing Area ($m^2$) | Boulder Fence Volume ($m^3$) | Warning Signs | Comments/Notes |
| Main Pit | All | 1680 | 14% | 750 | 10 | 1.5 | 1.3 | 0.3 | 40 | 1 | 2741 | 100 | 6 | 3.4 | 4,860 | 7,500 | 52 | 6 | |
| Area 2 Pit (updated for 2017 | Yr0 | 1838 | 14% | 0 | 10 | 1.5 | 1.3 | 0.3 | 20 | 1 | 1506 | 100 | 6 | 3.4 | 5,317 | 0 | 26 | 6 | |
| Area 2 Pit (inc. Stage 3) | EOM | 1838 | 14% | 0 | 10 | 1.5 | 1.3 | 0.3 | 20 | 1 | 1506 | 100 | 6 | 3.4 | 5,317 | 0 | 26 | 6 | |
| Area 118 Pit | All | 496 | 14% | 258 | 10 | 1.5 | 1.3 | 0.3 | 20 | 1 | 600 | 100 | 4 | 3.4 | 1,435 | 2,580 | 26 | 4 | |
| Minto North | All | 1248 | 14% | 590 | 10 | 1.5 | 1.3 | 0.3 | 20 | 1 | 1248 | 100 | 4 | 3.4 | 3,610 | 5,900 | 26 | 4 | |
| Ridgetop North | Peak | 1261 | 14% | 1011 | 10 | 1.5 | 1.3 | 0.3 | 20 | 1 | 1506 | 100 | 6 | 3.4 | 3,648 | 10,110 | 26 | 6 | |
| Ridgetop South | Peak | 534 | 14% | 534 | 10 | 1.5 | 1.3 | 0.3 | 20 | 1 | 1506 | 100 | 6 | 3.4 | 1,545 | 5,340 | 26 | 6 | |

**Notes:**
1. Vegetated areas of the highwall require clearing to ensure visibility of the safety berm.
2. Main Pit Rock fence assumed to be placed near the entrance ramp of the pit.

# Worksheet 28 - Resloping Quantity Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**Notes/Instructions:** 1. When adding a new row, make sure all columns are copied (there are a lot of calculations hidden in columns to the right).
2. Once complete, check that the Dozer used on this sheet matches the correct task unit rate used on the cost estimate worksheet
**References (dwgs/plans):** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\l040_AutoCAD\1CM002-45_ClosureQuantities.dwg
(Layer ~Regrading)

## A: Slopes

| | | Dump | | | | | | | Dozing Conditions | | | | | Calculated Quantities | | | | | Total Quantities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility | Segment | Mid-bench length (m) | Height (m) | Existing Side Slope Angle (H:1V) | Final Side-Slope Angle (H:1V) | Underlying slope grade (%) (See Note 2) | Does regrading increase the dump footprint? | Soil Cover Thickness (m) | Dozer Size | Material Type | Dozing Condition | Bank or Placed? (See note 3) | Slot or Side-by-side Dozing? | Cut Volume per m crest ($m^3$) | Average Regrade Push Distance (m) | Unfactored Dozer Productivity ($Lm^3/hr$) | Factored Dozer Productivity ($Bm^3/hr$) | Time to complete 1m width (hrs) | Time Required - Regrading (Hrs) | Time Required - Spreading Cover (hrs) | Total Regrade Volume ($Bm^3$) | 3D Surface Area ($m^2$) | 2D Sloped Area ($m^2$) | 2D Footprint increase due to regrading ($m^2$) | Comments/Notes |
| **Existing Facilities** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Camp Area | R1 | 309 | 18 | 1.3 | 3 | 0 | Yes | 0.5 | D10 | Sand & gravel, | Normal | Placed | No | 68.9 | 37.9 | 1114.1 | 873.5 | 0.1 | 24 | 10 | 21,275 | 17,589 | 16,686 | 4,728 | |
| Camp Area | R2 | 73 | 3 | 1.3 | 3 | 0 | No | 0.5 | D10 | Sand & gravel, | Normal | Placed | No | 1.9 | 6.3 | 2293.7 | 1798.4 | 0.0 | 0 | 0 | 140 | 693 | 657 | 0 | |
| Camp Area | R3 | 44 | 3 | 1.3 | 3 | 0 | Yes | 0.5 | D10 | Sand & gravel, | Normal | Placed | No | 1.9 | 6.3 | 2293.7 | 1798.4 | 0.0 | 0 | 0 | 84 | 417 | 396 | 112 | |
| **Camp Area** | **TOTAL** | | | | | | | | | | | | | | | | | | **24** | **10** | **21,498** | **18,699** | **17,739** | **4,840** | |
| DSTSF - WR Shell | R1 | 3211 | 4 | 1.3 | 4 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 5.4 | 11.0 | 2293.7 | 1309.0 | 0.0 | 13 | 14 | 17,339 | 52,957 | 51,376 | 0 | |
| **DSTSF - WR Shell** | **TOTAL** | | | | | | | | | | | | | | | | | | **13** | **35** | **17,339** | **52,957** | **51,376** | **0** | |
| DSTSF - South end | R1 | 500 | 5 | 1.3 | 4 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 8.4 | 13.7 | 2293.7 | 1309.0 | 0.0 | 3 | 3 | 4,219 | 10,308 | 10,000 | 0 | |
| **DSTSF - South End** | **TOTAL** | | | | | | | | | | | | | | | | | | **3** | **72** | **4,219** | **10,308** | **10,000** | **0** | |
| IROD Laydown | R1 | 101 | 14 | 3.5 | 3.5 | 0 | No | 0 | D10 | Sand & gravel, | Normal | Placed | No | 0.0 | 0.0 | 2293.7 | 1787.2 | 0.0 | 0 | 0 | 0 | 5,147 | 4,949 | 0 | |
| **IROD Laydown** | **TOTAL** | | | | | | | | | | | | | | | | | | **0** | **0** | **0** | **5,147** | **4,949** | **0** | |
| Main Dump (2014) | R1 | 282 | 60 | 2.5 | 3 | 2 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 226.2 | 127.2 | 377.5 | 227.7 | 1.0 | 280 | 89 | 63,786 | 53,790 | 51,029 | 4,489 | |
| Main Dump | R2 | 185 | 35 | 2.5 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 76.6 | 73.8 | 614.4 | 370.7 | 0.2 | 38 | 21 | 14,164 | 20,476 | 19,425 | 0 | |
| Main Dump | R3 | 358 | 15 | 1.3 | 3 | 0 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 22 | 8 | 17,117 | 16,981 | 16,110 | 4,565 | |
| Main Dump | R5 | 266 | 22 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 102.9 | 46.4 | 931.0 | 561.6 | 0.2 | 49 | 12 | 27,358 | 18,506 | 17,556 | 0 | |
| Main Dump | R6 | 73 | 17 | 1.5 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 54.2 | 35.8 | 1172.6 | 707.4 | 0.1 | 6 | 2 | 3,956 | 3,924 | 3,723 | 0 | |
| Main Dump | R7 | 50 | 7 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 10.4 | 14.8 | 2293.7 | 1383.7 | 0.0 | 0 | 0 | 521 | 1,107 | 1,050 | 0 | |
| Main Dump | R11 | 200 | 20 | 1.3 | 3 | -75 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 65.2 | 32.9 | 1267.0 | 764.4 | 0.1 | 17 | 5 | 13,049 | 9,861 | 9,355 | 0 | |
| Main Dump | R12 | 75 | 5 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 5.3 | 10.5 | 2293.7 | 1383.7 | 0.0 | 0 | 0 | 398 | 1,186 | 1,125 | 0 | |
| Main Dump | R13 | 93 | 20 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 85.0 | 42.2 | 1013.9 | 611.6 | 0.1 | 13 | 4 | 7,905 | 5,882 | 5,580 | 0 | |
| Main Dump | R14 | 123 | 30 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 191.3 | 63.2 | 705.3 | 425.5 | 0.4 | 55 | 10 | 23,524 | 11,669 | 11,070 | 0 | |
| Main Dump | R15 | 205 | 10 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 4 | 2 | 4,356 | 6,483 | 6,150 | 0 | |
| Main Dump | R16 | 112 | 20 | 1.3 | 3 | -75 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 65.2 | 32.9 | 1267.0 | 764.4 | 0.1 | 10 | 3 | 7,307 | 5,522 | 5,239 | 0 | |
| Main Dump Extension | R17 | 964 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 58 | 22 | 46,091 | 45,727 | 43,380 | 0 | |
| Main Dump Extension | R18- | 990 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 60 | 22 | 47,334 | 46,960 | 44,550 | 0 | |
| Main Dump Extension | R19 | 1000 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 60 | 23 | 47,813 | 47,434 | 45,000 | 0 | |
| **MWD & MWDE (Year 0)** | **TOTAL** | | | | | | | | | | | | | | | | | | **672** | **224** | **324,679** | **295,506** | **280,341** | **9,053** | |
| Main Dump Wrap | R1 | 560 | 20 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 85.0 | 42.2 | 1013.9 | 611.6 | 0.1 | 78 | 22 | 47,600 | 35,418 | 33,600 | 0 | |
| Main Dump Wrap | R2 | 600 | 20 | 1.3 | 4 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 135.0 | 55.0 | 799.6 | 456.3 | 0.3 | 178 | 39 | 81,000 | 49,477 | 48,000 | 0 | |
| **Main Dump Wrap** | **TOTAL** | | | | | | | | | | | | | | | | | | **255** | **61** | **128,600** | **84,895** | **81,600** | **0** | |
| Main Pit Dump - Yr0 | R1 | 277 | 16 | 1.3 | 3 | 15 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 65.2 | 40.8 | 1043.9 | 629.8 | 0.1 | 29 | 10 | 18,066 | 16,956 | 16,086 | 6,268 | |
| Main Pit Dump - Yr0 | R2 | 566 | 15 | 1.3 | 3 | 0 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 34 | 13 | 27,062 | 26,848 | 25,470 | 7,217 | |
| Main Pit Dump - Yr0 | R3 | 384 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 23 | 9 | 18,360 | 18,215 | 17,280 | 0 | |
| Main Pit Dump - Yr0 | R4 | 711 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 43 | 16 | 33,995 | 33,726 | 31,995 | 0 | |
| Main Pit Dump - Yr0 | R5 | 700 | 12 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 30.6 | 25.3 | 1601.5 | 966.2 | 0.0 | 22 | 10 | 21,420 | 26,563 | 25,200 | 0 | |
| Main Pit Dump - Yr0 | R6 | 100 | 21 | 1.5 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 82.7 | 44.3 | 970.5 | 585.5 | 0.1 | 14 | 4 | 8,269 | 6,641 | 6,300 | 0 | |
| Main Pit Dump - Yr0 | R7 | 226 | 14 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 41.7 | 29.5 | 1395.1 | 841.6 | 0.0 | 11 | 4 | 9,413 | 10,005 | 9,492 | 0 | |
| Main Pit Dump - Yr0 | R8 | 354 | 11 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 25.7 | 23.2 | 1731.2 | 1044.4 | 0.0 | 9 | 4 | 9,102 | 12,314 | 11,682 | 0 | |
| Main Pit Dump - Yr0 | R9 | 355 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 21 | 8 | 16,973 | 16,839 | 15,975 | 0 | |
| **Main Pit Dump - Yr 0 (2018** | **TOTAL** | | | | | | | | | | | | | | | | | | **207** | **79** | **162,660** | **168,106** | **159,480** | **13,485** | |
| MVFE Stage 1 and 2 | R1 | 255 | 17 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 61.4 | 35.8 | 1172.6 | 707.4 | 0.1 | 22 | 7 | 15,660 | 13,708 | 13,005 | 0 | |
| MVFE Stage 1 and 2 | R2 | 188 | 12 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 30.6 | 25.3 | 1601.5 | 966.2 | 0.0 | 6 | 3 | 5,753 | 7,134 | 6,768 | 0 | |
| MVFE Stage 1 and 2 | R3 | 250 | 10 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 5 | 3 | 5,313 | 7,906 | 7,500 | 0 | |
| MVFE Stage 1 and 2 | R4 | 265 | 12 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 30.6 | 25.3 | 1601.5 | 966.2 | 0.0 | 8 | 4 | 8,109 | 10,056 | 9,540 | 0 | |
| MVFE Stage 1 and 2 | R5 | 400 | 5 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 5.3 | 10.5 | 2293.7 | 1383.7 | 0.0 | 2 | 2 | 2,125 | 6,325 | 6,000 | 0 | |
| **MVFE Stage 1 and 2** | **TOTAL** | | | | | | | | | | | | | | | | | | **43** | **18** | **36,959** | **45,129** | **42,813** | **0** | |
| Minto South Portal | R1 | 200 | 7 | 1.3 | 3 | 0 | Yes | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 10.4 | 14.8 | 2293.7 | 1383.7 | 0.0 | 2 | 0 | 2,083 | 4,427 | 4,200 | 1,190 | |
| Minto South Portal | R2 | 133 | 10 | 1.3 | 3 | 10 | Yes | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 23.6 | 23.5 | 1710.6 | 1032.0 | 0.0 | 3 | 0 | 3,142 | 4,689 | 4,448 | 1,535 | |
| Minto South Portal | R3 | 200 | 7 | 1.3 | 3 | 10 | No | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 11.6 | 16.5 | 2353.9 | 1420.0 | 0.0 | 2 | 0 | 2,315 | 4,936 | 4,682 | 0 | |
| Minto South Portal | R4 | 80 | 10 | 1.3 | 3 | 10 | No | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 23.6 | 23.5 | 1710.6 | 1032.0 | 0.0 | 2 | 0 | 1,890 | 2,820 | 2,676 | 0 | |
| Minto South Portal | R5 | 490 | 20 | 2.5 | 3 | 0 | No | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 25.0 | 42.2 | 1013.9 | 611.6 | 0.0 | 20 | 0 | 12,250 | 30,990 | 29,400 | 0 | |
| **Minto South Portal** | **TOTAL** | | | | | | | | | | | | | | | | | | **28** | **0** | **21,678** | **47,862** | **45,406** | **2,725** | |
| Southwest Dump | Allowance | 1000 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 60 | 23 | 47,813 | 47,434 | 45,000 | 0 | |
| **Southwest Dump** | **TOTAL** | | | | | | | | | | | | | | | | | | **60** | **23** | **47,813** | **47,434** | **45,000** | **0** | |
| SWD - High Grade Waste | R1 | 320 | 8 | 1.3 | 5 | 0 | Yes | 1 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 29.6 | 27.2 | 1501.2 | 796.2 | 0.0 | 12 | 11 | 9,472 | 13,053 | 12,800 | 4,736 | |
| SWD - High Grade Waste | R2 | 113 | 11 | 1.3 | 5 | 0 | Yes | 1 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 56.0 | 37.4 | 1128.9 | 598.7 | 0.1 | 11 | 7 | 6,324 | 6,338 | 6,215 | 2,300 | |
| SWD - High Grade Waste | R3 | 245 | 17 | 1.3 | 5 | 2 | Yes | 1 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 139.0 | 60.1 | 738.1 | 391.4 | 0.4 | 87 | 37 | 34,054 | 22,093 | 21,664 | 8,394 | |
| **SWD - High Grade Waste** | **TOTAL** | | | | | | | | | | | | | | | | | | **109** | **55** | **49,849** | **41,485** | **40,679** | **15,430** | |
| Tailings Diversion Ditch | R1 | 260 | 7 | 1.3 | 3 | 17 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 13.0 | 18.6 | 2108.3 | 1271.9 | 0.0 | 3 | 2 | 3,368 | 7,257 | 6,884 | 2,833 | |
| Tailings Diversion Ditch | R2 | 454 | 13 | 1.3 | 3 | 10 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 39.9 | 30.6 | 1352.6 | 816.0 | 0.0 | 22 | 10 | 18,123 | 20,807 | 19,739 | 6,811 | |
| Tailings Diversion Ditch | R3 | 311 | 7 | 1.3 | 3 | 13 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 12.1 | 17.2 | 2259.2 | 1362.9 | 0.0 | 3 | 2 | 3,757 | 8,035 | 7,623 | 2,823 | |
| **Tailings Diversion Ditch** | **TOTAL** | | | | | | | | | | | | | | | | | | **28** | **14** | **25,248** | **36,099** | **34,246** | **12,467** | |
| W15 Sump Area | R1 | 124 | 6 | 1.3 | 3 | 0 | Yes | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 7.7 | 12.6 | 2293.7 | 1383.7 | 0.0 | 1 | 0 | 949 | 2,353 | 2,232 | 632 | |
| W15 Sump Area | R2 | 92 | 6 | 1.3 | 3 | 15 | Yes | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 9.2 | 15.3 | 2511.4 | 1515.1 | 0.0 | 1 | 0 | 844 | 2,112 | 2,003 | 781 | |
| **Minto South Portal** | **TOTAL** | | | | | | | | | | | | | | | | | | **1** | **0** | **1,792** | **4,465** | **4,235** | **1,413** | |
| **Future Facilities** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Area 118 Backfill Dump | R1 | 1227 | 5 | 1.3 | 3 | 0 | No | 0 | D10 | Earth, moist | Normal | Placed | No | 5.3 | 10.5 | 2293.7 | 1648.3 | 0.0 | 4 | 0 | 6,518 | 19,401 | 18,405 | 0 | Source: A118 Backfill Dump.dwg |
| **Area 118 Backfill Dump** | **TOTAL** | | | | | | | | | | | | | | | | | | **4** | **0** | **6,518** | **19,401** | **18,405** | **0** | |
| Main Pit Dump - EOM | R1-EOM | 1284 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 78 | 29 | 61,391 | 60,905 | 57,780 | 0 | |
| Main Pit Dump - EOM | R6 | 203 | 21 | 1.5 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 82.7 | 44.3 | 970.5 | 585.5 | 0.1 | 29 | 9 | 16,786 | 13,481 | 12,789 | 0 | |
| Main Pit Dump - EOM | R7 | 176 | 14 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 41.7 | 29.5 | 1395.1 | 841.6 | 0.0 | 9 | 3 | 7,330 | 7,792 | 7,392 | 0 | |
| Main Pit Dump - EOM | R8 | 170 | 11 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 25.7 | 23.2 | 1731.2 | 1044.4 | 0.0 | 4 | 2 | 4,371 | 5,913 | 5,610 | 0 | |
| Main Pit Dump - EOM | R9 | 355 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 21 | 8 | 16,973 | 16,839 | 15,975 | 0 | |
| **Main Pit Dump - EOM** | **TOTAL** | | | | | | | | | | | | | | | | | | **141** | **51** | **106,852** | **104,931** | **99,546** | **0** | |
| Ridgetop South Backfill Dum | R1 | 257 | 15 | 1.3 | 3 | 17 | Yes | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 59.5 | 39.9 | 1065.8 | 643.0 | 0.1 | 24 | 0 | 15,287 | 15,371 | 14,582 | 6,001 | |
| Ridgetop South Backfill Dum | R2 | 253 | 10 | 1.3 | 3 | 0 | No | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 5 | 0 | 5,376 | 8,001 | 7,590 | 0 | |
| Ridgetop South Backfill Dum | R3 | 200 | 10 | 1.3 | 3 | 0 | No | 0 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 4 | 0 | 4,250 | 6,325 | 6,000 | 0 | |
| **Ridgetop Waste Dump** | **TOTAL** | | | | | | | | | | | | | | | | | | **32** | **0** | **24,913** | **29,696** | **28,172** | **6,001** | |
| Ridgetop Waste Dump | R1 | 919 | 20 | 1.3 | 3 | 17 | Yes | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 105.7 | 53.2 | 823.9 | 497.0 | 0.2 | 196 | 56 | 97,182 | 73,285 | 69,524 | 28,609 | |
| Ridgetop Waste Dump | R2 | 1183 | 15 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 47.8 | 31.6 | 1311.6 | 791.2 | 0.1 | 71 | 27 | 56,562 | 56,115 | 53,235 | 0 | |
| Ridgetop Waste Dump | R3 | 1495 | 10 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 28 | 16 | 31,769 | 47,276 | 44,850 | 0 | |
| Ridgetop Waste Dump | R4 | 1265 | 10 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 24 | 13 | 26,881 | 40,003 | 37,950 | 0 | |
| Ridgetop Waste Dump | R5 | 203 | 10 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 21.3 | 21.1 | 1885.4 | 1137.4 | 0.0 | 4 | 2 | 4,314 | 6,419 | 6,090 | 0 | |
| Ridgetop Waste Dump | R6 | 1530 | 13 | 1.3 | 3 | 0 | No | 0.5 | D10 | Waste Rock (M | Rock, ripped or | Placed | No | 35.9 | 27.4 | 1490.8 | 899.4 | 0.0 | 61 | 26 | 54,946 | 62,898 | 59,670 | 0 | |
| **Ridgetop Waste Dump** | **TOTAL** | | | | | | | | | | | | | | | | | | **383** | **140** | **271,654** | **285,996** | **271,319** | **28,609** | |

**Notes:**
1. Regrading productivity calculations/details are provided in below (spreadsheet).
2. A positive grade indicates the toe is being extended downward; a negative valley indicates the dump toe is moving uphill.
2. Bank materials are insitu, natural soils. Placed are materials that have been placed and compacted and are generally denser than Bank/In-situ materials. See densities and bulking factors below (spreadsheet). **For Waste Rock - Use 'Placed"**.

## B: Flat Area Tertiary Catchments

| | Dimensions | | | | Dozing Conditions | | | | Calculated Quantities | | | | | | | Total Quantities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility | Total Flat Area ($m^2$) | Maximum Tertiary Catchment Area ($m^2$) | Avg. Final Slope (%) | Length of dozing direction over-ride (m) | Dozer Size | Material Type | Dozing Condition | Bank or Placed? (See note 3) | Number of catchments | Catchment Length (in dozing direction) (m) | Average Regrade Push Distance (m) | Unfactored Dozer Productivity ($Lm^3$/hr) | Factored Dozer Productivity ($Bm^3$/hr) | Cut Volume Per Catchment ($Bm^3$) | Time to complete 1 catchment (hrs) | **Total Time Required (Hrs)** | **Avg. Regrade Productivity ($m^2$/hr)** | **Comments/Notes** |
| A118 Backfill dump (2018) | 41,899 | 15,000 | 3% | 50 | D10 | Sand & gravel | Normal | Placed | 3 | 50.0 | 33.3 | 1251.2 | 560.6 | 2,813 | 5.0 | 14 | 2,990 | |
| A118 Backfill dump (EOM) | 50,033 | 15,000 | 3% | 50 | D10 | Sand & gravel | Normal | Placed | 3 | 50.0 | 33.3 | 1251.2 | 560.6 | 2,813 | 5.0 | 17 | 2,990 | |
| Camp Area | 20,626 | 15,000 | 3% | 50 | D10 | Sand & gravel | Normal | Placed | 1 | 50.0 | 33.3 | 1251.2 | 560.6 | 2,813 | 5.0 | 7 | 2,990 | |
| Crusher Area | 26,964 | 15,000 | 3% | 50 | D10 | Sand & gravel | Normal | Placed | 2 | 50.0 | 33.3 | 1251.2 | 560.6 | 2,813 | 5.0 | 9 | 2,990 | |
| DSTSF | 0 | 15,000 | 1% | | D10 | Earth, moist | Normal | Placed | 0 | 122.5 | 81.6 | 561.2 | 241.3 | 2,296 | 9.5 | 0 | #DIV/0! | |
| Explosive Plant/Storage area | 55,113 | 15,000 | 3% | 60 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 4 | 60.0 | 40.0 | 1062.8 | 418.8 | 3,375 | 8.1 | 30 | 1,861 | |
| Fuel Storage Area | 8,400 | 15,000 | 3% | 60 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 1 | 60.0 | 40.0 | 1062.8 | 418.8 | 3,375 | 8.1 | 5 | 1,861 | |
| Ice Rich Overburden Dump | 0 | 15,000 | 3% | 80 | D10 | Earth, moist | Normal | Placed | 0 | 80.0 | 53.3 | 821.5 | 337.4 | 4,500 | 13.3 | 0 | #DIV/0! | |
| IROD Laydown | 18,106 | 15,000 | 3% | 80 | D10 | Sand & gravel | Normal | Placed | 1 | 80.0 | 53.3 | 821.5 | 368.1 | 4,500 | 12.2 | 15 | 1,227 | |
| Main Dump | 90,055 | 15,000 | 3% | | D10 | Waste Rock ( | Hard to cut; fro | Placed | 6 | 122.5 | 81.6 | 561.2 | 221.1 | 6,889 | 31.2 | 187 | 481 | Total Flat Area was reduced by 13.5 ha (flat area at the top of the MWDE) that is being constructed at a 2% grade during ops. |
| Main Dump Wrap | 16,446 | 15,000 | 3% | 50 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 1 | 50.0 | 33.3 | 1251.2 | 493.0 | 2,813 | 5.7 | 6 | 2,629 | |
| Main Pit Dump (Yr 0) | 90,540 | 15,000 | 3% | 70 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 6 | 70.0 | 46.7 | 925.8 | 364.8 | 3,938 | 10.8 | 65 | 1,390 | |
| Main Pit Dump (EOM) | #REF! | 15,000 | 3% | 70 | D10 | Waste Rock ( | Hard to cut; fro | Placed | #REF! | 70.0 | 46.7 | 925.8 | 364.8 | 3,938 | 10.8 | #REF! | #REF! | |
| Mill Area | 42,365 | 15,000 | 3% | 100 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 3 | 100.0 | 66.7 | 672.8 | 265.1 | 5,625 | 21.2 | 60 | 707 | |
| MVFE Stage 1 and 2 | 114,853 | 15,000 | 3% | 100 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 8 | 100.0 | 66.7 | 672.8 | 265.1 | 5,625 | 21.2 | 162 | 707 | |
| Minto South Portal | 62,765 | 15,000 | 3% | 75 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 4 | 75.0 | 50.0 | 870.4 | 343.0 | 4,219 | 12.3 | 51 | 1,219 | |
| Ore Stockpile Area | 139,307 | 15,000 | 3% | | D10 | Waste Rock ( | Hard to cut; fro | Placed | 9 | 122.5 | 81.6 | 561.2 | 221.1 | 6,889 | 31.2 | 289 | 481 | |
| Pelly Laydown | 51,710 | 15,000 | 3% | | D10 | Waste Rock ( | Hard to cut; fro | Placed | 3 | 122.5 | 81.6 | 561.2 | 221.1 | 6,889 | 31.2 | 107 | 481 | |
| Reclamation OVB Dump | 297,857 | 15,000 | 3% | | D10 | Earth, moist | Normal | Placed | 20 | 122.5 | 81.6 | 561.2 | 230.5 | 6,889 | 29.9 | 594 | 502 | |
| Ridgetop South Backfill Dum | 8,491 | 15,000 | 3% | | D10 | Earth, moist | Normal | Placed | 1 | 122.5 | 81.6 | 561.2 | 230.5 | 6,889 | 29.9 | 17 | 502 | |
| Ridgetop Waste Dump | 44,126 | 15,000 | 3% | | D10 | Earth, moist | Normal | Placed | 3 | 122.5 | 81.6 | 561.2 | 230.5 | 6,889 | 29.9 | 88 | 502 | |
| SWD - High Grade Waste | 15,583 | 15,000 | 3% | | D10 | Earth, moist | Normal | Placed | 1 | 122.5 | 81.6 | 561.2 | 230.5 | 6,889 | 29.9 | 31 | 502 | |
| W15 Sump Area | 9,484 | 15,000 | 3% | 80 | D10 | Waste Rock ( | Hard to cut; fro | Placed | 1 | 80.0 | 53.3 | 821.5 | 323.7 | 4,500 | 13.9 | 9 | 1,079 | |
| | | | | | | | | | | | | | | | | | | |

**Notes:**
1. Regrading productivity calculations/details are provided in below (spreadsheet).
2. Productivity calculations assumes the dozer is pushing uphill
3. Dozer pushing distance calculations assume the tertiary catchments are approximately square, unless the 'length of dozing direction' user over-ride is used.
4. Bank materials are insitu, natural soils. Placed are materials that have been placed and compacted and are generally denser than Bank/In-situ materials (See densities and bulking factors below). **For Waste Rock - Use 'Placed"**.

## C: Miscellaneous Regrading

| Facility | Volume to Push ($m^3$) | Avg. Grade (%) | Dozer Size | Material Type | Dozing Condition | Bank or Placed? (See note 3) | Average Regrade Push Distance (m) | Unfactored Dozer Productivity ($Lm^3$/hr) | Factored Dozer Productivity ($Bm^3$/hr) | **Total Time Required (Hrs)** | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mill Pond Backfilling | 7,088 | 0% | D10 | Waste Rock ( | Hard to cut, fr | Placed | 50.0 | 870.4 | 367.0 | **19** | Assumes material pushed from the north (crusher area) |
| SWD Cover placement on st | 0 | 20% | D10 | Earth, moist | Loose Stockp | Placed | 40.0 | 1062.8 | 315.4 | **0** | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

**Notes:**
1. Regrading productivity calculations/details are provided in below (spreadsheet).
2. Productivity calculations assumes the dozer is pushing uphill
3. Dozer pushing distance calculations assume the tertiary catchments are approximately square, unless the 'length of dozing direction' user over-ride is used.
4. Bank materials are insitu, natural soils. Placed are materials that have been placed and compacted and are generally denser than Bank/In-situ materials (See densities and bulking factors below). **For Waste Rock - Use 'Placed"**.

# Worksheet 29 - Revegetation Prescriptions

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## A: Tractor-Applied Seed Mixes

### Seed Mix 1 - DRY AREA SEED MIX

| Item | Target Application Rate (kg/ha) | Over-application Allowance (%) | Applied Rate (kg/ha) | Unit Cost ($/kg) | Item Cost ($/ha) | Comment |
|---|---|---|---|---|---|---|
| Seed Mix | 30 | | 45 | $16.12 | $725.22 | |
| Fertilizer | 200 | 25% | 250 | $1.12 | $280.50 | |
| Mulch | 0 | 0% | 0 | $1.02 | | |
| Tackifier | 0 | 0% | 0 | $3.69 | | |
| **TOTAL SEED MIX COST PER HA:** | | | | | **$1,005.72** | |

### Seed Mix 2 - WET AREA SEED MIX

| Item | Target Application Rate (kg/ha) | Over-application Allowance (%) | Applied Rate (kg/ha) | Unit Cost ($/kg) | Item Cost ($/ha) | Comment |
|---|---|---|---|---|---|---|
| Seed Mix | 30 | | 45 | $16.12 | $725.22 | |
| Fertilizer | 200 | 25% | 250 | $1.12 | $280.50 | |
| Mulch | 0 | 0% | 0 | $1.02 | $0.00 | |
| Tackifier | 0 | 0% | 0 | $3.69 | $0.00 | |
| **TOTAL SEED MIX COST PER HA:** | | | | | **$1,005.72** | |

## B: Tree Planting

| Item | Target Application Rate (stem/ha) | Over-application Allowance (%) | Applied Rate (kg/ha) | Unit Cost ($/kg) | Item Cost ($/ha) | Comment |
|---|---|---|---|---|---|---|
| Trees | Seedlings per ha | | | | | |
| Tree seedlings | 1,000 | 0% | 1,000 | | | Target application rates from Closure Plan |
| Subtotal - Seed Mix | 1000 | | 1000 | $0.39 | $388 | |
| Fertilizer | 1000 | 0% | 1000 | $0.08 | $82.11 | |
| **TOTAL TREE PLANTING COST PER HA:** | | | | | **$470** | |

# Worksheet 30-Road Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dv**\\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\\040_AutoCAD\1CM002-45_ClosureQuantities.dwg

## A: Exploration Roads

| | | Road Parameters | | | | | | Safety Berms | | | | Reclamation Prescription | | | | X-Section Quantities | | | | Total Quantities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Description | Length (m) | Width (at crest) (m) | Average Fill Height (m) | Number of slopes to regrade (0, 1 or 2) | Existing Side Slope Angle (H:1V) | Final Side-Slope Angle (H:1V) | Number of Berms (0, 1 or 2) | Berm Height (m) | Berm Side-Slope Angle (H:1V) | Berm Crest Width (m) | Dozer Size | Scarify (y/n) | Growth Media Thickness (m) | Revegetate (y/n) | Berm Volume (1-side) ($m^3/m$) | Regrade Cut Volume ($m^3/m$) | Average Regrade Push Distance (m) | Factored Dozer Productivity (m/hr) | Scarification Area ($m^2$) | Cover Volume ($Cm^3$) | Revegetation Area (ha) | Regrade Hours | Comments/Notes |
| Airstrip East | Area east of airstrip | 4581 | 3 | | 0 | 1 | 3 | 0 | 0 | 0 | 0 | | Yes | 0 | Yes | 0.0 | 0.0 | 0.0 | #N/A | 13,743 | 0 | 1.37 | 0.0 | |
| Airstrip West | Area west of airstrip | 4299 | 3 | | 0 | 1 | 3 | 0 | 0 | 0 | 0 | | Yes | 0 | Yes | 0.0 | 0.0 | 0.0 | #N/A | 12,897 | 0 | 1.29 | 0.0 | |
| Ridgetop | | 4252 | 3 | | 0 | 1 | 3 | 0 | 0 | 0 | 0 | | Yes | 0 | Yes | 0.0 | 0.0 | 0.0 | #N/A | 12,756 | 0 | 1.28 | 0.0 | |
| North | North of Main Pit | 4963 | 3 | | 0 | 1 | 3 | 0 | 0 | 0 | 0 | | Yes | 0 | Yes | 0.0 | 0.0 | 0.0 | #N/A | 14,889 | 0 | 1.49 | 0.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| **TOTALS** | | | | | | | | | | | | | | | | | | | | **54,285** | **0** | **5** | **0** | |

**Notes:**
1. Dozer regrading productivity calculations details are provided in the "reslope" worksheet.
2. If a side slope is not regraded, it is assumed that it is not revegetated, and no cover is placed.

## B: Access Roads

| | | Road Parameters | | | | | | Safety Berms | | | | Reclamation Prescription | | | | X-Section Quantities | | | | Total Quantities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Description | Length (m) | Width (at crest) (m) | Average Fill Height (m) | Number of slopes to regrade (0, 1 or 2) | Existing Side Slope Angle (H:1V) | Final Side-Slope Angle (H:1V) | Number of Berms (0, 1 or 2) | Berm Height (m) | Berm Side-Slope Angle (H:1V) | Berm Crest Width (m) | Dozer Size | Scarify (y/n) | Growth Media Thickness (m) | Revegetate (y/n) | Berm Volume (1-side) ($m^3/m$) | Regrade Cut Volume ($m^3/m$) | Average Regrade Push Distance (m) | Factored Dozer Productivity (m/hr) | Scarification Area ($m^2$) | Cover Volume ($Cm^3$) | Revegetation Area (ha) | Regrade Hours | Comments/Notes |
| Airstrip | Airport Access Road | 968 | 14 | 1.5 | 2 | 1.3 | 3 | 2 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 3.2 | 3.2 | 266.0 | 13,552 | 0 | 2.27 | 3.6 | |
| | Betw. Landfill/waste storage | 236 | 10 | 1.5 | 0 | 1.3 | 3 | 1 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 1.3 | 3.2 | 648.8 | 2,360 | 0 | 0.24 | 0.4 | |
| | Old Exploration camp road | 460 | 10 | 1.5 | 0 | 1.3 | 3 | 1 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 1.3 | 3.2 | 648.8 | 4,600 | 0 | 0.46 | 0.7 | |
| Camp | 2 Access Roads | 238 | 14 | 1.5 | 2 | 1.3 | 3 | 2 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 3.2 | 3.2 | 266.0 | 3,332 | 0 | 0.56 | 0.9 | |
| Explosives | Roads between explosive plant | 1633 | 10 | 2 | 1 | 1.3 | 3 | 1 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 1.7 | 4.2 | 501.9 | 16,330 | 0 | 2.67 | 3.3 | |
| IROD Laydown | Road between yard areas | 703 | 10 | 0 | 0 | 1.3 | 3 | 0 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 0.0 | 0.0 | #DIV/0! | 7,030 | 0 | 0.70 | 0.0 | |
| W15 Laydown | 2 "F" shaped roads | 388 | 14 | 0 | 1 | 1.3 | 3 | 1 | 1 | 1.3 | 0 | D8 | Yes | 0 | Yes | 1.3 | 1.3 | 0.0 | 648.8 | 5,432 | 0 | 0.54 | 0.6 | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| **TOTALS** | | | | | | | | | | | | | | | | | | | | **52,636** | **0** | **7** | **9** | |

**Notes:**
1. Dozer regrading productivity calculations details are provided in the "reslope" worksheet.
2. If a side slope is not regraded, it is assumed that it is not revegetated, and no cover is placed.

## C: Haul Roads

| | | Road Parameters | | | | | | Safety Berms | | | | Reclamation Prescription | | | | X-Section Quantities | | | | Total Quantities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Description | Length (m) | Width (at crest) (m) | Average Fill Height (m) | Number of slopes to regrade (0, 1 or 2) | Existing Side Slope Angle (H:1V) | Final Side-Slope Angle (H:1V) | Number of Berms (0, 1 or 2) | Berm Height (m) | Berm Side-Slope Angle (H:1V) | Berm Crest Width (m) | Dozer Size | Scarify (y/n) | Growth Media Thickness (m) | Revegetate (y/n) | Berm Volume (1-side) ($m^3/m$) | Regrade Cut Volume ($m^3/m$) | Average Regrade Push Distance (m) | Factored Dozer Productivity (m/hr) | Scarification Area ($m^2$) | Cover Volume ($Cm^3$) | Revegetation Area (ha) | Regrade Hours | Comments/Notes |
| Main Pit | Mill to Main Dump | 1193 | 28 | 1.5 | 0 | 1.3 | 3 | 1 | 1.5 | 1.3 | 0 | D8 | Y | 0 | Yes | 2.9 | 2.9 | 3.2 | 288.3 | 33,404 | 0 | 3.34 | 4.1 | |
| Area 118 | Area 118 Backfill Road | 1060 | 28 | 1.5 | 2 | 1.3 | 3 | 2 | 1.5 | 1.3 | 0 | D8 | Y | 0 | Yes | 2.9 | 6.7 | 3.2 | 125.8 | 29,680 | 0 | 3.97 | 8.4 | |
| Minto North Hai | MWDE to Minto North | 1000 | 28 | 1.5 | 2 | 1.3 | 3 | 2 | 1.5 | 1.3 | 0 | D8 | Y | 0 | Yes | 2.9 | 6.7 | 3.2 | 125.8 | 28,000 | 0 | 3.75 | 8.0 | |
| TDD Road | Area costed as WR dump | | | | | | | | | | | | | | | 0.0 | | | | 0 | 0 | 0.00 | 0.0 | Area costed as WR Dump |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| **TOTALS** | | | | | | | | | | | | | | | | | | | | **91,084** | **0** | **11** | **21** | |

**Notes:**
1. Dozer regrading productivity calculations details are provided in the "reslope" worksheet.
2. If a side slope is not regraded, it is assumed that it is not revegetated, and no cover is placed.
3. Most haul road costs are included within their respective areas.

## D: Culvert Removal

| | | Input Parameters | | | | | | | Total Quantities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Description | Qnty | Culvert length (m) | Culvert Diameter (m) | Average Excavation Depth (m) | Excavation Side-Slope (H:1V) | Excavation Base Width (m) | Mobilization time (hrs) | Mobilization/Demobilization Hours | Excavation Volume (BCM) | Demolition Volume (LCM) | Comments/Notes |
| Mill Water Pond | Upstream Culvert | 1 | 210 | 1.4 | 4 | 2 | 2 | 0 | 1.0 | 8,400 | 69 | Average excavation depth assumed |
| | Tailings line to Main Pit | 1 | 38 | 1 | 4 | 2 | 2 | 0 | 0.0 | 1,520 | 9 | diameter assumed |
| | Reclaim line culvert by ore stockpile | 1 | 35 | 1 | 2 | 2 | 2 | 0 | 0.0 | 420 | 8 | diameter assumed |
| Mill | Tailings line culverts between confluence area and mill | 4 | 50 | 1 | 2 | 2 | 2 | 0 | 0.0 | 2,400 | 12 | diameter assumed |
| | Culverts between mill and main access road | 2 | 50 | 1 | 2 | 2 | 2 | 0 | 0.0 | 1,200 | 12 | diameter assumed |
| Area 2 | Tailings discharge culvert by Area 2 pit | **1** | 86 | 1 | 2 | 2 | 2 | 0 | 1.0 | 1,032 | 20 | diameter assumed |
| | Culvert for water line between Main and Area 2 pit | **1** | 54 | 1 | 2 | 2 | 2 | 0 | 0.0 | 648 | 13 | diameter assumed |
| Pelly laydown | | **1** | 200 | 1 | 2 | 2 | 2 | 0 | 1.0 | 2,400 | 47 | diameter assumed |
| **TOTAL** | | | | | | | | | **3.0** | **18020.0** | **190.1** | |

**Notes:**
1. Demolition volume assumes culvert is flattened and then has an average height of 15 cm.

# Worksheet 31 - Surface Infrastructure Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans):** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\!040_AutoCAD\1CM002-45_ClosureQuantities.dwg
**Layer:** ~Pipelines

## A. Conveyance Pipelines

**Calculation Inputs**
Pipe Debris Bulking Factor: 1.30

| | | | | | Pipeline Details | | | | | Calculated Quantities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | HDPE Pipe Demolition Lengths (m) | | | | |
| Line | Type | Details | From | To | Length (m) | Pipe Diameter (inches) | Total Diameter (incl. insulation) (inch) | Pipe Diameter Category | Lines to flush | 0.75 to 4 inch | 6 to 8 inches | 10 to 18 inches | 20 to 36 inches | Pipe Debris Volume (Lm3) | Comments/Notes |
| 8" Insulated tailings lines | Tailings | 8" Insulated discharge | varies | varies | 2600 | 8 | 12 | 6 to 8 inch | 1 | 0 | 2,600 | 0 | 0 | 247 | |
| 4" HDPE lines | Tailings | | | | 2800 | 4 | 8 | 6 to 8 inch | 1 | 0 | 2,800 | 0 | 0 | 118 | |
| 4" Insulated HDPE lines | | | | | 1400 | 4 | 4 | 0.75 to 4 inch | 1 | 1,400 | 0 | 0 | 0 | 15 | |
| 4" Steel lines, heat traced | | | | | 450 | 4 | 4 | 0.75 to 4 inch | 1 | 450 | 0 | 0 | 0 | 4 | |
| 8" HDPE | | | | | 1400 | 8 | 8 | 6 to 8 inch | 1 | 0 | 1,400 | 0 | 0 | 45 | |
| 3: HDPE | | | | | 600 | 3 | 3 | 0.75 to 4 inch | 1 | 600 | 0 | 0 | 0 | 3 | |
| 10" Steel | | | | | 240 | 10 | 10 | 10 to 18 inch | 1 | 0 | 0 | 240 | 0 | 12 | |
| 16" HDPE | | | | | 1500 | 16 | 16 | 10 to 18 inch | 1 | 0 | 0 | 1,500 | 0 | 195 | |
| 24" HDPE | | | | | 885 | 24 | 24 | 20 to 36 inch | 0 | 0 | 0 | 0 | 885 | 0 | |
| **TOTALS:** | | | | | | | | | 8 | **2,450** | **6,800** | **1,740** | **885** | **638** | |

**Notes:**
Updated to match Table 6.1 in RCP

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## B. Pipeline Infrastructure/Equipment

| Area | Details | Quantity | Estimated Weight (kg) | Total Weight (kg) | Comments/Notes |
|---|---|---|---|---|---|
| **Pumps** | | **15** | | | |
| Main Pit | Reclaim Pump | 6 | 100 | 600 | |
| Area 2 | Dewatering Pumps | 1 | 500 | 500 | |
| Misc Pumps | Tsynami | 7 | 200 | 1400 | |
| W15 Sump | W15 Pump | 1 | 200 | 200 | |
| **Barges/Misc. Equipment** | | **2** | | | |
| Main Pit | Reclaim Barge | 1 | 2000 | 2000 | |
| Main Pit | Power Shack | 1 | 2000 | 2000 | |
| TOTALS: | | | | **6700** | |

**Notes:**
1. Weights of pumping equipment are assumed
2. Equipment is assumed to be placed in semi-trailers for transport to Whitehorse for disposal/salvage.

## C. Power Line and Substation Removal

| | | | | Off-site Disposal Trips | | | | |
|---|---|---|---|---|---|---|---|---|
| Line | Power Line Length (km) | Number of power poles | Number of Transformers | Power Pole Trips | Power Line Reels | Transformer/ Powerline Trips | TOTAL TRIPS | Comments/Notes |
| Mill to Water Storage Pond | 1.58 | 30 | 2 | 1.2 | 5.2 | 1.5 | | |
| Mill to Minto South Portal | 1.58 | 30 | 2 | 1.2 | 5.2 | 1.5 | | |
| | | | | | | | | |
| **TOTALS:** | **3.16** | **60** | **4** | **3** | **11** | **4** | **18** | |

**Notes:**
1. Power line lengths and number of poles provide by Minto in file "powerpoles.dxf"

# Worksheet 32- Underground

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans):** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\!040_AutoCAD\1CM002-45_ClosureQuantities.dwg

## A: Existing Portals

| | Inputs | | | | | | | Calculated Quantities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Height (m) | Width (m) | Backfill Plug Thickness (m) | Backfill height above portal opening (m) | Backfill width outside of portal (m) | Backfill outside side slope (H:1V) | Relocation Cost Code for LHD | Underground Plug Volume ($m^3$) | Plug Volume in Front of Portal (m3) | Total Plug Volume ($m^3$) | Backfill LHD Productivity ($m^3$/hr) | Small Dozer Hours | Comments/Notes |
| **Existing Portals** | | | | | | | | | | | | | |
| Minto South Portal | 5 | 7 | 15 | 5 | 12 | 3 | R.001 | 788 | 1,800 | 2,588 | 159 | 16 | |
| Minto North Portal | 5 | 7 | 15 | 5 | 12 | 3 | R.001 | 788 | 1,800 | 2,588 | 159 | 16 | |
| Minto North Portal Egress | 5 | 7 | 15 | 5 | 12 | 3 | R.001 | 788 | 1,800 | 2,588 | 159 | 16 | |
| **Future Portals** | | | | | | | | | | | | | |
| | | | | | | | | 0 | 0 | 0 | #N/A | #N/A | |

**Notes:**

## B: Shafts and Vent Raises

| | Inputs | | | | | | | | Calculated Quantities | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility | Length (m) | Width (m) | Depth to competent material (m) | Concrete Cap Length (m) | Concrete Cap Width (m) | Concrete Slab Thickness (m) | Concrete Slab rebar layers | Backfill Thickness over cap (m) | Concrete Cap Perimeter (m) | Excavation Volume (m3) | Vent Raise Pipe Length (m) | I-beams required (W 250x33) | Total I-Beam Length (m) | Concrete Ring Wall Formwork (m2) | Concrete Ring Wall Rebar Length (m) | Ringwall Dowell Length (m) | Steel Decking (q-deck) (m2) | Total Rebar Length (m) | Total Concrete Volume (m3) | Backfill Volume (m3) | Comments/Notes |
| **Existing shafts and vent raises** | | | | | | | | | | | | | | | | | | | | | |
| Area 118 Vent Raise | 3 | 3 | 0.5 | 4 | 4 | 0.45 | 2 | 1 | 16 | 4.0 | 4 | 2 | 8 | 8 | 16 | 16 | 16 | 32 | 8.6 | 25 | |
| Minto East | 3 | 3 | 0.5 | 4 | 4 | 0.45 | 2 | 1 | 16 | 4.0 | 4 | 2 | 8 | 8 | 6 | 8 | 16 | 14 | 8.6 | 25 | Assumed same dimentions as Area 118 |
| Minto East 2 | 3 | 3 | 0.5 | 4 | 4 | 0.45 | 2 | 1 | 16 | 4.0 | 4 | 2 | 8 | 8 | 16 | 0 | 16 | 16 | 8.6 | 25 | |
| **Future shafts and vent raises** | | | | | | | | | | | | | | | | | | | | | |
| Minto South | | | | | | | | | | | | | | | | | | | | | |
| Wildfire | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |

## CALCULATION INPUTS

**Vent Raise design**

| | |
|---|---|
| I-Beam spacing (m): | 2 |
| Concrete ring wall height (m): | 0.5 |
| Concrete ring wall rebar spacing (into bedrock) (m): | 1 |
| Concrete ring wall rebar (into bedrock) length (m): | 1 |
| Ringwall dowel spacing at top of wall (m): | 0.4 |
| Ringwall dowel length (m): | 0.4 |
| Concrete slab rebar spacing: | 0.2 |

# Worksheet 33 - Waste Disposal

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans):** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\I040_AutoCAD\1CM002-45_ClosureQuantities.dwg

## A: Reagents

| | | Inputs | | | | | Calculated Quantities | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **Reagents** | Solid/Liquid | Mass of Solid (kg) | Volume of Liquid ($m^3$) | Container Type | Disposal Fee (per container) | Number of drums | Number of tote bags | Number of Solid Bulk Carriers | Number of Small Tankers | Number of Large Tankers | Loading Time (hrs) | Trips Required - 55 Gal. Drums | Trips Required - Tote Bags | Disposal Fees ($) | **TOTAL TRIPS** | Comments/Notes |
| Mill Area | PAX | Solid | 2,000 | | 55 gal. drum | $0 | 7 | 0 | 0 | 0 | 0 | 1 | 0.1 | 0.0 | $0 | | |
| | MIBC | Solid | 3,652 | | 55 gal. drum | $0 | 12 | 0 | 0 | 0 | 0 | 2 | 0.1 | 0.0 | $0 | | |
| | MagnaFlocc 338 | Solid | 5,000 | | 55 gal. drum | $0 | 17 | 0 | 0 | 0 | 0 | 3 | 0.2 | 0.0 | $0 | | |
| | MagnaFlocc 155 | Solid | 500 | | 55 gal. drum | $0 | 2 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | $0 | | |
| | Filter cleaning agent (HNC | Liquid | | 3.20 | Liquid - 2,200 gal. tank | $0 | 0 | 0 | 0 | 1 | 0 | 4 | 0.0 | 0.0 | $0 | | |
| Water Treatment Plant | Reagents | Solid | 20,000 | | Tote bags | $0 | 0 | 15 | 0 | 0 | 0 | 8 | 0.0 | 0.4 | $0 | | Assumes 15 totes remaining |
| MVF Reagent Tent | Reagents | Solid | 20,000 | | Tote bags | $0 | 0 | 15 | 0 | 0 | 0 | 8 | 0.0 | 0.4 | $0 | | Assumes 15 totes |
| | | | | | | | | | | | | | | | | | |
| **TOTAL** | **TOTAL** | | | | | | 38 | 30 | **0** | **1** | **0** | **25** | **0.4** | **0.9** | **$0** | **2.2** | |

**Notes:**
1. See details on container types below
1. Reagents assumed to be returned to supplier (no disposal fee)

## B: Hazardous Materials

| | | Inputs | | | | | Calculated Quantities | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **Description** | Solid/Liquid | Mass of Solid (kg) | Volume of Liquid ($m^3$) | Container Type | Disposal Fee (per container) | Number of drums | Number of tote bags | Number of Solid Bulk Carriers | Number of Small Tankers | Number of Large Tankers | Loading Time (hrs) | Trips Required - 55 Gal. Drums | Trips Required - Tote Bags | Disposal Fees ($) | **TOTAL TRIPS** | Comments/Notes |
| Mill Area | Misc. drums, oils, glycol & | Solid | 20,000 | | 55 gal. drum | $750 | 65 | 0 | 0 | 0 | 0 | 65 | 0.6 | 0.0 | $48,750 | | |
| Camp Area | Misc. oils, cleaning supplie | Solid | 100 | | 55 gal. drum | $750 | 1 | 0 | 0 | 0 | 0 | 1 | 0.0 | 0.0 | $750 | | |
| Fuel Farm Area | Misc. fuel containers/oil | Solid | 500 | | 55 gal. drum | $750 | 2 | 0 | 0 | 0 | 0 | 2 | 0.0 | 0.0 | $1,500 | | |
| Explosives Plant | Misc. explosive material | Solid | 2,000 | | Solid - Bulk | $0 | 0 | 0 | 1 | 0 | 0 | 4 | 0.0 | 0.0 | $0 | | Assumed |
| Airport Laydown | Misc. fuel containers/oil | Solid | 500 | | 55 gal. drum | $750 | 2 | 0 | 0 | 0 | 0 | 2 | 0.0 | 0.0 | $1,500 | | Assumed |
| Pelly Laydown | Misc. fuel containers/oil | Solid | 500 | | 55 gal. drum | $750 | 2 | 0 | 0 | 0 | 0 | 2 | 0.0 | 0.0 | $1,500 | | Assumed |
| Minto South Portal | Misc. fuel containers/oil | Solid | 500 | | 55 gal. drum | $750 | 2 | 0 | 0 | 0 | 0 | 2 | 0.0 | 0.0 | $1,500 | | Assumed |
| Airstrip Area | Recycling storage area ma | Solid | 3,000 | | 55 gal. drum | $750 | 10 | 0 | 0 | 0 | 0 | 10 | 0.1 | 0.0 | $7,500 | | Assumed |
| | | | | | | | | | | | | | | | | | |
| **TOTAL** | | | | | | | 84 | 0 | **1** | **0** | **0** | **88** | **0.8** | **0.0** | **$63,000** | **1.8** | |

**Notes:**
1. See details on container types below
2. Mill area parameters are assumed, and were adjusted to total $61,000 in the cost estimate to match a contractor quote from General waste management to MEL.

## C: Metal Contaminated Soils

| | | | Inputs | | | | Calculated Quantities | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **Description** | Disposal Location | Suspected Contaminated Area (m2) | Test Grid Spacing (m) | Assumed % Contaminated | Assumed Average Excavation Depth (m) | Delineation Test Pits Required | Confirmation Tests Required | Volume of Contaminated Soil (m3) | Comments/Notes |
| Crusher Area | Metal Contaminated Soils | UG | 19,661 | 10 | 50% | 0.3 | 197 | 197 | 2949 | Suspected area is near processing/tailings/concentrate buildings |
| Mill Area | Metal Contaminated Soils | UG | 19,822 | 10 | 50% | 0.3 | 198 | 198 | 2973 | Suspected area is near processing/tailings/concentrate buildings |
| | | | | | | | | | | |
| **TOTAL** | | | | | | | 395 | | 5922 | |

**Notes:**
1. During investigation program, 2 soil tests completed per grid location (1 near surface and 1 at depth)

## D: Hydrocarbon Contaminated Soils

| | | | Inputs | | | | Calculated Quantities | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Area** | **Suspected location** | Disposal Location | Suspected Contaminated Area (m2) | Test Grid Spacing (m) | Assumed % Contaminated | Assumed Average Excavation Depth (m) | Delineation Test Pits Required | Confirmation Tests Required | Volume of Contaminated Soil (m3) | Comments/Notes |
| Fuel Storage Area | near fueling areas | Landfarm | 1,644 | 10 | 15% | 1.0 | 16 | 16 | 247 | Entrance, fueling area, and near generators. |
| Mill area | near mechanic shop | Landfarm | 550 | 10 | 15% | 1.0 | 6 | 6 | 83 | |
| Airstrip | allowance | Landfarm | 500 | 10 | 15% | 1.0 | 5 | 5 | 75 | |
| Dundas area | allowance | Landfarm | 500 | 10 | 15% | 1.0 | 5 | 5 | 75 | |
| Pelly laydown | allowance | Landfarm | 1,644 | 10 | 15% | 1.0 | 16 | 16 | 247 | |
| | | | | | | | | | | |
| **TOTAL** | | | | | | | 48 | | 725.7 | |

**Notes:**
1. During investigation program, 2 soil tests completed per grid location (1 near surface and 1 at depth)

## E: Landfarm

| | | Inputs | | | | | | Calculated Quantities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Facility** | **Location** | Total Volume to be treated (m3) | Maximum thickness (m) | Containment berm height (m) | Liner Protection Layer thickness (m) | Mixing events per year | Years mixing required | Landfarm Area (m2) | Landfarm Length/Width (m) | Landfarm Perimeter Length (m) | Containment Berm Volume (m3) | Liner Area (m2) | Total Mixing Events | Comments/Notes |
| Existing Landfarm | Airstrip | 726 | | | | 4.0 | 3.0 | 4265 | | | | 4265 | 12 | Overall areas provided by Minto |
| | | | | | | | | | | | | | | |
| **TOTAL** | | | | | | | | 4265 | | 0 | 0 | | | |

**Notes:**
1. During investigation program, 2 soil tests completed per grid location (1 near surface and 1 at depth)

## F: Solid Waste Landfill

| | | Inputs | | | | | | Calculated Quantities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Facility** | **Location** | Total Demolition Waste to be stored (LCM) | Assumed Percentage of fill to be added to provide compaction | Maximum fill thickness (m) | Landfill Side slopes (H:1V) | Landfill base length (m) | Landfill cover thickness (m) | Compacted Waste Volume (CCM) | Fill Volume (CCM) | Total Required Landfill Volume (CCM) | Calculated Landfill Volume (CCM) | Landfill Cover Volume | Revegetation Area (ha) | Comments/Notes |
| Solid Waste Landfill | Airstrip | 12,920 | 30% | 5 | 4 | 73 | 0.6 | 11,235 | 3,371 | 14,606 | 14712 | 5024 | 0.55 | |
| | | | | | | | | | | | | | | |
| **TOTAL** | | | | | | | | | | | | | | |

**Notes:**
1. During investigation program, 2 soil tests completed per grid location (1 near surface and 1 at depth)

# Worksheet 34 - Water Conveyance/Storage Quantity Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

**References (dwgs/plans):** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\!040_AutoCAD\1CM002-45_ClosureQuantities.dwg
**Layer:** For secondary conveyance channel - "Drainage Paths"

## A: Primary Conveyance Channels

| | Channel Parameters | | | | | | | | | | | | | X-Section Quantities | | | | | Total Quantities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Length (m) | Channel Base Width, Bc (m) | Side Slope, z (:1) | Average Final Channel Depth, Df (m) | Flow depth including Freeboard, D (m) | Excavation Volume User Over-ride (BCM) | Rip-Rap Thickness (m) | Bedding Layer Thickness (m) | Geotextile Layers | Liner? (Y/N) | Geosynthetic Wastage | Geosynthetic Anchor Trench Allowance (m) | Average Excavation Depth (m) | Average Excavated Area ($m^2$) | Rip-Rap Area ($m^2$) | Bedding Layer Area ($m^2$) | Geotextile Length (m) | Liner Length (m) | Excavation Volume ($m^3$) | Rip-Rap Volume (CCM) | Bedding Layer Volume (CCM) | Geotextile Area ($m^2$) | Liner Area ($m^2$) | Comments/Notes |
| WSP Breach Channel Restoration (pilot channel | 250 | 2 | 2 | 2 | 1 | | 0.5 | 0.3 | 1 | No | 10% | 0.3 | 2.8 | 22.3 | 3.9 | 2.9 | 11.0 | 0.0 | 5,584 | 964 | 726 | 3,033 | 0 | |
| Channel A1 (W15 to Main Pit) | 83 | 10 | 2 | 10 | 1.5 | 40300 | 0.6 | 0 | 1 | No | 10% | 0.3 | n/a | 485.5 | 10.9 | 0.0 | 20.3 | 0.0 | 40,300 | 906 | 0 | 1,851 | 0 | 1CM002-042/Jan. 16. |
| Channel A2 | 159 | 10 | 2 | 1.5 | 1.5 | 0 | 0.4 | 0 | 1 | No | 10% | 0.3 | n/a | 0.0 | 7.1 | 0.0 | 19.3 | 0.0 | 0 | 1,126 | 0 | 3,373 | 0 | 1CM002-042/Jan. 16. |
| Channel A3 | 107 | 10 | 2 | 1.5 | 1.5 | 0 | 0.9 | 0 | 1 | No | 10% | 0.3 | n/a | 0.0 | 17.0 | 0.0 | 21.8 | 0.0 | 0 | 1,823 | 0 | 2,561 | 0 | 1CM002-042/Jan. 16. |
| **SUBTOTAL - Channel A** | | | | | | | | | | | | | | | | | | | 40,300 | 3,855 | 0 | 7,785 | | |
| Channel B1 (W35 to Area 2 Pit ) | 72 | 7 | 2 | 2 | 1.35 | | 0.4 | 0 | 1 | No | 10% | 0.3 | 2.4 | 28.8 | 5.6 | 0.0 | 15.6 | 0.0 | 2,072 | 404 | 0 | 1,237 | 0 | 1CM002-042 |
| Channel B2 | 52 | 7 | 2 | 2 | 1.23 | | 0.6 | 0 | 1 | No | 10% | 0.3 | 2.6 | 32.5 | 8.4 | 0.0 | 16.1 | 0.0 | 1,688 | 436 | 0 | 919 | 0 | 1CM002-042 |
| Channel B3 | 83 | 7 | 2 | 10 | 1 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 10.9 | 318.6 | 12.3 | 0.0 | 16.5 | 0.0 | 26,440 | 1,023 | 0 | 1,508 | 0 | 1CM002-042 |
| Channel B4 | 56 | 7 | 2 | 10 | 1 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 10.9 | 318.6 | 12.3 | 0.0 | 16.5 | 0.0 | 17,839 | 690 | 0 | 1,018 | 0 | 1CM002-042 |
| **SUBTOTAL - Channel B** | | | | | | | | | | | | | | | | | | | 48,038 | 2,554 | 0 | 4,682 | 0 | |
| Channel C (Main Pit to Main Access Road) | 182 | 7 | 2 | 3 | 1.4 | | 0.4 | 0 | 1 | No | 10% | 0.3 | 3.4 | 47.6 | 5.7 | 0.0 | 15.8 | 0.0 | 8,656 | 1,037 | 0 | 3,171 | 0 | 1CM002-042 |
| Channel D1 (Area 2 Pit to Main Pit Channel) | 160 | 7 | 2 | 4 | 2.1 | | 0.4 | 0 | 1 | No | 10% | 0.3 | 4.4 | 70.4 | 7.0 | 0.0 | 19.0 | 0.0 | 11,256 | 1,112 | 0 | 3,339 | 0 | 1CM002-042 |
| Channel D2 | 78 | 7 | 2 | 4 | 1.4 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 4.9 | 84.4 | 13.9 | 0.0 | 18.3 | 0.0 | 6,583 | 1,087 | 0 | 1,571 | 0 | 1CM002-042 |
| **SUBTOTAL - Channel D** | | | | | | | | | | | | | | | | | | | 17,840 | 2,199 | 0 | 4,910 | 0 | |
| Channel E1 (Mill area) | 278 | 7 | 2 | 2 | 2 | | 0.4 | 0 | 1 | No | 10% | 0.3 | 2.4 | 28.8 | 6.8 | 0.0 | 18.5 | 0.0 | 7,999 | 1,883 | 0 | 5,664 | 0 | 1CM002-042 |
| Channel E2 to E6 | 647 | 7 | 2 | 2 | 2 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 2.9 | 38.4 | 16.4 | 0.0 | 21.0 | 0.0 | 24,814 | 10,580 | 0 | 14,942 | 0 | 1CM002-042 |
| Channel E7 | 33 | 7 | 2 | 2 | 2 | | 1.2 | 0 | 1 | No | 10% | 0.3 | 3.2 | 44.7 | 22.7 | 0.0 | 22.5 | 0.0 | 1,475 | 749 | 0 | 816 | 0 | 1CM002-042 |
| Channel E8 | 46 | 7 | 2 | 2 | 2 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 2.9 | 38.4 | 16.4 | 0.0 | 21.0 | 0.0 | 1,764 | 752 | 0 | 1,062 | 0 | 1CM002-042 |
| Channel E9 | 150 | 7 | 2 | 2 | 2 | | 2 | 0 | 1 | No | 10% | 0.3 | 4 | 63.8 | 41.8 | 0.0 | 26.4 | 0.0 | 9,567 | 6,267 | 0 | 4,361 | 0 | 1CM002-042 |
| Channel E10 | 20 | 7 | 2 | 2 | 2 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 2.9 | 38.4 | 16.4 | 0.0 | 21.0 | 0.0 | 767 | 327 | 0 | 462 | 0 | 1CM002-042 |
| **SUBTOTAL - Channel E (SEE NOTE 3)** | | | | | | | | | | | | | | | | | | | 46,386 | 20,558 | 0 | 27,307 | 0 | |
| Tailings Diversion Ditch | 420 | 0 | 6 | 0.5 | 0.8 | 0 | 1.6 | 0 | 1 | No | 10% | 0.3 | n/a | 0.0 | 31.4 | 0.0 | 30.1 | 0.0 | 0 | 13,169 | 0 | 13,889 | 0 | 1CM002-042 |
| Mill Valley Fill Wetland conveyance channels | 160 | 4 | 2 | 1 | 1 | | 0 | 0.3 | 1 | Yes | 10% | 0.3 | 1.3 | 8.8 | 0.0 | 2.8 | 10.6 | 10.6 | 1,402 | 0 | 442 | 1,858 | 1,858 | 1CM002-042 |
| Minto Creek Wetland By-Pass Channel | 569 | 7 | 2 | 3 | 2 | | 0.6 | 0 | 1 | No | 10% | 0.3 | 3.6 | 52.1 | 10.5 | 0.0 | 19.5 | 0.0 | 29,668 | 5,950 | 0 | 12,212 | 0 | |
| Minto North Spillway | 250 | 7 | 2 | 3 | 1 | | 0.6 | 0 | 1 | No | 10% | 0.3 | 3.6 | 52.1 | 7.8 | 0.0 | 15.0 | 0.0 | 13,035 | 1,943 | 0 | 4,136 | 0 | Allowance |
| Ridgetop North Outlet Channel (to Minto Crk) | 290 | 3 | 2 | 2 | 1 | | 0.9 | 0 | 1 | No | 10% | 0.3 | 2.9 | 26.8 | 8.7 | 0.0 | 12.5 | 0.0 | 7,758 | 2,531 | 0 | 3,995 | 0 | |

**Notes:**
1. See channel drawing and parameter definitions below.
2. Channel A rip-rap thickness is a weighted average based on Jan. 16. 2018 design drawings.
3. 27,500 m3 of bulk fill required to form Channel E - this volume has been hardcoded into the cost estimate (A13.5). Volume was calculated in AutoCAD Civil3d

## B: Secondary Conveyance Channels

| | Channel Parameters | | | | | | | | | | X-Section Quantities | | | | Total Quantities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Length (m) | Channel Base Width, Bc (m) | Side Slope, z (:1) | Average Final Channel Depth, (m) | Rip-Rap Thickness (m) | Bedding Layer Thickness (m) | Geotextile Layers | Geotextile Wastage | Geosynthetic Anchor Trench Allowance (m) | Average Excavation Depth (m) | Average Excavated Area ($m^2$) | Rip-Rap Area ($m^2$) | Bedding Layer Area ($m^2$) | Geotextile Length (m) | Excavation Volume ($m^3$) | Rip-Rap Volume (CCM) | Bedding Layer Volume (CCM) | Geotextile Area ($m^2$) | Comments/Notes |
| **Southwest Dump** | | | | | | | | | | | | | | | | | | | |
| SWD SC1 - Shallow grade | 389 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 2,398 | 842 | 0 | 3,661 | See Note 1 |
| SWD SC3 - Shallow grade | 825 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 5,085 | 1,785 | 0 | 7,764 | |
| SWD SC4 - Shallow grade | 276 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 1,701 | 597 | 0 | 2,597 | |
| SWD SC5 - Shallow grade | 260 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 1,603 | 563 | 0 | 2,447 | |
| SWD SC1 - Steep grade | 21 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 171 | 78 | 53 | 225 | |
| SWD SC2 - Steep grade | 240 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 1,953 | 888 | 604 | 2,570 | |
| SWD SC3 - Steep grade | 225 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 1,831 | 832 | 566 | 2,409 | |
| SWD SC4 - Steep grade | 190 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 1,546 | 703 | 478 | 2,034 | |
| SWD SC5 - Steep grade | 140 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 1,139 | 518 | 352 | 1,499 | |
| **SUBTOTAL - South West Dump** | | | | | | | | | | | | | | | **17,427** | **6,806** | **2,054** | **25,206** | |
| **Main Waste Dump** | | | | | | | | | | | | | | | | | | | |
| MWD - Shallow grade | 1051 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 6,477 | 2,274 | 0 | 9,888 | |
| MWD - Steep grade | 490 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 3,986 | 1,812 | 1,233 | 5,244 | |
| **SUBTOTAL - Main Waste Dump** | | | | | | | | | | | | | | | **10,462** | **4,086** | **1,233** | **15,132** | |
| **Reclamation Overburden Dump** | | | | | | | | | | | | | | | | | | | |
| ROD - Shallow grade | 793 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 4,886 | 1,715 | 0 | 7,460 | |
| ROD - Steep grade | 370 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 3,007 | 1,367 | 930 | 3,956 | |
| **SUBTOTAL - Reclamation Overburden Dump** | | | | | | | | | | | | | | | **7,893** | **3,083** | **930** | **11,416** | |
| **Ridgetop Waste Dump** | | | | | | | | | | | | | | | | | | | |
| RWD - Shallow grade | 93 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 574 | 201 | 0 | 876 | |
| RWD - Steep grade | 43 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 353 | 161 | 109 | 465 | |
| **SUBTOTAL - Ridgetop Waste Dump** | | | | | | | | | | | | | | | **927** | **362** | **109** | **1,341** | |
| **Dry Stack Tailings Storage Facility and Mill Valley Fill Buttress (Stage 1 and 2)** | | | | | | | | | | | | | | | | | | | |
| DSTSF - Shallow grade | 692 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 4,263 | 1,497 | 0 | 6,509 | |
| MVFE - Shallow grade | 505 | 2 | 2 | 1 | 0.3 | 0 | 1 | 10% | 0.3 | 1.3 | 6.2 | 2.2 | 0.0 | 8.6 | 3,115 | 1,094 | 0 | 4,756 | |
| DSTSF - Steep grade | 322 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 2,623 | 1,193 | 812 | 3,452 | |
| MFVE - Steep grade | 236 | 2 | 2 | 0.6 | 0.6 | 0.3 | 1 | 10% | 0.3 | 1.5 | 8.1 | 3.7 | 2.5 | 9.7 | 1,917 | 872 | 593 | 2,522 | |
| **SUBTOTAL - DSTSF and MVFE** | | | | | | | | | | | | | | | **11,919** | **4,655** | **1,405** | **17,239** | |
| **TOTAL - Year 0 Estimate** | 7024 | | | | | | | | | | | | | | | | | | |
| **TOTAL - Peak Liability Estimate** | 7024 | | | | | | | | | | | | | | | | | | |

**Notes:**
1. SWD secondary channel lengths obtained from SRK project number 1CM002.031 (Progressive reclamation)
2. Channel lengths for all other dumps were based on SWD design scaled by area. 26.6 m of shallow sloped channel length per dump area (ha) were applied, and 12.4 m of steep sloped channel length area
3. 26.6 m of shallow sloped channel length per dump area (ha) was applied, and 12.4 m of steep sloped channel length per dump area (ha) was applied
4. Approx. dump areas used in the calculations are: SWD - 65.8 ha, MWD - 39.5 ha, ROD - 29.8 ha, DSTSF - 26 ha, and MVFE - 19 ha.

## C1: Construct New Ponds/Sediment Basins

| | Pond Parameters | | | | | | | | | | | | | | Total Quantities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Pond Base Length (m) | Channel Base Width, Bc (m) | Side Slope, z (:1) | Final Pond Depth, Df (m) | Protected depth including Freeboard, D (m) | Excavation Volume User Over-ride (BCM) | Rip-Rap Thickness (m) | Rip-Rap Volume User Over-ride (BCM) | Bedding Layer Thickness (m) | Geotextile Layers | Liner? (Y/N) | Geosynthetic Wastage | Geosynthetic Anchor Trench Allowance (m) | Excavation Depth (m) | Excavation Volume (BCM) | Rip-Rap Volume (CCM) | Bedding Layer Volume (CCM) | Geotextile Area ($m^2$) | Liner Area ($m^2$) | Comments/Notes |
| Stilling Basin at MVFE Stage 2 Toe | 15 | 5 | 2 | 2.5 | 2.5 | | 0 | 75 | 0.3 | 1 | No | 10% | 0.3 | 2.8 | 645 | 75.00 | 131 | 540 | 0 | Rip-rap assumes an area of 75m2 at both the inlet and outlet with a thickness of 0.5m |
| | | | | | | | | | | | | | | | | | | | | |

**Notes:**
1. See channel drawing and parameter definitions below.

## C2: Decommission Ponds/Sediment Basins

| | Pond Parameters | | | | | | | Calculations | | | Total Quantities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Base Length (m) | Base Width (m) | Pond Side Slope (:1) | Pond Depth (m) | Sediment Depth (m) | Water Depth (m) | Liner Bulking Factor (See note 1) | Top Length (m) | Top Width (m) | Liner X-Section Width (mid-pond) (m) | Backfill Volume (m3) | Water Volume ($m^3$) | Sediment Volume (BCM) | Liner Area ($m^2$) | Liner Debris Volume (LCM) | Source, Comments/Notes |
| Mill Water Pond | 43 | 2.5 | 4 | 5 | 0.5 | 4 | 10 | 83.0 | 42.5 | 43.7 | 7,088 | 4,366 | 101 | 3,630 | 54 | Pond to be Filled In; dimension source: 2011 Annual Review plan drawing |
| Sewage Lagoon at IROD Laydown | 35 | 25 | 3 | 3 | 0 | 0 | n/a | 53.0 | 43.0 | 44.0 | 4,488 | 0 | 0 | 2,331 | #VALUE! | No liner present - dimensions from AutoCAD |
| W15 Sump | | | | | | | 10 | 131.0 | 10.0 | 10.0 | | | | 1,310 | 20 | Liner Length from AutoCAD; width/depth assumed |
| Fuel Tank Farm | 45 | 30 | 1 | 2 | 0.45 | 0 | 10 | 49.0 | 34.0 | 35.7 | 3,008 | 0 | 623 | 1,747 | 26 | Farm dimensions from AutoCAD; |
| Waste Oil Tanker Containment | 12 | 8 | 1 | 2 | 0.45 | 0 | 10 | 16.0 | 12.0 | 13.7 | 280 | 0 | 47 | 219 | 3 | Farm dimensions from AutoCAD; |

**Notes:**
1. Liner assumed to be 60mil HDPE (thickness 1.5mm); bulking factor estimated

## D: Dams

| | Dewatering Inputs | | | | Dam Volumes | | | | | | | | Calculations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Storage Capacity ($m^3$) | Pond Drawdown Rate ($m^3$/hr) | Seepage during drawdown (L/s) | Pump dewatering system install time (hrs) | Stripping Volume (BCM) | General backfill (CCM) | Upstream Shell (CCM) | Dam Core (CCM) | Filter Layers (CCM) | Downstream Shell (CCM) | Toe Berm (CCM) | Spillway Rip-rap (CCM) | Rip-rap % able to be reused | Time Required to dewater (days) | Total Dewatering Volume ($m^3$) | Rip-rap for Reuse (CCM) | Rip-rap to discard (CCM) | Total Dam Fill Vol | General Fill to Breach (CCM) | Dam Core to Breach (CCM) | Downstream Shell to breach (CCM) | Source, Comments/Notes |
| Water Storage Pond Dam | 360,000 | 1080 | 30 | 4 | 33,031 | 10,740 | 30,449 | 29,883 | 31,630 | 43,005 | 6,013 | 5,800 | 50% | 15 | 400,000 | 19,285 | 19,285 | 157,520 | 62,301 | 23,617 | 38,571 | Max drawdown rate: 300L/s (1,080m3/hr) |
| | | | | | | | | | | | | | | | | | | | | | | |

**Notes:**
1. WSP max drawdown rate from "Dam Stability Analysis - Water Retention Dam Reservoir Dewatering (EBA 2008)
2. Dam volumes from asbuilt report (EBA 2008)
3. Upstream shell is residuum, downstream shell is rip-rap sized material, the core is fine-grained clayey material, the filters are screened/crushed materials

## E: Intake Structures

| | Pond Parameters | | | | | | | Total Quantities | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Quantity | Length (m) | Width (m) | Height (m) | Depth to Competent Foundation (m) | Over-excavation Allowance (m) (See note 1) | Excavation Side Slopes (H:1) | Excavation Volume (BCM) | Backfill volume (CCM) | Source, Comments/Notes |
| Main Pit Pre-cast concrete intake structure | 1 | 15 | 4 | 3 | 3 | 2 | 1 | 2,450 | 2,450 | Based on pre-cast concrete panel wall manufactured by Precon |
| Area 2 Pit pre-cast concrete intake structure | 1 | 15 | 4 | 3 | 5 | 2 | 1 | 4,453 | 4,453 | Based on pre-cast concrete panel wall manufactured by Precon |

**Notes:**
1. The perimeter around the intake structure assumed to be over excavated around the perimeter to for worker access during installation.

## F: Passive Treatment System/Wetlands

| | Valley Fill Parameters | | | | Wetland Cell Parameters | | | | | | | | | | | | Calculated Quantities | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Length (m) | Average Width (m) | Average Fill Thickness (m) | Valley Fill Volume User Over-ride (CCM) | Number of cells | Base of organics Length (m) | Base of organics width, Bc (m) | Organic Thickness (m) | Final Pond Depth, Df (m) | Side Slope, z (:1) | Excavation Volume User Over-ride (BCM) | Organic Volume User Over-ride (BCM) | Geotextile Layers | Liner? (Y/N) | Geosynthetic Wastage | Geosynthetic Anchor Trench Allowance (m) | Valley Fill Volume | Cell Excavation Depth (m) | Cell Excavation Volume (BCM) | Organic Media Volume (CCM) | Subgrade preparation area (m2) | Geotextile Area ($m^2$) | Liner Area ($m^2$) | Comments/Notes |
| Stilling Basin at MVFE Stage 2 Toe | 400 | 40 | 4.5 | | 7 | 41 | 15 | 1 | 1.3 | 2 | | | 1 | Yes | 10% | 0.3 | 72,000 | 2.3 | 14,459 | 5,122 | 9,273 | 10,201 | 10,201 | |
| | | | | | | | | | | | | | | | | | | | | | | | | |

**Notes:**
1. See channel drawing and parameter definitions below.
2. The domains/formulas in the channel drawing below are adjusted in the Wetlands calculations as follows: Wetland media is the equivalent of 'water' (blue), the protection layer is the equivalent to bedding/filter layer (green), and rip-rap was not included in the calculations.

# Worksheet 35 - Annual Water Treatment Cost Calculations

**Project:** Minto Mine Closure Cost Estimate - RCP 2018-01
**Project No.:** 1CM002.045
**Client:** Minto Explorations Ltd.
**Date of Submission:** February 6, 2018
**File Location:** \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.045_ClosureCosts\RCP2018-1_CostEstimate\

## A: Active Treatment

**Adjustment Factors**

Inflation factor 1.03 Applied to 2015 site costs to 2017 Dollars based on Bank of Canada Inflation Calculator

### Operating Costs

| Item | Crew/ Unit | Hours | Materials ($) | Labor Cost ($/hr) | Equipment Cost ($/hr) | Total Materials ($) | Total Labor ($/hr) | Total Equip ($/hr) | Total Cost ($) | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Contractor Equipment | 1 | 1 | | | $38,831 | $0 | $0 | $38,831 | $38,831 | |
| Reagents | 1 | 1 | $47,277 | | | $47,277 | $0 | $0 | $47,277 | |
| Filters | 1 | 1 | $63,963 | | | $63,963 | $0 | $0 | $63,963 | |
| Operating Parts | 1 | 1 | $198,584 | | | $198,584 | $0 | $0 | $198,584 | |
| Power | 1 | 1 | $146,260 | | | $146,260 | $0 | $0 | $146,260 | |
| O&M Supplies | 1 | 1 | $16,377 | | | $16,377 | $0 | $0 | $16,377 | |
| Membranes | 1 | 1 | $39,346 | | | $39,346 | $0 | $0 | $39,346 | |
| Labour | 1 | 1241 | | $52.53 | | $0 | $65,194 | $0 | $65,194 | Based on plant availability 34%, 10hr/day. |
| **TOTAL - Annual Active Treatment Operating Costs** | | | | | | **$511,807** | **$65,194** | **$38,831** | **$615,832** | |

**NOTES:**
1. Based on site costs - 2015, which have been found to be a typical year for the plant operation.
2. Source: "2015 - WTP Costs.xlsx' supplied by Minto in April 2016.

### Capital Replacement Costs

| Item | Crew/ Unit | Hours | Materials ($) | Labor Cost ($/hr) | Equipment Cost ($/hr) | Total Materials ($) | Total Labor ($/hr) | Total Equip ($/hr) | Total Cost ($) | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Mechanical/Electrical Parts | 1 | 1 | $61,903 | | | $61,903 | $0 | $0 | $61,903 | |
| Pipes & Fittings | 1 | 1 | $25,029 | | | $25,029 | $0 | $0 | $25,029 | |
| Replacement Labour | 1 | 80 | | $52.53 | | $0 | $4,203 | $0 | $4,203 | Hours assumed. |
| **TOTAL - Annual Active Treatment Operating Costs** | | | | | | **$86,932** | **$4,203** | **$0** | **$91,135** | |

**NOTES:**
1. Based on site costs - 2015
2. Source: "2015 - WTP Costs.xlsx' supplied by Minto in April 2016.

## B: Passive Treatment

### Wetland maintenance

| Item | Crew/ Unit | Hours | Materials ($) | Labor Cost ($/hr) | Equipment Cost ($/hr) | Total Materials ($) | Total Labor ($/hr) | Total Equip ($/hr) | Total Cost ($) | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Excavator | 1 | 80 | | $44 | $113 | $0 | $3,551 | $9,073 | $12,624 | |
| Std. Dump Truck | 2 | 80 | | $44 | $25 | $0 | $7,014 | $3,956 | $10,970 | |
| Misc. supplies | 1 | 1 | $10,000 | | | $10,000 | $0 | $0 | $10,000 | Reveg, bacteria, etc. |
| Labour | 1 | 40 | | $36 | | $0 | $1,421 | $0 | $1,421 | |
| **TOTAL - Annual Active Treatment Operating Costs** | | | | | | **$10,000** | **$11,986** | **$13,029** | **$35,015** | |

**NOTES:**
1. Assumed costs for earthwork repairs/cell repair and hydraulic adjustments.