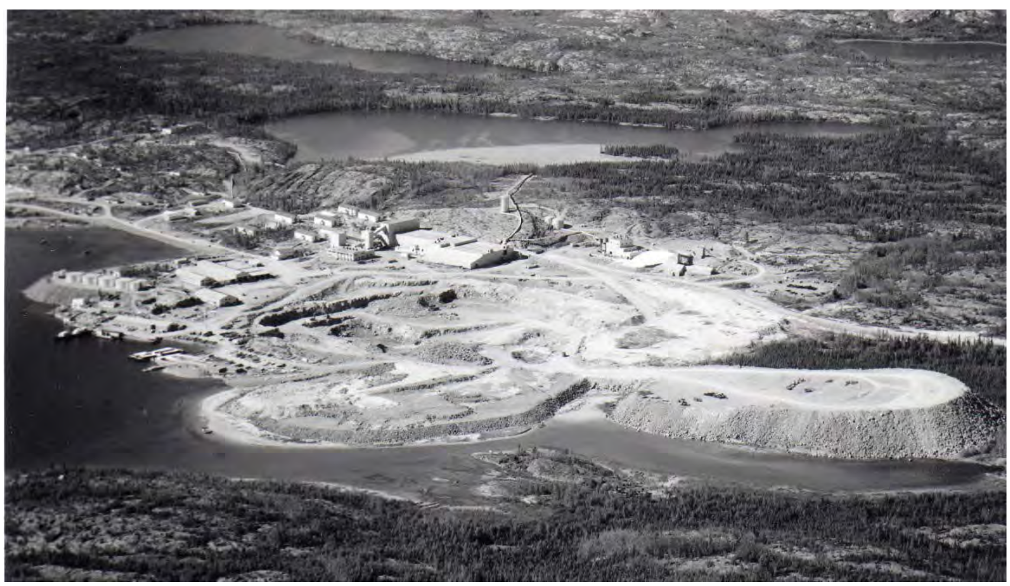
Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design

Prepared for

Saskatchewan Research Council



Prepared by

SRK Consulting (Canada) Inc.
1CS056.003
July 2016

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Executive Summary

SRC issued a request for proposal (RFP) #1617-004 entitled “Final Engineering Design Services for Gunnar Site Aspects” dated April 13, 2016. SRC awarded a contract to SRK Consulting (Canada) Inc. (SRK) on April 25, 2016 to complete the work scope outlined in the RFP.

The present report presents an update to the preliminary plan for remediation of the “other site aspects”, which builds upon the designs that were proposed in the 2015 Preliminary Design Report. The outline of the present report is consistent with the 2015 Preliminary Remediation Report. However, sections have been revised to include changes and additional supporting information completed as part of additional engineering studies. These studies primarily focused on addressing review comments on the 2015 design report from the CNSC and comments received during the April 2016 CNSC stakeholder engagement meeting.

The other site aspects include non-contaminated demolition debris, contaminated soil/waste rock, waste rock, general site, and Gunnar Pit. In summary, the following tasks were completed to address the objectives of the scope of work:

- Review of relevant background information to support the remedial options assessment for each of the other site aspects.
- Implementation of an adapted top down approach to identify any new remediation alternatives.
- Multiple accounts analysis (MAA) of the various remedial options for each of the other site aspects.
- Selection of the preferred remedial option for each of the other site aspects.
- Refinement of the load calculations of uranium and radium-226 to Zeemel Bay and the Gunnar Pit and St. Mary’s Channel following implementation of the preferred remedial options.
- Advancement of the preliminary design of the remedial options for each of the other site aspects. The next phase of the design will include detailed engineering that will include issued for review drawings and specifications.

The MAA—which included evaluation criteria such as risk and adaptive management, cost, and public perception—resulted in selection of preferred preliminary remediation designs for each of the other site aspects. A general description of these preferred designs are as follows:

<u>Non-Contaminated Demolition Debris:</u>

- Consolidate the non-contaminated demolition debris into one landfill located at the Mill Complex area.
- Place all asbestos containing material (ACM) at the base of the landfill followed by the steel and concrete demolition debris.

- Wood debris will be chipped/mulched and if possible, will initially be utilized for erosion control to support the waste rock pile cover systems. For volumetric assessment purposes (i.e. to ensure landfill capacity is conservatively high), the preliminary design of the non-hazardous landfill incorporates approximately half of the total wood debris volume. The chipped/mulched wood debris will be placed in thin layers over the steel demolition debris with the intent to fill in voids.
- The final configuration of the landfill will have 4H:1V side slopes in accordance with the Landfill Code (EMPA, 2010). This slope configuration will also include microtopography features, which will provide short term stability during vegetation establishment.
- Construct a minimum 0.5 m thick cover in accordance with Saskatchewan Environmental Code for Landfills. The cover will direct surface flow towards St. Mary's Channel.
- Re-vegetate the surface of the cover system with native plant species.

<u>Contaminated Soil/Waste Rock and Debris:</u>

- Excavate and remove pH impacted waste rock and soil from the Acid Plant footprint and dispose in GMT.
- Prepare the bedrock foundation so that it meets the hydraulic conductivity requirement stipulated in the Saskatchewan Environmental Code for landfills.
- Consolidate the contaminated soil/waste rock demolition debris into one landfill located at the Acid Plant area.
- Construct a minimum 1.0 m thick low permeability cover (compacted clay cover) that will tie-in to the Acid Plant prepared bedrock surface and/or concrete pad. Construct a 3.3 m thick frost protection layer comprised of non-hazardous waste (concrete and/or waste rock). This layer will be accommodated by the non-hazardous landfill as it abuts against the slope of the compacted clay layer. The exterior of the landfill will include a 0.5 m thick vegetated cover consisting of coarse textured borrow material. This layer will direct surface water flow towards St. Mary's Channel.
- Re-vegetate the surface of the cover system with native plant species.

<u>Waste Rock:</u>

- Re-establish the historical drainage channel below the East Waste Rock Pile.
- Re-grade both the East and South Waste Rock Piles in accordance with the design (slopes range from 4H:1V to 5H:1V) and during this process haul the required volume of waste rock to accommodate the tailings remediation design (OKC, 2016).
- Incorporate microtopography features such as slope texturing, organic fibre rolls/wattles, sediment fences, rolled erosion controlled products, and seeding.
- Construct a minimum 0.5 m thick gamma cover over the East and South Waste Rock Piles.
- Re-vegetate the surface of the gamma reduction cover system with native plant species.

- Re-grade the waste rock slopes along the shoreline of the former fuel tank farm area and by the School/Community Center to 2.5H:1V and 2H:1V, respectively. The gamma signature in these areas are below the radiation exposure reduction limits for the Project and a cover system will not be required. The excavated waste rock will be clean and utilized in the non-hazardous landfill construction.

General Site:

- Construct an engineered cap over the vent raise, mine shaft and back raise in accordance with The Mines Regulations (2003) / Ontario Ministry of Northern Development and Mines.
- Construct a minimum 0.5 m thick gamma reduction cover over the general site areas that have elevated gamma signatures (exclusive of the tailings areas which have specific cover design and the Catchment 3 area).
- Leave the elevated gamma areas identified in Catchment 3 (exclusive of the back release triangular area adjacent to GMT) "as is" (Figure 1). A monitoring program and adaptive management plan will be developed to address residual risks due to the elevated dose rate.

Gunnar Pit:

- Reduce loadings to the Gunnar Pit by remediating the other site aspects (i.e. removal of low pH material at the Acid Plant, remediation of non-contaminated/contaminated waste, and reduce the loading from the waste rock piles) and keep pit water isolated from St. Mary's Channel via the waste rock plug. A monitoring program will be developed to assess and address residual risks associated with loading (contaminants of potential concern) from Gunnar Pit to Lake Athabasca.

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1 Introduction

1.1 Context

The Saskatchewan Research Council (SRC) is managing the Cleanup of Abandoned Northern Sites (CLEANS) on behalf of the Saskatchewan Ministry of Economy. The Gunnar Mine Site (the Site) is one of 37 northern Saskatchewan sites that will be remediated as part of Project CLEANS. The key objective of the Gunnar Mine Site Remediation Project is long-term mitigation of residual public safety, environmental and human health risks.

An Environmental Impact Statement (EIS) was completed in 2013 that included site-wide studies of the Site. Remedial planning has focused on a concise list of “Site Aspects” for major contaminant source and/or risk areas at the site including:

1. Tailing Deposits (Gunnar Main, Gunnar Central and Langley Bay)
2. Non-contaminated Demolition Debris
3. Contaminated Soil/Waste Rock and Debris
4. Waste Rock
5. General Site
6. Gunnar Pit

The EIS included an assessment of remedial options for each of the Site Aspects, which was based on Environment Canada’s 2011 Guidelines for the Assessment of Alternatives for Mine Waste Disposal (SRC, 2013). The results of this analysis were further evaluated in a Decision Tree Process. The results, as presented in the EIS identified that several of the site aspects required further investigation to make a positive decision with regards to the preferred remediation option for each site aspect given the inter-relationship of many of the site aspects. The primary objective of the proposed investigations was to refine the information on surface water and groundwater pathways at the Gunnar Mine Site. Following the 2013 EIS, such investigations have been carried out or are currently in progress.

This report specifically addresses Items 2 to 6 above, which are referred to as the “other site aspects”. The detailed remediation design for the three tailings deposits has been completed by O’Kane Consultants Inc. (OKC) and is provided in a separate report (OKC, 2016).

In addition, this report is a revised report which supersedes the 2015 Preliminary Design Report. The purpose of this revision is to provide additional supporting information to the proposed remedial options that addresses comments provided by the CNSC on December 18, 2015 (Appendix A) as well as additional comments provided during the CNSC stakeholder engagement meeting held on April 28, 2016 in Saskatoon, Saskatchewan. Specific locations within this report where these comments have been addressed are outlined in Table 1-1 - Concordance Table.

Table 1-1: Concordance Table

CNSC Comments E-doc: 4906911, Issued December 18, 2015	Comment addressed in the Following Location of this Report
Comment 1: The MAA in Table 5-5 needs further information to improve the clarity and transparency needed to properly support the approach for remediation (e.g. excavating waste rock down to the original channel bed). For example, Table 5-5 contains a blank space in the cell where the advantages of backfilling the pit could be listed. Furthermore, there is no mention of several disadvantages of backfilling the pit such as the risk of worker safety related to potential collapse of backfilled waste rock in underground workings in the pit bottom and the requirement of perpetual treatment of contaminated water from the pit. SRC is expected to provide a clear and transparent discussion of the advantages and disadvantages of backfilling both waste rock piles into the pit versus excavating a channel and covering the remaining waste rock piles.	Section 5, Tables 5-1, 5-3, 5-5. Section 5.5.3 and Appendix A
Comment 2: Site specific remedial objectives (SSROs) presented in Table 3-2 are higher than the current water quality conditions in Zeemel Bay and St. Mary's Channel. In the past, Environment Canada (EC-6) questioned the acceptability of the Surface Water Remedial Objectives in the Gunnar EIS and the local communities have expressed concerns about elevated SSROs. SRC needs to demonstrate that SSROs will be re-evaluated to reflect improvements in water quality that are expected to occur over time and to demonstrate that the remediation project is in line with the practices of pollution prevention and keeping releases as low as reasonably achievable (ALARA). The absence of an objective for Ra-226 in particular needs to be addressed as the relative hazards of uranium and Ra-226 (and other radioactive daughters) are fundamentally different (chemical toxicity versus radiotoxicity). Stakeholder concerns about radioactivity in the aquatic environment, and the ability of Ra-226 to act as an indicator of the presence of other "hard-to-measure" radionuclides (Addendum to this memo) are other factors to be taken into consideration in developing more comprehensive SSROs. SRC is expected to re-evaluate the SSROs to reflect the existing water quality in Zeemel Bay, long-term water quality improvements expected at the site, and what is sustainable at this remote site. Furthermore, a SSRO value for Ra-226 should be developed.	Section 3.4 Appendix A

Comment 3: The proposed plan measures remediation success in Zeemel Bay based on general surface water quality objectives. This is an insufficient means to track the success of remediation and to confirm a major reduction in loadings to the receiving environment. The choice of the excavated channel through the waste rock pile is based on model predictions of water quality in Zeemel Bay. It is recommended that water quality objectives or indicators be developed to monitor loadings to the environment at or near the source of contamination and to monitor water quality in upper Zeemel Bay. SRC is expected to also describe what kind of contingency measures are in place should concentrations in future years deviate from predicted values.	Appendix A This comment will be further addressed in the next phase of engineering for this project under the monitoring section.
Comment 4: In the EIS, the proposed and assessed design storm for the surface water drainage systems was a 1,000-year storm, but SRC uses a 200-year design storm in the current report without explanation. This is a significant reduction of flood protection capacity from the EIS. SRC should provide justification for reducing the design storm from 1,000 years in the EIS to 200 years in the current report. Selection of design storm duration needs to take into consideration the drainage basin size. SRC proposes to use a 24-hour design storm without justification. For such smaller drainage basins, the maximum peak flow will most likely be generated by a design storm with a shorter duration. As such the 24-hour duration storm may not be conservative. SRC is expected to conduct a design storm duration analysis to select a design storm duration that would generate the maximum peak flow rate.	Section 5.5 Appendix D and H
Comment 5: The landform design of Gunnar other site aspects remediation is to promote use of a landform consistent with current landscape, promote sustainable vegetation, ensure positive drainage, and reduce erosion potential. The landform designed should not only be stable geotechnically, but should also maintain the long-term integrity of the remediated features such as the waste rock pile and the landfill. The side slopes of the landfill containment structures for non-contaminated demolition debris and for contaminated and hazardous materials, and the side slopes of waste rock piles are designed with a gradient of 1V:3H without sufficient justification for their long term integrity. The experience from mine reclamation in northern Saskatchewan such as the Cluff Lake waste rock pile reclamation and the Rabbit Lake waste rock pile reclamation implies that a gentler landform slope is needed in order to ensure the integrity of waste disposal structures (i.e., landform and waste rock piles). SRC is expected to justify the side slope gradient of the waste disposal structures to ensure their long-term integrity or otherwise to provide sufficient information to demonstrate the integrity of the designed structures is in the long term, should the proposed options be justified adequately by addressing other comments.	Sections 5.1, 5.2 and 5.3 Appendices E, G and H
Comment 6: One of the remediation objectives is to minimize contaminant loadings to St. Mary’s Channel and Zeemel Bay. In order to achieve this objective, the cover system should be designed to limit the net infiltration and ensure its long term integrity. The current cover design of 0.5 m medium to coarse borrow materials seems not well justified to support achieving this objective. Based on the site investigation, a significant amount of fine-grained borrow material are available and should be used to enhance the cover design. SRC is expected to justify the current design of cover thickness. The fine-grained borrow materials should be considered to enhance the cover design and its performance.	Section 3.2 Appendices E and H

CNSC Stakeholder Engagement Meeting – Gunnar Workshop April 28, 2016	Comment addressed in the Following Location of this Report
Question 1: Was the bidding process for a primary contractor sent out through Sask Tenders?	Not relevant to the subject matter of this report, therefore not addressed herein.
Question 2: Fond du Lac hasn’t heard about any training. We need more communication to know what is going on, possibly PAGC needs better direction?	Not relevant to the subject matter of this report, therefore not addressed herein.
Question 3: If we have another mild winter will there be an issue with the stability of the ice road?	Not relevant to the subject matter of this report, therefore not addressed herein.
Question 4: Why did the Gunnar mine shut down? Was it mined out?	Not relevant to the subject matter of this report, therefore not addressed herein.
Question 5: The design you presented, is it a final design?	Executive Summary
Question 6: What are you planning on doing with the slurry that contains arsenic, which is currently in the snow and ice?	Not relevant to the subject matter of this report, therefore not addressed herein. This is addressed in the O’Kane 2016 report (OKC, 2016).
Question 7: There is not a plan to put waste rock into the pit. Do you have any thoughts on this?	Section 5.3 and 5.5
Question 8: Where did the rocks come from? They should be put right back where they came from. What do we do if we have a rainy season, the pit could leach? What if the levels of Lake Athabasca lower? I am not so concerned with Uranium; I am more concerned about arsenic levels?	Sections 4 and 5.5 Appendix B
Question 9: Is the pit at a higher level than Lake Athabasca?	Section 2.5
Question 10: Our elders have really pushed and let their voices be heard. They have indicated they would like the waste rock material to go back into the ground where it came from.	Tables 5-1, 5-3 and Section 5.5

Question 11: If you removed the water from the pit and treated it, would you anticipate you would drive down the ramp and put debris/equipment into the pit	Tables 5-1, 5-3 and Section 5.5
Question 12: Is water treatment considered for the pit? If the water gets treated, what is the end result? What would a water treatment plant cost?	Section 5.5
Question 13: We haven’t talked about doing a onetime treatment of the water. Pros and cons. What would that look like?	Section 5.5.3
Question 14: You are assuming the rock taken out of the channel is suitable for cover.	Section 5.3.5 and OKC, 2016
Question 15: You have to take into account, the land under the channel was mined as well. Is there seepage coming in? What are you doing with the high grade you find? When you start digging, you are going to dig up a lot of garbage, it will not be easy.	Section 5.3.2
Question 16: Everything comes down to money, we are not concerned about money. We see a cover up, not a cleanup. We cannot live from store bought food. We are worried about the land and water. Is it safe enough to go hunting and fishing?	Section 3 and 4 Appendix B
Question 17: What are we doing with Zeemel Bay? By leaving the sediments in Zeemel Bay we are leaving the contaminants still there?	Sections 4, 5.3 Appendix B
Question 18: From reading the preliminary design report, I got the impression radium 226 is not being reduced?	Sections 4 and 5.5.1 Appendix B
Question 19: What about radon gas?	Section 2.8 and 6

Question 20: We used to walk around Zeemel Bay, there were also families that stayed in that area. We are all alive and well today. If it is that dangerous, why am I still here?	Rhetorical question. Therefore, not addressed herein.
Question 21: Do you plan on putting piezometers out for monitoring?	Section 6 In addition, this comment will be further addressed in the next phase of engineering for this project under the Monitoring section.
Questions 22: This is a bigger picture comment that involves the role of the government of Canada. The government encouraged uranium mining for atomic weapons production. The government bought all the uranium from this mine and sold it to the U.S. Who bears responsibility for the clean-up of the site?	Not relevant to the subject matter of this report, therefore not addressed herein.
Question 23: The regulator has to ensure there is adequate funding. There should be a regional decision making process, monitoring long term. I am meaning the whole region, not just Gunnar, Lorado and satellite sites. There should be a regional monitoring process.	Not relevant to the subject matter of this report, therefore not addressed herein.

1.2 Background

The Gunnar uranium deposit was discovered in July 1952 and production commenced in September 1955. The Site consisted of an on-site mill, numerous support buildings and facilities and a town site to support mine workers and families.

The Open Pit operated from 1955 to 1961, was mined to a depth of approximately 115 m below ground surface and had a diameter of approximately 290 m at the surface. Underground mine operations commenced in 1957 through to 1963, which extended approximately 500 m below the pit bottom. It is estimated that 5.5 million tonnes (Mt) of ore was mined during operation of the Gunnar Mine. The mine closed in 1964, which consisted of flooding of the Open Pit and little decommissioning activity. In 2010 and 2011, demolition of buildings and structures was carried out under Order No.10-1 of the Canadian Nuclear Safety Commission (CNSC) to address the potential risk to public safety associated with deterioration of the site infrastructure.

1.3 Scope of Work and Approach

The primary objective of the scope of work is to develop a preliminary remedial design for each of the other site aspects and to outline the load reductions and associated human health and ecological risk implications.

In general, the scope of work herein was to take all available information for each of the other site aspects as input data to a decision making process developed by SRK, referred to as the Top Down Approach (SRK, 2002). The results of this process were then evaluated through a multiple accounts analysis (MAA) process. The findings of this process were then vetted against the Gunnar EIS Decision Tree Process in order to ensure the results of the preliminary designs presented herein meet the overall objectives of the Gunnar EIS.

The Top Down Approach did not identify new remediation alternatives, but rather slight variations on the same themes presented in the EIS (SRC, 2013). The accounts, sub-accounts and weighting factors used in the MAA are listed in Table 1-2, and are consistent with what was used in the 2013 EIS as part of the value-based decision process (SRC, 2013). Due to the variability of Public Perception, this Account in the MAA was based on the written and verbal input gathered throughout the Environmental Assessment (SRC, 2013).

Table 1-2: Characterization Criteria, Accounts and Sub-Accounts used in MAA

Characterization Criteria / Accounts	Sub-Accounts	Score (Total Points)	Weighting
Risk and Adaptive Management (A.M.)	Human Health Risks Ecological Risks Active Remediation Risks	10	50%
Cost	Constructability Feasibility Efficacy	10	30%
Public Perception	N/A	10	20%

In order for consistency and further transparency during the evaluation process, a set of assumptions were developed for each site aspect and these assumptions were carried through for each of the remediation options throughout the MAA. At the conclusion of the MAA, each preferred remedial option identified was then vetted against the appropriate decision trees provided in the 2013 EIS to confirm that the three "Areas of Risk" (Source, Intermediate Pathways and Receiving Environment) were eliminated or remediated to the extent possible. Contaminant load calculations for current conditions and future conditions subsequent to the implementation of the preferred remediation options were completed for the Gunnar Pit and Zeemel Bay to assess the potential human health and ecological risks. The loadings presented in the 2013 EIS for current conditions of the Gunnar Pit and Zeemel Bay were re-assessed and updated to include new information from site investigations and studies completed subsequent the 2013 EIS.

The final step was to prepare preliminary engineering designs for each of the preferred remediation alternatives for each of the other site aspects.

1.4 Preliminary Design Team

For the preliminary design phase of this project, SRK partnered with Arcadis Canada (formerly SENES) to provide expertise in the field of human health and ecological risk assessments (HHERA) and CanNorth Environmental Services (CanNorth) in order to provide expertise related to the ecological aspects of the HHERA. Since the completion of that phase of the project CanNorth has purchased the Arcadis HHERA team (i.e. essentially all remaining professionals who collectively made up the SENES HHERA team prior to the sale of SENES to Arcadis Canada). For consistency between the preliminary and updated preliminary plan, these members from CanNorth provided technical support associated with the HHERA aspects for this phase of the Project.

1.5 Report Layout

The remainder of this report is broken down into eight sections. Section 2 is a summary of the site description; Section 3 includes the details regarding the design criteria and objectives; Section 4 outlines the methodology used in the risk modelling to assess current and future loadings to Zeemel Bay and the Open Pit; Section 5 provides the details and results of the remedial options analysis for the other site aspects as well as a summary of the updated preliminary designs for each of the preferred remedial options; Section 6 outlines a high-level approach for field performance monitoring; and Section 7 is report closure followed by a comprehensive list of references provided in Section 8.

2 Site Description

2.1 Location and Access

The Gunnar Mine Site is located the on the south end of Crackingstone Peninsula adjacent to Lake Athabasca in Northern Saskatchewan (Figure 1). The site is approximately 25 km southwest of Uranium City and is not accessible by road. The site is accessible by boat/barge in the summer, by ice roads in the winter, and by light aircraft year round.

2.2 Layout and General Site Conditions

The Site layout prior to demolition is shown in Figure 1, and the layout subsequent to demolition is shown in Figures 12 and 14. The post-demolition figures show current site conditions including the locations of the debris piles and other areas requiring at least some level of remediation.

The open pit is adjacent to St. Mary's Channel of Lake Athabasca and has a surface diameter of approximately 290 m and is approximately 115 m deep (Figure 2). The Open Pit is connected to the underground workings of the mine (Figure 3) and was flooded shortly after mining operations ceased (Figure 2).

The majority of the mine infrastructure was located adjacent to the Open Pit, primarily on its west side. This infrastructure included the Acid Plant, water and acid tanks, the Mill Complex, the powerhouse, the maintenance plant, offices, the headframe, and other buildings and infrastructure. In addition to the mine infrastructure, numerous other buildings were present on site including houses, apartments, a school, and a community center. These other facilities were generally located west of the mine infrastructure; however, there were a number of cabins and other buildings located south of the open pit immediately adjacent to St. Mary's Channel.

There are two large waste rock piles on site: the South Waste Rock Pile (SWRP) and the East Waste Rock Pile (EWRP). The SWRP and EWRP are located directly southeast and east of the Open Pit, respectively. A portion of the waste rock piles were built into Zeemel Bay of Lake Athabasca. Based on historical air photos of the site, the toe of the EWRP extends into Zeemel Bay, while a large portion of the SWRP was deposited into the bay. In addition to these waste rock piles, relatively smaller quantities of waste rock have been deposited throughout the site in areas such as the western-most subdivision, the sports field, and the Mill Complex area.

The tailings are situated northwest of the Site and are located in three separate areas: the Gunnar Main Tailings (GMT) area, the Gunnar Central Tailings area, and the Langley Bay Tailings area. The GMT area is located closest to the mine site area and is at an elevation of approximately 20 m higher than the majority of the mine infrastructure, which has some impact on site drainage. The two other tailings areas are located farther north and drain away from the Site.

2.3 Climate

The climate at the Site is typical of the northern Prairie Provinces. The climate is considered humid subarctic continental, which is characterized by long, cold winters and short, cool to mild summers. The average daily temperature is below 0°C for six months of the year and the average annual total precipitation is 362 mm.

2.4 Surface Geology and Vegetation

The two major types of bedrock present at the Site are Granitic orthogneiss and Gunnar Granite (SRC, 2013a). The Granitic orthogneiss is grey to white or buff to pink, fine- to medium-grained, and is predominantly located near the GMT deposit and west of Zeemel Creek. Gunnar Granite is a pink coarse-grained rock that is found in areas that surround the open pit and east of Zeemel Creek (SRC, 2013a). The bedrock in the area is somewhat fractured, and its surface shows pitting in certain areas due to weathering.

Vegetation in the area is typical of subarctic continental climates. The landscape is dominated by black spruce, jack pine, lichens, and peat moss. Vegetation was disturbed throughout mining operations, yet some of the previously disturbed areas have revegetated naturally (SRC, 2013a).

2.5 Hydrology

The direction and volume of surface water flow has an impact on each of the aspects of this project. The surface water flow of concern, with respect to the “other site aspects” remediation can be broken into four main catchments: Catchment 3, the Acid Plant area, the Mill Complex/West Gunnar Pit area, and the waste rock piles. The catchment areas and general directions of flow are shown in Figure 4.

Surface water from Catchment 3 flows south towards the main access road to a point across from the EWRP. At this location, the water flows either under or over the road and into the waste rock. The water then flows under/through the EWRP along the alignment of a historical channel and then reports to Zeemel Bay of Lake Athabasca. This outflow point is commonly referred to as the SP-1 seep. The flow path underneath the EWRP was confirmed by a tracer test conducted in 2014 (SNC, 2016).

The surface water from the acid plant along with that of the Mill Complex/West Pit area and approximately 50% of the flow from the waste rock piles drains towards the open pit. The remaining 50% of the waste rock surface water flows directly into Zeemel Bay as stated in Appendix U of the EIS (SRC, 2013a). It should be noted that the majority of surface water infiltrates and reaches its destination as groundwater.

Water in the Open Pit flows into Lake Athabasca via a former blasted channel that was created in order to flood the pit upon termination of mining operations (Figure 2). The channel was later filled with waste rock that allows some water to seep through. Typically, the water level in the Open Pit is approximately two to three meters higher than that of Lake Athabasca. A culvert is situated in the waste rock plug that may have once acted as a spillway. The culvert is currently partially crushed and plugged, but some water has been observed to flow through it. Both surface and subsurface flow occur at this location.

2.6 Hydrogeology

A comprehensive groundwater study of the Site is provided in the EIS in Appendix D (SRC, 2013a).

Standpipe piezometers have been installed at the Site in the following locations: the Gunnar Pit, the Mill Complex, the Acid Plant, Gunnar West, the tailings areas and waste rock piles, as well as in overburden in Catchment 3. The following list is a summary of the most recent information regarding groundwater movement at the Site (SNC, 2016).

Groundwater flow generally mirrors topography and flows from GMT north towards Gunnar Central tailings, east into Catchment 3, and south towards Lake Athabasca.

- As discussed in Section 2.5, water from Catchment 3 reaches Zeemel Bay via an inferred buried channel under the EWRP.
- Groundwater movement in the Acid Plant area is dependent on the water table elevation, the particular source locations within the Acid Plant area, and climatic conditions. Work done as part of the Supplemental Gunnar Subsurface Characterization Program (SNC, 2016) included tracer studies as well as a follow up numerical analysis. The study concluded that groundwater flow in the Acid Plant area is predominantly toward the Gunnar Pit with overland flow toward the EWRP only occurring during high groundwater conditions. Based on this work, it was assumed that 100% of loadings from the Acid Plant Area reports to the Open Pit.
- Surface water flow from Catchment 3 drains south and collects in a small pond north/upstream of the East Waste Rock Pile. The tracer study completed by SNC revealed that 100% of the ponded water seeps through the waste rock and reports to Zeemel Bay.
- The majority of the groundwater from the GMT area flows north towards the Gunnar Central Tailings area; however, some flow reports east to Catchment 3, and some flows south through the Gunnar west area/Site.

SNC developed a potentiometric surface to determine the above stated groundwater flow paths (SNC, 2016). The potentiometric surface is shown in Figure 5.

2.7 Borrow Sources

2.7.1 Studies

Information regarding the borrow sources near the Site is included in Appendix H of the EIS (SRC, 2013a) and in a technical memorandum prepared by OKC (OKC, 2016).

2.7.2 Areas and Quantities

OKC characterized the borrow material near the Site in June, 2015. The borrow material was characterized as coarser textured (20-40% cobbles and gravel, 30-80% sand, 0-40% silt and clay), medium textured (0-20% cobbles and gravel, 10-100% sand, 0-70% silt and clay) or finer textured material (0-30% sand, 70-100% silt and clay). The medium and coarser textured material would be well suited as cover material, while the finer material is not ideal for cover construction given its susceptibility to erosion, depending on the overall grade of the material being covered. The erosion susceptibility for each of the three borrow types are discussed in Section 3.3 and in more detail in Appendix H.

The quantity of the available fine, medium and coarse textured material is approximately 2,407,230 m^3, 473,320 m^3 and 815,340 m^3, respectively, which includes Borrow Areas 1, 2, 3, 6S, 6V, 6W, 6U, 6 Contingency, 11, 12, 13 and the West Airstrip. However, only Borrow Areas 5, 6 and the West Airstrip will be developed as medium and coarse textured material is required for the remediation designs. Borrow area locations and additional details in regards to volumes are included in Appendix H and in the Detailed Tailings Remediation Design (OKC, 2016).

2.7.3 Relevant Geotechnical Characteristics

Based on the information provided by OKC, the medium to coarser textured material can be classified as a sand to a loam, while the finer textured material can be classified as a silt loam to a clay loam. Using these classifications in conjunction with available Atterberg test results, the saturated hydraulic conductivity of the medium to coarser materials and the finer materials will likely exhibit ranges of $1x10^{-5}$ to $1x10^{-7}$ m/s and 10^{-7} m/s to 10^{-9} m/s, respectively (Budhu, 2010).

2.7.4 Revegetation Potential

Between 2011 and 2013, SRC completed field trials at the Site to determine if revegetation of the borrow material is possible. SRC found that the mechanical-physical properties of the borrow material is suitable for a grass/forb canopy, but that it is low in nitrogen and phosphorous. If fertilizer is applied to the surface of the placed borrow material and native plants are seeded, revegetating the borrow material should be achievable (SRC, 2013b&c). Appendix J discusses the current revegetation plan for the "other site aspects".

2.8 Geochemistry

The Contaminants of Potential Concern (COPC) at the Site include arsenic, cadmium, lead, uranium, and natural radionuclides of uranium decay series which include lead-210, polonium-210, radium-226 and thorium-230. These constituents mobilize by becoming soluble in the pore water of the material that contains the contaminant. The waste rock and tailings are the main sources of the majority of the constituents, which have been detected at high concentrations in Zeemel Bay and St. Mary's Channel. The waste rock and tailings causing the loadings in these locations are the EWRP, the SWRP, and the tailings that have migrated into Catchment 3.

A Screening Level Risk Assessment was carried out for the Site in 2006 (SENES, 2006) and a Detailed Quantitative Risk Assessment was performed in 2013 in support of the Gunnar EIS (SENES, 2013). Both of these risk assessments examined the risks associated with a wide range of contaminants of concern including arsenic, cadmium, lead, nickel and uranium as well as the uranium series radionuclides. These assessments determined there were no COPC related human health risks at the Site but there were potentially some ecological risks associated with uranium and radionuclides (in particular radium-226) in the Open Pit and Zeemel Bay for aquatic receptors, small terrestrial receptors and aquatic plants. Further details of these assessments are provided in Appendix J in the EIS (SRC, 2013a). Thus, this report focuses on uranium and radium-226.

2.9 Current Loadings to Zeemel Bay and Open Pit

Since the submission of the EIS in 2013, additional studies have been carried out to get a better understanding of the groundwater flows throughout the property. Based on these studies, it has been concluded that there are no groundwater inputs from GMT into the Gunnar Pit. In addition, the studies have determined that the loads from the Acid Plant report predominantly to the Gunnar Pit. For the current assessment, it was conservatively assumed that 100% of the loads report to the Open Pit. Figures 6 and 7 show the current understanding of the uranium and radium-226 loads to the Gunnar Pit. It should be noted that the Acid Plant groundwater loadings were based on updated measured data from 2012 to 2014. The Acid Plant runoff has been added to the loads to Gunnar Pit and were obtained from Table 8.1 in Appendix U of the EIS (SRC, 2013a). In summary, the current understanding of the loads to Gunnar Pit is as follows:

- The GMT contributes no loads to the Gunnar Pit
- One-hundred percent of the loads from the Acid Plant end-up in the Gunnar Pit
- contributions from surface runoff from the Acid Plant also ends up in the Gunnar Pit

The above inputs result in a uranium load to the Gunnar Pit of 19.9 kg U/a and a radium-226 load of 281 MBq/a. Both Figures 8 and 9 demonstrate that runoff is a larger contributor to the loads than groundwater. These loads result in a uranium concentration of 0.94 mg/L and a radium-226 concentration of 0.305 Bq/L in the Open Pit, which were obtained from Table 8.3 in Appendix U of the EIS (SRC, 2013a). Due to the large volume of water in the pit and the fact that the seepage to St. Mary's Channel and evaporation are the only form of water loss in the Open Pit, it is expected that these concentrations will remain constant for a long period of time (decades).

There is seepage from the Gunnar Pit to St Mary's Channel via the backfilled channel comprised of waste rock. Appendix U of the EIS indicates that the uranium and radium-226 loads to St. Mary's Channel were 16.7 kg/a and 202 MBq/a, respectively (SRC, 2013a). These loads result in a uranium concentration of 0.008 mg/L in St Mary's Channel in the vicinity of the outflow. This concentration is below Canadian Water Quality Guidelines as well as the Saskatchewan Environmental Quality Standard for surface water. The radium-226 concentrations are 0.004 Bq/L as presented in Appendix J of the EIS (SRC, 2013a), which are considered to represent background.

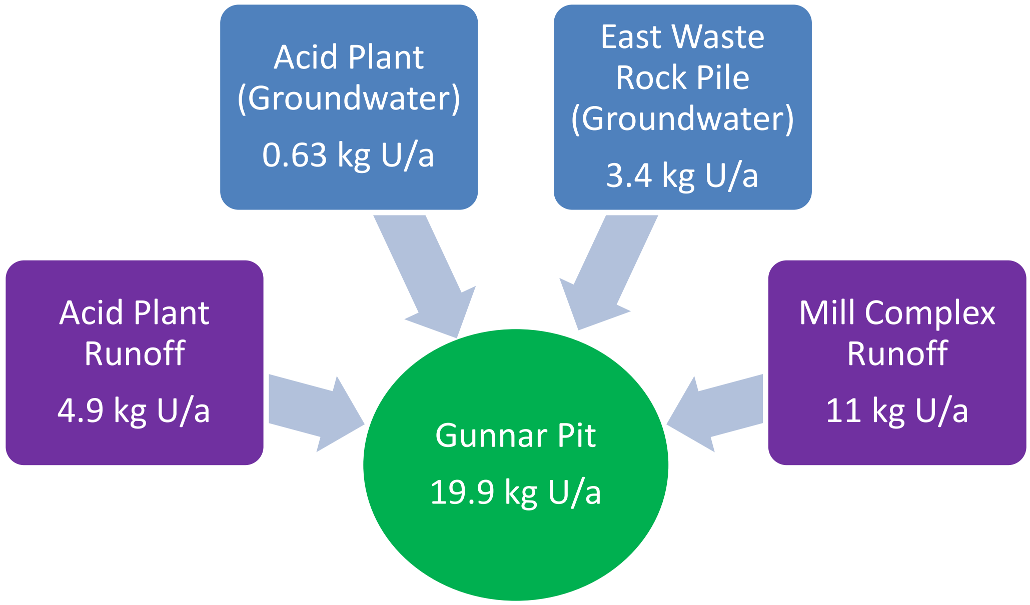

Figure 6: Schematic of Current Uranium Loads to Gunnar Pit

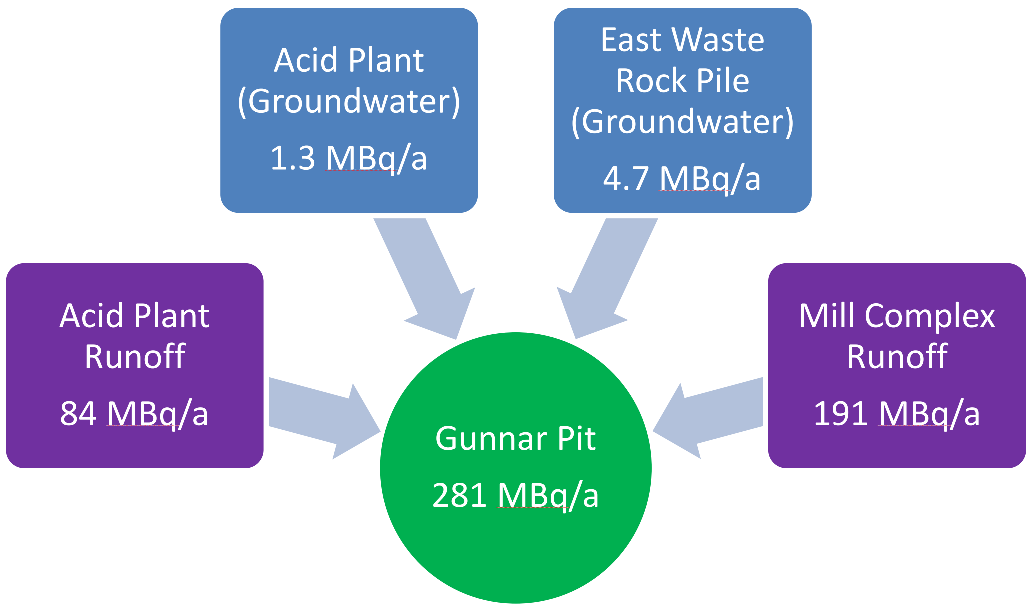

Figure 7: Schematic of Current Radium-226 Loads to Gunnar Pit

Uranium loads to Zeemel Bay come from the following sources:

- Catchment 3 and the East Waste Rock Pile (EWRP)
- South Waste Rock Pile (SWRP)
- Zeemel Creek
- Gunnar Main Tailings (GMT)

Surface runoff from Catchment 3 currently collects in a wide ditch that runs along the access road for the Site. As there is no surface outlet for the ditch, the surface runoff infiltrates through the East Waste Rock Pile (EWRP) and eventually reaches Zeemel Bay as a waste rock seep (Seep 1). The multiyear concentrations of uranium in Catchment 3 average to approximately 0.2 mg/L and by the time it flows through the East Waste Rock Pile and enters Zeemel Bay via Seep 1, the uranium concentrations are 12 mg/L.

Figures 8 and 9 show the uranium and radium-226 loads to Zeemel Bay. The uranium and radium-226 loads to Zeemel Bay via Catchment 3 and Zeemel Creek are based on the flow provided in Table 7.1 of Appendix U of the EIS (SRC, 2013a) and the geometric mean of measured concentrations (see Appendix B of this report). Measured concentrations from seeps located in the SWRP were not available as they are generally dry; hence, the loads from the SWRP to Zeemel Bay provided in Table 10.5 in Appendix U of the EIS were used (SRC, 2013a). Uranium loads from Appendix U in the EIS for the EWRP agree well with the estimated loads presented in Figure 8, therefore it was assumed that the use of the uranium loads from Appendix U for the SWRP is appropriate. In Appendix U, it has been acknowledged that there is an overestimation of radium-226 loadings in the model used. Therefore, instead of directly using predicted Ra-226 loads from South Waste Rock Pile provided in Appendix U of the EIS, the ratio of Ra-226 loads from the EWRP and SWRP was estimated (a factor of 17 lower in the SWRP) and applied to the estimated loads of all radionuclides from the EWRP. In essence, the loads of radionuclides in the SWRP were 17 times lower that the loads from the EWRP (Figure 9). Uranium and radium-226 groundwater loads from the GMT to Zeemel Bay are consistent with those provided in Table 10.5 in Appendix U in the EIS.

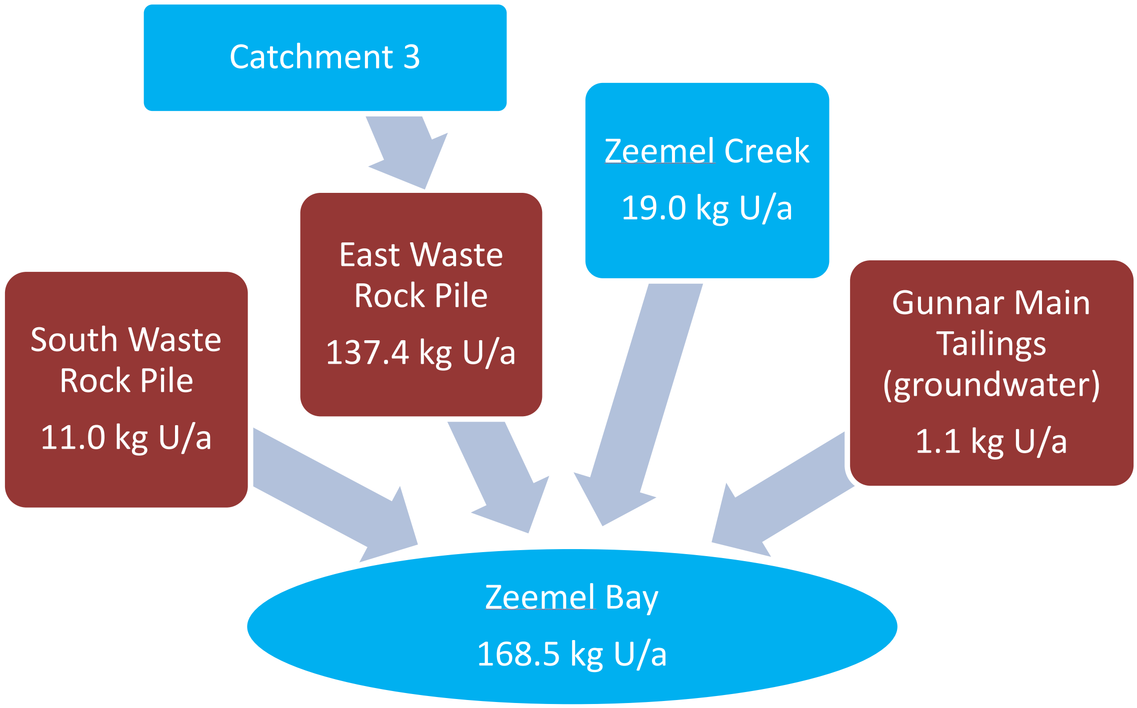

Figure 8: Schematic of Current Uranium Loads to Zeemel Bay

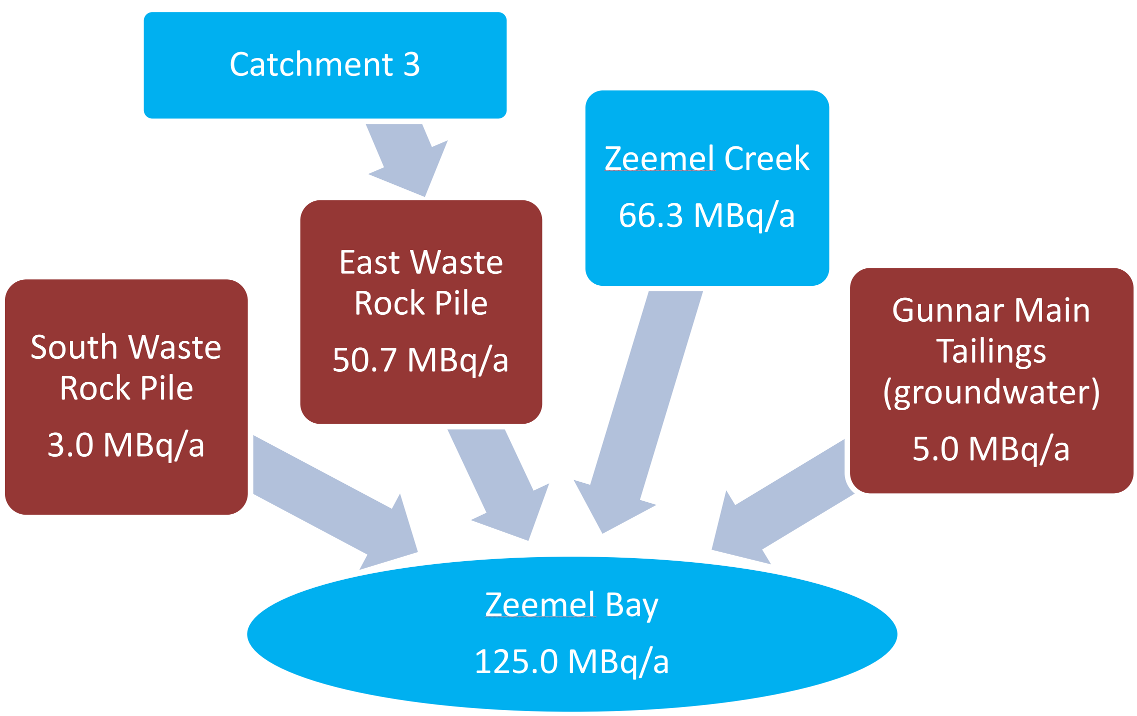

Figure 9: Schematic of Current Radium-226 Loads to Zeemel Bay

2.10 Gamma Radiation Sources

A remediation performance criterion for gamma radiation was established as part of the EIA (SRC, 2013a). Several gamma radiation surveys have been completed at the Gunnar Mine Site that range from 1986 to 2009. The results of the most recent gamma survey completed in 2009 and 2011 are summarized in Table 2-1 (SRC, 2013a). The gamma survey completed in 2011 was undertaken in the Catchment 3 area.

Table 2-1: Summary of the 2009/2011 Gamma Surveys at the Gunnar Mine Site (SRC, 2013a)

Location	2009 / 2011SRC Gamma (µSv/hr) (Survey at 1 m above ground surface)
Areas Associated with "Other Site Aspects Remediation"	
Acid Plant	1.12 Average (Max. 3.17)
Mill Yard Annex, Labs & Packaging Area	1.34 Average (Max. 2.25)
Mill Yard in front of Crushers	2.47 Average (Max. 4.44)
South Waste Rock Pile	1.29 Average (Max. 4.39)
East Waste Rock Pile	1.83 Average (Max. 11.63)
Catchment 3 Area	2.32 Average (Max. 2.8)
Areas Associated with "Tailings Remediation"	
Tailings Line Spill Areas	No average (Max 2.68)
Gunnar Main Tailings	4.81 Average (Max. 12.43)
Gunnar Extension ("triangle" East of the berm)	5.25 Average (Max. 9.27)
Gunnar Central Tailings	3.41 Average (Max. 9.18)
Langley Bay Tailings	6.09 Average (Max. 11.82)

It can be seen in Table 2-1 that average gamma dose rates for the areas associated with the other site aspects range from 1.12 to 2.47 µSv/hr and the maximum dose rate is 11.63, which is located at the East Waste Rock Pile. It is understood that this elevated maximum dose rate may be attributed/influenced from the debris located along the crest of the EWRP in the vicinity of the survey (OCK, 2016). The average gamma signatures associated with the other site aspects are approximately 60 to 65% lower than the tailings areas.

Gamma signatures for the "other site aspects" are shown in Figure 10, which were detected during the 2009/2011 surveys. The figure presents the same data as shown on Map V2-61 in Volume 2 of the EIS.

2.11 New Understanding of Contaminated/Non-contaminated Waste Material

2.11.1 Wood Waste

All wood debris and hydrocarbon impacted soil/waste rock was considered contaminated material in the Preliminary Design Report. Wood was considered hazardous because it was assumed that most of the wood contained lead paint and that the lead was leachable.

SRK subsequently reviewed the *Gunnar Mine Rehabilitation Project Inventory of Hazardous Substances and Materials* report that was submitted to SRC by AECOM in 2010 (AECOM, 2010). The report was written as a regulatory requirement prior to the demolition of the former mine infrastructure and other site buildings. Materials identified as potentially hazardous were tested and characterized to determine safe disposal methods following demolition.

The AECOM report characterized the wood waste and presented Toxicity Characteristic Leaching Procedure (TCLP) test results from 23 wood samples taken from various areas of the site that contained what was thought to be lead based paint. TCLP tests simulate highly acidic landfill conditions that are ideal for the production of contaminated leachate. Wood waste was considered hazardous if the concentrations of lead yielded from the TCLP test was greater than 5 mg/l.

Only one test exceeded the criteria at 12 mg/l, which was from a sample taken from the barge window frames and doors. It is understood that the barge was disposed of in the wood piles, which was stockpiled between the two waste rock piles (SRC, 2012).

The remaining 22 samples yielded lead concentrations of less than 5 mg/l. These samples were taken from a variety of locations including the Acid Plant, the Married Quarters and the Mill. Of all samples (including the sample from the barge), the average lead concentration was 0.87 mg/l and the median was 0.076 mg/l. The difference between the mean and median shows that the majority of the samples yielded very low concentrations while a few samples were substantially higher than most, with the majority remaining below regulatory limits.

Based on the findings of the 2010 Inventory of Hazardous Substances and Materials, the assumption in the 2015 Preliminary Design Report that all wood debris was contaminated has been refuted. This change in classification has resulted in a significant change in the proportions of contaminated and non-contaminated waste and will be further discussed in Section 5.

3 Design Criteria and Objectives

3.1 Remediation Objectives

The purpose of remediating the Site is to reduce the risks that the site poses to human health, safety of the public, and integrity of the environment (SRC, 2013a). The remediation objectives that pertain to the other site aspects are to:

- Stabilize waste rock slopes;
- Minimize human health risks posed by gamma dose rates;
- Consolidate and permanently dispose of demolition debris following the Saskatchewan Environmental Code for landfills;
- Consolidate and permanently dispose of contaminated earthen and industrial materials following the Saskatchewan Environmental Code for landfills;
- Minimize contaminant loadings to St. Mary’s Channel and Zeemel Bay; and
- Take measures to ensure public and environmental health and safety during and after the remediation activities through appropriate monitoring.

3.2 Remediation Design Criteria

In general, the parameters listed in Table 3-1 were considered as overarching design criteria for each of the other site aspects. Further detail of specific design criteria that pertains to each of the other site aspects are defined in Section 5.

Table 3-1: Gunnar Other Site Aspects Overall Remediation Design Criteria

Parameter	Criteria
Design Life	The remediation of the other site aspects is expected to be effective in perpetuity. However, it is not credible to suggest the design criteria listed in this table can be met in geological timeframes. Therefore, a 100-year design life has been adopted similar to that of the Lorado Remedial Project (SRK, 2014a). A design life longer than 100 years is achievable provided proper monitoring and maintenance is performed.
Land Use	General wilderness area. Large and small terrestrial animals, birds and aquatic life will be present (Flora and Fauna adjacent to and within the Site must not be significantly impacted). Humans could travel through the area infrequently (maintain traditional land use adjacent to and within the site). Special measures to preclude access not required.
Landform	Promote use of landforms consistent with current landscape. Cover to promote sustainable vegetation, ensure positive drainage and reduce erosion potential.
Physical Exposure	As far as practicable no visible signs of hazardous materials or demolition debris. Includes weathering due to repeated wetting/drying and/or freeze/thaw cycles, forest fires and burrowing animals.
Radiation Exposure Reduction	Gamma radiation and radon gas exposure limit measured 1 m above impacted area must be no greater than 2.64 µSv/hr (2.5 µSv/hr above background) as a spot reading and no higher than 1.14 µSv/hr (1.0 µSv/hr above background) as an average measured over 1 ha. Background gamma dose rate over 1 ha is 0.14 µSv/hr.
Surface Water Quality	Meet site-specific remedial objectives (SSROs) in St. Mary’s Channel and Zeemel Bay as listed in Table 3.2.

Parameter	Criteria
Groundwater Quality	Remediation designs developed attempted to improve groundwater quality in an effort to meet the Environment Canada 2010 Interim Tier 2 commercial / industrial guidelines at receiving environments.
Air Quality	During the active remediation phase: Keep concentrations of particulate matter (PM) emissions to: <10 µm below the 24 hour criteria of 50 µg/m^3; and ≤2.5 µm below the Canada Wide Standard of 28 µg/m^3.
Covers	Minimum thickness of 0.5 m at any location so that areas elevated in gamma meet the radiation criteria (Section 3.3). Must be able to support self-sustaining vegetation and reduce erosion. For landfills, covers must meet the design objectives (EMPA 2010). There is no requirement for infiltration reduction or oxygen reduction; however, the design of the cover system will be completed in accordance with the ALARA principle ('As Low as Reasonably Achievable')
Seismicity	Peak Ground Acceleration (PGA) equal to the 1 in 2,475 year average recurrence interval (ARI). PGA = 0.031g.
Slope Stability	Waste Rock slopes accommodate closure cover and are stable under static and dynamic loading conditions.
Overland Flow and Surface Water Erosion	Maximum permissible velocity for surface flow on cover material prior to establishing vegetation is 1 m/s. Velocities >1 m/s require hydrotechnical design. No visible damage over cover for 24 hour duration precipitation event less than 1 in 200 year recurrence interval. Short term ponding on remediated surface permitted. Prolonged ponding resulting in vegetation dieback should be discouraged. Soil loss due to erosion ≤ 6t/ha/yr.
Hydraulic Structure Design	All hydrotechnical aspects have been designed for the 1 in 200 year return period (24-hour duration rainfall event adjusted for climate change) Re-established Channel through the waste rock piles sized to safely convey the 1 in 1000 year design storm event.
Landfill Design (If required)	As far as practical meet the objectives of the Saskatchewan Environmental Code (EMPA, 2010). Reduce the potential for frost heave of landfill debris. Up to 0.3 m differential settlement expected and acceptable.
Vegetation	Promote establishment of self-sustaining vegetation cover compatible with surrounding ecosystems. No requirement to preclude specific species from establishing on cover areas. Minimum growth medium thickness of 0.3 to 0.4 m.

3.3 Cover System

Gamma Assessment

Certain areas of the site emit elevated levels of gamma radiation. These areas will be covered to reduce the potential for exposure to elevated gamma. Cover systems can act as a gamma shield and lower surface levels by adsorping and scattering radiation. Required cover thickness is dependent on material thickness, density, and the amount of pore space as well as the energy of the source gamma radiation (McAlister, 2013).

For consistency, cover system gamma attenuation has been estimated using the same method that was presented by OKC in the *Gunnar Tailings Remediation Detailed Design Report* (OKC, 2016). Eight different cover system scenarios were assessed for their ability to attenuate gamma. The scenarios include a range of properties of material available on site and gamma sources. The available material considered ranged from fine borrow to waste rock. For the areas associated with the other site aspects, the source gamma ranged from 2.64 µSv/h to

11.63 µSv/h; these values are consistent with the 75th percentile and maximum spot gamma readings, respectively, taken 1 m above the surface of the waste rock piles as presented in the EIS (SRC, 2013a). The scenarios are shown in Table 3-2.

Table 3-2: Gamma Attenuation for Different Cover Scenarios

Scenario	Material Description	Dry Density (g/cm³)	Gravimetric Moisture Content	Source Gamma Field (µSv/h)
1	Fine Borrow	1.2	0.10	2.64
2	Medium-Fine Borrow	1.5	0.05	2.64
3	Coarse Borrow	1.7	0.05	2.64
4	Waste Rock or Rip Rap	2.2	0.00	2.64
5	Medium-Fine Borrow	1.5	0.05	6.00
6	Coarse Borrow	1.7	0.05	6.00
7	Coarse Borrow	1.7	0.05	11.63
8	Waste Rock or Rip Rap	2.2	0.00	11.63

The EIS proposed an average gamma radiation measurement target of 1.14 µSv/h (SRC, 2013a). Figure 11 presents the gamma radiation attenuation results for each cover scenario. In each scenario, a cover system of greater than 0.3 m thickness reduces the gamma radiation to below the target value. With the exception of Scenario 7, which involves the highest spot reading on the waste rock piles, each of the cover scenarios reduces the gamma radiation to below the target value at a thickness of 0.2 m or greater.

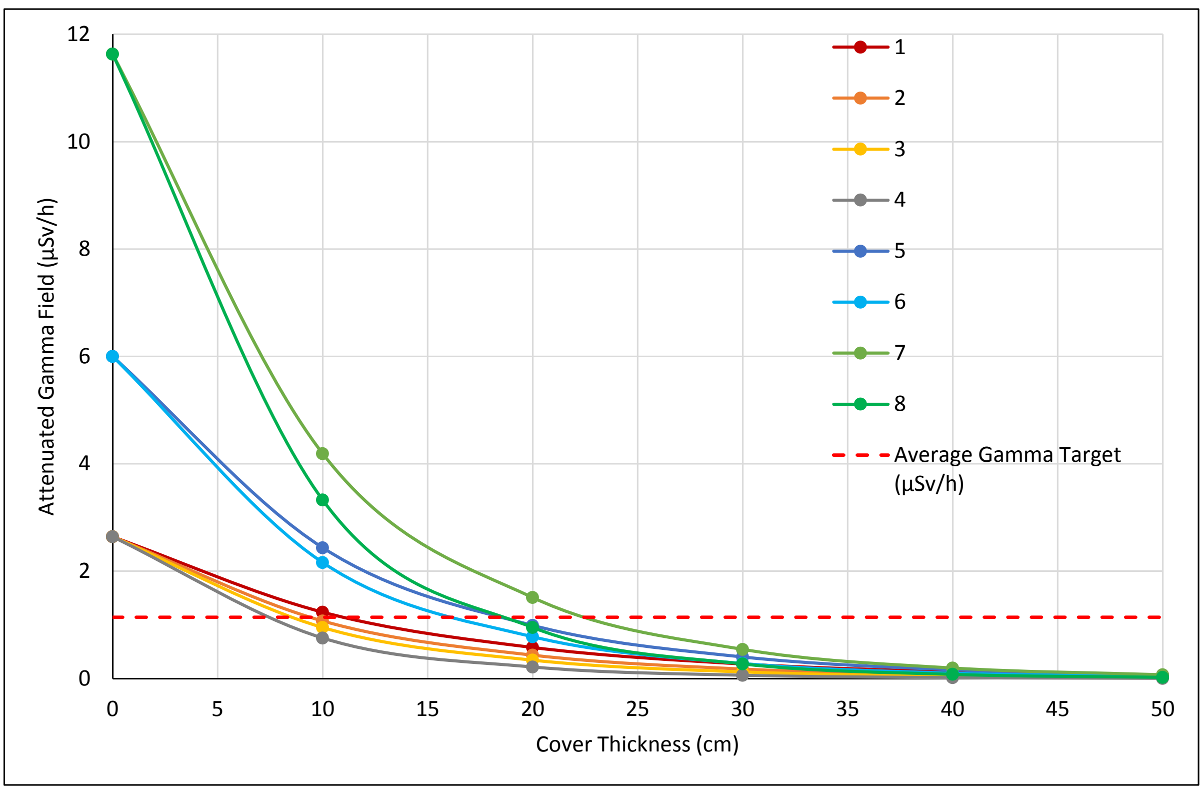

Figure 11: Gamma Attenuation Estimates

Cover Material Trade-Off Study

SRK completed a trade-off study to determine if utilizing fine-textured borrow can further reduce infiltration, and to provide a comparative evaluation of the available borrow materials in consideration of erosion susceptibility, constructability, performance, footprint of borrow areas and cost.

To support this study, an erosion analysis for both short and long term stability against wind and water was carried out, which considered the following factors: slope length, slope steepness and shape, soil type, vegetation and surface cover, climate and storm events. The target soil loss quantity was 6 Tonnes/hectare/year or less as a greater soil loss typically causes a reduction in the long term productivity of the soil (Wall et al., 2002).

Borrow material availability was also assessed, which determined there is insufficient medium textured borrow but enough fine and/or coarse textured borrow to meet the cover design criteria for the other site aspects. Therefore, the trade-off study only considered the fine textured and coarse textured borrow materials.

In summary the trade-off study concluded that the coarse textured material is recommended for use as the gamma cover system for the Other Site Aspect. Details of the study are included in Appendix H.

Cover System Thickness

A long term erosion analysis was completed and determined design life soil loss may be as high as 0.086 m for a non-vegetated, 100 m, 3H:1V slope comprised of coarse textured borrow. This was considered conservative as the proposed design slopes are 4H:1V, or flatter, and are generally shorter in length. In maintaining a conservative approach to soil loss, a thickness of 0.1 m was considered appropriate to protect against long-term erosion. Based on the work associated with the revegetation plan, it is understood that approximately 0.3 to 0.4 m of coarse textured borrow is required to support vegetation for the cover systems (SRC, 2016). Therefore, the minimum cover thickness proposed for any of the "Other Sites Aspects" is a thickness of 0.5 m, which provides a more than adequate protection from gamma radiation (minimum 0.2 m thick), an adequate growth medium for vegetation (0.3 to 0.4 m thick), and will also provide a contingency should there be loss due to erosion (estimated to be less than 0.1 m thick). Additional details in regards to the design of the cover system is provided in Appendix H.

3.4 Surface Water Quality

The Gunnar EIS provided SSROs that were developed (calculated) using species sensitivity distribution curves for arsenic, cadmium, copper, lead, and uranium (i.e., the identified COPCs for the Site) in surface waters being released from the Site and taking into account type and size of receiving ecosystems. The selection of these SSROs is discussed in Section 4.0. Concentrations providing protection to 80 and 90% of aquatic species were considered for the selection of SSROs, which are provided in Table 3-3.

Table 3-3: Gunnar Surface Water SSROs

Constituent of Potential Concern	SSRO for St. Mary’s Channel and Langley Bay (µg/L)	SSRO for Zeemel Bay (µg/L)
Arsenic	100	390
Cadmium	0.30	0.85
Copper	5	12
Lead	13	35
Uranium	90	200

When the calculated SSROs exceed the actual (pre-remediation) COPC concentrations in the affected water bodies, they will be primarily used as environmental performance criteria during and shortly after the remediation activities. Other, more conservative criteria, such as Saskatchewan Environmental Quality Guidelines (SEQG) and Guidelines for Canadian Drinking Water Quality (CCME) will be utilized to assess the remediation success on a longer-term basis.

3.5 Peak Design Flow

Two years of hydrometric monitoring data have been collected from site stations to date. This data was reviewed with the aim of developing a calibration to confirm and/or improve previous peak flow estimations; however, due to the lack of site monitoring data, it was not possible to correlate such data to any regional flow records or precipitation gauges. Therefore, the regional analysis used to estimate unit peak flows for the updated preliminary design has been replaced with a hydrologic rainfall runoff model. The revisions and associated comments are provided in Table 3-4. This assessment is detailed in the Hydrology review memorandum included in Appendix C. Additional details on the peak flow estimation procedure as well as specific peak flows calculated for each hydrotechnical feature are provided in Appendix D.

Table 3-4: Comparison of 2015 Preliminary Design to 2016 Updates

Parameter	2015 Preliminary Design	Updated Preliminary Design	Comments
Design storm - Frequency - Depth (mm)	1 in 200 year event, 24-hr 94.5 mm	1 in 200 year event, 24-hr 118 mm (after climate change)	Storm depth increased to account for climate change.
Peak flow calculation method	Regional analysis, based on observed flows from nearby stations.	TR-55 model, based on an SCS Type II storm distribution and assumed CN values	Conservatively selected since Type II has the most intense storm distribution (O’Kane, 2016).
Estimated peak flow (converted to unit peak flow)	1 $m^3/s/km^2$	Unique peak flows are calculated for each area of interest. Dividing the calculated peak flows by the catchment area yields average unit peak flows in the order of ~3 $m^3/s/km^2$	Peak flows are calculated specifically for each area of interest and vary depending on the catchment area, slope, and length. The 2016 calculated peak flows have been converted to an approximate unit peak flow for comparison.

4 Human Health and Ecological Risk Evaluation

Human health and ecological risk assessments (HHERA) have been an integral part of the ongoing work at the Gunnar Mine Site. A Screening Level Risk Assessment was completed in 2006 to determine what the potential issues were at the Site. The conclusions of the risk assessment were that there were elevated gamma readings on the waste rock and tailings areas that may represent a risk to humans. In addition, uranium and radionuclide concentrations associated with the seep from the East Waste Rock Pile represented a risk for aquatic receptors in Zeemel Bay. No risks to small terrestrial ecological populations or humans were determined for exposure to contaminants in the Open Pit.

The Detailed Quantitative Risk Assessment provided in Appendix J of the Gunnar EIS (SRC, 2013a) found similar conclusions to the original risk assessment except for human exposure. The risk assessment determined that human exposure and risks associated with spending a total of 1.5 months at the Site were below regulatory benchmarks and thus there is no concern from a human perspective. Subsequent to this conclusion the risk evaluation in this report focused on ecological receptors. For Zeemel Bay, a quantitative assessment was carried out for aquatic receptors (aquatic plants, small organisms and plants and fish) as these would be most exposed. For the Open Pit, a qualitative analysis of small terrestrial animals’ drinking water from the pit was carried out. The risk evaluation discussed in the following sections used the receptors, benchmarks and methodologies as outlined in Appendix J of the EIS (SRC, 2013a).

5 Other Site Aspects

5.1 Non-Contaminated Demolition Debris

5.1.1 General

In the EIS, the areas containing non-contaminated demolition debris were the Mill Complex area, waterfront areas, waste rock piles and select areas near the Site. The Site areas that contain non-contaminated demolition debris are shown in Figure 12. For this study, all demolition debris was considered non-contaminated, which included asbestos containing material (ACM), both friable and non-friable, steel, concrete, and wood. As discussed in Section 2.11.1, wood waste was classified as hazardous waste in the Preliminary Remediation Design, but is now considered non-hazardous based on the 2010 waste characterization study completed by AECOM (AECOM, 2010).

As part of the demolition work completed in 2010 and 2011, asbestos abatement included double-bagging friable asbestos and storing it in the dock warehouse. Non-friable asbestos was wrapped in Super Sacks and stored in designated areas with appropriate signage in accordance with regulatory requirements. The decision to include ACM as non-contaminated was a function of the material’s physical and essentially benign characteristics once it is properly disposed of in a landfill setting. The dock warehouse, which is currently being used to store friable asbestos, will be demolished as part of the site remedial activities, and that demolition debris was also considered non-contaminated.

Steel and broken concrete was stockpiled in select areas near the Mill Complex and Waterfront and is understood to be non-hazardous and not pose immediate environmental or public risks. Much of the steel consists of segments of beams, string filters and framing that are too large and irregularly shaped to be effectively stored and covered. These materials will require resizing prior to landfilling. A number of concrete building foundations were left largely intact that need to be excavated and demolished prior to landfilling. Steel components that are stockpiled on site such as string filters from the Mill Complex have been drained to remove historic hydrocarbons.

The risks associated with the non-contaminated demolition debris are physical hazards due to the exposed piles and human health risks associated with handling ACM. Both risks will be addressed in the standard operating procedures developed as part of the detailed engineering phase (SRC, 2013a).

5.1.2 Design Objective and Criteria

The remedial objective is to design a landfill that is permanent and will remove the physical hazards posed to humans and wildlife. To meet this objective, the design criteria that specifically applies to the demolition debris disposal options includes:

1. Meets regulatory requirements
2. Has a 100-year design life
3. Will accommodate terrestrial animals and maintain traditional land use adjacent to the Site
4. Has a landscape and cover that promotes positive drainage and is compatible with natural surroundings
5. Promotes establishment of self-sustaining vegetation

5.1.3 Assumptions

Assumptions regarding non-contaminated demolition debris are as follows:

- Non-hazardous demolition debris includes concrete, steel, ACM, and wood.
- Wood debris will be chipped/mulched and if possible, should initially be utilized for erosion control to support the cover systems. However, for volumetric assessment purposes it was assumed that approximately half of the total material volume will be placed in the Non-Hazardous Landfill and the remaining half will be strategically placed within the re-graded East Waste Rock Pile (Section 5.3).
- Total volume of demolition debris is estimated to be 99,000 m^3.
- All non-contaminated demolition debris should be consolidated in a single location, separated from contaminated materials and hazardous debris.
- Demolition debris is classified as Type 1 Waste (EMPA, 2010).
- The landfill Type is classified as Type 2A, which calls for a final cover soil comprising D_{10} < 0.075 millimetre with a thickness of 0.90 m for design and a 0.15 m topsoil layer that will sustain vegetation growth (EMPA, 2010). However, the landfill debris will be inert and the objective of the cover is not to reduce percolation, it is to mitigate the hazards associated with exposed waste and to provide a vegetative cover with a low susceptibility to erosion. Therefore, a 0.5 m coarse borrow cover is appropriate to meet the non-hazardous landfill design objectives.
- A low permeability liner/leachate collection system is not required for a landfill containing only Type I Waste (EMPA, 2010).
- Friable asbestos is double bagged, with the outer bag consisting of a 6 mm polyethylene bag, conspicuously labelled and immediately buried.
- Clean waste rock can be utilized as rip rap to support the hydrotechnical designs.
- There will be adequate quantities of clean waste rock available for use as intermediate layers in the landfill.
- A vegetative cover can be established.

The total volume of non-contaminated demolition debris was determined utilizing the 2015 aerial imagery provided by SRC. Areas of the debris piles were delineated from the aerial imagery and approximate heights were estimated from site photos and videos provided by SRC.

5.1.4 Remedial Alternatives Analysis

EIS Remedial Options

The remedial options for non-contaminated soil and debris previously identified in the EIS Remedial Options Analysis (SRC, 2013a), included:

- Do nothing
- Place in a purpose built dedicated on-site landfill
- Place in landfill constructed in northwest waste rock area
- Pump down Open Pit and place soil/debris in Open Pit
- Collect all debris and transport off-site for disposal

The "do nothing" option was eliminated during the pre-screening assessment and the remaining options were carried forward into the MAA (SRC, 2013a). Subsequently, Decision Trees were developed and during this process the "collect all debris and transport off-site" option was eliminated.

Preliminary Design Study - MAA of Remedial Options

The remedial options for non-contaminated demolition debris considered in this study are consistent with options identified in the EIS Decision Trees, with the exception of the GMT, which was added as an additional remedial option. The remedial options included relocation to:

- Gunnar Main Tailings (GMT)
- East Waste Rock Pile
- Open Pit
- Alternate Terrestrial Location

The primary rational for considering the GMT area as an additional remedial option is the site is in close proximity to the non-contaminated demolition debris and that the material could be incorporated under the tailings cover.

Two options considered for an alternate terrestrial landfill location included the Mill Complex area and the Acid Plant area. The primary rationale for selecting these two areas was the bedrock relief whereby excavation to bedrock could be readily utilized in the landfill designs and the two areas were in close proximity to most of the demolition debris.

The four potential areas to consolidate and permanently store the non-hazardous demolition debris are shown in Figure 12. Advantages and disadvantages along with the results of the MAA are summarized in Table 5-1 below.

Table 5-1: Multiple Accounts Analysis for Non-Contaminated Demolition Debris Remedial Options

Remedial Option	Account (Sub-Accounts)								Total MAA Rating
	Risk and Adaptive Management (A.M.) (Human Health / Ecological / Active Remediation Risks)			Cost (Constructability / Feasibility / Efficacy)			Public Perception		
	Weighting 50%			Weighting 30%			Weighting 20%		
	Score	Advantages	Disadvantages	Score	Advantages	Disadvantages	Score	Comments	
1 - Gunnar Main Tailings	3	• Relatively low permeable foundation in fine tailings area (1X10^{-7} m/s).	• Degree of A.M.: Poor. Design modifications / further remediation would be complex. Would require alteration to tailings cover design. • Adds complications to tailings cover design (i.e. differential settlement). • May receive negative feedback for placing non-radioactive material in tailings facility.	2		• Longest haul distance compared to other options, cost not favorable.	3	• Mixed public perception: - Landfill is situated away from Zeemel Bay and St. Mary's Channel. - May be perceived to impact Langley Bay.	2.7
2 - East Waste Rock Pile	3	• Degree of A.M.: Moderate. Area is relatively accessible.	• Waste Rock is porous and location is close to Zeemel Bay. Difficult to intercept potential seepage should adaptive management be required.	3	• Second lowest cost compared to other options.	• Longer haul distance than Option 3.	2.5	• Poor to moderate public perception: Landfill is situated near Zeemel Bay.	2.9
3 – Mill Complex/Acid Plant Area	3	• Degree of A.M.: Moderate to good. Material is accessible, low permeability element could be incorporated. • Open pit provides downstream catchment prior to St. Mary's Channel to act as a buffer if needed. • Can utilize bedrock foundation (1 - 2 m) deep below waste rock.		3.5	• Lowest cost compared to other options. • Other than Option 4, shortest haul distance and most efficient option.		3.5	• Moderate public perception: Landfill is situated away from Zeemel Bay and St. Mary's Channel.	**3.25**
4 - Open Pit (see details in Section 5.5.3)	1	• If the pit were to be backfilled; contaminated debris, non-contaminated debris, waste rock and impacted subsoils would all be placed in the pit. The advantage would be the consolidation of all impacted material.	• Impractical to remove debris from pit once placed. • Contaminant re-suspension. • Settlement/deformation into underground workings. • Unstable pit bottom due to communication with the underground workings creates serious H&S risks (Figure 2) • Large borrow material volumes may be required. • If pit is not dewatered, placement is complex and presents H&S risk. • If pit dewatered, stability of pit walls may be compromised and will require stabilization.	1.5		• Highest cost compared to other options, mainly due to treatment of pit water. • Shortest haul distance, however, additional costs associated with placement in Open Pit safely (i.e. barge) • Additional costs associated with stabilization of Open Pit if dewatered prior to placement.	1	• Poor public perception: May impact water quality in the pit and St. Marys Channel. • Public concerns expressed regarding the understanding that mine equipment may already be in the pit.	1.15
Total Score	10			10			10		10

Notes:

(1) Highest score indicates preferred remedial option. 2) Weighting factors consistent with 2013 EIS.

The preferred remedial option for permanent storage of the non-contained demolition debris is Option 3 (Acid Plant/Mill Complex areas) based on the advantages/disadvantages and scoring provided in Table 5-1. The storage capacity at both the Acid Plant and Mill Complex areas was assessed and it was determined that total volume of non-contaminated material could be accommodated within the combined Mill Complex/Acid Plant footprint area.

Risk Reduction Results

Implementation of the Option 3 remedial design, which includes placement and consolidation of the non-contaminated demolition debris at the Mill Complex/Acid Plant area, is a permanent storage solution that will eliminate the current physical hazards posed to humans and wildlife, which was identified as a "Source" area of risk in the Mill Complex area and Waterfront Decision Trees. Consolidating the material and covering removes the associated physical hazards from site.

Decision Tree Process

The preferred remediation plan for the non-contaminated demolition debris addresses uncertainties identified in the EIS Decision Tree Process, specifically in the Mill Complex/Acid Plant area, Waterfront, Waste Rock and Open Pit Decision Trees. These uncertainties include whether or not debris and/or waste rock will be placed in the Open Pit, if the non-contaminated/contaminated waste will be co-disposed, and if there will be enough borrow material to accommodate all of the remedial designs for the Site Aspects.

The preferred remediation plan for the three tailings areas do not use all of the available till borrow material (OKC, 2016) and the volume of borrow required for the non-contaminated waste landfill is now known. This influences all of the Decision Trees and the uncertainty regarding whether or not there is enough borrow to accommodate all of the Site Aspects will be determined once the preliminary remedial designs for the remaining "other site aspects" have been determined.

5.1.5 Updated Preliminary Remedial Design

Configuration

The preferred design for consolidation and permanent disposal of the demolition debris is a dedicated landfill in the Mill Complex/Acid Plant area (Figure 13). The configuration includes:

- Waste rock/soil excavation to bedrock within the Acid Plant area (pH impacted material), but not within the Mill Complex Area. This material will be placed in Gunnar Main Tailings as part of the Tailings Remediation Design (OKC, 2016).
- Placement of the ACM bags in the lowest excavated area within the Acid Plant area (expected to be in the southern toe of the Acid Plant area). The ACM bags will be covered by a 0.3 m layer of fine borrow material that will be nominally compacted. The rational for covering the ACM with borrow material is to reduce the potential for the bags to become torn during remediation activities, which is a consistent procedure at landfills in Saskatchewan.

- Placement of all other non-contaminated materials. The waste material will be placed in layers that will alternate with layers of clean waste rock. The addition of waste rock layers will help achieve adequate compaction of the waste and will also allow for equipment trafficking throughout construction. Clean waste rock will be obtained from the re-graded areas along the shore line (near the tank farm and camp areas). If there is not enough clean waste rock to accommodate landfill construction, borrow material will be used to supplement the intermediate layers. The material layers will be placed in the following order:
  - ~1.1 m of steel waste
  - 0.25 m of mulched wood waste – layer included for volumetric estimate; however, this material will likely fill voids within the lower layer of steel waste and may not have a substantial stand-alone thickness
  - 0.5 m of waste rock
  - ~1.1 m of steel waste
  - 0.25 m of mulched wood waste – layer included for volumetric estimate; however, this material will likely fill voids within the lower layer of steel waste and may not have a substantial stand-alone thickness
  - 0.5 m of waste rock
  - ~1.0 m of concrete
  - 0.25 m of waste rock – this layer of waste rock will reduce the amount of rebar that may be protruding from the surface of the concrete waste
  - 0.5 m, nominally compacted coarse borrow cover (from Borrow Area 6W)

Steel, concrete, and wood will be placed in lifts and will be nominally compacted by construction equipment during placement of the intermediate cover layers. As mentioned above, the wood waste is anticipated to fill the voids of the steel material below and may not contribute to the total exterior volume of the landfill. The exterior of the landfill will have a final 4H:1V slope that consists of a 0.5 m waste rock layer followed by 0.5 m of coarse borrow material.

Surface Water and Erosion Management

Based on the results of the soil erosion analysis (Appendix H), a 4H:1V slope was considered for the exterior slope of the landfill, which also conforms to the Landfill Code (EMPA, 2010). This slope configuration with the microtopography features prescribed in Appendix H and Attachment C will provide short term stability during vegetation establishment. Once vegetation establishes to an anticipated surface coverage of 40%, soil losses will be substantially below the target value of 6 T/ha/yr.

The crest of the landfill cover will be graded at 1% to 2%, which will concentrate and direct surface flow towards rip rap channels lined with non-woven geotextile (Figure 13). These channels will be situated along the 4H:1V slope, which will feed into a channel situated along the toe of the landfill that directs runoff away from the Open Pit and towards St. Mary's Channel. This channel will be lined with a Rolled Erosion Control Product (RECP) such as a coconut or turf reinforced mat to accommodate the flow velocities and mitigate erosion.

The surrounding area will also be graded to promote positive surface water drainage towards St. Mary’s Channel. The subtle contouring and grades will reduce flow velocities and erosion and will promote sustainable vegetation.

Stability Assessment

Using an infinite slope analysis, the factor of safety (FoS) against sliding finds that the cover material with an assumed friction angle of 30° and at a slope of 4H:1V or 14°, has a FoS >2.0. This is considered to be the FoS against surficial ravelling and a deeper-seated failure through the cover material would likely have a greater FoS. In addition, the landfill has been designed in accordance with the Landfill Code for Saskatchewan.

Neat Line Material Quantities

A summary of the neat line volumes associated with the landfill design are provided in Table 5-2. The total waste volumes include a 25% contingency.

Table 5-2: Neat Line Material Quantities for Non-Contaminated Waste Remedial Option

Item	Units	Estimated Quantities[1]	Design Quantities[,2]
ACM	m^3	5,000	6,200
Steel	m^3	46,500	58,000
Concrete	m^3	19,000	23,800
Wood	m^3	23,500	11,000
Waste Rock Cover Layers	m^3		50,000
Coarse Borrow Material	m^3		17,000
Rip Rap	m^3		20
Seeding and Fertilizer	m^2		35,000
Total Volume	**m^3**		**166,000**

Notes:

1. Volumes were estimated based on aerial photography and the digital elevation model provided by SRC.
2. The values represent the total volumes plus a 25% contingency.
3. The volume of wood is likely to be reduced once mulching and compaction occurs; mulched wood may also fill voids within other layers of waste in the landfill and may contribute to less of an overall landfill volume increase.

5.1.6 Considerations for Detailed Design

A Failure Modes and Effects Analysis (FMEA) will be completed as part of the detailed design.

5.2 Contaminated and Hazardous Materials

5.2.1 General

Contaminated soils are present in multiple areas at the site including the areas that have been identified as the Tank Farm, the Acid Plant area, the Waste Oil Storage Area, the Pump Island, the Powerhouse Building, the Cold Storage Building, and the Temporary Waste Storage Compound (TWSC) (SRC, 2013a). The majority of the areas are contaminated with hydrocarbons while the Acid Plant area is contaminated with both hydrocarbons and low pH material likely caused by the presence of sulphur.

All soil that is considered potentially contaminated will be processed through a screening system to segregate the contaminated soil from the non-contaminated soil. Screening of the soil brings key advantages in terms of improving homogeneity, reducing the volume of the material requiring further treatment, aerating the soil, and allowing for the bulk segregation of soil by PHC concentrations as indicated through the use of field tests, supported by laboratory analysis.

The method involves the use of a vibrating screen to separate stones and boulders from the soil fines. Large size non porous materials (>10 cm) such as the stones and boulders contained within the soil do not retain PHC contamination. Contamination is typically found within the finer grain particles that have a greater surface area to volume ratio. Systematic field testing of the soil fines would then allow for the segregation of soil that is contaminated from soil that does not likely require further treatment. The soil management procedure is described in Appendix F.

The screening and removal of coarse fractions is standard practice in the treatment of contaminated soil and has been applied at numerous remediation projects in Canada and elsewhere. SRK has successfully implemented the use of a vibrating screener to remediate PHC contaminated soil at the Nanisivik Mine, Nunavut (SRK, 2014b). At Nanisivik, the PHC concentrations were decreased by approximately 50% when the soil was passed through the screener and field testing program and the volume requiring further treatment was reduced by about 35%.

Areas of hydrocarbon contamination have not been delineated in detail and a high level volume estimate of 3,000 m^3 was presented in the EIS (SRC, 2013a). Although this volume may be reduced via a screening system, the quantity has been conservatively increased to 4,000 m3 (30% contingency) for design purposes to account for uncertainty. Areas of contaminated soil are shown on Figure 14.

The pH impacted fill within the Acid Plant area is shown in Figure 14. In addition to these areas, the material under the waterfront docks near the warehouse also contains high quantities of sulphur. Regardless of location, all of the high acidity material will be remediated in the same manner (relocated to GMT).

The risks associated with the contaminated materials on site include human health and ecological risks. Contaminated materials can affect both aquatic and terrestrial wildlife at site.

5.2.2 Design Criteria and Objectives

The remedial objective is to design a permanent storage repository that will remove the physical and ecological hazards posed to humans and wildlife by the contaminated waste material on the Site. The design criteria that specifically applies to the contaminated soil/waste rock options includes:

1. Meets regulatory requirements
2. Has a 100-year design life
3. Will accommodate terrestrial animals and maintain traditional land use adjacent to site
4. Reduces human and ecological risk
5. Has a landscape and cover that reduces infiltration, promotes positive drainage and is compatible with natural surroundings
6. Promotes establishment of self-sustaining vegetation

High acidity and acid generating materials will not be deposited in the contaminated waste landfill. The relatively low volumes of the high acidity and acid generating material will not negatively impact the loadings to Langley Bay if the material is incorporated into the tailings prior to cover placement. Thus, this material will be deposited in the Gunnar Main Tailings area.

5.2.3 Assumptions

Assumptions pertaining to the permanent storage of contaminated material on Site include:

- pH impacted material within the Acid Plant area will be hauled to the GMT Tailings area
- Contaminated materials include hydrocarbon contaminated soil
- Residual tailings infrastructure in the vicinity of GMT will be buried in GMT and remediated as part of the tailings cover design, due to the expected relatively high gamma signature of this material
- Total volume of contaminated material is estimated to be 4,000 m^3
- Consolidate all material in one location, separate from the non-contaminated material
- Contaminated waste is considered Type II waste as defined in Saskatchewan Environmental Code (EMPA, 2010)
- Potential landfill locations will require a low permeability element (either natural or synthetic, EMPA, 2010) encapsulating the contaminated material
- The landfill will not include a leachate collection system
- Revegetation of the final cover surface is possible

5.2.4 Remedial Alternatives Analysis

EIS Remedial Options

The Remedial Options Analysis in the 2013 EIS identified:

- Do nothing
- Scarify ground to promote aeration/volatilization
- Excavate affected soil and transport off-site for disposal
- Excavate affected soil for pit disposal
- Excavate affected soil and consolidate in on-site landfill

The "do nothing" and "scarify ground to promote aeration/vitalization" options were eliminated during the pre-screening assessment and the remaining options were carried forward into the MAA (SRC, 2013a). Similar to the non-contaminated demolition debris, the "collect all debris and transport off-site" option was eliminated in the Decision Tree assessment (SRC, 2013a).

Preliminary Design Study - MAA of Remedial Options

The remedial options for contaminated soil and debris considered in this study included:

- Excavate contaminated soil/debris and consolidate in the GMT area
- Excavate contaminated soil/debris and consolidate in a designated area at the East Waste Rock Pile
- Excavate affected soil and consolidate in on-site landfill
- Excavate contaminated soil/debris for open pit disposal

Due to the contamination of the waste, a landfill separated from the non-contaminated demolition debris landfill (Section 5.1) was considered in the options assessment. The former sulphur storage area within the Acid Plant area was selected as the alternate terrestrial landfill location as the concrete base is in good condition and can be upgraded with minor modifications to achieve a low-permeability base. Furthermore, waste rock overlying the bedrock foundation was relatively thin, approximately 2 m thick, and the bedrock relief could be utilized as a low permeable element in the landfill design.

The four areas identified as potential remedial options for the contaminated soil/debris are shown in Figure 14. Details of the MAA are provided in Table 5-3.

Table 5-3: Multiple Accounts Analysis for Contaminated Soil/Debris Remedial Options

Remedial Option	Account (Sub-Accounts): Risk and Adaptive Management (A.M.) (Human Health / Ecological / Active Remediation Risks) — Weighting 50%			Cost (Constructability / Feasibility / Efficacy) — Weighting 30%			Public Perception — Weighting 20%		Total MAA Rating
	Score	Advantages	Disadvantages	Score	Advantages	Disadvantages	Score	Comments	
1 - Gunnar Main Tailings	2	• Relatively low permeability foundation in fine tailings area (1X10^{-7} m/s).	• Degree of A.M.: Poor. Design modifications / further remediation would be complex. Would require alteration to tailings cover design. • Amendment of tailings foundation or incorporation of geosynthetics would be more difficult than Options 2 and 3. • Wet area compared to Options 2 and 3. • Potential contaminant loading to Langley Bay. • Adds complications to tailings cover design (i.e. differential settlement). • Possible opposition to placing non-radioactive material in tailings facility.	2.75		• Foundation preparation may be required to achieve permeability requirements of a Type II landfill. • Longest haul distance compared to other options, cost not favorable.	3.5	• Mixed public perception: - Landfill is situated away from Zeemel Bay and St. Mary's Channel. - May be perceived to impact Langley Bay.	2.5
2 - East Waste Rock Pile	2.5	• Degree of A.M.: Moderate. Area is relatively accessible.	• Waste Rock is porous and location is close to Zeemel Bay. Difficult to intercept potential seepage should adaptive management be required.	2		• Longer haul distance than Option 3. • Poorest foundation condition, foundation preparation is required. Likely geosynthetics would be utilized and therefore finite design life unlike bedrock or tailings foundations.	2	• Moderate to poor public perception: Landfill is situated near Zeemel Bay.	2.3
3 - Acid Plant	4.5	• Degree of A.M.: Good. Potential seeps can be collected, diverted, and managed. The pit acts as a buffer prior to Lake Athabasca. • Risk of contaminant migration is low, utilize bedrock and existing concrete foundation.		3	• Foundation consists of concrete pad and prepared bedrock.		3.5	• Moderate to Good public perception: Landfill is situated away from Zeemel Bay and St.Mary's channel.	**3.9**
4 - Open Pit (see details in Section 5.5.3)	1	• If the pit were to be backfilled; contaminated debris, non-contaminated debris, waste rock and impacted subsoils would all be placed in the pit. The advantage would be the consolidation of all impacted material.	• Impractical to remove debris from pit once placed. • Hydrocarbons on site may float and mobilize to Lake Athabasca. • Contaminant re-suspension. • Settlement/deformation into underground workings. • Unstable pit bottom due to communication with the underground workings creates serious H&S risks (Figure 2) • Large borrow material volumes may be required. • If pit is not dewatered, placement is complex and presents H&S risk. • If pit dewatered, stability of pit walls may be compromised and will require stabilization.	2.25	• No landfill construction required.	• Cost risk: may require treatment if contaminants are re-suspended and if hydrocarbons float.	1	• Poor public perception: placing contaminants in open pit that could impact St. Mary's Channel.	1.4
Total Score	10			10			10		10

Notes: (1) Highest score indicates preferred remedial option. 2) Weighting factors consistent with 2013 EIS.

The MAA results presented in Table 5-3 indicate that the preferred remedial option to permanently store the contaminated soil/debris is Option 3, within the sulphur pad / Acid Plant footprint. Option 3 had the highest score for all accounts and the rationale is provided in the advantages and disadvantages listed in Table 5-3.

Risk Reduction Results

Landfilling the contaminated materials will reduce their ability to become mobile and affect surrounding areas and terrestrial and aquatic wildlife. Furthermore, the pH impacted material will be removed from the Acid Plant area and waterfront (if required) as part of the remedial design. Therefore, both physical and ecological hazards associated with the contaminated soil/debris have been removed.

Decision Tree Process

All Decision Trees are essentially interconnected; however, the main uncertainties associated with the contaminated soil/debris are similar to uncertainties discussed in Section 5.1.3 for the non-contaminated demolition debris; whether or not debris and/or waste rock will be placed in the Open Pit; co-disposal of contaminated/non-contaminated waste; and if there is enough till borrow for all remedial designs for the Site Aspects.

As stated above, the chosen remedial option for the contaminated waste is a permanent landfill situated at the Acid Plant, which addresses the uncertainties in the Decision Trees in the same manner described in Section 5.1.3.

5.2.5 Updated Preliminary Remediation Design

Configuration

The former sulphur storage area near the Acid Plant area was the preferred location for the contaminated waste landfill (Figure 15). The north side of the former sulphur storage area has a vertical bedrock face, while the base is concrete. The landfill will be positioned against the face to create a sloped landform. The bedrock surface will be geomechanically inspected. The concrete base will be cleaned and any cracks will be repaired. Provisions such as slush grout and dental concrete will be incorporated to achieve the design hydraulic conductivity prior to placement of waste. The concrete base is above the normal groundwater table, and above the seasonally high groundwater level.

The contaminated waste rock/soil will be placed in lifts between 0.5 m and 1.0 m thick. Finer-grained borrow materials, obtained from Borrow Area 6 will be used to construct a 1.0 m thick compacted clay cover over the waste. The compacted clay cover will be targeted to achieve an average hydraulic conductivity of 1×10^{-9} m/s to restrict infiltration through the cover, and into the waste. Due to the one-time placement of waste, and the characteristics of the proposed low-permeability cover, a leachate collection system is not proposed to be incorporated into the landfill design.

To protect the integrity of the compacted clay liner, a 3.3 m thick frost protection layer will be constructed, comprised of 2.8 m of non-hazardous waste (concrete or waste rock), and 0.5 m of coarse textured borrow as a final cover (nominally compacted). The coarse borrow material will reduce the potential for erosion and will act as a growth medium. Differential settlement of the cover is not anticipated. Further details relating to the selection of the cover for the hazardous waste is provided in Appendix G.

Surface Water and Erosion Management

The Non-Hazardous landfill has been designed to abut/tie-into the Hazardous Landfill as concrete and/or waste rock will be utilized as frost protection. Therefore, the surface water and erosion management features for the combined facilities are discussed in Section 5.1.5.

Stability Assessment

A stability assessment was not required for the Hazardous Landfill as the exterior slopes of the combined facilities was assessed in Section 5.1.5.

Neat Line Quantities

A summary of the neat line quantities for the Acid Plant area landfill are provided in Table 5-4.

Table 5-4: Neat Line Material Quantities for Contaminated Waste Remedial Option

Item	Units	Quantities[1]
Excavated – pH Impacted Waste Rock	m^3	15,000
Excavated – pH Impacted Foundation Soil	m^3	9,000
Contaminated Soil/Waste Rock	m^3	4,000[2]
Compacted Clay Cover (Fine Borrow Material)	m^3	2,200
Frost Protection Layer (concrete)	m^3	8,700
Cover (Coarse Borrow)	m^3	N/A (see Non-Hazardous Landfill)
Seeding and Fertilizer	m^2	N/A (see Non-Hazardous Landfill)
Total Volume	**m^3**	**14,900**

Notes:

1. Only fill volumes are included in the total.
2. Includes a 30% contingency to account for uncertainty in volume estimation.

Considerations for Detailed Remediation Design

A FMEA will be completed as part of the detailed design.

5.3 Waste Rock

5.3.1 General

In general, the EIS identified four risks that are associated with waste rock (particularly the EWRP and SWRP) and Catchment 3. These risks include: 1) Physical Hazards; 2) Human Health Risks; 3) Ecological Risks, and 4) Gamma Exposure Risks.

The physical hazards are related to the current waste rock slopes at the EWRP, SWRP, the former fuel tank farm area and the shoreline by the School/Community Center (Figure 16). The slopes range from approximately 1.3H:1V to 1.8H:1V and are close to the angle of repose for the Gunnar Mine waste rock, which is assumed to be approximately 1H:1V based on the observed grain size.

The human health risks are from the waste rock piles and include gamma exposure and inhalation and inadvertent ingestion of dust.

The ecological risks are to the receiving environment (St. Mary’s Channel, Zeemel Bay of Lake Athabasca) and pertain to aquatic organisms via direct contact with water and sediment. As stated in Section 2.9, the uranium and radionuclides in Zeemel Bay were the main concerns for both aquatic receptors, small terrestrial receptors and aquatic plants. In general, uranium and Ra-226 loadings to Zeemel Bay are generated from Catchment 3 surface water flows (which is also elevated in Ra-226) through the EWRP and from precipitation that either enters Zeemel Bay via surface water flow or as seepage through the waste rock piles (i.e. Seep-1 from EWRP and Seep-3 from the SWRP).

Areas at the Site that have elevated gamma radiation are summarized in Table 2-1 in Section 2. Exclusive of the tailings areas, the main areas of concern that pertain to the “Other Side Aspects” are the waste rock piles, Catchment 3, and the general mine site area.

5.3.2 Design Criteria and Objectives

The remedial objective is to mitigate the risks identified above. To meet this objective, the design criteria that specifically applies to the waste rock and Catchment 3 includes:

1. Has a 100-year design life.
2. Will accommodate terrestrial animals and maintain traditional land use adjacent to the Site.
3. Has a landscape that reduces infiltration, promotes positive drainage and is compatible with natural surroundings.
4. Debris encountered will be removed and disposed of in a designated location (i.e. landfill). Landfills have been designed with a contingency to accommodate such debris.
5. Reduce gamma to levels as listed in Table 3-1.
6. Meets SSROs in St. Mary’s Channel and Zeemel Bay during and immediately after the remediation activities and will result in further improvement of the water quality parameters in these water bodies on a long-term basis.
7. Waste rock slopes that are over steepened are graded to a stable configuration as listed in Table 3-1.
8. Promotes establishment of self-sustaining vegetation.

5.3.3 Assumptions

The assumptions associated with the remedial options for waste rock and Catchment 3 includes:

- The total volume of waste rock in the EWRP and SWRP is approximately 2.24 Mm^3.
- Approximately 813,000 m^3 of waste rock and 14,000 of foundation soils will be removed from the combined EWRP and SWRP and hauled to GMT as per the tailings design requirement of 851,000 m^3 by OKC (OKC, 2016). The remaining volume of 24,000 m^3 includes the pH impacted material from the Acid Plant area (Section 5.2).
- Waste rock slopes at the EWRP, SWRP, the former fuel tank farm area and the shoreline by the School/Community Center require grading.
- COPC loadings to Zeemel Bay and St. Mary’s Channel are reduced.
- EWRP and SWRP require a gamma and vegetative cover if left on surface.

5.3.4 Remedial Alternatives Analysis

EIS Remedial Options

There were several candidate remedial alternatives identified in the pre-screening assessment for the aspects associated with the waste rock at the Gunnar Mine Site (SRC, 2013a). A comprehensive list of the remedial alternatives considered in the assessment are provided in Table 5-1 of the EIS (Vol 1, SRC, 2013a).

The remedial options associated with the waste rock in the preliminary screening assessment were revised in the development of the EIS Decision Trees and options from the screening assessment were not carried forward into the Waste Rock Decision Tree. Instead, new options were developed based on the risks to human and ecological health posed by 1) the source of contaminants, 2) the pathway of contaminants and 3) the receiving environment. The remedial options identified in the Waste Rock Decision Tree are listed below for each area of risk. The risks associated with each “area of risk” are discussed above in Section 5.3.1.

<u>Source</u>

- “Do nothing”
- Cover all or part of the waste rock
- Relocate all or part of the waste rock
- Flatten slopes

<u>Intermediate Pathways</u>

- None

Receiving Environment

- “Do nothing”
- Management of Water in Catchment 3 (Divert up-gradient of Waste Rock Deposits)
- Management of Water in Catchment 3 (Restore Historical Creek Channel through Waste Rock Deposits)

Preliminary Design Study - MAA of Remedial Options

For this study, the remedial options for the Waste Rock Piles were based on the Decision Tree options listed above and are summarized as:

- Re-establishment of the historical channel below the EWRP and grade/cover/vegetate Waste Rock Piles
- Diversion of Catchment 3 around the EWRP and into Zeemel Creek and grade/ cover/ vegetate Waste Rock Piles
- Placement of both the EWRP and SWRP in the Open Pit

The tailings remedial design called for 851,000 m^3 of waste rock (OKC, 2016) and placement of additional waste rock or all of the waste rock in the tailings areas was not considered an option as it would impact the proposed remedial design.

Assessment of remedial options were not required for the waste rock areas at the former fuel tank farm and shoreline by the School/Community Center as the remedial objective was to grade the over steepened slopes and remove the physical hazard.

The three remedial options considered in the MAA for the Waste Rock Piles are shown in Figure 16. Results of the MAA are summarized in Table 5-5.

Table 5-5: Multiple Accounts Analysis for Waste Rock Remedial Options

Remedial Option	Account (Sub-Accounts)								Total MAA Rating
	Risk and Adaptive Management (A.M.) (Human Health / Ecological / Active Remediation Risks)			Cost (Constructability / Feasibility / Efficacy)			Public Perception		
	Weighting 50%			Weighting 30%			Weighting 20%		
	Score	Advantages	Disadvantages	Score	Advantages	Disadvantages	Score	Comments	
1 - Re-Establish Historic Channel and Grade/Cover/vegetate Waste Rock Piles	5.5	• Degree of A.M.: Moderate to Good. Channel configuration permits remedial efforts. • Determined to have lowest risk out of the 3 options.		5	• Tailings design requires 820,000 m^3 of waste rock and material excavated from the channel will go to tailings. Option 1 was the most cost efficient. • Covering the waste rock is more economic than hauling to the pit or elsewhere. • For Option 3, a similar borrow quantity will be required to cover the foundation footprint of the waste rock piles once removed.	• Unknown as to what may be exposed during excavation. May be additional cost to accommodate.	3.33	• Public perception was assumed equal for all three options.	**4.9**
2 - Divert Catchment 3 and Grade/ Cover/vegetate Waste Rock Piles	3.5	• Degree of A.M.: Moderate. Channel will be relatively accessible, however, remedial efforts deemed to be more extensive than Option 1.	• Risk of higher loadings than predicted due to residual flow through historic buried channel. • Diversion channel would disturb new land outside of mine footprint as well as Zeemel Creek.	4	• Low cost option compared to Option 3. • Covering the waste rock is more economic than hauling to the pit or elsewhere. • For Option 3, a similar borrow quantity will be required to cover the foundation footprint of the waste rock piles once removed. • May provide clean quarry rock if required for remedial designs.	• Higher cost option than Option 1. • Costs associated with A.M. would be higher than Option 1.	3.33	• Public perception was assumed equal for all three options.	3.6
3 - Relocate Waste Rock Piles to Open Pit **(see details in Section 5.5.3)**	1	• All waste rock will be excavated and stored in the pit, reducing source load from waste rock and sub-soil. • Non-contaminated and contaminated demolition debris, waste rock and sub-soil will be consolidated below waste rock piles.	• Contaminant re-suspension. • Hydrocarbons in pit water. • Settlement/deformation into underground workings. • Unstable pit bottom due to communication with the underground workings creates serious H&S risks (Figure 2) • Impractical to remove waste rock from pit once placed. • Large borrow material volumes may be required. • If pit is not dewatered, placement is complex and presents H&S risk. • If pit dewatered, stability of pit walls may be compromised and will require stabilization. • Difficult logistics of waste rock placement at pit bottom.	1		Highest cost option: • Large volume to be hauled to the open pit. • Water treatment. If pit is not filled and covered, perpetual water treatment may be required. • Waste rock footprint (similar area to existing pile) will require a cover. • Pit wall stabilization if backfilled in non-flooded state. • Geotechnical monitoring during remediation	3.33	• Public perception was assumed equal for all three options.	1.5
Total Score	10			10			10		10

Notes:

(1) Highest score indicates preferred remedial option. (2) Weighting factors consistent with 2013 EIS

Based on the results of the MAA, the selected remedial option for the waste rock piles is Option 1 (Figures 17 to 25), which comprises:

- Re-establish the historical channel below the EWRP
- Grade and contour the waste rock piles
- Cover and re-vegetate waste rock piles

Human and Ecological Risk Evaluation for Zeemel Bay

The assessment for future loads used the anticipated water quality and flows within the restored Catchment 3 drainage channel. It has been assumed that the entire flow from Catchment 3 would flow through the restored historical Catchment 3 drainage channel resulting in a reduced flow through the East Waste Rock Pile (EWRP). In addition, the regrading and covering of the waste rock piles will reduce the percolation through the SWRP and EWRP. Future percolation rates resulting from cover of the waste rock piles were developed for a range of waste rock cover materials; the loads presented in this section correspond to a coarse textured till cover material for the reasons outlined in Section 3.3. Figures 26 and 27 provide schematics of the future loads of uranium and radium-226 to Zeemel Bay. The future concentrations from the EWRP were assumed to be the arithmetic mean of the current seep concentrations which is thought to represent the expected future conditions. The reduction in loads from the South Waste Rock Pile was assumed to be proportional to the reduction in water flow through the contaminated material (waste rock). Figures 26 and 27 illustrate the restoration of the channel and cover of the waste rock/tailings will result in a reduction of the total uranium load to Zeemel Bay by more than one half (load is reduced from 168.5 kg/a to 80.0 kg/a) and the radium-226 load will be reduced from 125.0 MBq/a to 111.5 MBq/a. Predicted uranium and radium-226 groundwater loads from the GMT to Zeemel Bay after cover of the tailings are consistent with estimates provided in (EcoMetrix, 2016).

Table 5-6 summarizes the current and future concentrations of uranium and radionuclides to Zeemel Bay. Current concentrations are represented by the geometric mean of measured data in Zeemel Bay, while the future concentrations in Zeemel Bay are estimated based on the changes to loads in the future. Along with the current and estimated future concentrations, Table 5-6 provides the selected water quality guidelines (WQGs) (Canadian Water Quality Guidelines for Drinking Water, CCME 2012) for site and the site-specific remedial objective (SSRO) for uranium in Zeemel Bay that was provided in the Gunnar EIS. As seen from the table, the current concentrations of uranium in Zeemel Bay exceed the WQG. However, the restoration of the Catchment 3 drainage channel will reduce the quantity of the EWRP seep that enters Zeemel Bay and this will have a positive impact on the predicted uranium concentrations in Zeemel Bay. The future uranium concentrations will be below the WQG as well as the SSRO under expected conditions, indicating that current adverse effects on aquatic receptors such as fish in Zeemel Bay will be reduced.

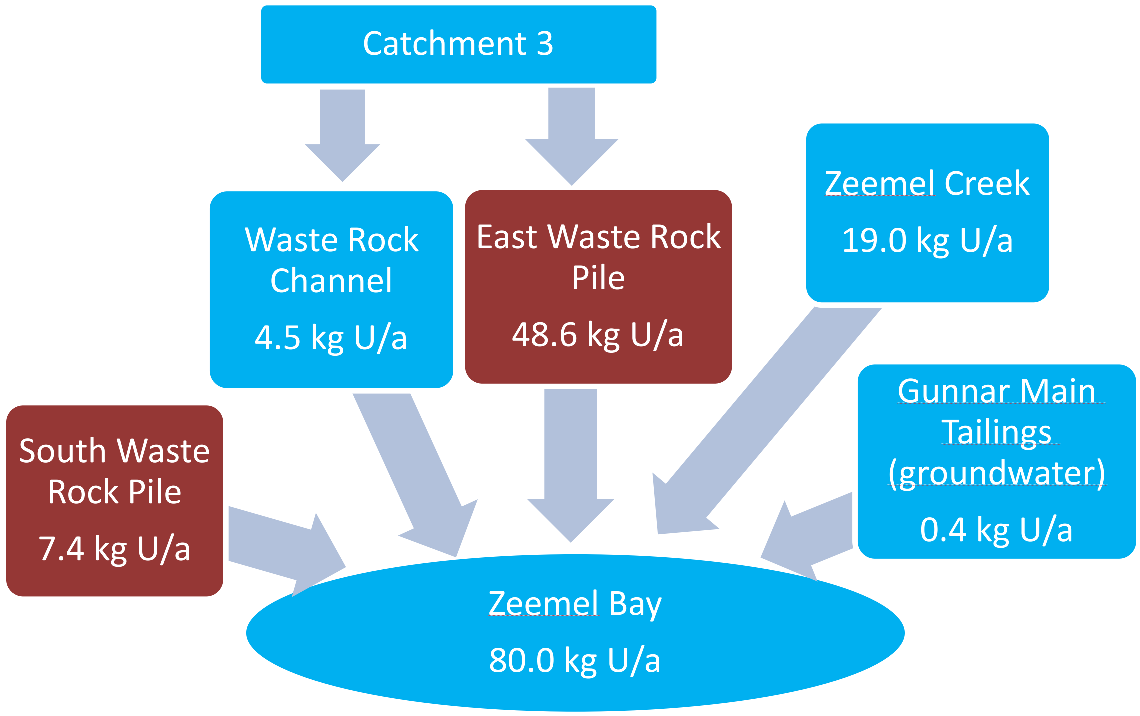

Figure 26: Schematic of Uranium Loads to Zeemel Bay following Restoration of Historic Waste Rock Channel

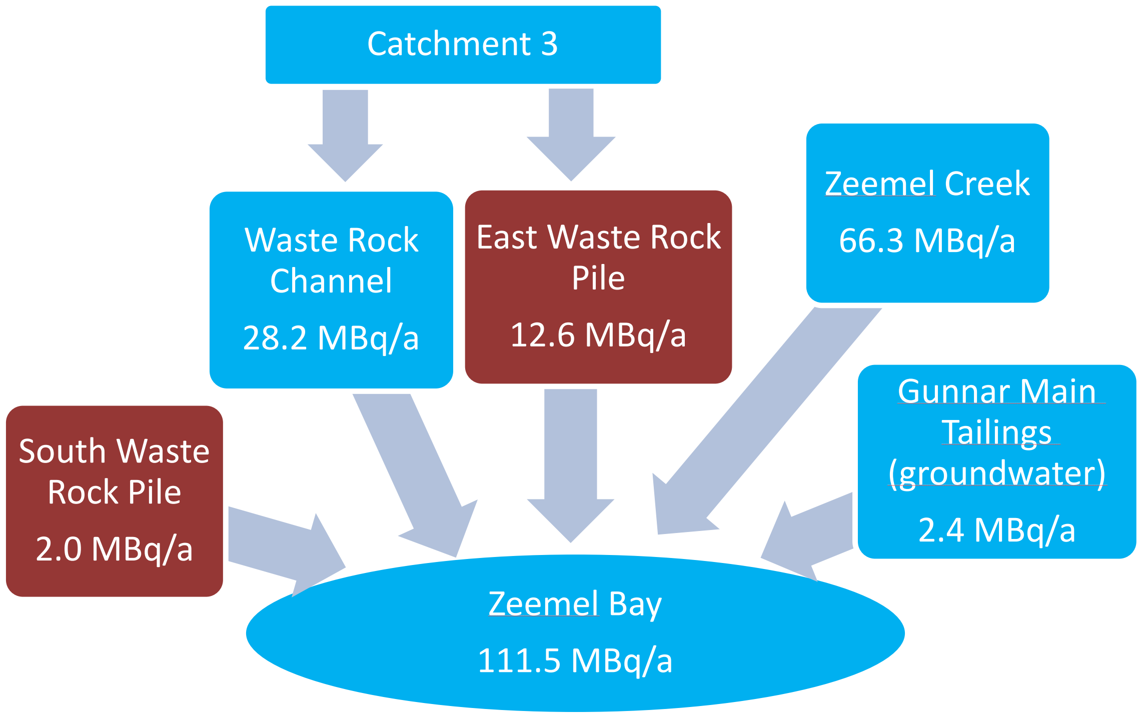

Figure 27: Schematic of Radium-226 Loads to Zeemel Bay following Restoration of Historic Waste Rock Channel

Table 5-6: Assessment of Predicted Concentrations in Zeemel Bay

	Predicted Concentrations [a]				
	Uranium	**Thorium-230**	**Lead-210**	**Radium-226**	**Polonium-210**
Units	mg/L	Bq/L	Bq/L	Bq/L	Bq/L
Current Conditions	**<u>0.018</u>**	0.016	0.024	0.012	0.008
Future Conditions	0.008	0.017	0.024	0.011	0.007
WQG[b]	0.015	0.6	0.2	0.11	0.1
SSRO[c]	0.2	-	-	-	-

Note(s):

Zeemel Bay future concentrations presented above were calculated using loads associated with waste rock percolation rates through a coarse textured till cover.

a – based on geometric mean concentrations.
b – water quality guidelines (WQG) for thorium-230, lead-210, and polonium-210 are CWQG (Canadian Water Quality Guidelines for drinking water, CCME 2012); uranium is the Saskatchewan Environmental Quality Standard for Surface Water (Saskatchewan Environment 2015). Radium-226 is a historical Saskatchewan Surface water Quality Objective, but is retained for completeness in the absence of other values.

c – site-specific remedial objective (SSRO) for uranium derived from the species sensitivity distribution (SSD).
\- Not applicable

<u>Bold underlining</u> indicates exceedance of the WQG.

An assessment of the potential radiological effects on aquatic receptors in Zeemel Bay from the restoration of the Catchment 3 drainage channel was completed and the results indicated that there are currently no potential radiological effects on aquatic receptors in Zeemel Bay and there are no potential radiological effects on aquatic receptors in Zeemel Bay predicted in the future when the catchment 3 drainage channel is restored. Detailed results are provided in Appendix B.

While predicted loads and concentrations shown in this section correspond to application of a coarse textured till cover on the waste rock pile, the overall conclusions are unchanged if calculations are performed for medium or fine textured till cover material. There is predicted to be slightly less percolation through the waste rock cover (and correspondingly lower loads) for fine textured till cover than with coarse or medium textured till, however, this slight benefit is not expected to outweigh the additional long-term erosion concerns associated with the fine textured till, which is further discussed in Appendix H.

In summary, human and ecological risks are not expected in Zeemel Bay following the implementation of the remedial activities proposed for the waste rock and the Catchment 3 drainage.

Decision Tree Process

Selection of the preferred remedial option for the waste rock piles addresses the "decision point" uncertainties in the Waste Rock Decision Tree, which were whether or not there is enough borrow to accommodate all of the Site Aspects and the risks associated with Catchment 3 flow through the waste rock and the associated loadings to Zeemel Bay. The volume of borrow required to cover the waste rock piles is now known and it has been confirmed that the loadings to Zeemel Bay will have no adverse effects on the Aquatic Environment.

Furthermore, selection of the remedial designs for the waste rock and contaminated and non-contaminated waste dictates the selection of the preferred remedial option for the Open Pit, which is discussed in Section 5.5.

5.3.5 Updated Preliminary Remediation Design

Based on the MAA, the preferred remedial design option is to re-establish the historical drainage channel, which will route Catchment 3 flow to Zeemel Bay without contacting the EWRP and to grade, cover and re-vegetate the remaining waste rock piles, following the relocation of 827,000 m^3 to the GMT for grading prior to cover placement (Figures 17 to 25). Additional remedial work associated with waste rock on site the former fuel tank farm area and the shoreline by the School/Community Center will consist of regrading to a stable slope, which was determined to be 2.5H:1V and 2H:1V, respectively (Appendix E).

Preliminary Design to Re-establish Historic Drainage Channel

Catchment 3 will be routed through a trapezoidal channel along the historical drainage path through the EWRP and will discharge into Zeemel Bay (Figure 17). A temporary culvert will be installed through the access road at the inlet of the channel to accommodate the closure monitoring period. At the end of this period the culvert will be removed and the area will be graded and armored in accordance with the channel design. Alternatively, a low level crossing can be installed in-place of the proposed culvert, which will be considered in the next design phase.

A majority of the channel will be excavated into the silt/clay foundation; however, it is expected that areas may be founded on/or in bedrock (Figure 21). It was assumed that the sub-cut channel bottom shown in profile on Figure 21 would be sufficient to remove material that may be contaminated. The volume associated with this sub-cut is approximately 14,000 m^3, which will be hauled to tailings and incorporated as part of the tailings remediation design. The bottom of the channel will be armored with rip rap and the channel side slopes will be offset at the top of the armoring so that a 1.6 m wide bench can be established on both sides of the channel side slopes. This bench will be used to accommodate placement of the vegetated cover layer and will also serve as a sediment catch until vegetation is established along the slopes.

Non-woven geotextile will be placed against the till foundation along the excavated channel and will be keyed-in to an anchor trench. Rip rap will then be placed against the non-woven geotextile. The non-woven geotextile will prevent migration of fine particles through the rip rap and into the channel water. The non-woven geotextile and the rip rap will be installed up the side slopes of the channel to a minimum height of 1.2 m or to a minimum elevation of 211.0 m, which accommodates the high water mark in Lake Athabasca at Environment Canada’s Cracking Stone monitoring station in the relative vicinity of Zeemal Bay (210.65 m). The depth and diameter of the rip rap were calculated using the unit peak flow rate described in Appendix C. Gamma radiation will be measured in the field during construction, and where required, additional cover will be placed to meet the gamma exposure objective.

The upper portion of the channel side slopes above the rip rap will be protected with a rolled erosion control product (RECP) to stabilize the cover material until vegetation is established. The channel design is illustrated in Figures 21 to 25 and design details are presented in Table 5-7.

Table 5-7: Summary Design Details for Re-established Historic Drainage Channel

Parameter	Criteria	Source/Details
Till Borrow Cover	0.5 m	Based on Section 3.0.
Design Flow	8.0 m^3/s	Based on unit peak flow established in Appendix D.
Base Width	6 m	For constructability.
Side Slopes	3H:1V	Slope angle that will accommodate till cover, RECP/vegetation, and volumetric design.
Rip rap D_{50}	0.1 to 0.5 m	Based on maximum velocities during the design event
Rip rap Height within Channel	1.2 m	Based on normal depth in channel during design event plus freeboard.
Rip rap Thickness	0.3 to 1.5 m	Based on 2 x D_{50}
Minimum Rip rap Elevation	211 masl	High water mark in Zeemel Bay (210.65 masl) (Canada, 2015) with the addition of freeboard.
Channel Outlet Elevation	209 masl	Average water level in Zeemel Bay (Canada, 2015)

EWRP and SWRP Regraded Slopes (Optimization of Preliminary Remediation Landform)

In general, the preliminary remediation design for the EWRP and SWRP included excavating 8 to 10 m wide benches every 6 m around the perimeter of the piles to form an overall average slope of approximately 5H:1V. The slope between the benches were to be graded 3H:1V and the final landform configuration was to be covered with 0.5 m thick layer of coarse till borrow and revegetated (SRK, 2015).

Following further engineering studies, the preliminary remediation design has been updated. The details of these updates are provided in Appendix H. In summary, the changes include:

- Waste rock slopes > 50 m in length will be graded to 5H:1V
- Waste rock slopes ≤ 50 m in length will be graded to 4H:1V
- Microtopography features have been incorporated into the design, which include slope texturing, organic fibre rolls/wattles, sediment fences, RECPs, and seeding

These changes result with a more robust design that will meet the design objectives of the cover system by providing enhanced stability and erosion protection from that of the 2015 preliminary design. The revised configuration of the EWRP and SWRP are shown in Figures 17 to 23. The total waste rock cut and fill volumes to achieve the desired landform is approximately 930,000 and 103,000 m^3, respectively, which results in a total volume of 827,000 m^3 coming from the waste rock piles to accommodate the tailings remediation. An isopach showing the cut and fill locations at the EWRP and SWRP is provided in Figure 18. As previously stated, the tailings remediation project calls for 851,000 m^3 and the remaining 24,000 m^3 will come from the excavation at the Acid Plant (Section 5.2.5).

The bulk of the waste rock allocated to GMT will come from the EWRP to lower the overall height of the pile by approximately 14 to 20 m. The current configuration of the EWRP slopes north to south, therefore the reduction in overall height once remediated will vary. The northeast corner of the EWRP is the highest section of the pile at elevation 244.0 m, which stands approximately 15 m higher than the SWRP. The final configuration of the EWRP will have two tiers, the west tier will crest at elevation 224 m and the east tier at elevation 230 m (Figure 17).

Since a majority of the waste rock will come from the EWRP, the crest of the SWRP will only be lowered by approximately 5 m (Figures 18 and 19). However, the existing SWRP is at elevation 228 m, approximately 16 m lower than the existing EWRP and therefore the excavation was concentrated at the EWRP. The remediated configuration for the SWRP will have a final crest at approximately elevation 221 m, which will essentially match the elevation of the west tier of the EWRP.

Surface Water and Erosion Management

Gently sloping landform swales are the preferred surface water management strategy to facilitate water-shedding and limit erosion on the waste rock piles. Where expected velocities are less than or equal to 1 m/s, a vegetated channel/swale is sufficient to convey surface water flows without causing significant erosion. The features will convey surface water flows into the re-established Catchment 3 drainage channel, and towards Zeemel Bay. In areas that have higher flow velocities in concentrated areas, RECPs and/or rip rap is required for erosion control. The location of water conveyance structures is shown in Figure 17 and hydrotechnical design details are provided in Appendix D.

Microtopograhic features will be incorporated in the remediation plan to further reduce erosion potential of the waste rock pile’s cover material and to facilitate revegetation (Appendix H). This will include slope texturing via trackwalking or imprinting on all slopes graded 5H:1V or steeper. Additionally, the 3H:1V slopes of the re-established drainage channel will be lined with a RECP to provide protection against erosion by serving as cover and increasing the stability of vegetation roots and shoots, once established. Organic fibre rolls/wattles will be placed at the crest and along the slopes to reduce effective slope lengths along all slopes 5H:1V or steeper. Further, where sedimentation to natural waterbodies is a potential concern (e.g., Zeemel Bay/St. Mary’s Channel), check structures and/or sediment fences will be installed at the base of slopes to promote the deposition of soil particles upslope before they are transported to nearby waters.

Re-graded Slopes for General Mine Site Areas

The general Site areas that require re-grading are the former fuel tank farm area and the shoreline by the School/Community Center (Figure 17). Based on the results of the gamma radiation surveys provided in the EIS, these areas will not require a gamma reduction cover as they are understood to be at/lower than 1.14 µSv/hr. Therefore, these slopes may be graded to a stable configuration that is steeper than areas required to accommodate the till cover material. A slope stability analysis to determine the minimum slope angle for closure of re-graded slopes with and without cover is discussed in the following section.

Stability Assessment

A stability assessment of the Gunnar Mine waste rock piles was undertaken using the slope stability software package, SLIDE (Version 6.0) developed by Rocscience. Cross-sections through the highest and steepest sections of the existing waste rock piles were first assessed to assist in back-calculating assumed material strength parameters. Once suitable material properties were determined, sections through the re-graded waste rock piles were assessed for long-term static and pseudo-static stability. The minimum static and pseudo-static factor of safety was considered to be 1.5 and 1.1, respectively as recommended by the British Columbia Mine Waste Rock Pile Research Committee (BCMWRPRC) (BCMWRPRC, 1991). The pseudo-static analysis used a conservative Peak Ground Acceleration (PGA) of 0.031g, which is equal to the 1 in 2,475 year average recurrence interval (ARI).

Little to no geotechnical strength testing of the materials included in the assessment (e.g. waste rock, borrow, shoreline sediments and lake bed sediments) was available to assess their shear strength behaviour. Therefore, SRK used engineering judgement and recommended shear strength parameters from literature to define the material properties. Assumed values were determined conservatively and a sensitivity check of the assumed values was undertaken to confirm they were appropriate. Borehole logs from the SNC-Lavalin report, *Supplemental Gunnar Subsurface Characterisation Program* (SNC, 2016), were used to characterise the subsurface geotechnical profile. In some areas, the density of boreholes is high; however, in most areas there is only one or sometimes no boreholes available to classify the subsurface conditions. Hence a high level of interpretation into the subsurface conditions has been undertaken and SRK has adopted the critical subsurface profile in all cases.

The stability assessment considered sections through the following waste pile areas:

- Gunnar open pit waste rock plug (refer to Section 5.5.4)
- Shoreline waste rock piles, including:
  - Camp area
  - Fuel tank farm area
- South waste rock pile
- East waste rock pile
- Re-established Catchment 3 drainage channel

The results of the stability assessment revealed the following:

- The Gunnar Open pit plug is stable under both long-term static and seismic conditions
- The shoreline waste rock piles at the Fuel Farm and Camp areas meet the minimum FoS at a slope of 2.5H:1.0V and 2H:1V, respectively
- The South Waste Rock Pile is stable under both long-term static and seismic conditions at a slope of 5H:1V
- The East Waste Rock Pile is stable under both long-term static and seismic conditions at a slope of 5H:1V
- The waste rock slopes at the re-established Catchment 3 drainage channel are stable under both long-term static and seismic conditions at a slope of 3H:1V

A detailed discussion of the stability assessment is included in Appendix D.

Neat Line Material Quantities

A summary of the neat line volumes associated with the waste rock remedial design are provided in Table 5-8.

Table 5-8: Neat Line Material Quantities for Waste Rock Remedial Design

Item	Units	Quantities[1]
Waste Rock Removal to Tailings	m^3	813,000
Re-establish Historic Drainage Channel: Foundation Removal to Tailings	m^3	14,000
Acid Plant: Foundation Removal to Tailings	m^3	24,000
Cover (Coarse Borrow)	m^3	113,000
Rip Rap	m^3	2,500
Non-Woven Geotextile	m^2	10,000
RECP	m^2	16,000
Seeding and Fertilizer	m^2	208,000
Total Excavated Volume	$\mathbf{m^3}$	**851,000**
Total Fill Volume	$\mathbf{m^3}$	**115,500**

Notes:

Only excavated and fill volumes are included in the totals.

5.3.6 Considerations for Detailed Design

A FMEA will be completed for the proposed drainage channel and waste rock remedial design.

5.4 General Site

5.4.1 Context

There are three openings on site that require an engineered cap for proper closure: the mine shaft, the vent-raise and the back-raise. The locations of the openings are shown in Figure 28.

A considerable amount of surface area throughout the site including the area surrounding the Open Pit, General Mine Site Area, the West Town Site, and Catchment 3 emit gamma radiation at levels greater than 1.0 µSv/hr above background levels. In most of the areas, the gamma emitting material is waste rock that was historically used to build up and/or flatten areas for infrastructure or access. In Catchment 3, the gamma emitting material consists mostly of tailings that appear to have migrated from the GMT in the vicinity of the back release area. These aforementioned areas with elevated gamma radiation levels are shown in Figure 28.

5.4.2 Objectives and Criteria

Mine Openings

The mine openings cause physical risks to the public and therefore require remediation. The design objective in remediating the mine openings risks is to permanently close off the openings.

The Mines Regulations (2003) and/or the requirements of the Ontario Ministry of Northern Development and Mines will be used in the detailed design. The Ontario guideline is considered best practice and is widely used in Canada.

Criteria adopted for stainless steel caps previously designed and installed on uranium mine openings in the Uranium City area will be used. The design criteria include a lifetime sufficient to ensure permanent closure; the ability to resist deterioration; a load capacity based on projected vehicle, wildlife, snow drift, soil overburden, and industrial loads; limited rain and snowmelt water accumulation on cap and surrounding ground; secure placement; ventilation (air and water); minimal field cut walls; minimal rock removal; and the cost-saving initiatives. Further details of these designs are found in Appendix I, Section I.

Elevated Gamma Radiation Levels

Most site areas that are emitting gamma radiation may be subjected to sustained human/wildlife interaction. Therefore, the remedial objective is to reduce gamma radiation levels to meet the criteria listed in Table 3-1. If the areas are covered with borrow material to reduce radiation, an additional design objective will be to minimize erosion of the cover as much as possible.

Consistent in all aspects of this project, reducing risk to both human health and wildlife is an important remedial design consideration. However, in Catchment 3, the gamma radiation which is on average 2.32 µSv/hr will pose minimal risk to human health and wildlife. The area is not easily accessible (predominately wet boggy area) and very little human traffic is expected. The area of Catchment 3 that is elevated in gamma is very small in comparison to the overall foraging area of the native herbivorous species. This reduces the potential gamma exposure to such species; especially large angulates such as moose and deer that frequently migrate through the area. Furthermore, remediation would consist of a soil borrow gamma cover over an area of approximately 2.5 ha. Such remediation would include removal and disposal of the impacted vegetation and would require a significant amount of borrow, especially over boggy areas for constructability purposes. In summary, covering Catchment 3 would not be an effective use of the borrow material available on site, would have a net negative ecological impact on the local area (large land disturbance in Catchment 3 and borrow area), and the gamma radiation in this particular area poses a low risk to human health and wildlife due to its ecological characteristics (muskeg) and subsequent infrequent usage. For these reasons, no remedial actions are proposed for Catchment 3.

5.4.3 Updated Preliminary Remedial Design

Mine Openings

The mine shaft and openings will be closed using stainless steel caps designed on a site-specific basis for the main mine shaft, the ventilation raise, and the back raise (Appendix I). Stainless steel was chosen over galvanized or weathered steel, aluminum, and concrete because it is strong, durable, easy to fabricate and modify in the field, readily available, and the fabricators and installation contractors are known. Appendix I, Section E, provides the structural design specifications for beams and joists, vertical supports, and side plates.

As part of the detailed design stage, each opening will be inspected and surveyed in terms of size and location relative to competent bedrock, grading (drainage), risks posed by up-slope rock, and site accessibility. Field data will be combined with a 3D model in AutoCAD Civil 3D to design engineered caps that fit site contours and minimize the plan dimensions.

Stainless steel caps will be secured with anchor bolts with dimensions that balance structural integrity with installation effort. The bolt embedment length will extend through the bedrock surface layer, which may be fractured. Bolts will be grouted with epoxy to provide lateral load resistance and prevent structure movement.

Elevated Gamma Radiation Levels

The site areas emitting elevated levels of gamma radiation excluding Catchment 3 will be covered with a minimum of 0.5 m of medium to coarse borrow material. The borrow material will be graded and contoured to reduce flow velocities below 1 m/s, which will reduce erosion and permit revegetation for long-term erosion control.

Decommissioning of Monitoring Wells

Monitoring wells have been installed throughout the Gunnar Mine Site (Figure 5), which where possible will be utilized during post remediation monitoring. Some of the existing wells will need to be decommissioned prior to remediation of the other site aspects, which will be carried out in accordance with industry standards.

Monitoring wells have been installed throughout the Gunnar Mine Site (Figure 5), which where possible will be utilized during post remediation monitoring. Some of the existing wells will need to be decommissioned prior to remediation of the other site aspects, which will be carried out in accordance with industry standards.

Incidental Legacy Debris

It is expected that incidental debris will be encountered during remediation of both tailings and the other site aspects. Such debris will be classified on site visually by designated project personnel to determine if the material will be placed in the hazardous or non-hazardous landfill. If the debris cannot be classified on site, samples will be prepared and sent for laboratory testing in accordance with SRC's standard operating procedures.

5.4.4 Considerations for Detailed Design

A FMEA for the mine shaft/openings closure caps will be completed as part of the detailed remedial designs for the other site aspects.

5.5 Open Pit

5.5.1 General

The Gunnar Pit was flooded during closure in 1964, by way of a blasted channel between the Pit and Lake Athabasca. The channel was later backfilled with waste rock isolating the pit from the lake. Currently the pit maintains a water elevation that is about 2 m higher than Lake Athabasca (SRC, 2013a). The estimated volume of water in the open pit, not accounting for the underground workings, is about 3.2 Mm3 and the surface area is approximately 70,600 m2 (SRC, 2013a).

Water sampling has indicated that a chemocline (interface above chemically denser water), occurs at about 60 m below the surface of the water in the Gunnar Pit (SRC, 2013a). The concentrations of many constituents in the water above the chemocline are lower than those below the 60 m depth with the exception of uranium which shows higher concentrations above the chemocline. It is understood that the chemocline is relatively stable and that the pit water does not fully mix or develop a uniform concentration. Based on the screening assessments completed for the Gunnar Mine Site, it was determined that the primary COPC's in the open pit are uranium and radium-226. For existing conditions, the average uranium and radium-226 concentrations in the pit are approximately 0.97 mg/L and 0.33 Bq/L, respectively (Appendix A). The loadings to the pit are provided in Section 2.10.

In regards to physical stability, the pit has remained stable over the last 50 years subsequent to closure and a stability assessment completed by CH2M Hill that considered various potential failure mechanisms confirmed the pit is stable (SRC, 2013a).

The risks associated with the Gunnar Pit that were identified in the EIS include ecological risks from the source and human health and ecological risks to the receiving environment (St. Mary's Channel) via flow from the pit through the waste rock.

5.5.2 Design Objective and Criteria

The remedial objective for the open pit is to reduce the human health and ecological risks. The design criteria that specifically applies for this Other Site Aspect includes:

- Meets SSROs in St. Mary's Channel during and immediately after the remediation activities; and
- Reduction in uranium and radium-226 loadings to the pit resulting in further improvement in the water quality parameters in St. Mary's Channel on a long term basis.

5.5.3 Remedial Alternatives Analysis

EIS Remedial Options

Several candidate alternatives were developed during the EIA that were assessed and pre-screened prior to further assessment in the MAA (SRC, 2013a). This process resulted in the following vetted remedial options:

- Maintain pit lake for use as a long-term periodic contaminated water collection storage and treatment facility – water displaced by waste is treated prior to being released to Lake Athabasca
- Pit remains an aquatic feature, water periodically treated for controlled release into Lake Athabasca into perpetuity
- One-time water treatment to backfill pit with waste rock, tailings and/or miscellaneous waste, cover with sufficient soil to act as a diffusion barrier and leave void at the pit top to naturally fill with water (untreated porewater and clean precipitation/Lake Athabasca water) – open pit remains as a pit lake
- One-time water treatment; backfill pit completely, using borrow material to supplement the volumes of waste rock and misc. debris; establish vegetation once filling is complete

During the Decision Tree Process these options were further refined and are summarized as:

- "Do nothing"
- Batch Treatment
- Pump and Treat by Mechanical/Chemical Method

Preliminary Design Study - MAA of Remedial Options

This study adopts the concepts of the remedial options identified in the Open Pit Decision Tree and produced the following three remediation options for further evaluation:

1. Fill existing pit with demolition debris, waste rock and Till borrow, and cover/revegetate the surface of the pit and waste rock footprints
2. Fill only a portion of the pit (i.e. no borrow) and maintain a water cover
3. Reduce loadings to the pit by remediating the other site aspects (removal of high pH material at the Acid Plant, remediation of non-contaminated/contaminated waste, and reduce the loading from the waste rock piles) and keep pit water isolated from St. Mary's Channel via the waste rock plug

A MAA was not required to assess the aforementioned remedial options because the selection of the preferred option for the pit was influenced/determined as a result of the selected remedial designs for the non-contaminated/contaminated waste and the waste rock piles. These remedial designs do not include placement of waste or waste rock in the pit. Although this option could potentially reduce (relocating waste rock to the pit could also result with an increase of loadings from this source) the source load from waste rock deposits and impacted sub-soil as well as result with the consolidation of all waste to one location there are many disadvantages that offset any potential benefits, such as:

- The remaining floor on the bottom of the pit could collapse into the underground workings (SRC 2013a, Appendix F).
- If the Open Pit is not dewatered prior to placement, a more complex disposal method will be required for safe placement and to reduce disturbance to the Open Pit sidewalls (barge, conveyors or rock chutes). End dumping at the pit crest will not be considered as a safe operating procedure.
- If the Open Pit is dewatered prior to placement, physical stability of the Open Pit walls will likely be compromised (SRC 2013a, Appendix F).
- The logistics of placing the waste rock at the bottom of the pit in both the flooded or non-flooded scenario are difficult and potentially unsafe, due to the direct communication between the underground workings and the pit bottom (Figure 2).
- Disturbance during material placement could re-suspend contaminants within the pit.
- Hydrocarbons in demolition debris could remain on the pit water surface, requiring additional water treatment to prevent mobilization to Lake Athabasca.
- If the pit is filled and covered, settlement/deformation into underground workings could occur.
- If the pit is not completely filled and covered, perpetual treatment of the overlying water may be required.
- If waste rock is placed in a water-filled Open Pit, quality control during filling will be difficult. A simple "end dump and push" backfilling technique cannot be utilized due to the lack of bottom in the open pit. Therefore, the absence of compaction may lead to significant deformation and subsidence.
- It is impractical to remove waste rock and/or debris from the Open Pit once placed, allowing no reversal of the process if it was implemented.
- Significant borrow material volumes will be required. The volume of fill required to backfill the Open Pit is approximately 3.5 Mm^3 (SRC 2013a, Appendix H). The combined volume of the East and South Waste Rock Piles is approximately 2.2 Mm^3, but the tailings cover requires approximately 851,000 m^3 of waste rock. If other waste rock areas at the site are not used as backfill, additional borrow will be required to eliminate a water cover on top of the fill, increasing the borrow source footprint.

In addition, waste rock placement had the highest cost compared to other remedial options. These increased costs were associated with hauling large volumes of material, potentially prolonged water treatment (in perpetuity), as well as the need for geotechnical instrumentation (well, piezometers, slope inclinators) to monitor the Open Pit during remediation. Therefore, Option 3 above was selected as the preferred remedial option for the pit and the reduction in loadings to the pit was subsequently assessed based on the remedial designs for the other site aspects.

Human and Ecological Risk Evaluation for the Open Pit

A number of options for the remediation of the Acid Plant and Mill Complex were considered and evaluated in the MAA. These options impact the loadings to the Open Pit. The preferential option for the Acid Plant involves the removal of the contaminated material in the plant area and placing it on the GMT and then using the area to manage the disposal of the contaminated demolition debris. The Mill Complex area will be used to dispose of clean demolition debris under an engineered cover. The remaining area considered to be part of the Mill Complex area will be graded and covered with a 0.5 m gamma cover.

Figures 26 and 27 show the effect on the loadings to the Gunnar Pit associated with these options. It has been assumed that:

- Groundwater loads from the Acid Plant to the Gunnar Pit will be essentially zero when all the contaminated material has been removed.
- Loadings from the Acid Plant and Mill Complex are reduced by 90% - based on the EIS Table 14-1, Volume 3 (SRC, 2013a).
- Loadings from the East Waste Rock Pile reduced by 33% based on reduced groundwater flow to Gunnar Pit from 6,408 m^3/a, Table 7.3, Appendix U of EIS (SRC, 2013a) to 4,299 m^3/a (calculated using estimated percolation rates for a coarse textured till waste rock cover).

As seen in Figures 26 and 27, the loadings of uranium and radium-226 to the Gunnar Pit are reduced by factors of approximately 5 and 9 respectively. The load reductions will eventually result in decreases in concentrations of these constituents in Gunnar Pit. However, given the volume of water in the Pit (3.3 million m^3), it is unlikely that changes in concentration will be observed for hundreds of years. There is seepage from the Gunnar Pit through the waste rock plug into St Mary's Channel at an average estimated rate of 23,000 m^3 to 37,000 m^3 m^3/a, Appendix U of the EIS (SRC, 2013a). It should be noted that the uranium concentrations near the seep in St Mary's Channel are 0.008 mg/L.

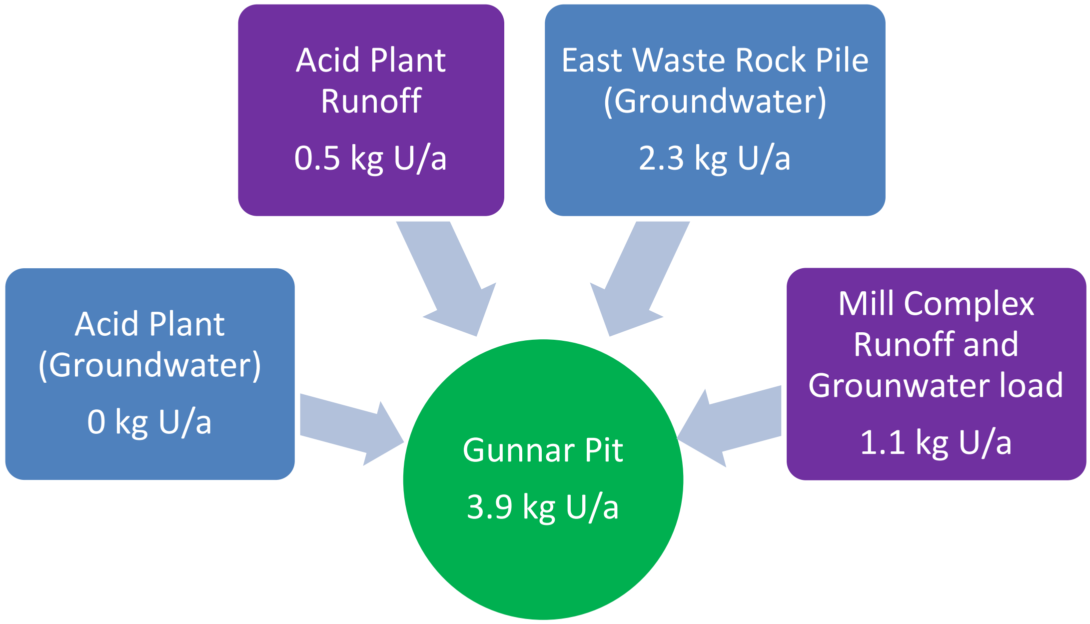

Figure 29: Schematic of Uranium Loads to Open Pit Associated with Remedial Actions

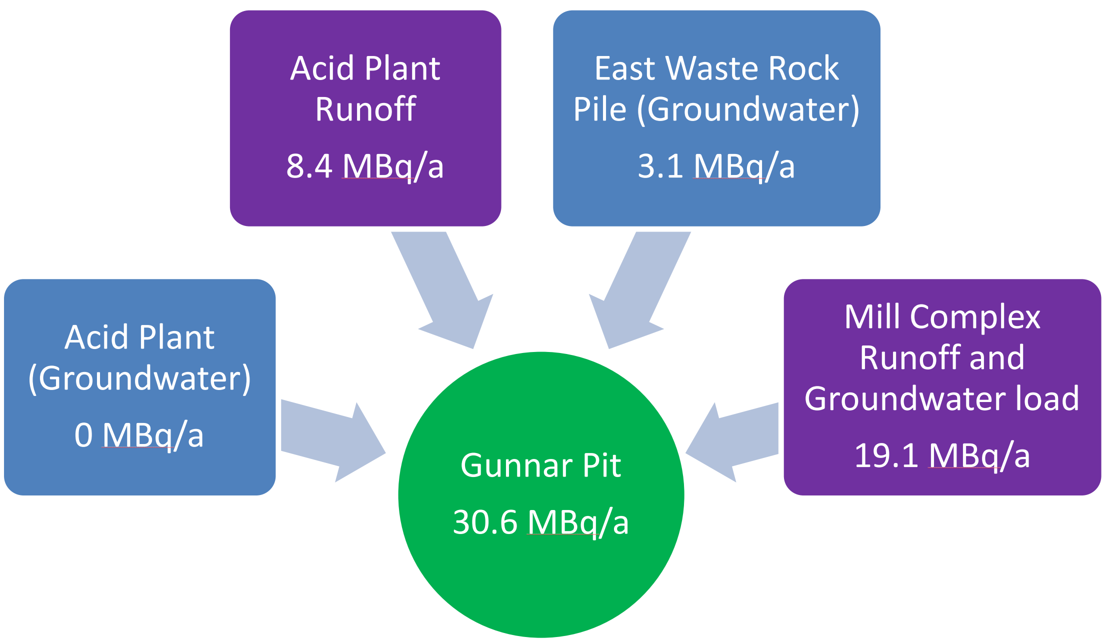

Figure 30: Schematic of Radium-226 Loads to Open Pit Associated with Remedial Actions

Risk Implications for Open Pit

A Screening Level Risk Assessment was carried out for the Gunnar Mine Site in 2006 (SENES, 2006). In that assessment, it was determined that there were no risks to human health; however, there were potential risks associated with the Open Pit with respect to uranium concentrations for aquatic receptors as well as for small individual terrestrial receptors. In addition, radium-226 was a potential issue for aquatic plants. As ecological risk assessments consider protection of populations of receptors and not individuals it is unlikely that adverse effects are being observed in ecological receptors at the Site. Given that the loadings of uranium and radium-226 to the Open Pit will decrease by almost an order of magnitude after remedial activities at the Acid Plant and Mill Complex area and conditions in the Pit will improve in the long term, it is unlikely that small terrestrial animal populations will experience any adverse effects associated with exposure to uranium and radium-226 in the Open Pit. In fact, Appendix R of the EIS indicates that in 2002 the pit was found to contain a good diversity of aquatic biota in a number of groups (phytoplankton, zooplankton, benthic macroinvertebrates, and macrophytes) as well as a self-sustaining population of northern pike.

In terms of the seepage into St Mary's Channel, monitoring data has shown that the uranium concentrations near the seepage are 0.008 mg/L which are below the Saskatchewan Environmental Quality Standard for surface water as well as below the Canadian drinking water quality guideline. This indicates that there will be no adverse effects to fish or other aquatic
quality guideline. This indicates that there will be no adverse effects to fish or other aquatic
species associated with the seepage from the pit.

Decision Tree Process

The uncertainty of whether or not the Open Pit will pose any human health and ecological risks to St. Mary's channel following the selection of remedial options for each of the other site aspects has been addressed.

5.5.4 Updated Preliminary Remedial Design

Preliminary design is not required for the open pit; however, the stability of the waste rock plug should be assessed particularly during storm events that may result in flow through/over the plug.

A perpendicular cross-section through the waste rock plug is provided in a Seepage Analysis Report completed by McElhanney Resource Services Inc. (Figure 5, McElhanney, 2013). This section was reviewed and the width of the waste rock plug (north to south) is over 40 m, which is situated on bedrock, and the downstream slope towards St. Mary's channel has a grade of approximately 3%. A stability analysis of the waste rock plug was completed, which assessed both the upstream and downstream slopes of the plug. The results of the analysis determined that the waste rock plug will be stable under long-term static and seismic conditions. A detailed discussion of the analysis and results is presented in a stability assessment memo (Appendix E).

The lowest section along the perimeter of the pit is at the waste rock plug, which has an invert elevation at approximately 211.5 m. It is understood that the water elevation in the pit remains relatively constant at this elevation and that the max fluctuation throughout a year is approximately 0.5 m, down to elevation 211.0 (McElhanney, 2013). This indicates that there is little to no storage in the open pit to accommodate additional inflows. To assess the stability of the waste rock plug during a significant precipitation event, a high-level hydrologic model was prepared to route the 1 in 200-year, 24-hour precipitation event over the waste rock plug. It should be noted that the waste rock plug could be described as a waste rock channel as the exterior bedrock ridges confine the lateral extent of the plug at the invert and the subtle slope towards St. Mary's is also contoured to confine flow over a 20 m width. Conservatively assuming that the pit is full (elev. 211.5 m) and that there would be no loss to runoff (i.e. runoff coefficient of 1.0), the peak flow through the waste rock plug/channel is equal to 3.0 m^3/s, which corresponds to a rip rap requirement of 0.10 m for the D_{50} diameter. The waste rock plug appears to have a gradation that is 0.6 m minus with a D_{50} of 0.3 m and would therefore be stable under such condition.

A 1 in 200-year, 24-hour precipitation event would result in a rainfall of 94.5 mm as defined in Section 3.0. Conservatively assuming the pit is at elevation 211.5 m and that there would be no loss to runoff that drains towards the pit, approximately 21,000 m^3 would report to the pit and be discharged through the waste rock plug. This condition would have a negligible impact to St. Mary's channel. Furthermore, a high-level water balance for Gunnar Pit (McElhanney, 2016) estimated the average annual seepage/flow to St. Mary's channel from the pit is estimated at approximately 46,000 m^3. This estimate assumes no runoff to the pit in the winter months. This value is greater than the range reported in Appendix U of the EIS (SRC, 2013a) of 23,000 m^3 to 37,000 m^3 but indicates that the 1 in 200-year, 24-hour precipitation event would result in a discharge to St. Mary's channel that is lower than the average annual flow to St. Mary's channel.

The high level assessment discussed above will be refined by calibrating the model with flow data collected from the pit outflow, which in turn will be used to develop a calibrated water and load balance for Gunnar Pit that can be used to refine the detailed remedial design in the next phase of engineering.

5.5.5 Considerations for Detailed Design

As discussed above data is being collected to calibrate a water balance for the Gunnar Pit. Once the pit water balance has been calibrated, a load balance model will be prepared using the water balance, observed changes in sulphate, uranium and radium 226 over time and the volume of the epilimnion (surface mixed layer). The load balance model will be calibrated by adjusting the average annual constituent load to match the observed concentration data. The calibrated constituent loads to the pit will then be allocated to the various surface water catchments and groundwater flows that discharge to the pit using information in EIS. This loading model for the pit can then be used to assess the effect of remedial options including treatment on the water quality of Gunnar Pit and the load contributed by the pit outflow to St. Mary's Channel.

A FMEA for the pit will be completed as part of the detailed remedial designs for the other site aspects.

5.6 Estimated Volume of Borrow for Updated Preliminary Designs

Table 5-9 includes a summary of the available borrow quantities and borrow requirements of the overall site. The quantities are the best estimates currently available. As shown in the table, there is an excess of fine and coarse textured borrow to complete both tailings and the other site aspects remediation designs.

Table 5-9: Site Borrow Quantities (Available and Required)

Borrow Material	**Grain Size Classification**		
Available above Water Table (OKC, 2016)	**Fine** 2,407,230	**Medium** 473,320	**Coarse** 815,340
Requirements			
Mill Landfill			17,000
Acid Plant Landfill	2,200		
Waste Rock Piles (East and South)			113,000
General Site Areas			115,000
Tailings Covers (OKC, 2016)		422,000	282,000
Totals	**2,200**	**422,000**	**527,000**

5.7 Re-vegetation Plan for Updated Preliminary Designs

In total, four following revegetation units were identified for assessment:

- Waste Rock Piles
- Process Area
- Townsite Area
- Temporary Infrastructure (access roads, maintenance areas, etc)

As stated in the design objectives, the goal is to establish vegetation as soon as possible to facilitate the cover systems in the short term and ensure their integrity in the long-term. The intent of the revegetation plan is to identify an optimal approach and techniques for the establishment of permanent vegetation. Details of the revegetation plan developed by SRC are included in Appendix J.

The cover systems will be seeded with native grasses and forbs. Prior to seeding, soil scarification (decompaction) will be done to a maximum depth of 10 cm below the finished cover surface to prepare seedbed and promote development of the plant root system. The following seed mixture is proposed:

Table 5-10: Seed Mixture Proposed for Gunner Mine Other Site Aspects

Plant species	PLS dry weight, %
Rocky Mountain Fescue (Festuca saximontana)	20
American Vetch (Vicia Americana)	20
Slender Wheat Grass (Elymus trachycaulus)	15
Rough Hair Grass (Agrostis scabra)	10
White Bluegrass (Poa glauca)	10
Fowl bluegrass (Poa palustris)	10
Tufted Hairgrass (Deschampsia caespitosa)	7
Canada Milkvetch (Astragalus canadensis)	5
Marsh Reed Grass (Calamagrostis Canadensis)	2
Common Yarrow (Achillea millefolium)	1

The seeding rates were developed on the basis of the SRC trials. These rates are also consistent with recommendations of the Yukon Revegetation Manual (Matheus, 2013). The following factors were taken into account:

- poor quality of the growing substrate
- availability of salvaged vegetation and topsoil
- risk of erosion
- soil treatment before and after seeding
- seeding methods
- intent to encourage establishment of woody species on the site

Proposed seeding rates vary from to 4,000 pure live seeds/m^2 (about 16 kg of bulk seed mixture per ha) on steeper slopes with poor soil to 1,000 pure live seeds/m^2 (about 2 kg of bulk seed mixture per ha) on flat areas with good topsoil quality. Seeding rates for bulk seed mixture can vary on an annual basis depending on the seed mixture composition and quality.

Revegetation trials at Gunnar showed that peat application at rates higher than 160 t/ha combined with fertilizer application at rates of 45 N kg/ha, 84 P2O5 kg /ha, 112 K2O kg/ha, and 20 S kg/ha resulted in 40% vegetation cover within a year after seeding, which is in line with the cover design requirements for steep slopes. For the rest of the site, soil conditioning will be mostly performed through application of mineral fertilizers. Recommended rates of mineral fertilizer application are 50 N kg / ha, 70 P2O5 kg / ha, 60 K2O kg / ha, and 20 S kg / ha.

The implementation of a number of measures to prevent distribution or introduction of invasive exotic and weed species in the revegetated areas will be undertaken. Site monitoring, including vegetation surveys, ongoing maintenance, and corrective action/adaptive management will be carried out until vegetation cover has become self-sustaining.

6 Preliminary Monitoring after Remediation

A post-construction or field performance monitoring program will be implemented to confirm if the remedial designs are performing as intended. Such monitoring may include regular geotechnical inspections by a qualified professional engineer as well as the monitoring listed in Table 6-1 to support the observations taken as part of the inspection. The post construction monitoring in Table 6-1 is preliminary and the final monitoring plan will be developed as part of the detailed design in accordance with Appendix V.2 Follow-up Program in the EIS (SRC, 2013a).

Table 6-1: Post Construction Monitoring

Remedial Design	Parameter	Methods
Landfills	Differential Settlement	Complete topographical surveys with a defined accuracy, visual inspection.
	Leachate	Existing monitoring wells and new wells (if required) will be established in defined areas within and downstream of the landfills to detect and monitor for leachate.
	Physical integrity	See Covers.
Covers (Landfills/WRP/WR Channel/General Mine Area)	Radiation Exposure	Radon gas measurements and gamma will be conducted using appropriate instrumentation.
	Physical integrity	Visual inspection of cover for damage, such as formation of sinkholes and erosion damage such as gulleys and/or rilling.
	Vegetation Integrity	Vegetation cover and community composition according to standard protocols. Vegetation tissue sampling for contaminants of concern.
Hydraulic Structures	Physical integrity	Visual inspection for plumes of suspended solids downstream of structures, signs of erosion and any alterations that may impact performance.
Mine Openings	Shaft Caps (3 on site)	Visual inspection for signs of deterioration or instability.
Open Pit	Water Quality	Surface water sampling at locations currently completed by SRC will continue.
	Physical integrity	Visual inspection of WR plug for signs of erosion or excessive vegetation in outlet.
Zeemel Bay/St. Mary’s Channel	Water Quality	Surface water sampling (frequency and location) currently completed by SRC will continue.
Langley Bay	Water Quality	Surface water sampling (frequency and location) currently completed by SRC will continue.
General Mine Site	Surface Water	Surface water sampling (frequency and location) currently completed by SRC will continue.
	Groundwater	Groundwater sampling (frequency and location) currently completed by SRC will continue.

Notes:

WRP = Waste Rock Piles

WR = Waste Rock

7 Summary of Considerations for Detailed Design

Several considerations for detailed design have been noted throughout this report and are summarized in Table 7-1.

Table 7-1: Summary of Considerations for Detailed Design.

Report Section	Description	Consideration
5.1	Non-Contaminated Demolition Debris	• Complete FMEA.
5.2	Contaminated and Hazardous Materials	• Complete FMEA.
5.3	Waste Rock	• Complete FMEA.
5.4	General Site	• Complete FMEA for the mine shaft/openings closure caps.
5.5	Open Pit	• Complete FMEA. • Complete water and load balance
6.0	Preliminary Monitoring after Remediation	• A detailed monitoring plan will be completed for implementation during remedial construction and post construction throughout the transitional monitoring phase of the project.

This final report, **Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design**, was prepared by:

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Staff Consultant

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Practice Leader/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.

8 References

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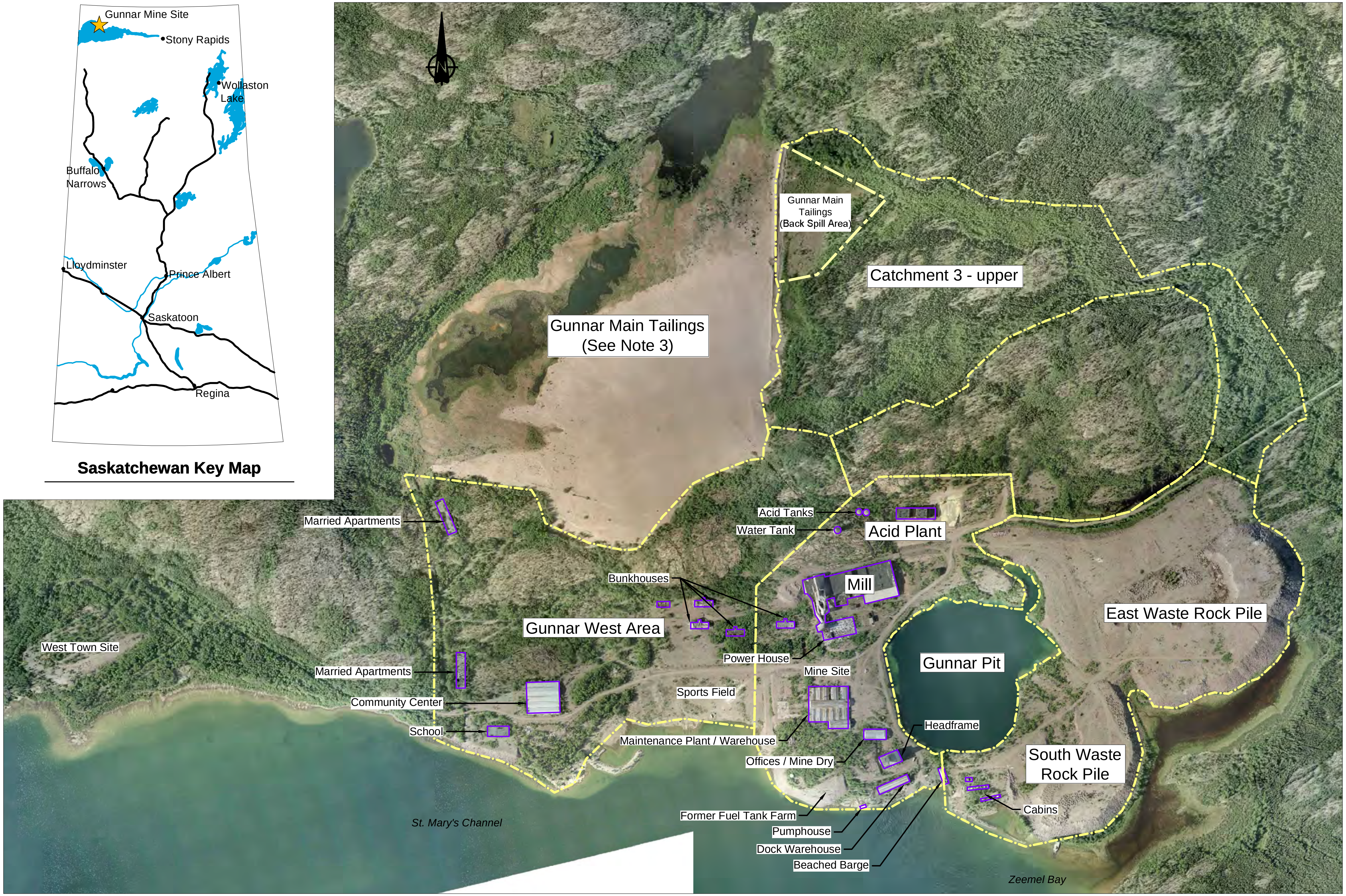
Figures



LEGEND

Study Region "Other Site Aspects"

Historical Building Location

NOTES

1. All boundaries shown are approximate.
2. All building locations shown are approximate.
3. Preliminary Remedial Designs for Gunnar Main Tailings, Gunnar Central Tailings, and Langley Bay Tailings Areas completed by O'Kane Consultants Inc.

REFERENCE

Boundaries shown adapted from SNC-Lavalin Figure 1.1 "Gunnar Site Location". Dwg. No. 619435-G-02-E-001, Rev 0. (EIS 2013)

Building locations shown adapted from SRC Map V1-2 "Site Features" Gunner Site Remediation Project, Saskatchewan Research Council (EIS 2013).

NAD83 UTM Zone 12.

Imagery provided by Saskatchewan Research Council.

0m 50 100 150 200 250 300

srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

SRK JOB NO.: 1CS056.002

FILE NAME: 1CS056.003 - Study Areas.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

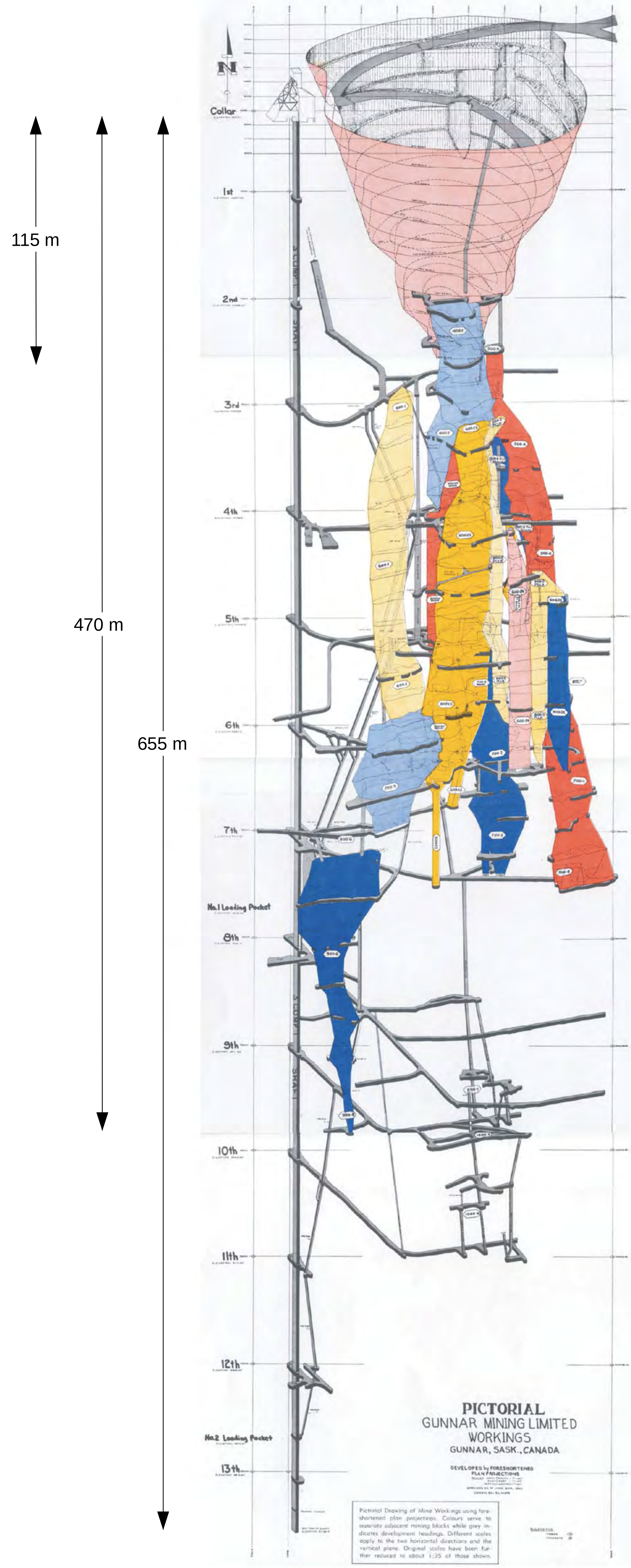
GUNNAR SITE LOCATION AND FEATURES

DATE:	APPROVED:	FIGURE:
July 2016	TPP/EMR	1

Source: https://www.thestar.com/news/ontario/2007/08/26/reviving_uranium_citys_nuclear_past.html

Notes:
1. Photos provided by Saskatchewan Research Council.

srk consulting	SRC Saskatchewan Research Council	UPDATED PRELIMINARY REMEDIATION DESIGN		
		GUNNAR PIT CONFIGURATION "PRIOR AND DURING FLOODING"		
Job No: 1CS056.003 Filename: 1CS056.003_FIGURE2-JULY2016.pptx	GUNNAR MINE "OTHER SITE ASPECTS"	Date: JULY 2016	Approved: TPP/MWL	Figure: 2



NOTES:
1. MAP NOT TO SCALE
2. DEPTHS ARE APPROXIMATE

srk consulting

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Job No: 1CS056.003
Filename: 1CS056_003_gunnar_fig##_schematic_sect

GUNNAR MINE "OTHER SITE ASPECTS"

PRELIMINARY REMEDIATION DESIGN

SCHEMATIC OF GUNNAR PIT AND UNDERGROUND WORKINGS

Date:	Approved:	Figure:
June 2016		3

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LEGEND

- Surface Water Flow
- Inferred Buried Channel
- Catchment 3 Watershed
- Open Pit Sub Catchments

REFERENCE:

Basemap data from the NTDB dataset (1:50k), Natural Resources Canada.

All other data provided by Saskatchewan Research Council.

NAD83 UTM Zone 12

0 75 150 225 300 375 450

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srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

Job No: 1CS056.003

Filename: 1CS056_002_gunnar_fig_02_sw_flow

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

CATCHMENT 3 AND SURFACE WATER FLOWS

Date:	Approved:	Figure:
JULY 2016	TPP / EMR	4

LEGEND

- Borehole
- Piezometer
- Water Elevation
- Inferred Water Elevation
- Inferred Buried Channel

NOTES:

Potentiometric elevations and interpreted groundwater flow adapted from SNC-Lavalin. Dwg. No. 619435-G-01-E-004, October 2014 Potentiometric Elevations and Interpreted Groundwater Flow Above First Silt and Clay, Rev 0. (SNC 2015)

REFERENCE:

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SNC-Lavalin Inc. (SNC, 2015). 2014 Gunnar Subsurface Characterization Program. February 2, 2015.

All other data provided by Saskatchewan Research Council.

NAD83 UTM Zone 12

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srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

UPDATED PRELIMINARY REMEDIATION DESIGN

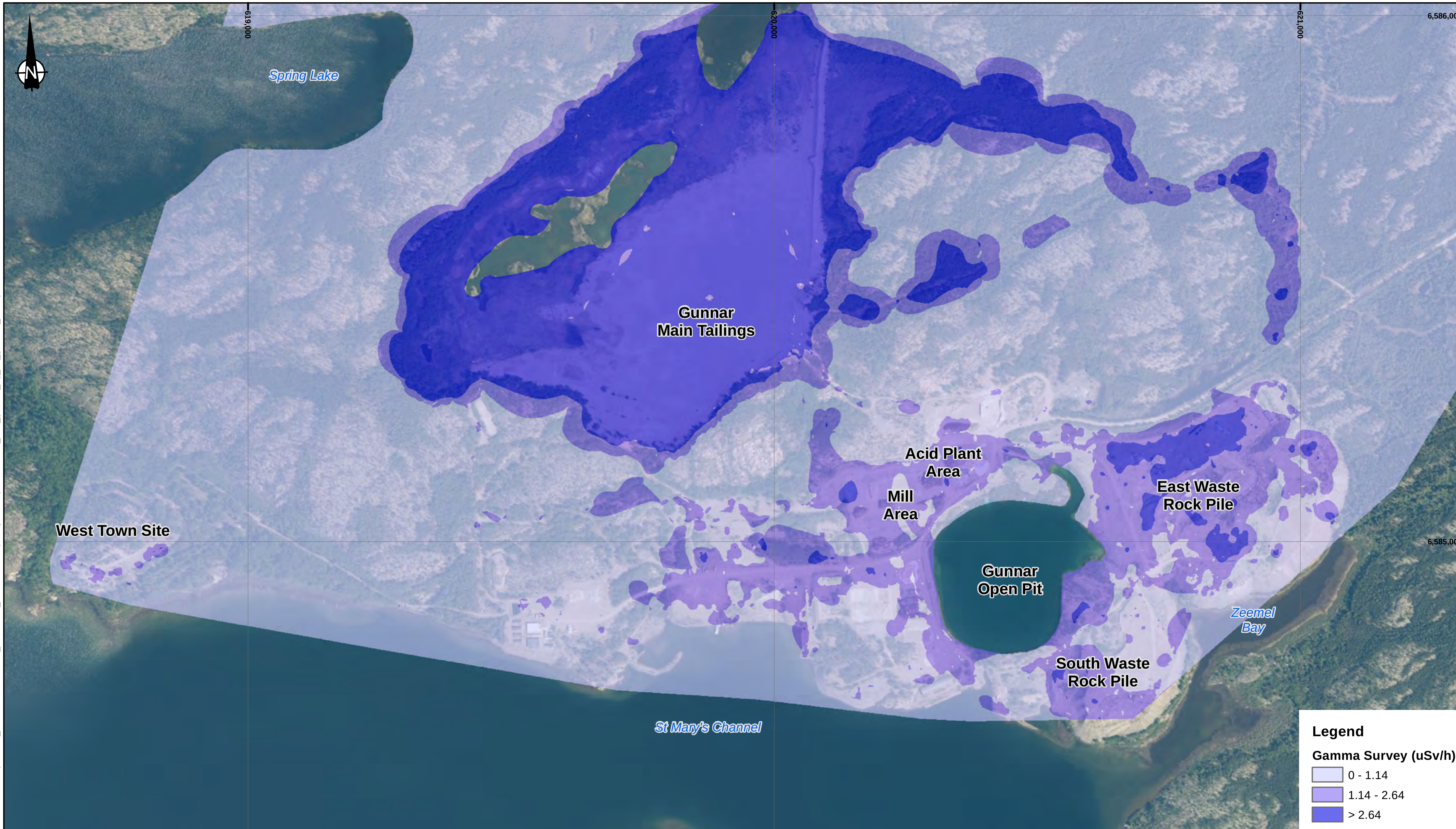
POTENTIONMETRIC ELEVATIONS AND INTERPRETED GROUNDWATER FLOW

Job No: 1CS056.003

Filename: 1CS056_002_gunnar_fig_03_gw_flow

GUNNAR MINE "OTHER SITE ASPECTS"

Date:	Approved:	Figure:
JULY 2016	TPP / EMR	5



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REFERENCE

Basemap data from the NTDB dataset (1:50k), Natural Resources Canada.

All other data provided by Saskatchewan Research Council.

NAD83 UTM Zone 12

0 240 480 Meters

srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

Job No: 1CS056.003

Filename: 1CS0056_003_gunnar_fig_10_gamma_survey

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

GAMMA SURVEY

Date:	Approved:	Figure:
JULY 2016	TPP / EMR	10

LEGEND

Debris Storage Option Area

Debris Classification

- ACM (Bags)
- CONCRETE
- MIXED (See Notes)
- STEEL
- Wood Debris

NOTES:

Review of available aerial imagery/video indicates that mixed piles are approximately 50% wood and 50% steel. Wood will be part of the contaminated waste remedial options.

REFERENCE:

Basemap data from the NTDB dataset (1:50k), Natural Resources Canada.

All other data provided by Saskatchewan Research Council.

NAD83 UTM Zone 12

srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

UPDATED PRELIMINARY REMEDIATION DESIGN

NON-CONTAMINATED DEMOLITION DEBRIS REMEDIAL OPTIONS

Job No: 1CS056.002

Filename: 1CS056_002_gunnar_fig_09_debris_classification

GUNNAR MINE "OTHER SITE ASPECTS"

Date:	Approved:	Figure:
JULY 2016	TPP / EMR	12

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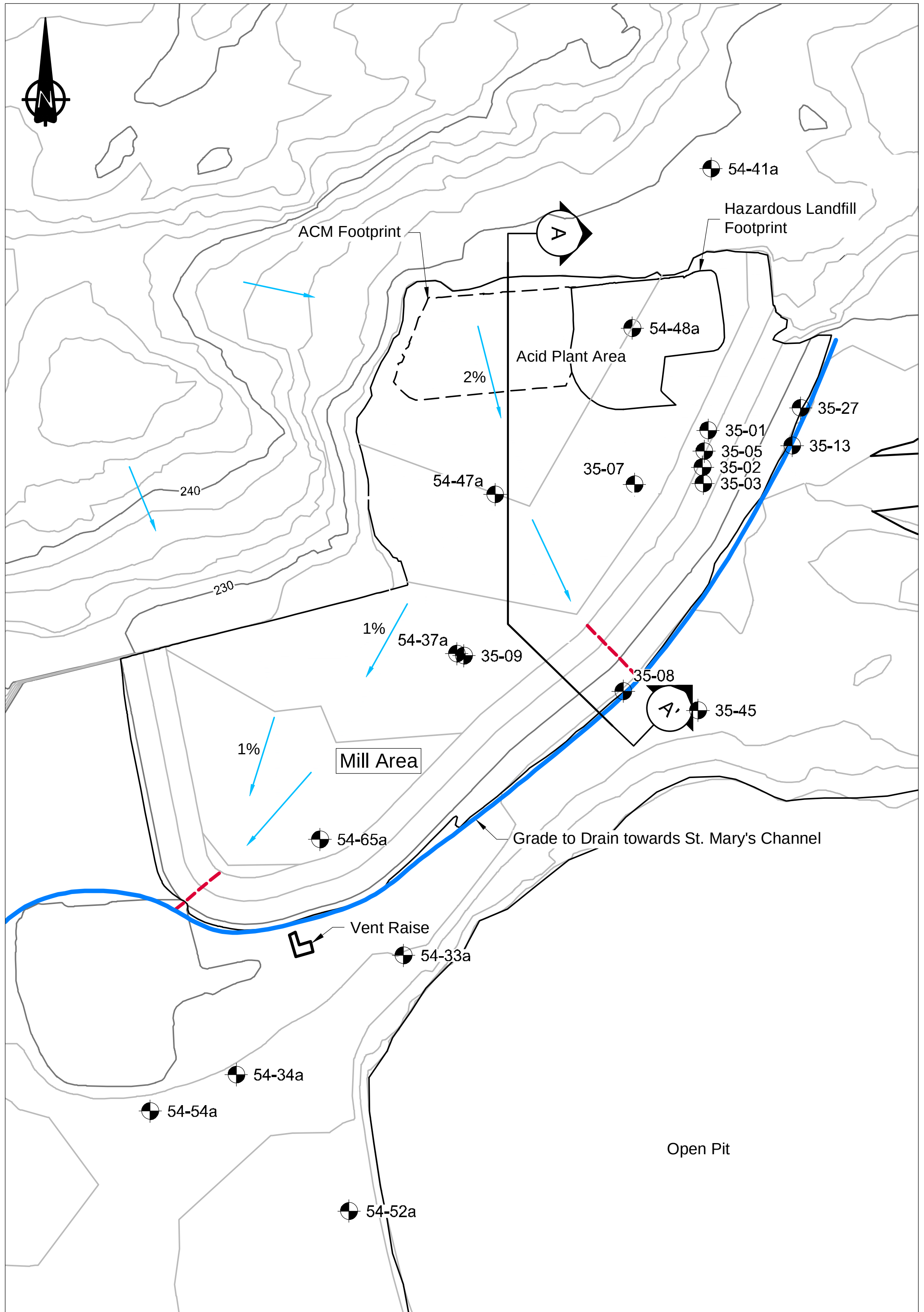
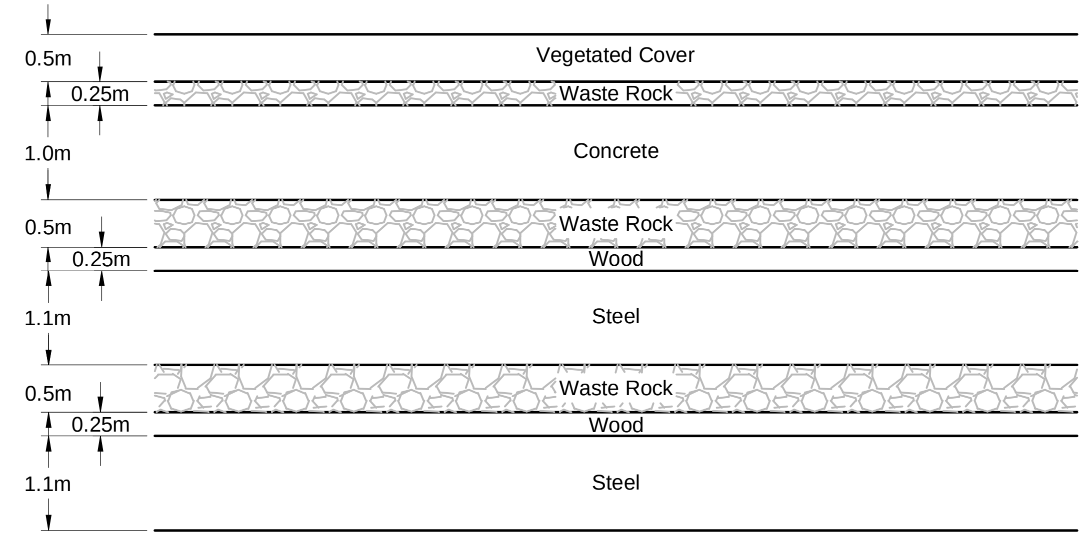


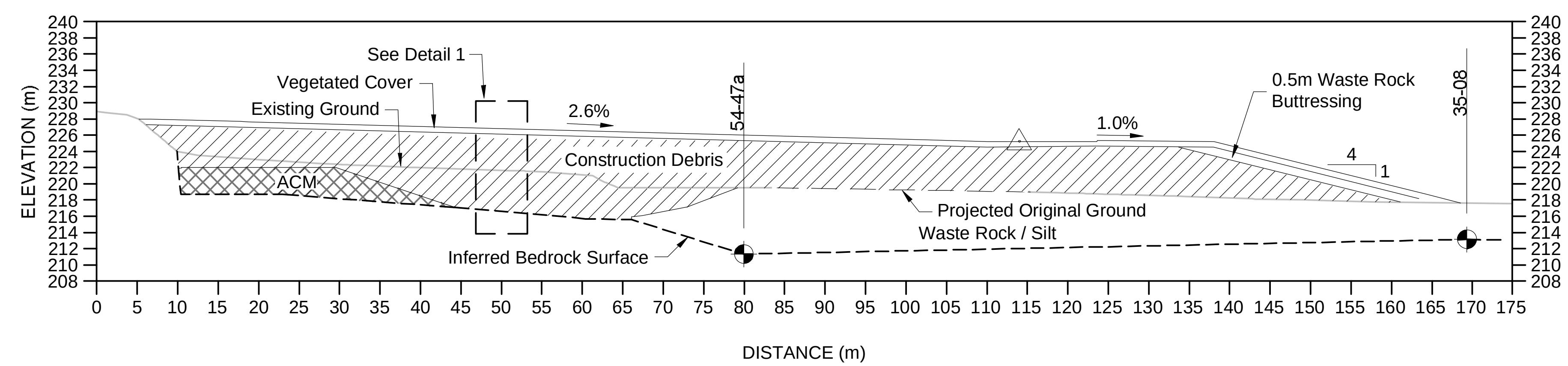
Mill Area - Non-Hazardous Landfill

0m 20 40 60 80



Detail 1

NOT TO SCALE



Cross Section A-A'

0m 10 20 30

LEGEND

- Borehole Location
- Surface Water Flow Direction
- Riprap Drainage Channel (See Detail 6, Figure 24)
- Coconut Mat Drainage Channel (See Detail 7, Figure 24)
- Construction Debris
- ACM

NOTES

1. Contours shown at 2.0m intervals.
2. Bottom of waste rock and bedrock contact inferred from borehole logs and lithologic sections (SNC Lavalin, SNC 2016 - 2014 Gunnar Subsurface Characterization Program).
3. If mulched wood debris cannot be used as erosion protection, layers of wood debris will be placed in landfill as shown in Detail 1. It was estimated that approximately half the wood debris will be placed in the East Waste Rock Pile and the remainder in the non-hazardous landfill.
4. Debris volumes include a 25% contingency with the exemption of the wood debris.

REFERENCE

NAD83 UTM Zone 12.
SNC-Lavalin Inc. (SNC, 2015). 2014 Gunnar Subsurface Characterization Program. February 2, 2015.

MATERIAL VOLUMES

ACM: 6,200m³
Concrete: 23,800m³
Steel: 58,000m³
Wood: 11,000m³
Waste Rock Cover Layers: 50,000m³
Vegetated Cover: 17,000m³
Total Volume: 166,000m³

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SRK JOB NO.: 1CS056.002
FILE NAME: 1CS056.002 - Acid Plant and Mill Area Landfills.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

MILL AND ACID PLANT (PRELIMINARY LANDFILL REMEDIAL OPTION FOR NON-COMTAMINATED WASTE)

DATE:	APPROVED:	FIGURE:
July 2016	TPP/EMR	13

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UPDATED PRELIMINARY REMEDIATION DESIGN

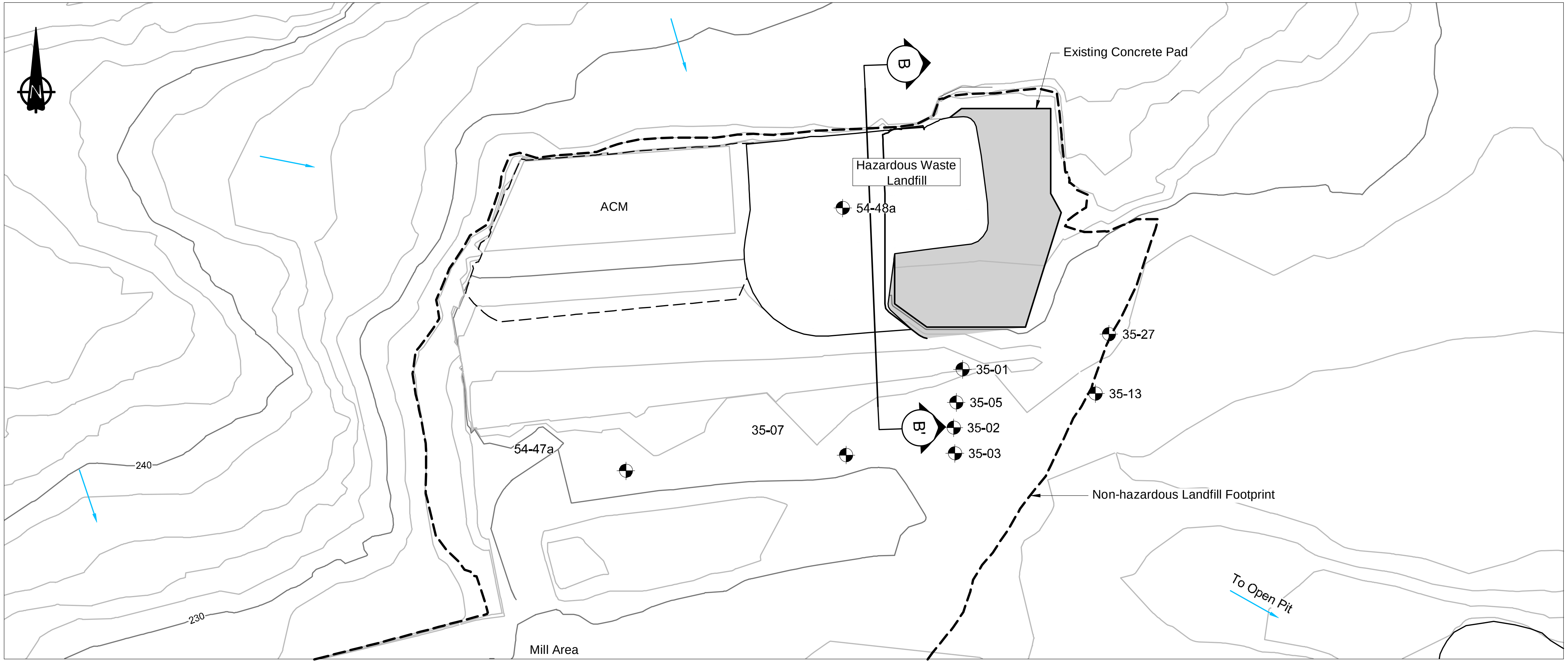
CONTAMINATED WASTE REMEDIAL OPTIONS

Job No: 1CS056.002

Filename: 1CS056_002_gunnar_fig_11_contaminated_soils

GUNNAR MINE "OTHER SITE ASPECTS"

Date:	Approved:	Figure:
JULY 2016	TPP / EMR	14



Acid Plant - Hazardous Landfill

0m 10 20 30 40

LEGEND

- Flow Direction
- Contaminated Earthen Materials

NOTES

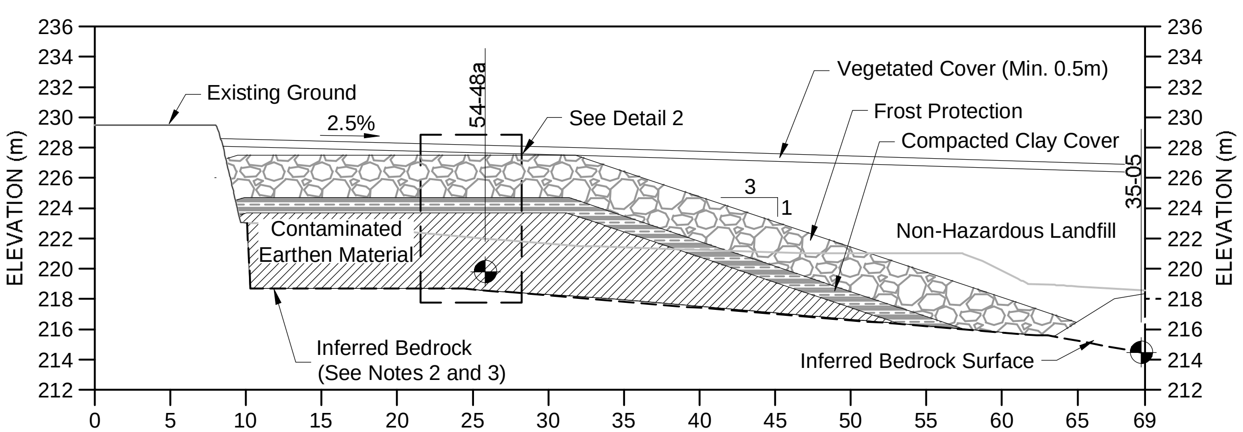
1. Contours shown at 2.0m intervals.
2. Bottom of waste rock and bedrock contact inferred from borehole logs and lithologic sections (SNC Lavalin, SNC 2016 - 2014 Gunnar Subsurface Characterization Program).
3. The bedrock surface will be inspected and the surface prepared with slush grout and/or dental concrete prior to placement of landfill materials.

REFERENCE

NAD83 UTM Zone 12.
SNC-Lavalin Inc. (SNC, 2015). 2014 Gunnar Subsurface Characterization Program. February 2, 2015.

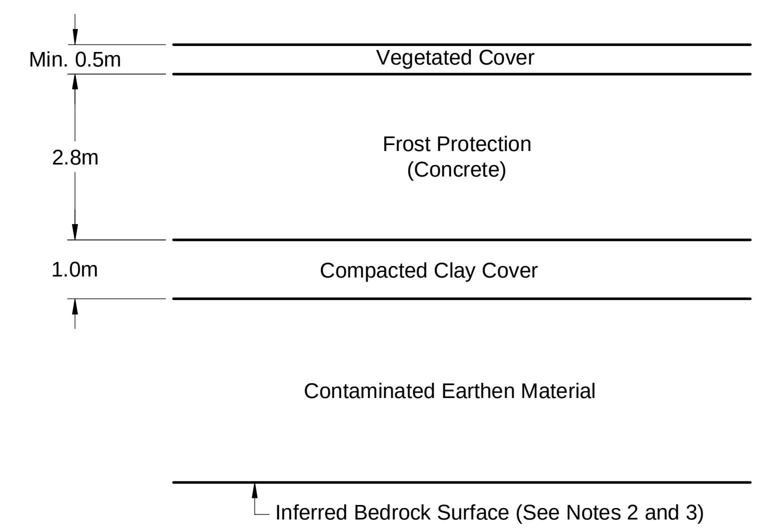
MATERIAL VOLUMES

Contaminated Earthen Material: 4,000m³
Compacted Clay Cover: 2,200m³
Frost Protection (Concrete): 8,700m³
Vegetated Cover: See Figure 12
Total Volume: 14,900m³



Cross Section B-B'

0m 5 10 15 20



Detail 2

NOT TO SCALE

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SRK JOB NO.: 1CS056.002
FILE NAME: 1CS056.002 - Acid Plant and Mill Area Landfills.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

ACID PLANT AREA (PRELIMINARY LANDFILL REMEDIAL OPTION FOR CONTAMINATED WASTE)

DATE:	APPROVED:	FIGURE:
July 2016	TPP/MWL	15

LEGEND

- General Site Waste rock slopes that require regrading/flattening
- Option 1 (See Note 1)
- Option 2 (See Note 2)
- Option 3 (See Note 3)

REFERENCE:
Basemap data from the NTDB dataset (1:50k), Natural Resources Canada.

All other data provided by Saskatchewan Research Council.

NAD83 UTM Zone 12

NOTES:

1) **Remedial Option 1:**
Re-Establish Historic Channel and Grade/ Cover/Vegetate Waste Rock Piles

2) **Remedial Option 2:**
Divert Catchment 3 and Grade/Cover/Vegetate Waste Rock Piles

3) **Remedial Option 3:**
Re-Locate EWRP and SWRP to Open Pit

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Job No: 1CS056.002
Filename: 1CS056_002_gunnar_fig_13_wr_remediation

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

WASTE ROCK
REMEDIAL OPTIONS

Date:	Approved:	Figure:
JULY 2016	TPP / EMR	16

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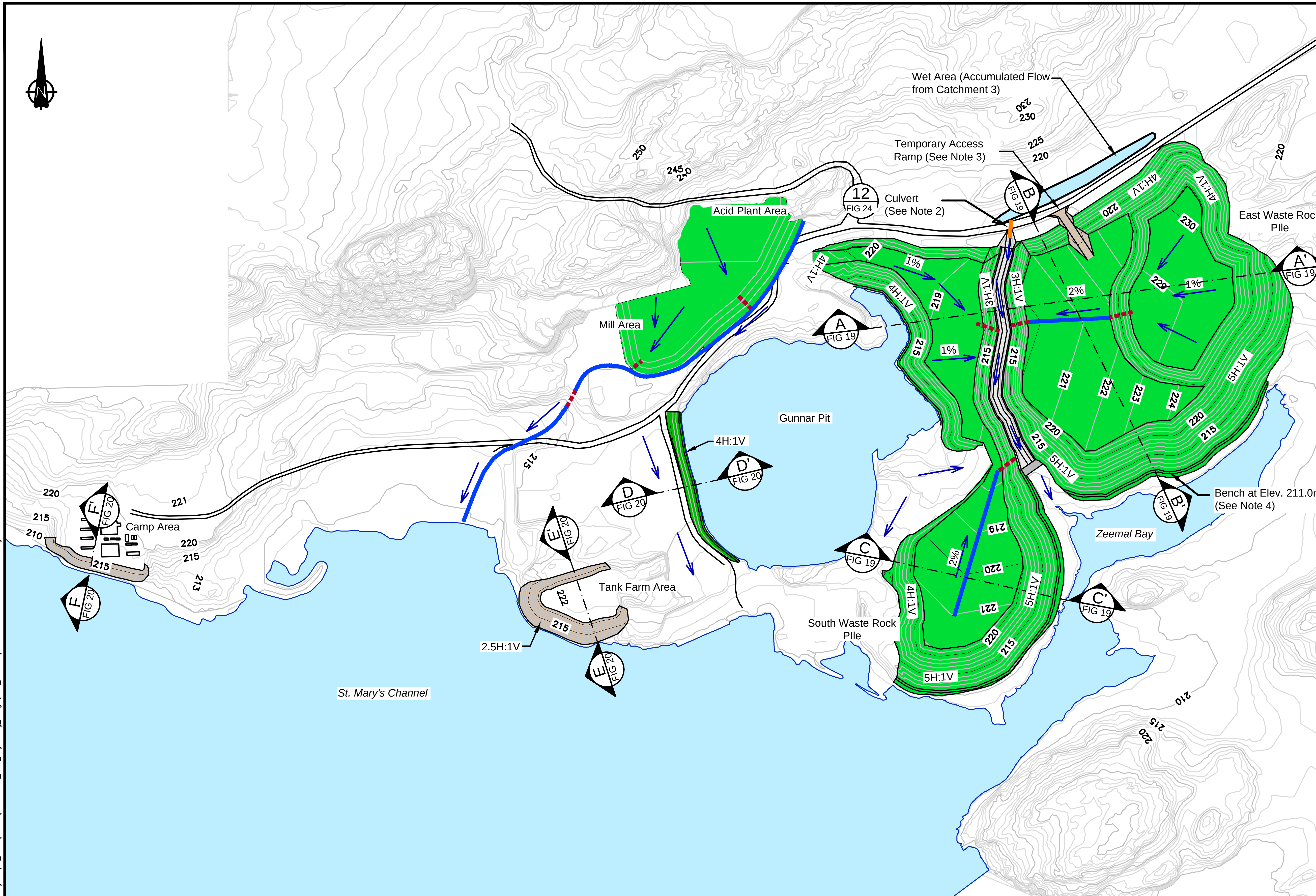

LEGEND

- Water
- Re-graded Surface (Non-Vegetated Gamma Cover)
- Re-graded Surface (Vegetated Gamma Cover)
- Rip rap Lined Channel
- Rip rap Apron
- Coconut Mat Drainage Channel (See Detail 7, Figure 24)
- Rip rap Drainage Channel (See Detail 6, Figure 24)
- Flow Direction

NOTES

1. General mine site areas shall be graded to promote positive surface water drainage towards St. Mary's Channel.
2. The existing roadway will be decommissioned and excavated as part of channel construction. A temporary and properly sized culvert will be installed to accommodate the closure monitoring period for the site. The culvert will be removed after the monitoring period and the channel inlet will be prepared in accordance with the design slope and armoring
3. Temporary access ramp will be removed subsequent to the closure monitoring period. The area will be graded to 4H:1V and vegetated.
4. A minimum 3.0m wide bench will be established above the historic high water mark (Elev. 210.65m) to accommodate the 0.5m thick vegetated gamma cover and to reduce sediment into Zeemal Bay.

REFERENCE

NAD83 UTM Zone 12.

0m 50 100 150 200

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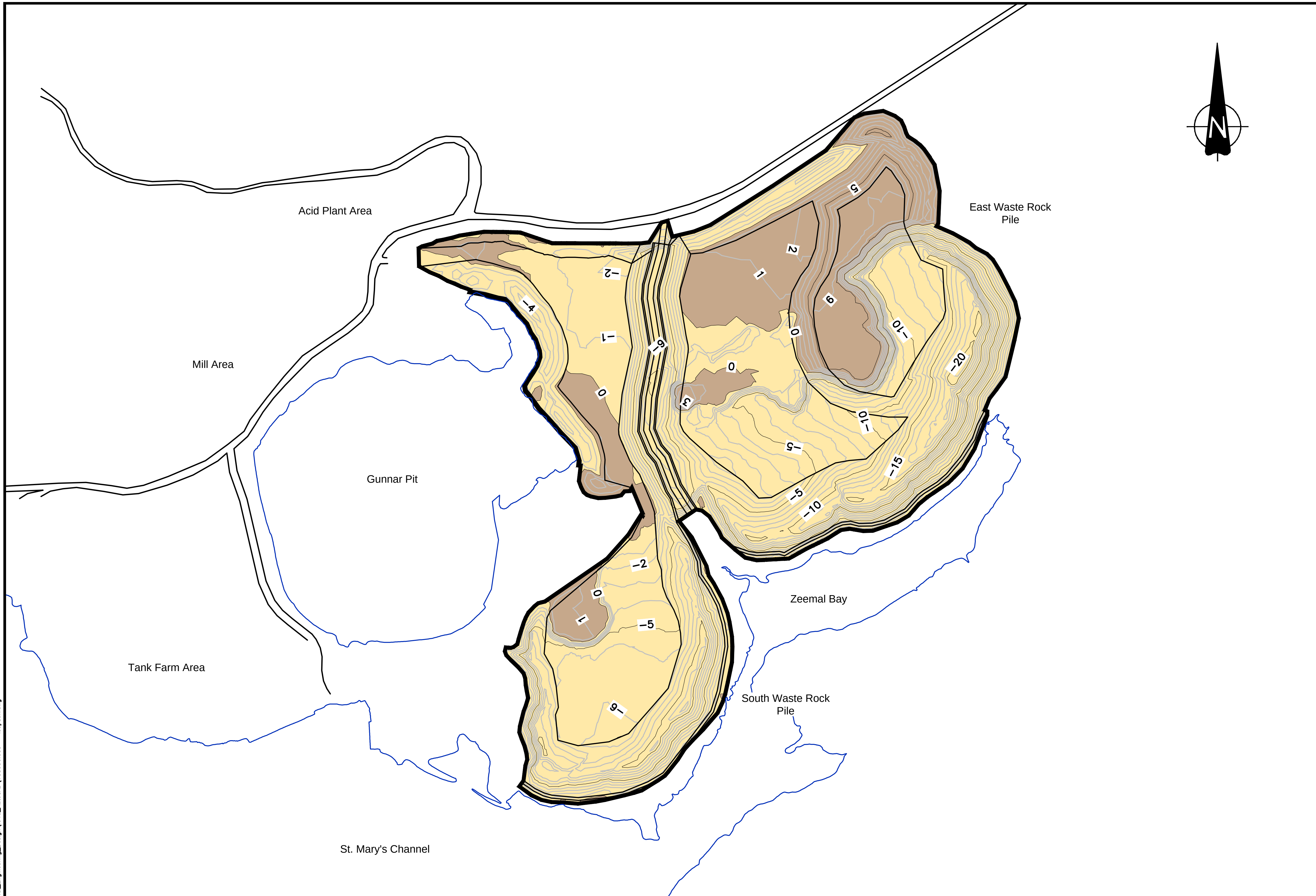
FILE NAME: 1CS056.003 - Plan and Sections.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

RE-ESTABLISH HISTORIC DRAINAGE CHANNEL (PRELIMINARY REMEDIAL OPTION FOR WASTE ROCK)

DATE:	APPROVED:	FIGURE:
JULY 2016	TPP/MWL	17



LEGEND

Waste Rock Cut

Waste Rock Fill

NOTES

1. If mulched wood debris cannot be used as erosion protection, layers of the wood debris will be alternated with waste rock lifts in the fill areas of the East Waste Rock Pile. The mulched wood waste will fill voids in the waste rock and is not expected to contribute to the overall volume of the pile. It was estimated that approximately half of the wood debris will be placed within the East Rock Pile while the remained would be placed in the Non-Hazardous Landfill.

REFERENCE

NAD83 UTM Zone 12.

MATERIAL VOLUMES

Total Cut: 931,000m³
Total Fill: 104,000m³
Total to Tailings: 827,000m³

0m 40 80 120 160

1 : 4000

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SRK JOB NO.: 1CS056.003

FILE NAME: 1CS056.003 - Isopach.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

ISOPACH OF WASTE ROCK PILE CUTS AND FILLS

DATE:	APPROVED:	FIGURE:
JULY 2016	TPP/MWL	18

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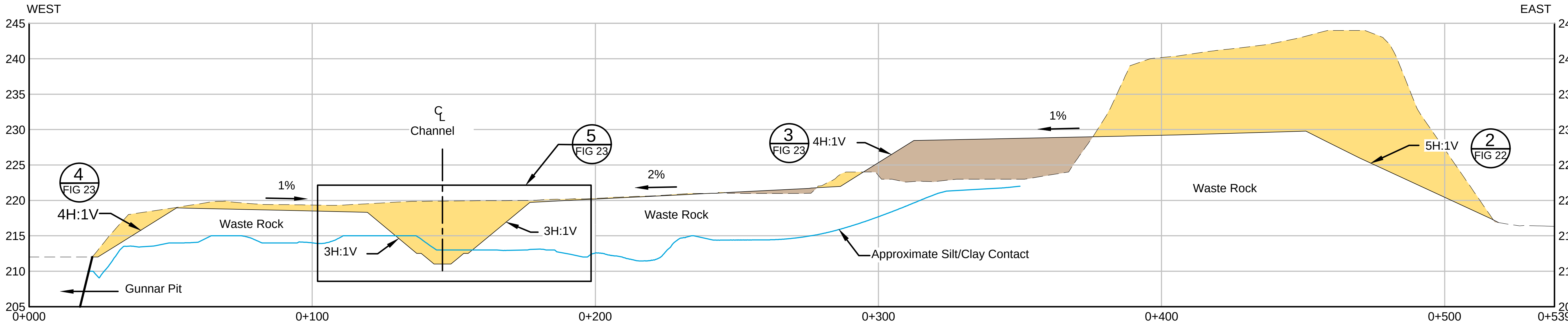
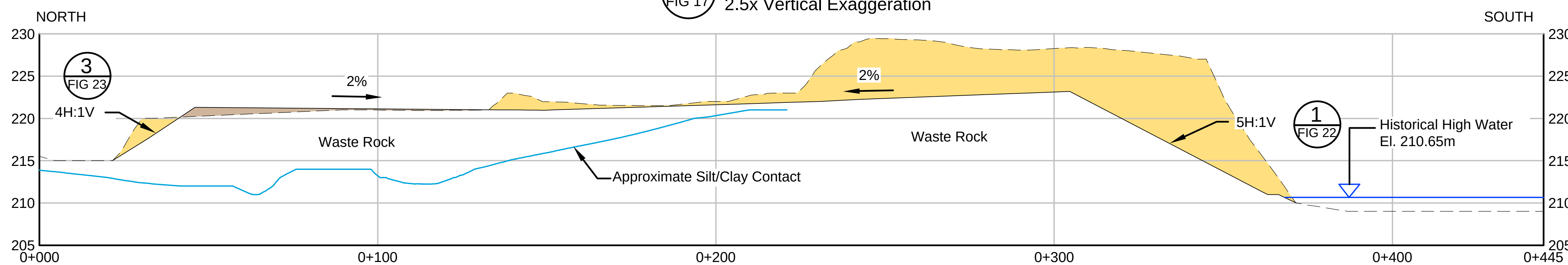
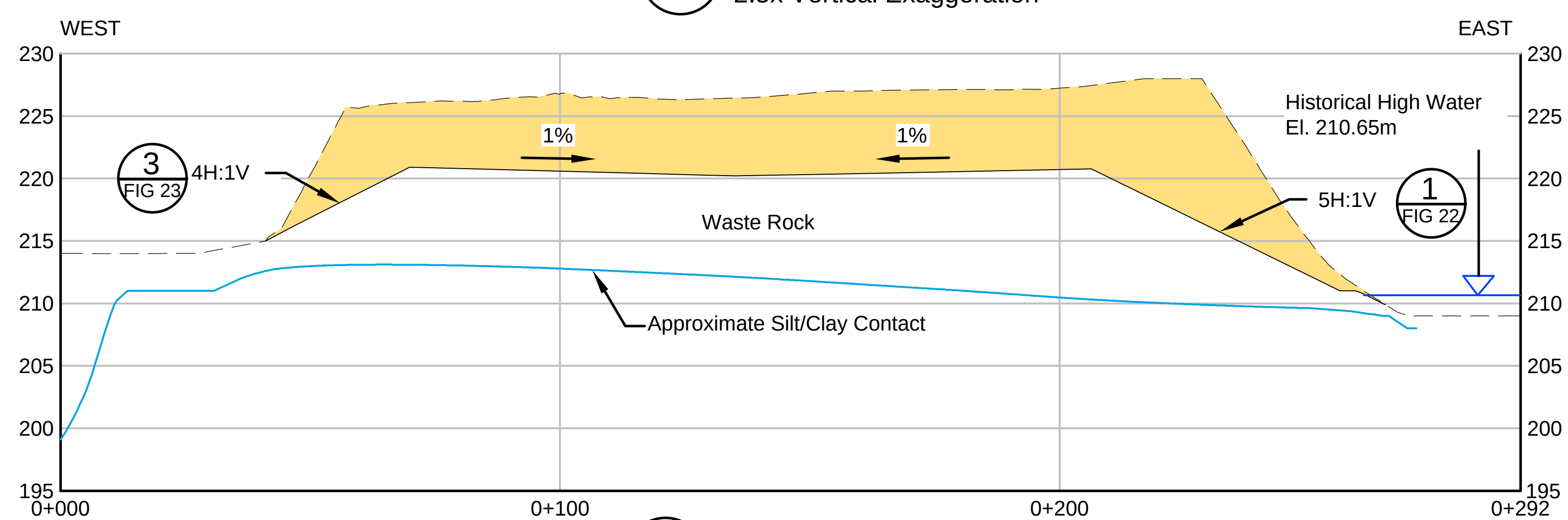


AA' FIG 17 SECTION
2.5x Vertical Exaggeration



BB' FIG 17 SECTION
2.5x Vertical Exaggeration



CC' FIG 17 SECTION
2.5x Vertical Exaggeration

LEGEND

- Existing Ground Surface
- Re-Graded Surface
- Approximate Silt / Clay Contact
- Fill Zone
- Cut Zone

NOTE

1. Approximate Silt/Clay Contact surface was inferred based on the logs contained within SNC's *Supplemental Gunnar Subsurface Characterization Program.* (SNC, 2016).

0m 10 20 30 40 50 60
1 : 1500 (Horizontal Scale)

0 10 20
1:600 (Vertical Scale)

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FILE NAME: 1CS056.003 - Plan and Sections.dwg

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GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

WASTE ROCK RE-GRADING
(SECTIONS AA' - CC')

DATE:	APPROVED:	FIGURE:
JULY 2016	TPP/MWL	19

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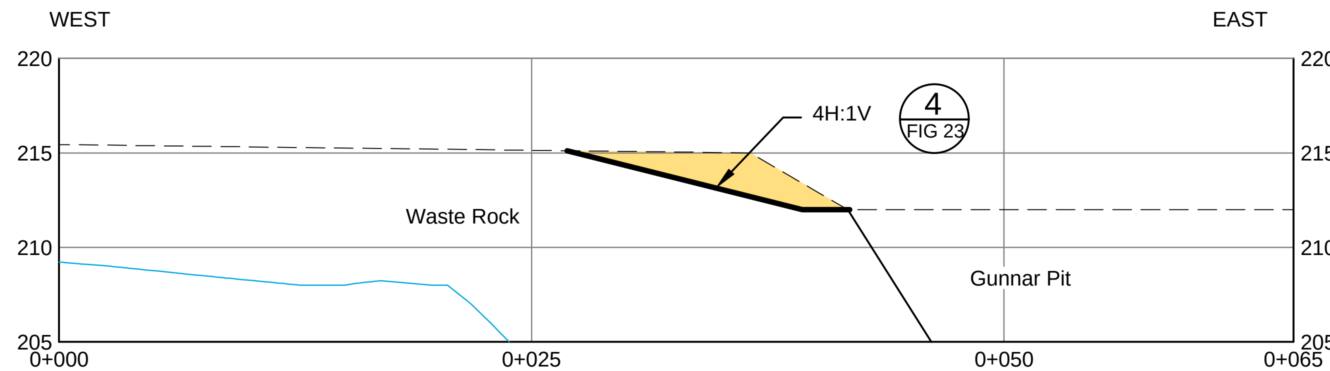
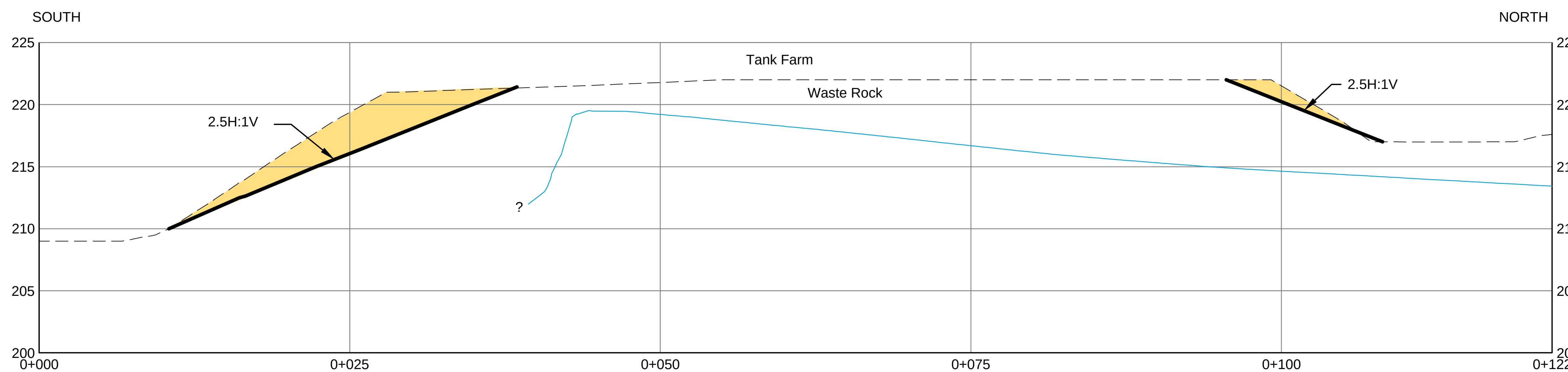
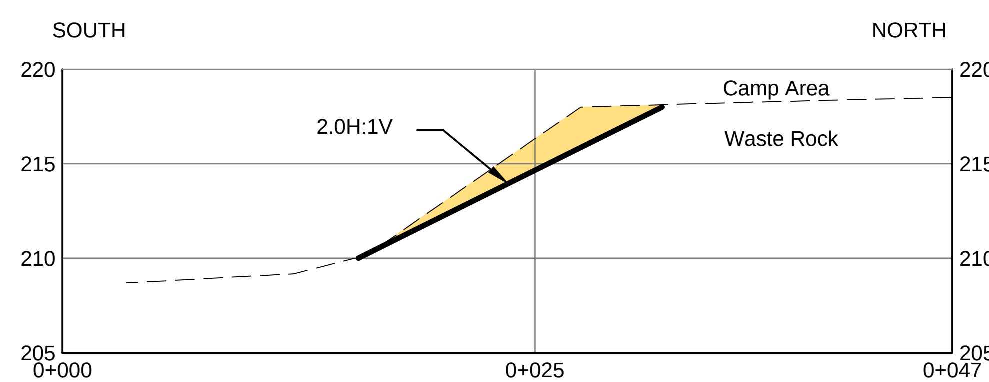


DD' FIG 17 SECTION
Natural Scale



EE' FIG 17 SECTION
Natural Scale



FF' FIG 17 SECTION
Natural Scale

LEGEND

- Existing Ground Surface
- Re-Graded Surface
- Approximate Silt / Clay Contact
- Fill Zone
- Cut Zone

0m 4 8 12 16
1 : 400

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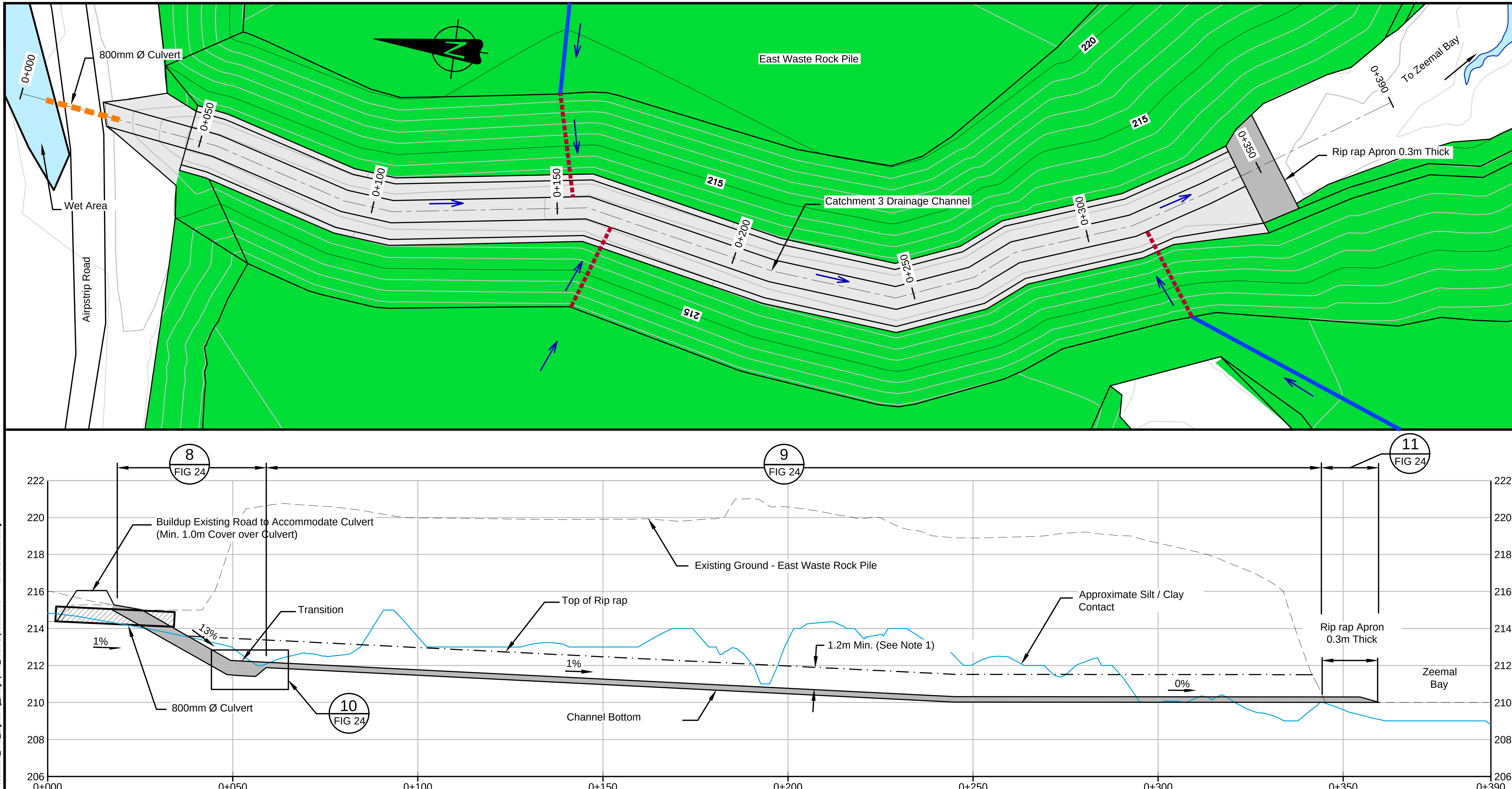
FILE NAME:	1CS056.003 - Plan and Sections.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

UPDATED PRELIMINARY REMEDIATION DESIGN

WASTE ROCK RE-GRADING
(SECTIONS DD' TO FF')

DATE:	APPROVED:	FIGURE:
JULY 2016	TPP/MWL	20



LEGEND

Re-graded Surface (Vegetated Gamma Cover)	Coconut Mat Drainage Channel (See Detail 7, Figure 24)
Rip rap Lined Channel	Rip rap Drainage Channel (See Detail 6, Figure 24)
Rip rap Apron	Flow Direction

NOTES

1. Minimum of 1.2 m or EL. 211 masl., whichever is greater.
2. Approximate Silt/Clay Contact surface was inferred based on the logs contained within SNC's *Supplemental Gunnar Subsurface Characterization Program.* (SNC, 2016).

REFERENCE

NAD83 UTM Zone 12.

0m 10 20 30 40
1 : 1000 (Horizontal Scale)

0m 2 4 6 8
1 : 200 (Vertical Scale)

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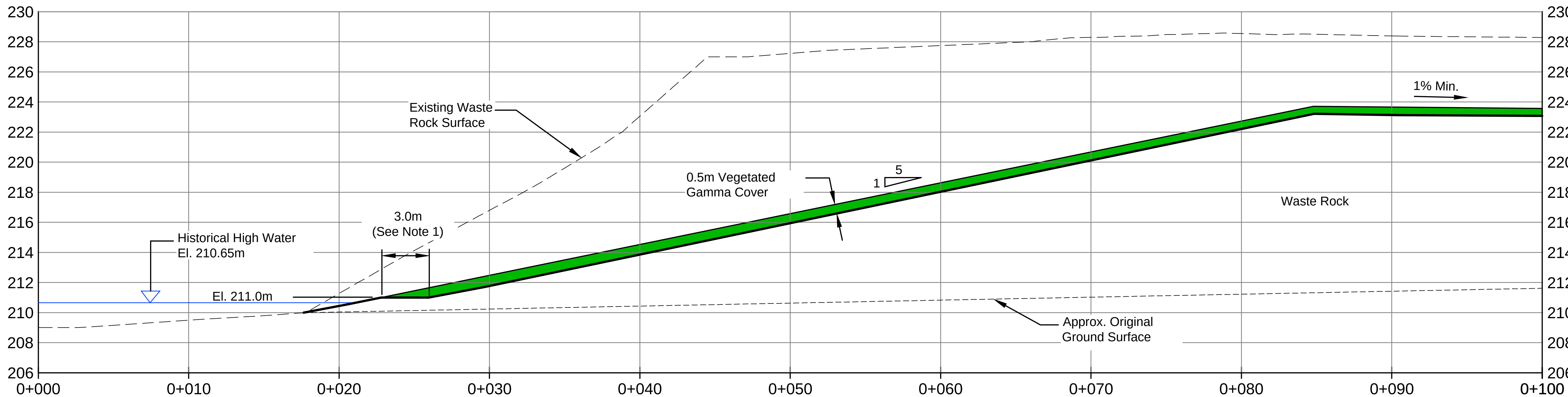
FILE NAME: 1CS056.003 - Plan and Sections.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

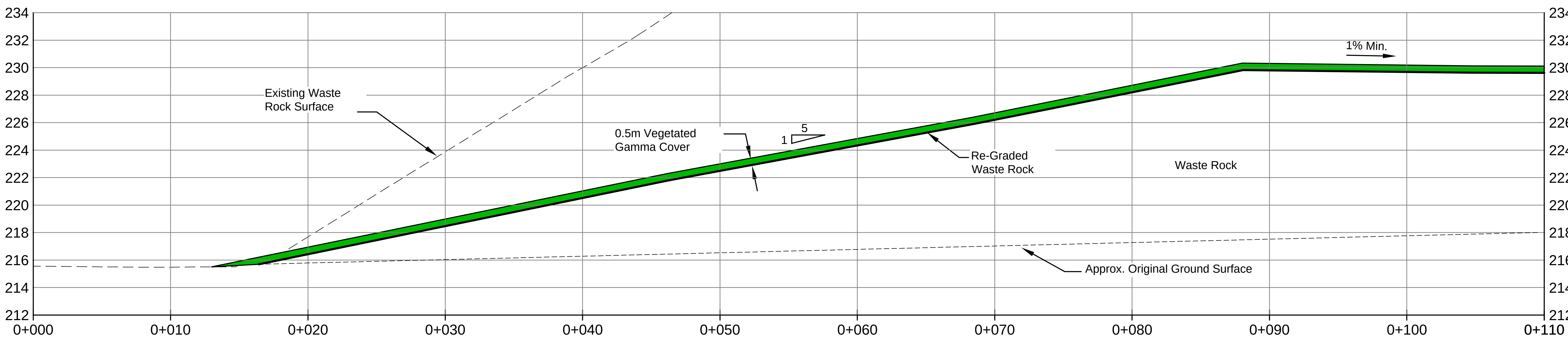
UPDATED PRELIMINARY REMEDIATION DESIGN

RE-ESTABLISHED HISTORIC DRAINAGE CHANNEL (PLAN AND PROFILE)

DATE:	APPROVED:	FIGURE:
JULY 2016	TPP/MWL	21



1 FIG 19 TYPICAL SECTION 5H:1V (3.0m BENCH AT TOE/WATER FRONT SECTIONS)



2 FIG 19 TYPICAL SECTION 5H:1V (NO BENCH AT TOE)

0m 3 6 9 12
1:300

LEGEND

Re-graded Surface (Vegetated Gamma Cover)

NOTES

1. A minimum 3.0m wide bench will be established above the historical high water mark (Elev. 210.65m) to accommodate the 0.5m thick vegetated gamma cover and to reduce the potential for sediment to enter Zeemel Bay.

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UPDATED PRELIMINARY REMEDIATION DESIGN

WASTE ROCK RE-GRADING TYPICAL SECTIONS 1 AND 2

GUNNAR MINE "OTHER SITE ASPECTS"

SRK JOB NO.: 1CS056.003	DATE: JULY 2016	APPROVED: TPP/MWL	FIGURE: 22
FILE NAME: 1CS056.003 - Plan and Sections.dwg			

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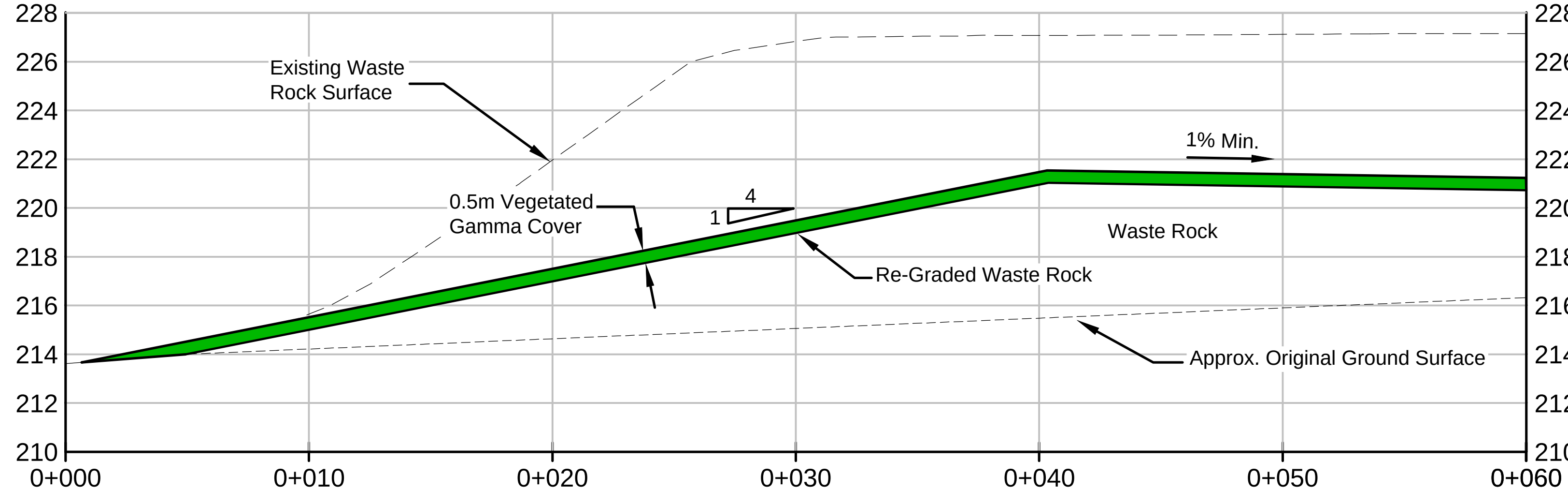
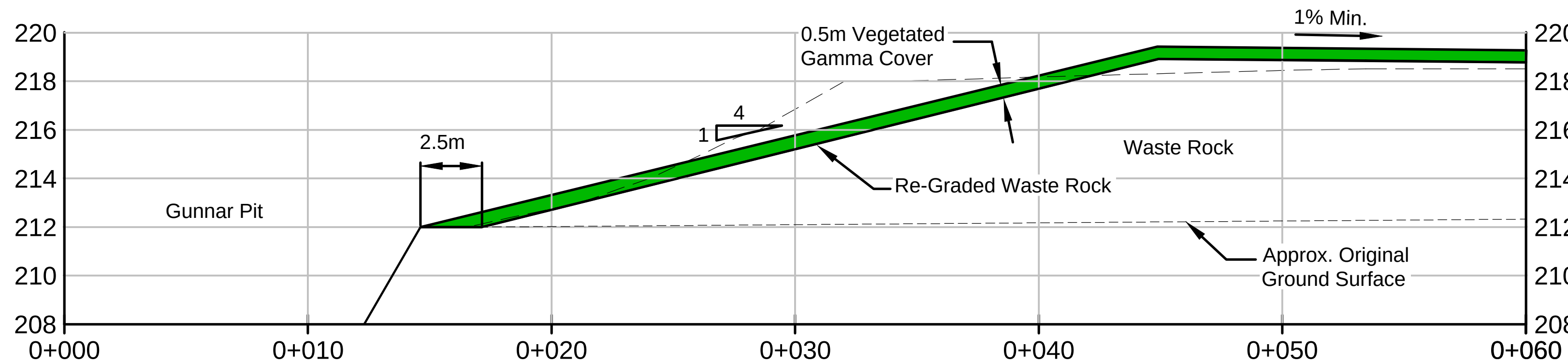
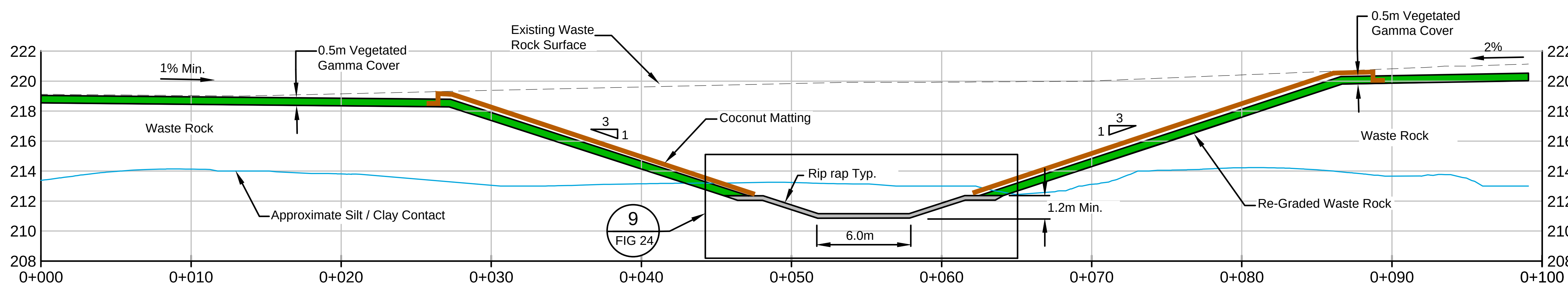


3 FIG 19 TYPICAL SECTION 4H:1V



4 FIG 19 TYPICAL SECTION 4H:1V (GUNNAR PIT)



5 FIG 19 SECTION THROUGH CHANNEL

0m 3 6 9 12
1:300

LEGEND

- Re-graded Surface (Vegetated Gamma Cover)
- Coconut Matting

NOTES

1. Approximate Silt/Clay Contact surface was inferred based on the logs contained within SNC's *Supplemental Gunnar Subsurface Characterization Program.* (SNC, 2016).

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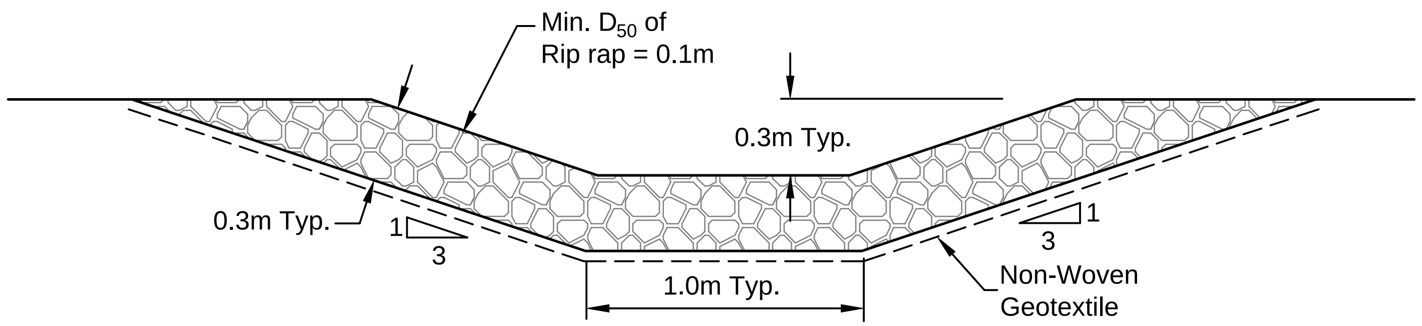
WASTE ROCK RE-GRADING (TYPICAL SECTIONS 3 TO 5)

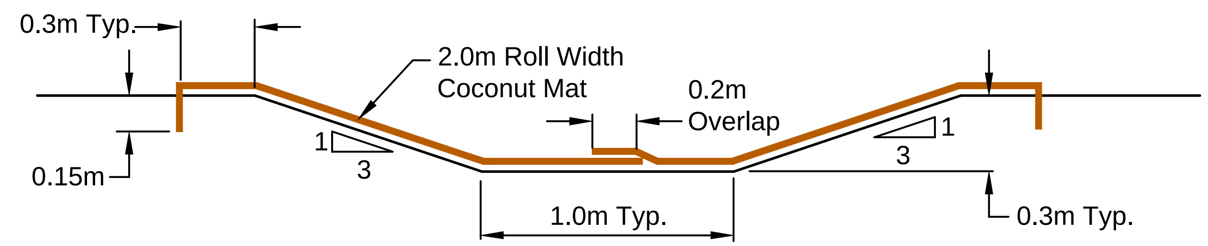
GUNNAR MINE "OTHER SITE ASPECTS"

SRK JOB NO.: 1CS056.003
FILE NAME: 1CS056.003 - Plan and Sections.dwg
DATE: JULY 2016
APPROVED: TPP/MWL
FIGURE: 23



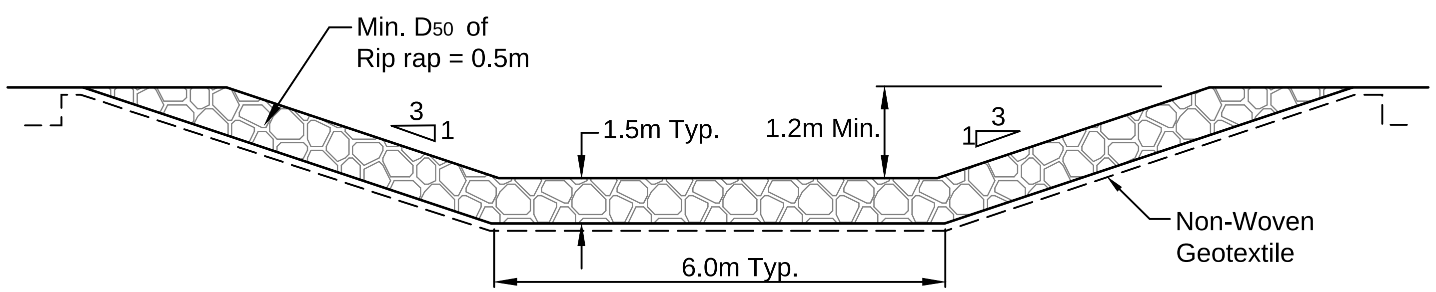
6 FIG 17 TYPICAL RIPRAP DRAINAGE CHANNEL SECTION

NTS



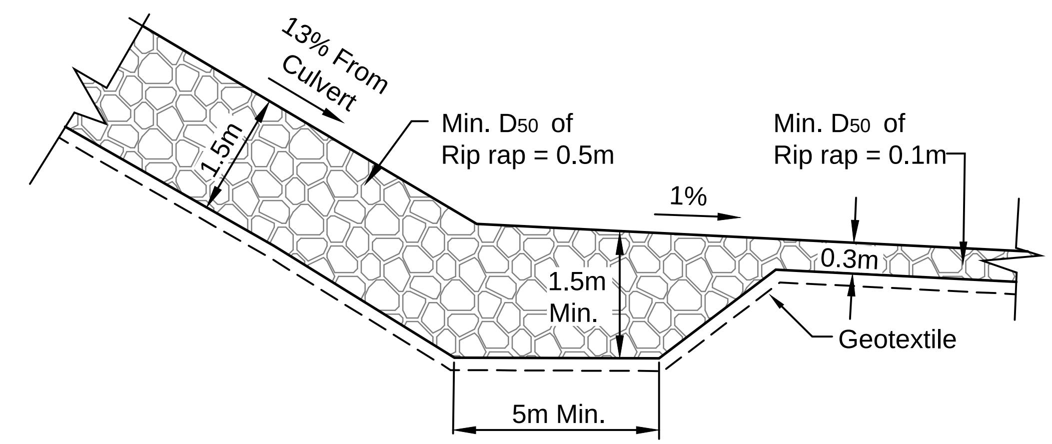
7 FIG 17 TYPICAL COCONUT MAT DRAINAGE CHANNEL SECTION

NTS



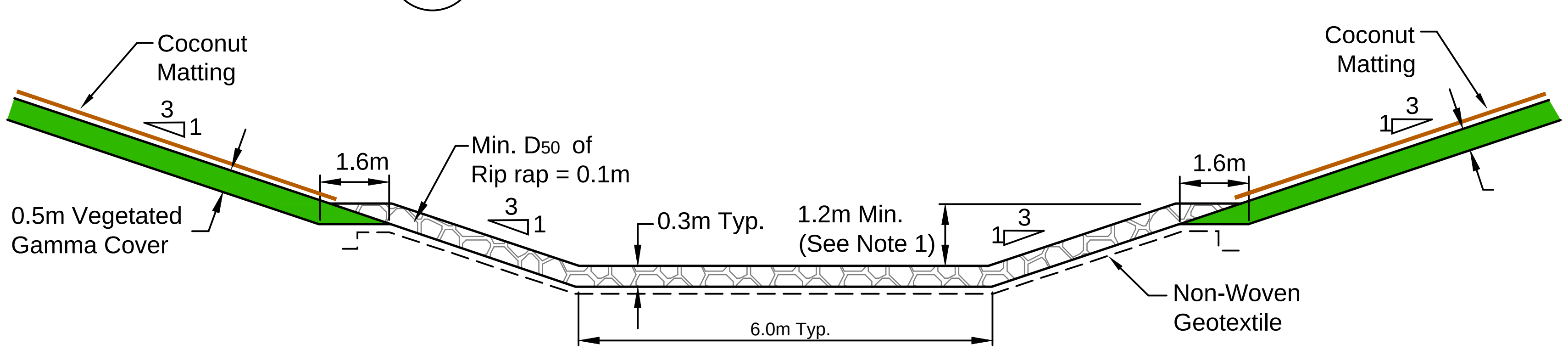
8 FIG 21 MAIN CHANNEL SECTION AT 13% SLOPE

NTS



10 FIG 21 TYPICAL TRANSITION SECTION

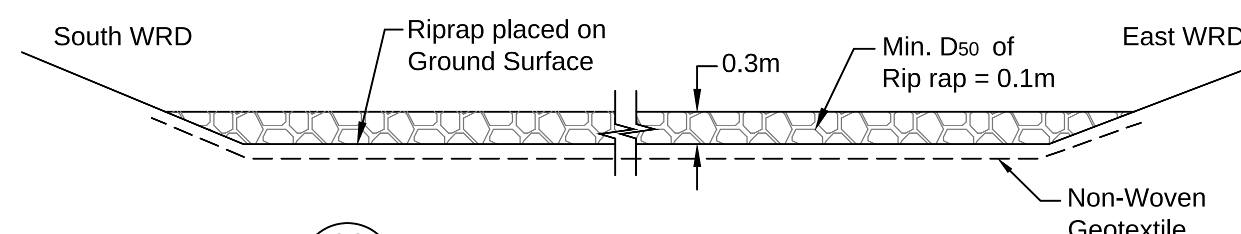
NTS



9 FIG 21 MAIN CHANNEL SECTION 0% TO 1%

NTS

1. The top surface of the rip rap channel needs to be a minimum of 1.2m above the base and needs to be at a minimum elevation of 211 masl.



11 FIG 21 TYPICAL RIP RAP APRON SECTION

NTS

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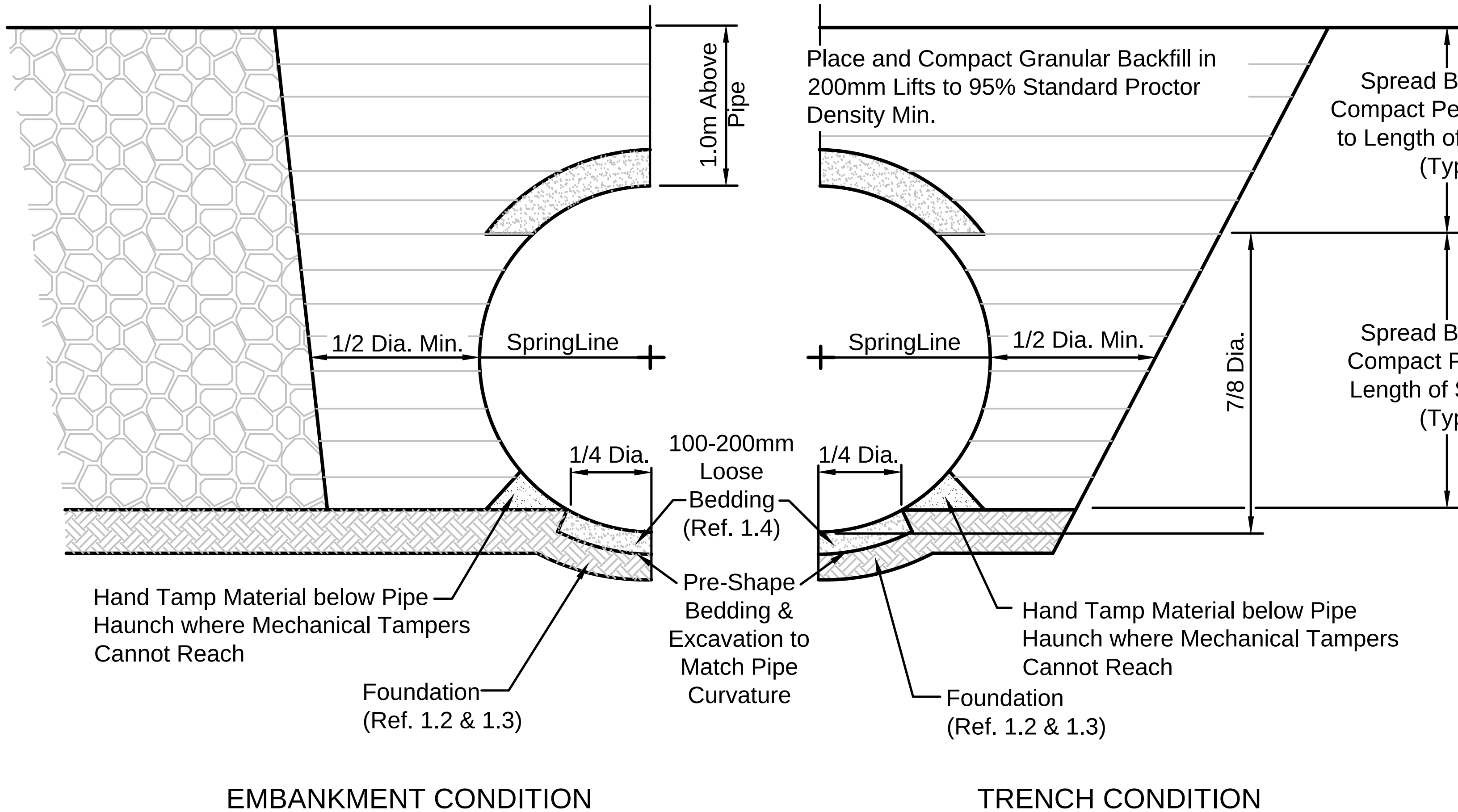
UPDATED PRELIMINARY REMEDIATION DESIGN

DRAINAGE CHANNELS AND RE-ESTABLISHED HISTORIC DRAINAGE CHANNEL (TYPICAL SECTIONS 6 TO 10)

GUNNAR MINE "OTHER SITE ASPECTS"

SRK JOB NO.: 1CS056.003	DATE: JULY 2016	APPROVED: TPP/MWL	FIGURE: 24
FILE NAME: 1CS056.003 - Plan and Sections.dwg			



12
FIG 2
TYPICAL CULVERT (800mm Ø CSP)

NOTES:

1. Bedding and Foundation

1.1. The foundation shall be free of rock formations, protruding stones, frozen lumps,

organic materials or other foreign matter that may cause unequal settlement.

1.2. Foundation must support pipe, backfill and traffic loads with minimal settlement. Remove soft yielding material to stabilize base as directed by the engineer. Foundation shall be approved by the engineer prior to pipe placement and backfilling.

1.3. Pre-spape foundation and bedding to match curvature of pipe invert. Engineered backfill material may be used for loose bedding placed below pipe invert (see culvert detail).

2. Shape Control and Monitoring

2.1. Measuring the rise and span at several points in the run shall be carried out during installation. Use soil placement and compaction methods which will ensure that the vertical pipe dimension (rise) does not increase in excess of 5% of the nominal diameter. Use methods which will ensure that the horizontal pipe dimension (span) does not increase in excess of 3% of the nominal diameter.

3. Backfill

3.1. A free draining, well graded granular backfill shall be placed in 200 mm lifts with each lift compacted to a minimum 95% standard proctor density.

3.2. Materials for the engineered backfill envelope shall conform to the following specifications and gradation requirements

- free draining uniformly graded granular
- unified soil classification gw, gp, sw, or sp
- 75 mm maximum particle size
- less than 10% fines smaller than no. 200 seive
- frozen backfill shall not be used
- place engineered backfill to the extents shown (see culvert detail)

3.1. Spread backfill in maximum loose-lift thickness of 200 mm along the full length of the pipe. Maintaining the optimum moisture content in the backfill will assist achieving the minimum 95% standard proctor density compaction requirement for each lift.

3.2. Equal depths of backfill along the sides of the pipe shall be maintained. The maximum difference in elevation shall be one lift (200 mm).

3.3. Compaction equipment shall run in a direction parallel to the pipe when compacting backfill along its sides.

3.4. Oversized compaction equipment may cause excessive deflection, distortion or damage to the pipe and shall not be used. Trucks shall unload a minimum of 1.5 m (5') from the sides of the pipe while moving out.

3.5. When the elevation of the backfill along the pipe sides reaches a height of approximately 90% of the rise, change the direction of spreading and compacting backfill materials. Continue spreading and compacting backfill in 200 mm lifts in a direction perpendicular to the pipes length up to the finished traveling surface after reaching this elevation.

3.6. The first lift of backfill placed overtop the pipe acts as cushion layer to protect the pipe from any equipment from coming into direct contact with the pipe wall.

3.7. Place a 200 mm cushion layer moderately compacted above the top of the culvert (need not reach 95% spd). All backfill lifts placed above the cushion layer shall be compacted to 95% spd.

3.8. The cushion layer shall be built up evenly from both sides of the pipe to prevent an unbalanced loading condition from occurring.

3.9. Placement and compaction of backfill overtop of the pipe shall be completed with smaller equipment with low ground pressures as not to damage the pipe during construction. (i.E. Cat d3, d4, jd350, bomag bw-75s).

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SRK JOB NO.: 1CS056.003	GUNNAR MINE "OTHER SITE ASPECTS"	UPDATED PRELIMINARY REMEDIATION DESIGN
FILE NAME: 1CS056.003 - Plan and Sections.dwg		TYPICAL CULVERT DETAIL
		DATE: JULY 2016 · APPROVED: TPP/MWL · FIGURE: 25

GAMMA SURVEY (µSv/h)

- ● Engineered Cap over Mine Opening
- Area with elevated gamma above 1.4 µSv/h per ha.
- Area requiring 0.5m thick borrow cover
- Cover completed via other remedial designs

NOTES

1. The Town Site and General Mine Site area with elevated gamma will be cover with a minimum medium/coarse till borrow thickness of 0.5m.
2. Catchment 3 is a wet muskey area with thick vegetation and no access. Gamma cover not proposed in this area.
3. Covers for the Tailings completed by O'Kane Consultants Inc.

REFERENCE

Figure adapted from data shown on EIS Map V2-62, 2009 and 2011 Gamma Survey - Interpolated Contours, Gunner Site Remediation Project, Saskatchewan Research Council.
Imagery provided by client.

0m 50 100 150 200 250 300

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PRELIMINARY REMEDIATION DESIGN

GENERAL SITE GAMMA REDUCTION AND MINE OPENINGS

GUNNAR MINE "OTHER SITE ASPECTS"

SRK JOB NO.: 1CS056.002

FILE NAME: 1CS056.003 - Gamma Map_rev02.dwg

DATE: July 2016

APPROVED: TPP/EMR

FIGURE: 28

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Appendix A – SRC's Response to CNSC Comments of SRC's Gunnar Site Remediation Project – Gunnar Mine "Other Site Aspects"

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February 5, 2016 **12194-410-11A16**

Karina Lang, PhD
Senior Project Officer
Directorate of Nuclear Cycle and Facilities Regulation
Canadian Nuclear Safety Commission
280 Slater Street
Ottawa, On K1P 5S9

Re: SRC's Response to CNSC Review Comments of SRC's Gunnar Site Remediation Project – Gunnar Mine "Other Site Aspects"

Dear Karina,

SRC, in consultation with the "Other Site Aspects" design engineer (SRK Consultants), has compiled the following responses to CNSC's previous review comments as follows:

Comment 1:
The MAA in Table 5-5 needs further information to improve the clarity and transparency needed to properly support the approach for remediation (e.g. excavating waste rock down to the original channel bed). For example, Table 5-5 contains a blank space in the cell where the advantages of backfilling the pit could be listed. Furthermore, there is no mention of several disadvantages of backfilling the pit such as the risk of worker safety related to potential collapse of backfilled waste rock in underground workings in the pit bottom and the requirement of perpetual treatment of contaminated water from the pit. SRC is expected to provide a clear and transparent discussion of the advantages and disadvantages of backfilling both waste rock piles into the pit versus excavating a channel and covering the remaining waste rock piles.

SRK Response:
In the following SRK responses, the Gunnar Mine "Other Site Aspects" Preliminary Design Report will be referred to as the "Draft Report" (SRK 2015) and the Gunnar Site Remediation Project Environmental Impact Statement as "EIS" (EIS 2013).

Section 5.0 as well as Tables 5-1, 5-2, 5-3 and 5-5 in the Draft Report will be revised so that advantages and disadvantages for each of the proposed remedial options are clear and transparent. For example, SRK will elaborate on the advantages and disadvantages of backfilling the Open Pit (Section 5.3), which will include:

Advantages of Backfilling Open Pit

- Potential to completely reduce the source load from waste rock deposits and impacted sub-soil as all of this material will be excavated and stored in the pit.
- Consolidation of non-contaminated and contaminated demolition debris, waste rock and impacted sub-soil below waste rock piles.

Disadvantages of Backfilling Open Pit

Human Health / Ecological / Active Remediation Risks

- Degree of Adaptive Management is poor as it will be extremely difficult to remove material from the Open Pit (not practical). Creating the potential for perpetual treatment.
- Disturbance from material placement in the Open Pit will cause mixing that may re-suspend contaminants.
- In regards to contaminated demolition debris, the majority of hydrocarbons on site have a density of <0.8 g/ml and may float. Creating the potential for hydrocarbons to remain on the surface of the pit water resulting in additional water treatment needs or mobilization of hydrocarbons to Lake Athabasca.
- If the Open Pit is completely filled and covered, there is risk of settlement/deformation into the underground workings. Significant borrow material volumes may be required, which will increase the borrow area footprints. If placement occurs within a water filled Open Pit, quality control during filling will be difficult and the absence of compaction may lead to significant deformation and subsidence.
- The volume of fill required to backfill the Open Pit is approximately 3.5 Mm^3 (SRC 2013, Appendix H). The combined volume of the East and South Waste Rock Piles is approximately 2.2 Mm^3, which will be reduced as the tailings cover requires approximately 820,000 m^3 of waste rock. If other waste rock areas at the site are not utilized as backfill, additional borrow will be required increasing the overall borrow source footprint.
- Placement of material in the pit during remediation has greater health and safety risks compared to other remedial options. Safety risks associated with placement include:
  - Potential collapse of underground workings at the bottom of the Open Pit (SRC 2013, Appendix F).
  - If the Open Pit is not dewatered, a more complex disposal method may be required for safe placement and to reduce disturbance to the Open Pit sidewalls (barge, conveyors or rock chutes).
  - Physical stability of the Open Pit walls may be compromised if dewatered prior to placement of debris, waste rock and/or soil (SRC 2013, Appendix F).

Construction / Feasibility / Efficiency

- Highest cost compared to other remedial options. Large volumes of material to be hauled to the Open Pit and water treatment is a significant cost.
- Perpetual water treatment may be required if the Open Pit is not completely filled and covered.
- The footprint of the excavated waste rock piles will require a cover.
- If the Open Pit is backfilled in a non-flooded state, the pit walls will require stabilization and access into the Open Pit may need to be established based on placement method.
- Geotechnical instrumentation will need to be established to monitor the Open Pit during remediation. This may include monitoring wells, piezometers and slope inclinometers.

Comment 2:
Site specific remedial objectives (SSROs) presented in Table 3-2 are higher than the current water quality conditions in Zeemel Bay and St. Mary's Channel. In the past, Environment Canada (EC-6) questioned the acceptability of the Surface Water Remedial Objectives in the Gunnar EIS and the local communities have expressed concerns about elevated SSROs. SRC needs to demonstrate that SSROs will be re-evaluated to reflect improvements in water quality that are expected to occur over time and to demonstrate that the remediation project is in line with the practices of pollution prevention and keeping releases as low as reasonably achievable (ALARA).

The absence of an objective for Ra-226 in particular needs to be addressed as the relative hazards of uranium and Ra-226 (and other radioactive daughters) are fundamentally different (chemical toxicity versus radiotoxicity). Stakeholder concerns about radioactivity in the aquatic environment, and the ability of Ra-226 to act as an indicator of the presence of other "hard-to-measure" radionuclides
(Addendum to this memo) are other factors to be taken into consideration in developing more comprehensive SSROs.

SRC is expected to re-evaluate the SSROs to reflect the existing water quality in Zeemel Bay, long-term water quality improvements expected at the site, and what is sustainable at this remote site. Furthermore, a SSRO value for Ra-226 should be developed.

SRK Response:
The overall objective of the Gunnar Mine Remediation Project (Project) is to reduce the risks that the site poses to human health, safety of the public, and integrity of the environment. This objective includes the "practices of pollution prevention and keeping releases as low as reasonably achievable (ALARA)". As documented in the Project's approved EIS (SRC 2013), in order to assist with the development of remedial options for the site, site specific remedial objectives (SSROs) have been developed for the discharge of site waters to the receiving environment.

The rationale and objectives for the development of the SSROs are provided in detail in the Project's approved EIS (SRC 2013, Appendix J). The development of these SSROs was largely based on the results of the Human Health and Ecological Risk Assessment. Ultimately the decision, as stated in Appendix J of the EIS, was made to not develop a SSRO for radionuclides in surface waters. Rather it was recommended and ultimately approved through the assessment process completed for the Project, that risks to human populations be controlled through enforcement of fish consumption advisories and continued monitoring of the expected declines in fish tissue radionuclide concentrations post remediation (SRC 2013, Appendix J). Although the SSROs are to be taken into account as an environmental health indicator during the active remediation and post remediation monitoring programs, the level of remediation success, will be assessed against Canadian and Saskatchewan water quality guidelines.

Implementation of the remedial options described in the Draft Report will result with reductions of concentrations of contaminants of potential concern (COPC) to levels well below the SSROs, with the overall objective of meeting Canadian Environmental Quality Guidelines (CEQG) and/or Saskatchewan Surface Water Quality Objectives (SSWQO) in St. Mary's Channel and Zeemel Bay for all the COPCs including Ra-226.

Comment 3:
The proposed plan measures remediation success in Zeemel Bay based on general surface water quality objectives. This is an insufficient means to track the success of remediation and to confirm a major reduction in loadings to the receiving environment. The choice of the excavated channel through the waste rock pile is based on model predictions of water quality in Zeemel Bay. It is recommended that water quality objectives or indicators be developed to monitor loadings to the environment at or near the source of contamination and to monitor water quality in upper Zeemel Bay. SRC is expected to also describe what kind of contingency measures are in place should concentrations in future years deviate from predicted values.

SRK Response:
Zeemel Bay has been identified as the immediate receiving environment for the Catchment 3 drainage (area directly east of Gunnar Main Tailings that drains towards the East Waste Rock Pile). As such, the potential impact to the surface water being conveyed by the waste rock channel into Zeemel Bay will be monitored extensively, with several monitoring stations being located in Zeemel Bay. The draft report will be amended to identify these monitoring stations as they are currently proposed. A detailed Monitoring Management Plan will be developed as part of the next phase of engineering of the Gunnar Mine "Other Site Aspects". This Management Plan will, among other things, outline a series of surface water quality and flow rate monitoring stations in the excavated channel with the purpose of estimating COPC loadings in Zeemel Bay.

A Failure Modes and Effects Analysis (FMEA) is scheduled as part of the next phase of engineering for all aspects of remediation design associated with the "Other Site Aspects". This exercise will identify all potential areas where the remediation designs could fail and the associated results of these potential failures. Subsequently, any adjustments and/or contingencies required to the engineering design will be developed and incorporated into the "next phase" design report.

Comment 4:

In the EIS, the proposed and assessed design storm for the surface water drainage systems was a 1,000-year storm, but SRC uses a 200-year design storm in the current report without explanation. This is a significant reduction of flood protection capacity from the EIS. SRC should provide justification for reducing the design storm from 1,000 years in the EIS to 200 years in the current report. Selection of design storm duration needs to take into consideration the drainage basin size. SRC proposes to use a 24-hour design storm without justification. For such smaller drainage basins, the maximum peak flow will most likely be generated by a design storm with a shorter duration. As such the 24-hour duration storm may not be conservative. SRC is expected to conduct a design storm duration analysis to select a design storm duration that would generate the maximum peak flow rate.

SRK Response:

It is standard engineering practice to use a 200-year return period for surface water drainage systems that have a low consequence classification. The proposed channels and ditches in the Draft Report were considered to have a "low consequence classification" as damage and loss related to a failure were deemed to be minimal.

The primary channel through the waste rock includes an over-designed (6 m) base width to facilitate construction, and the channel side slopes extend approximately 6 to 8 m into the covered waste rock piles. An extreme design storm event, such as a 1,000-year return period, would not result in overtopping of the channel. Further, the height of riprap within the channel was set to the high water level mark in Lake Athabasca, which is above the design depth for the 200-year event, and will prevent erosion of the cover material on the side slopes under larger return periods.

The peak flow estimate was based on a regional analysis of peak flows sourced from nearby gauging stations. The peak flow data is not based on a 24-hour duration, but includes all storm durations. A unit flow of 1 $m^3/s/km^2$ was used in the water drainage system designs, and is a conservative estimate (Figure 8, Draft Report). This rate is notably higher (approximately twice as high) than unit flows experienced at the regional gauges. The 24-hour duration rainfall was only used for the pit inflow estimate, since the 24-hour rainfall will produce the highest runoff volume. A shorter duration event may produce a higher peak flow rate, but will result in a smaller volume of water over the course of the event.

As stated in the Draft Report, a FMEA will be completed in the next phase of engineering to confirm the consequence classification and to address all aspects associated with the water drainage system designs such as storm event return period, storm duration, channel/ditch configurations, and extent/size of armoring.

Comment 5:
The landform design of Gunnar other site aspects remediation is to promote use of a landform consistent with current landscape, promote sustainable vegetation, ensure positive drainage, and reduce erosion potential. The landform designed should not only be stable geotechnically, but should also maintain the long-term integrity of the remediated features such as the waste rock pile and the landfill. The side slopes of the landfill containment structures for non-contaminated demolition debris and for contaminated and hazardous materials, and the side slopes of waste rock piles are designed with a gradient of 1V:3H without sufficient justification for their long term integrity. The experience from mine reclamation in northern Saskatchewan such as the Cluff Lake waste rock pile reclamation and the Rabbit Lake waste rock pile reclamation implies that a gentler landform slope is needed in order to ensure the integrity of waste disposal structures (i.e., landform and waste rock piles). SRC is expected to justify the side slope gradient of the waste disposal structures to ensure their long-term integrity or otherwise to provide sufficient information to demonstrate the integrity of the designed structures is in the long term, should the proposed options be justified adequately by addressing other comments.

SRK Response:
Both landfill and waste rock pile configurations, that include 3.0 Horizontal to 1.0 Vertical (H:V) slopes, were designed to be stable geotechnically and for the long term.

<u>Waste Rock Piles</u>
Preliminary engineering included access ramps to facilitate construction and to provide access should adaptive management measures for unforeseen events be required. Drainage channels were positioned along the 3.0H:1.0V slopes at a frequency where each channel will accommodate flow from a 1 ha area and the top surface of the waste rock piles and benches have a 1.0 % grade towards the drainage channels. The intent of this configuration was to reduce, surface flow velocities to below 1.0 m/s, the potential of surface erosion and to promote sustainable vegetation that will intern uphold the long-term integrity of the remediated waste rock piles.

The waste rock pile configurations include a series of 3.0H:1.0V slopes that are 6 m in height and are separated by benches that are 8 to 10 m in width. Such configuration results in an overall average slope angle of 4H:1.0V to 5.0H:1.0V. Therefore the benches could be excavated to form a gentler landform and the volumetrics will be the same. Landform design will be considered in the next phase of engineering, which will include a review of historical reclamation designs in Northern Saskatchewan, a trade-off study (benches vs. flatter uniform slope), and a FMEA to assess the consequences of erosion. This exercise will ultimately determine the final landform configuration for the waste rock piles.

<u>Waste Disposal Structures</u>
Both non-contaminated and contaminated landfill designs include surface/slope water management features that will promote sustainable vegetation, reduce the potential of erosion and thus facilitate the long-term integrity of the structure. Specifically, the crest of the non-

contaminated landfill will be graded at 1.0% to form a swale-like feature towards the center of the crest, which will ultimately drain towards the Open Pit via an armored drainage channel situated along the 3.0H:1.0V slope.

The crest of the contaminated landfill is much smaller and will therefore be graded at 1.0% towards the exterior slope. Water bars comprised of riprap will be situated along the 3.0H:1.0V slope of the landfill to manage sheet flow and to reduce the potential of erosion from runoff. Runoff from surrounding watersheds will be diverted around both landfills and towards the Open Pit.

The proposed landfill slopes were also designed using guidelines from the Saskatchewan Environmental Code for Landfills (EMPA, 2010) where the recommended landfill slopes for Type I and Type II waste range from 3.0H:1.0V and 4.0H:1.0V.

Landform design will be included in the next phase of engineering as well as a FMEA and if required, the slopes may be flattened to support the final landform configuration.

<u>Vegetation and Landform Design</u>

One of the key components in reducing short term erosion potential is the establishment of sustainable vegetation species native to the Gunnar site. SRC's vegetation study will be utilized in the next phase of engineering to confirm the re-vegetation potential and to develop a re-vegetation plan.

Comment 6:

One of the remediation objectives is to minimize contaminant loadings to St. Mary's Channel and Zeemel Bay. In order to achieve this objective, the cover system should be designed to limit the net infiltration and ensure its long term integrity. The current cover design of 0.5 m medium to coarse borrow materials seems not well justified to support achieving this objective. Based on the site investigation, a significant amount of fine-grained borrow material are available and should be used to enhance the cover design. SRC is expected to justify the current design of cover thickness. The fine-grained borrow materials should be considered to enhance the cover design and its performance.

SRK Response:

Medium to coarse grained borrow was proposed over fine grained borrow for the cover systems associated with the waste rock piles and peripheral areas, as these materials will be less susceptible to frost heaving and erosion. Further, this provided a conservative uranium load reduction estimate for Zeemel Bay (56% reduction) that was confirmed in the HHERA to have no adverse effects on humans and Aquatic Environment (SRK 2015).

A fine-grained borrow material can be used; however, flatter slopes and/or erosion control measures such as erosion control blankets and turf reinforcement mats may be required. A trade-off study utilizing the available information from the borrow investigation (O'Kane

Detailed Design Report) will be completed in the next phase of engineering to assess erosion susceptibility and the reduction in net percolation through a till cover with different thicknesses and gradation. This assumes that the available borrow information will include the geotechnical properties of each borrow source and the true available volumes above and below the water table.

I hope the information provided in this letter appropriately addresses the CNSC review comments. Please feel free to contact me should you have any questions or require any further information.

Best regards,

Ian Wilson
Environmental Remediation
Saskatchewan Research Council

cc. George Bihun, Environmental Protection Officer, Saskatchewan Ministry of Environment

REFERENCES:

Saskatchewan Research Council (SRC, 2013). Gunnar Site Remediation Project Environmental Impact Statement. Revised Volumes 1 to 3, November 2013.

SRK Consulting (Canada) Inc. (SRK, 2015). Gunnar Mine “Other Site Aspects” Preliminary Remediation Design. Prepared for Saskatchewan Research Council. August 2015.

Environmental Management Protection Act (EMPA 2010). Saskatchewan Environmental Code: Draft Landfill Chapter. Regina, Saskatchewan, 2010.

Appendix B – Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design: Risk Implications of Reduction of Loads related to the Gunnar Pit and Waste Rock Piles

TECHNICAL MEMORANDUM

Date: **July 11th, 2016**

To: **SRK Consulting**

From: **Harriet Phillips and Caroline Lucas**
Canada North Environmental Services

Subject: **Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design: Risk Implications of Reduction of Loads Related to the Gunnar Pit and Waste Rock Piles**

CanNorth No. 2397

Introduction

A Preliminary Remediation Design Report has been prepared by SRK Consulting (SRK) for the "Other Site Aspects" of the Gunnar Mine including, the Pit and the waste rock piles (SRK 2015). As part of that report, load calculations to the Gunnar Pit and Zeemel Bay before and after planned remedial activities were performed as well as a risk evaluation of the proposed remedial measures to ensure that humans and animals are protected at the site.

The loadings calculations of uranium and radium-226 into Zeemel Bay from the waste rock piles were based on:

- the preliminary design (SRK 2015), which involved cover of the waste rock piles with coarse borrow material,
- opening of the historical drainage channel through the East Waste Rock Pile (EWRP),
- groundwater flow rates through Catchment 3 and the EWRP provided in Appendix U of the Gunnar EIS document (SRC 2013), and
- groundwater and loads through the South Waste Rock Pile (SWRP) provided in Appendix U of the Gunnar EIS document.

The loadings calculations of uranium and radium-226 into Zeemel Bay and the Pit from other site features were based on:

- removal and placement of contaminated material from the acid plant to the Gunnar Main Tailings (GMT);
- cover of the GMT with waste rock from the EWRP; and
- removal of debris from the Mill Plant area.

Since the loadings for the Preliminary Design report were completed, additional work has been done at the Gunnar Site to refine the groundwater flows. These studies indicate that all the groundwater flows from the Acid Plant report to the Gunnar Pit instead of being split between the waste rock and the Pit. In addition, O'Kane Consultants have finalized their design calculations for the GMT Cover and have provided loads of uranium and radium-226 to Catchment 3.

This memo provides updated loading calculations to the Gunnar Pit and Zeemel Bay using the above information as well as consideration of various infiltration rates for the three different types of borrow material considered for the waste rock cover to determine the changes in loadings to Zeemel Bay. The human health and ecological evaluation for Zeemel Bay and the risk implications for the Open Pit have also been updated in this memo.

Assessment of Loads to Gunnar Pit

The information provided in Appendix U of the Gunnar Environmental Impact Statement, which discusses the Quantitative Site Loadings model, indicates that there are both groundwater and surface runoff inputs to the Gunnar Pit. The groundwater input loadings to the Gunnar Pit are derived from the GMT, the Acid Plant, and the EWRP, whereas surface loadings are associated with the Mill Complex runoff. Table 7.5 in Appendix U provides the groundwater loadings to the Gunnar Pit and Table 8.1 provides the surface water inputs. It is our understanding that the Mill Complex runoff also includes the groundwater loading from this area.

At present, the concentrations of uranium and radium-226 in the Pit are shown in Table 1.

Table 1: Summary statistics for measured concentrations of uranium and radium-226 in the Gunnar Pit

Constituent	Number of Samples	Measured Concentrations				
		Units	Minimum	Maximum	Mean	95% Upper Confidence Level of Mean (95UCLM)
Uranium	34	mg/L	0.33	1.11	0.97	1.0
Radium-226	16	Bq/L	0.23	0.51	0.33	0.34

Figure 1 provides a schematic of the uranium loadings to the Gunnar Pit based on the information provided in Appendix U of the 2013 Gunnar EIS document (SRC). As seen in the figure, the Mill Complex runoff accounts for 67% of the uranium load to the Gunnar Pit and the EWRP accounts for about 20% of the uranium load. The Acid Plant is the smallest contributor to the uranium load to the Gunnar Pit. For radium-226, the Mill Complex area accounts for about 94% of the load with less than 1% of the load coming from the Acid Plant.

Figure 1: Schematic of the uranium loads to Gunnar Pit based on information from Appendix U of EIS

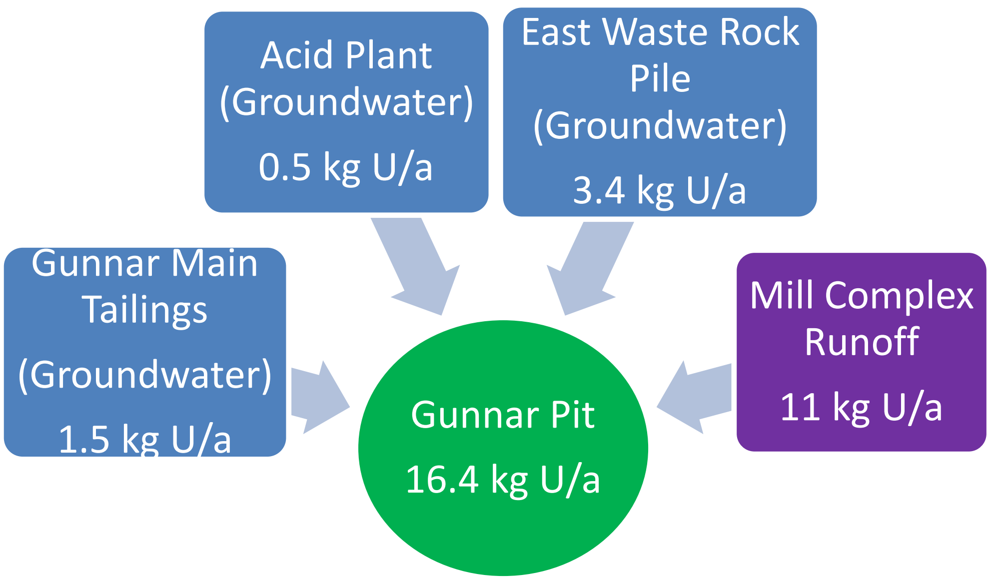
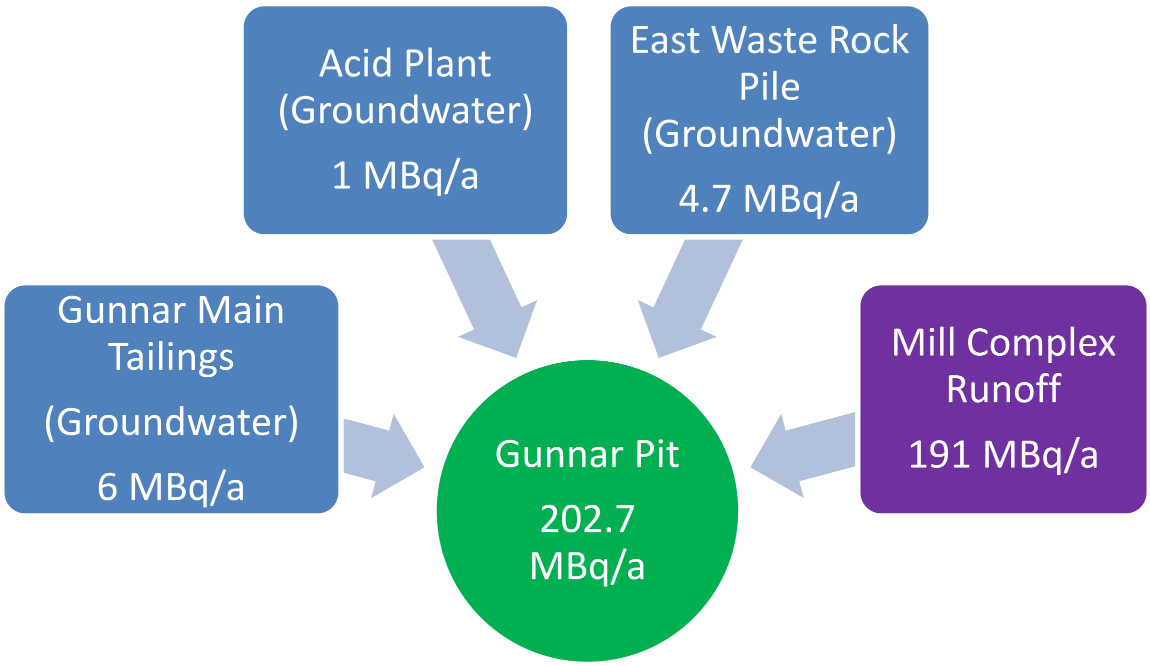


Figure 2: Schematic of the radium-226 loads to Gunnar Pit based on information from Appendix U of EIS



Since the submission of the EIS in 2013, additional studies were carried out to get a better understanding of the groundwater flows from the GMT area and from the Acid Plant. Based on these studies, it has been concluded that there is no groundwater input from GMT into the Gunnar Pit. For the Preliminary Design Report, the studies indicated that 80% of the loads from the Acid Plant report to the Gunnar Pit and 20% of the loads go to the EWRP, and calculations were completed using these formulations. Since then, SNC has updated their unserstanding of the groundwater flows (SNC 2016) resulting in the current understanding that 100% of the loads from the Acid Plant now report to the Gunnar Pit.

In summary, the current understanding of the loads to Gunnar Pit is as follows:

- the GMT contributes no loads to the Gunnar Pit;
- 100% of the loads from the Acid Plant end up in the Gunnar Pit; and
- contributions from surface runoff from the Acid Plant also ends up in the Gunnar Pit.

Figures 3 and 4 show the current understanding of the uranium and radium-226 loads to the Gunnar Pit. It should be noted that the acid plant groundwater loadings were based on updated measured data from 2012 to 2014 and on 100% of the groundwater flowing from Acid Plant to Gunnar Pit. The Acid Plant runoff has been added to the loads to Gunnar Pit and were obtained from Table 8.1 in Appendix U of the EIS.

As seen from Table 2, our current understanding of the uranium and radium-226 loads to the Gunnar Pit are 19.93 kg/a and 281 MBq/a, respectively. Both of these figures demonstrate that runoff is a larger contributor to the loads than groundwater.

Figure 3: Schematic of current understanding of the uranium loads to Gunnar Pit

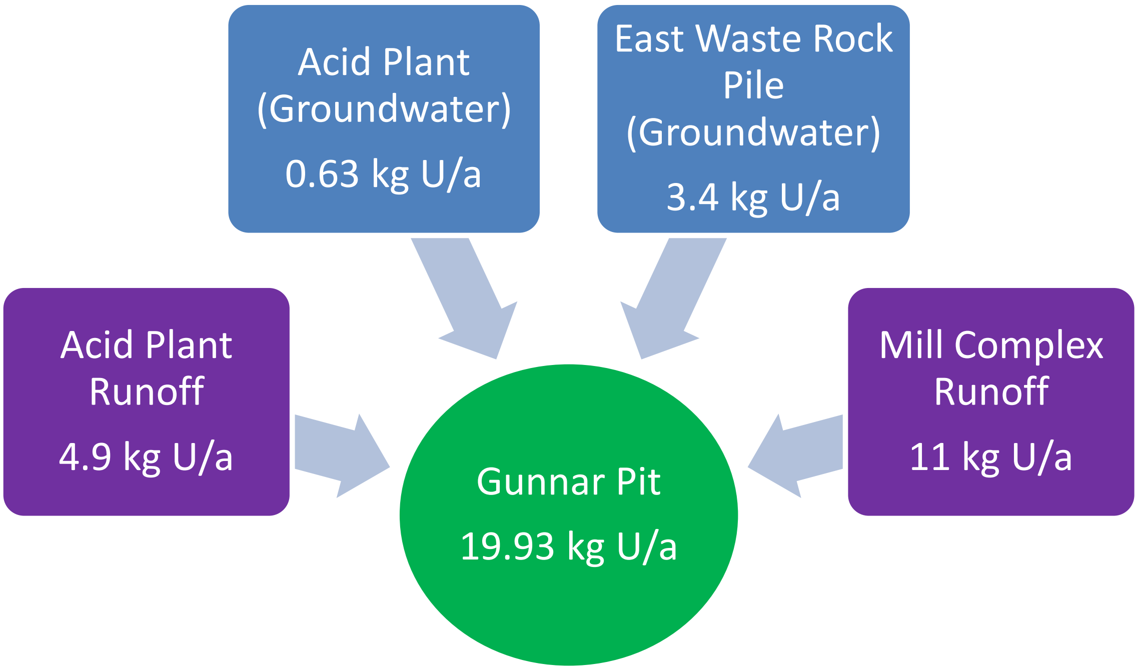


Figure 4: Schematic of current understanding of the radium-226 loads to Gunnar Pit

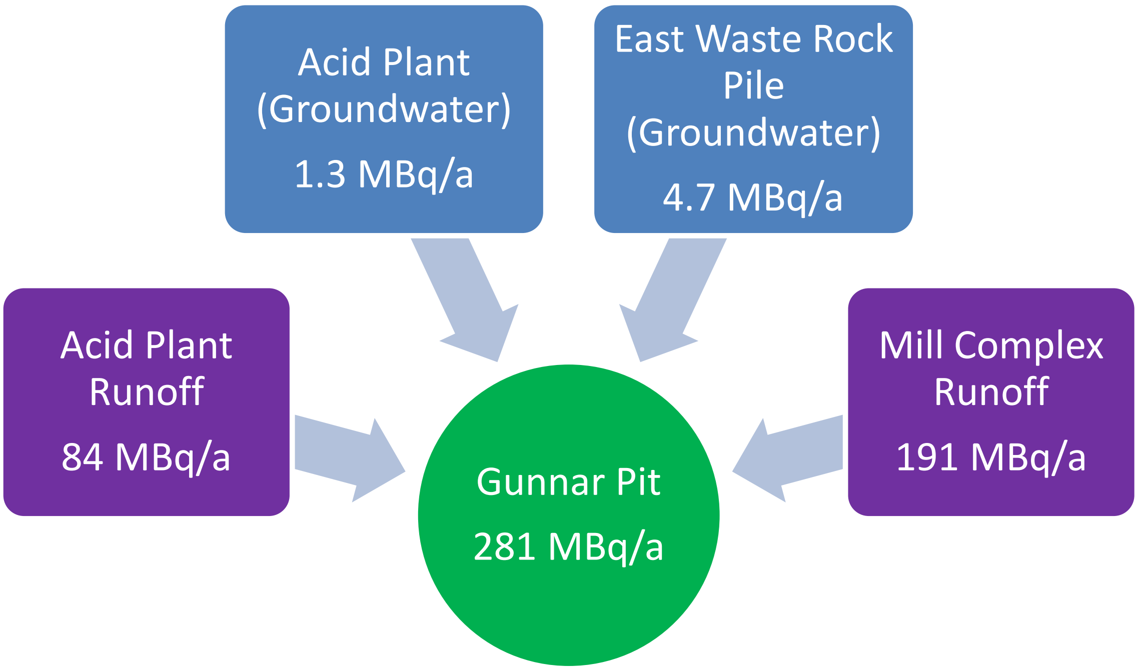


Table 2 provides a comparison of the loads between the Preliminary Design Report and the current understanding of the loads to Gunnar Pit.

Table 2: Comparison of uranium and radium-226 loads to the Gunnar Pit

Scenario	Uranium Loads (kg/a)		Radium Loads (MBq/a)	
	From Acid Plant	In Gunnar Pit	From Acid Plant	In Gunnar Pit
Preliminary Design Report	4.4	18.8	68	263.7
Current Understanding	5.53	19.93	85.3	281

Effect of Remedial Activities at Acid Plant and Mill Complex on Uranium and Radium-226 Loads to Gunnar Pit

The preferential option for the Acid Plant involves the removal of the contaminated material in the plant area and placing it on the GMT Area and then using the area to manage the disposal of the contaminated demolition debris under a cover of clean fill. The Mill Complex area will be used to dispose of clean demolition debris under an engineered cover. The remaining area considered to be part of the Mill area will be graded and covered with a 0.5 m till cover. The EWRP will be recontoured and covered with a 0.5 m till cover. Depending on what the till options are for the EWRP, the loadings to the Gunnar Pit will be slightly different based on the percolation rates. The use of the finer till material results in a material that may be subject to erosion and, thus, it may be more practical to use a coarser material for the EWRP cover.

In the Preliminary Design, it was assumed that the cover on the EWRP would result in a 63% reduction in the groundwater flow. In this assessment we have evaluated different cover options and the reduction in flows associated with the cover options. The percolation rates are discussed in the main document. Table 3 provides a summary of the flow rates associated with the different cover options.

Table 3: Summary of flow rates from the EWRP to Gunnar Pit associated with different cover options

Cover Material	Groundwater Flow from EWRP to Gunnar Pit (m^3/a)
Bare Waste Rock – Existing Conditions	6,408
Coarse Textured Till Cover	4,299
Medium Textured Till Cover	3,677
Fine Textured Till Cover	2,227

Note: Bare waste rock conditions were obtained from Table 7.3 Appendix U of EIS

As seen from the above table, the use of various coarse, medium, or fine textured till material results in groundwater flow rate reductions of 33%, 43%, and 65%, respectively.

Figures 5 and 6 show the effect on the loadings to the Gunnar Pit associated with the remedial options at the Acid Plant area, Mill area and the use of a coarse textured till cover on the EWRP. The assumptions used for the loadings are as follows:

- groundwater loads from the Acid Plant to the Gunnar Pit will be essentially zero when all the contaminated material has been removed,
- loadings from Acid Plant and Mill Complex reduced by 90% - based on similar assumptions provided in EIS Table 14-1, Volume 3 (SRC 2013), and
- loadings from the EWRP reduced by 33% based on reduced groundwater flow to Gunnar Pit from 6,408 m^3/a (Table 7.3 Appendix U) to 4,299 m^3/a (Table 3).

As seen from these figures, the loadings of uranium and radium-226 to the Gunnar Pit are reduced by factors of approximately 5 and 9 respectively. The load reductions will eventually result in decreases in concentrations of these constituents in Gunnar Pit. However, given the volume of water in the Pit (3.3 million m^3), it is unlikely that changes in concentration will be observed for hundreds of years. There is seepage from the Pit through the waste rock plug into St. Mary's Channel at an average estimated rate of 23,000 to 37,000 m^3/a (Appedix U). It should be noted that the uranium concentrations near the seep in St. Mary's Channel are 0.008 mg/L.

Figure 5: Schematic of uranium loads to Gunnar Pit associated with remedial actions

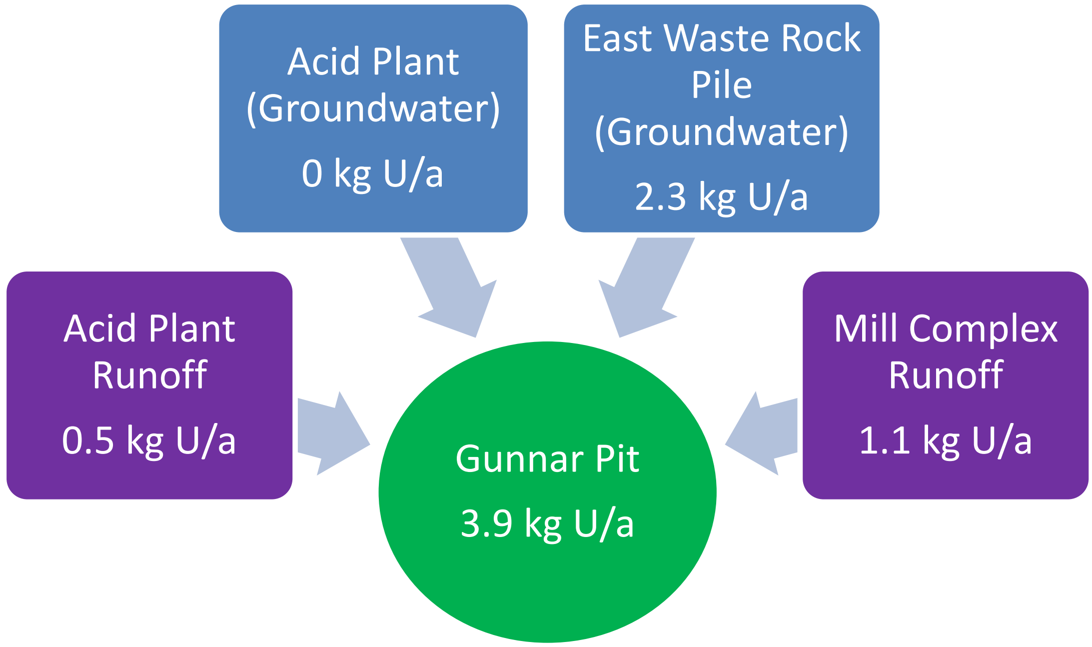
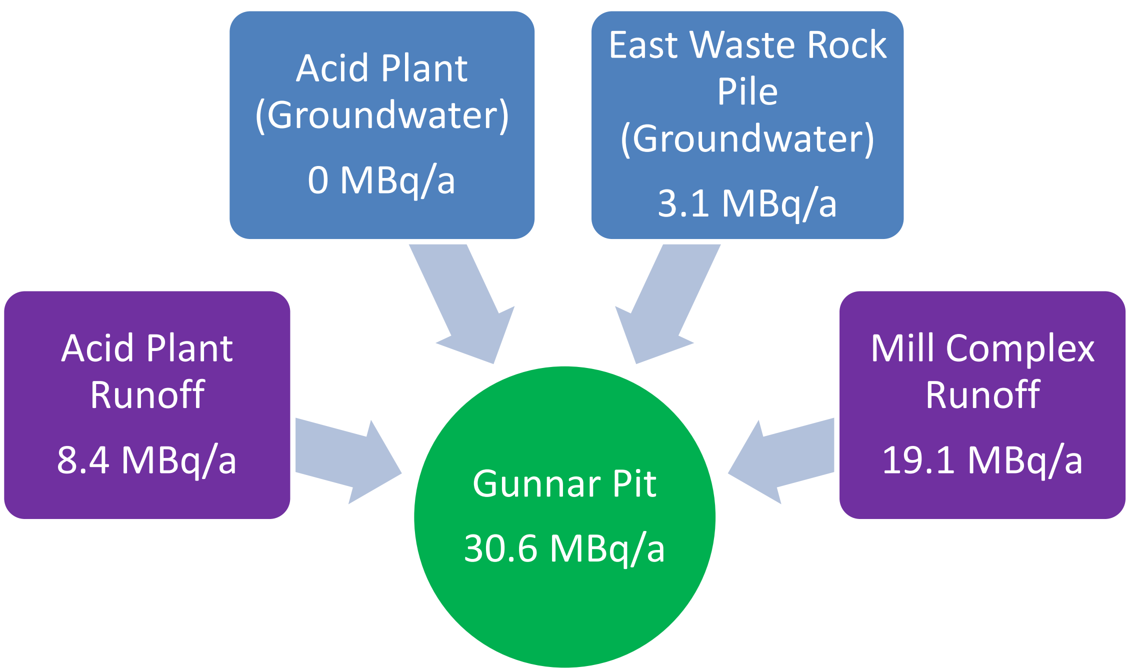


Figure 6: Schematic of radium-226 loads to Gunnar Pit associated with remedial actions



Risk Implications in Gunnar Pit

A Screening Level Risk Assessment was carried out for the Gunnar Site in 2006 (SENES 2006). In that assessment, it was determined that there were no risks to human health; however, there were potential risks in the Gunnar Pit associated with uranium concentrations for aquatic receptors as well as for small individual terrestrial receptors. In addition, radium-226 was an issue for aquatic plants. As ecological risk assessments consider protection of populations of receptors and not individual receptors, it is unlikely that adverse effects are being observed in ecological populations at the Gunnar Site. In fact, Appendix R of the EIS indicates that in 2002 the pit was found to contain a good diversity of aquatic biota in a number of groups (phytoplankton, zooplankton, benthic macroinvertebrates, and macrophytes) as well as a self-sustaining population of northern pike. It should be noted that low dissolved oxygen levels in the bottom half of the pit is a challenge for aquatic biota.

Given that the loadings of uranium and radium-226 to the Gunnar Pit will decrease by almost an order of magnitude after remedial activities at the Acid Plant and Mill Complex areas and that conditions in the Pit will improve in the long term, it is unlikely that small terrestrial animal populations will experience any adverse effects associated with exposure to uranium and radium-226 in the future in the Gunnar Pit if natural attenuation was the chosen option.

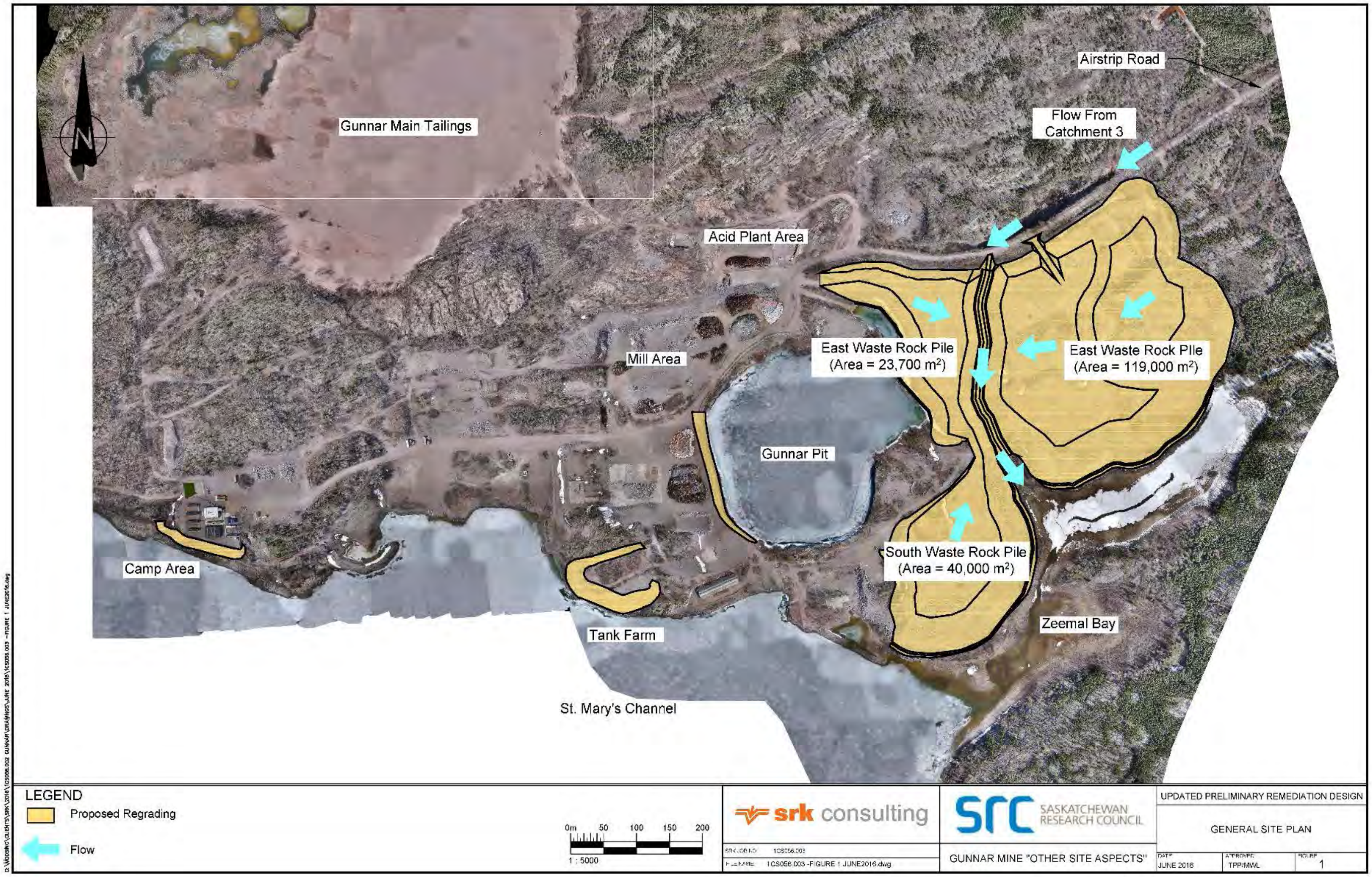
In terms of the seepage into St. Mary's Channel, monitoring data has shown that the uranium concentrations near the seepage are 0.008 mg/L, which are below the Saskatchewan Environmental Quality Standard for surface water as well as below the Canadian drinking water quality guideline. This indicates that there will be no adverse effects to fish or other aquatic species associated with the seepage from the Open Pit. In addition, the water in St. Mary's Channel is safe to drink.

Assessment of Loads to Zeemel Bay

The Preliminary Design Report indicated that the diversion of surface runoff from Catchment 3 into Zeemel Bay by restoring the historical drainage channel through the EWRP was determined to be the most appropriate action to decrease the loadings of uranium from the EWRP, which are currently reporting to Zeemel Bay. Load calculations were completed in the Preliminary Design Report for uranium and the uranium series radionuclides (e.g., thorium-230, lead-210, radium-226, and polonium-210). Loads to Zeemel Bay were calculated based on the concentrations of these contaminants of potential concern (COPC) in Catchment 3 runoff and the anticipated flows. From an aquatic risk perspective, the uranium concentration in Zeemel Bay was compared to the site-specific remedial objective selected for Zeemel Bay based on the species sensitivity distribution curve developed for the Gunnar site. Dose calculations for aquatic species were completed for the radionuclides.

Surface runoff from Catchment 3 currently collects in a ditch that runs along the access road for the Gunnar Mine Site. As there is no surface outlet for the ditch, the surface runoff infiltrates through the EWRP and eventually reaches Zeemel Bay as a waste rock seep. The proposed restoration of the historical Catchment 3 drainage channel would divert the surface runoff from Catchment 3 directly into Zeemel Bay, thereby reducing the transport of contaminated material from the EWRP to Zeemel Bay (Figure 7). Remedial actions for the other site aspects also include the removal of materials from Acid Plant as well as the placement of an engineered cover on the waste rock piles and the Mill Complex.

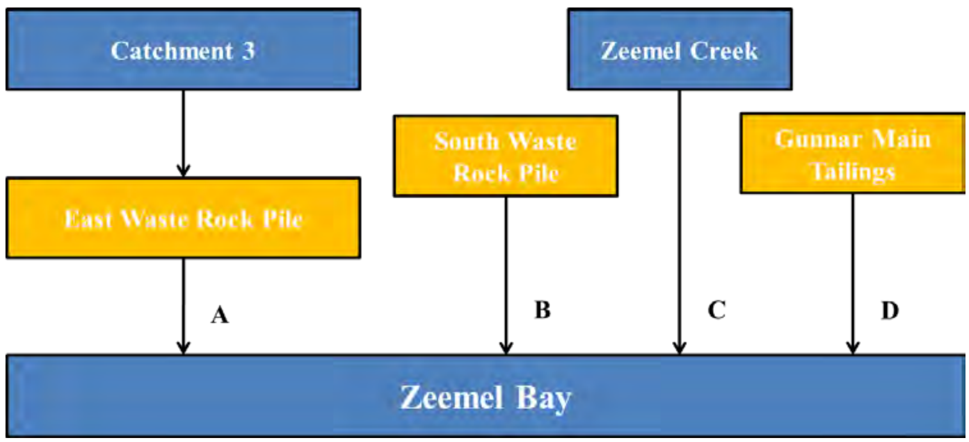
Figure 7: Schematic of surface areas associated with the proposed waste rock drainage channel



Source Characterization

Figures 8 and 9 provide the conceptual models (both before and after remediation of the waste rock pile and channel) for the assessment of Catchment 3 diversion. Current water quality data were provided in the Preliminary Design Report. As seen from the Conceptual Site Model, inputs from the GMT report to Catchment 3. Appendix U of the 2013 Gunnar EIS (Table 7.1) and Appendix G of the Tailings Remediation Detailed Design Report (O'Kane 2016) provided alternate estimates of uranium and radium-226 groundwater loads from the GMT to Catchment 3, while groundwater loads from the GMT to Catchment 3 after covering the tailings with waste rock and cover till material are provided in a Draft Memorandum from EcoMetrix (June 25th, 2016).

Figure 8: Schematic of conceptual model - current conditions



Notes: Conceptual only: not to scale.

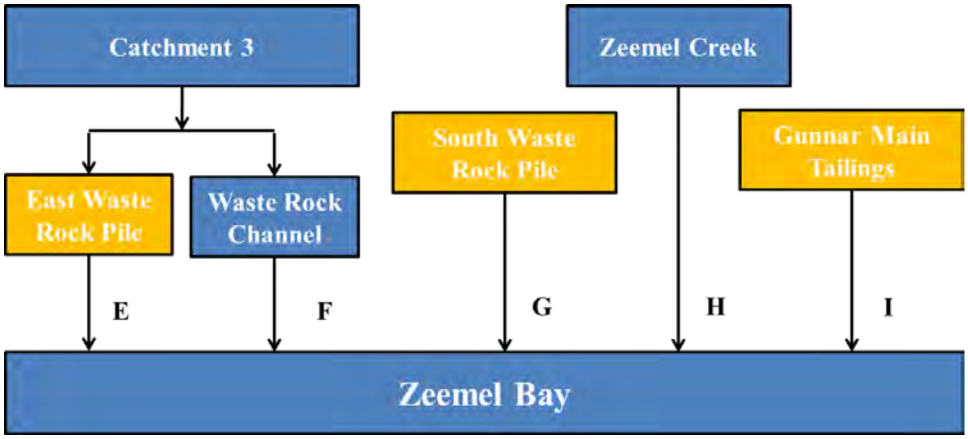
A – Seep from EWRP with surface water flow of 220,113 m^3/a (sum of flow from Catchment 3, Upper, Catchment 3, Lower and EWRP as summarized in Table 7.1, Appendix U. Gunnar EIS [SRC 2013]).

B – Loadings from SWRP with surface water flow of 7,040 m^3/a (estimated U load from Table 10.5, Appendix U, Gunnar EIS [SRC 2013]; percolation data from SRK).

C – Loadings from Zeemel Creek with surface water flow of 9,904,421 m^3/a (sum of flow from Zeemel Creek Lower and Zeemel Creek Upper as summarized in Table 7.1, Appendix U, Gunnar EIS [SRC 2013]).

D – Loadings from the Groundwater flow from the GMT (current loads estimated in Table 10.5, Appendix U, Gunnar EIS [SRC 2013]; Tables 3.10 to 3.14, Appendix G,Tailings Remediation Detailed Design Report [O'Kane 2016]).

Figure 9: Schematic of conceptual model - Restoration of waste rock channel



Notes: Conceptual only: not to scale.

E – Seep from EWRP with estimated reduced surface water flow. Reduced surface flow of 16,849 m^3/a corresponds to estimated percolation through waste rock pile with coarse textured till cover; percolation rates from SRK.

F – Estimated surface water flow through the restored waste rock channel = current flow of seep (220,113 m^3/a) – estimated flow of seep in reduced case (16,849 m^3/a) = 203,264 m^3/a.

G – Loadings from SWRP with reduced surface water flow of 4,723 m^3/a (percolation rates from SRK).

H – Loadings from Zeemel Creek with surface water flow of 9,904,421 m^3/a (same as current conditions).

I – Loadings from GMT with waste rock cover applied (estimated loads provided in EcoMetrix Draft Memorandum dated June 25th, 2016).

According to Figure 7, with the restoration of the waste rock channel and the regrading/covering of the waste rock piles, the estimated percolation through the EWRP and the channel area will be 14,420 m^3/year. The future volume of water diverted to the restored channel is estimated to be 203,264 m^3/year (220,113 m^3/year – 16,849 m^3/year). The current surface water flow from the SWRP to Zeemel Bay is 7,040 m^3/year and will be reduced to 4,723 m^3/year (using percolation rates provided by SRK and SWRP surface area shown in Figure 7). The flow from Zeemel Creek to Zeemel Bay is assumed to remain unchanged at 9,904,421 m^3/year (sum of flow from Catchment 4 to Zeemel Creek Lower and from Catchment 5 to Zeemel Creek Upper in Table 7.1, Appendix U, Gunnar EIS [SRC 2013]).

Assessment of Loads and Concentrations in Zeemel Bay– Expected Scenario

Current concentrations and flows from Zeemel Creek and the waste rock seep were considered for the assessment of current loads. Measured concentrations from seeps located in the SWRP were not available as they are generally dry; hence, the loads from the SWRP to Zeemel Bay provided in Appendix U of the EIS were used (Table 10.5, Appendix U, Gunnar EIS, [SRC 2013]). The assessment for future loads used the anticipated water quality and flows within the restored waste rock channel. This was the approach used in the Preliminary Design Report.

Table 4 summarizes the flow and the estimated loads to Zeemel Bay under current conditions and in the future conditions with the restoration of the historic Catchment 3 channel. Table 4 also provides a comparison between the values provided in the Preliminary Design Report and our current understanding of the loads, which includes groundwater loads from the remediated GMT. Descriptions of how the flows were determined are provided in Figures 8 and 9.

As discussed in the Preliminary Design, the radium-226 loads provided in Appendix U of the 2013 EIS were overestimated. Therefore, instead of directly using predicted radium-226 loads from SWRP provided in Appendix U of the EIS, the ratio of radium-226 loads from the EWRP and SWRP was estimated (a factor of 17 lower in the SWRP) and applied to the estimated loads of radium-226 from EWRP. In essence, the load of radium-226 in the SWRP was 17 times lower that the loads from the EWRP. The reduction in loads from the SWRP in the future after the restoration of the channel was assumed to be proportional to the reduction in flow from the SWRP.

Table 4: Comparison of estimated flows and loads to Zeemel Bay

	Flow (m^3/a)		Uranium Load (kg/a)		Radium-226 Load (MBq/a)	
	Preliminary Design [1]	Current Update	Preliminary Design [1]	Current Update	Preliminary Design [1]	Current Update
Current Conditions						
EWRP	225,347	220,113 [2]	140.7	137.4	51.9	50.7
SWRP	12,312	7,040 [3]	11.0	11.0	3.0	3.0
Zeemel Creek	9,904,421	9,904,421	19.0	19.0	66.3	66.3
GMT	-	-	1.1 [4,5]	1.1 [4]	5 [4,5]	5 [4]
Total Load to Zeemel Bay			**170.7**	**168.5**	**121.3**	**125.0**
Future Conditions [6]						
EWRP	16,480	16,849	47.6	48.6	12.3	12.6
Waste Rock Channel	208,867	203,264	4.6	4.5	28.9	28.2
SWRP	3,660	4,723	3.3	7.4	0.9	2.0
Zeemel Creek	9,904,421	9,904,421	19.0	19.0	66.3	66.3
GMT with Waste Rock Cover	-	-	- [5]	0.4 [7]	- [5]	2.4 [7]
Total Load to Zeemel Bay			**74.5**	**80.0**	**108.5**	**111.5**

[1]Values from the assessment completed as part of the Preliminary Design (SRK 2015).
[2]Flows from the Seep were updated to remove the 20% contribution from the Acid Plant runoff, which is now believed to flow entirely towards the Pit.
[3]Flows from the SWRP were updated to be consistent with the footprint of the waste rock pile instead of the waste rock pile sub-catchment surface area, which was used in previous calculations.
[4]Estimated GMT groundwater loading from Table 10.5, Appendix U of the 2013 Gunnar EIS; not showing alternate GMT groundwater loading found in Appendix G of Tailings Remediation Detailed Design Report (O'Kane 2016).
[5]Did not consider groundwater loading from GMT to Catchment 3 in the preliminary assessment as these loads were less than 1% of loadings to Zeemel Bay.
[6]Future conditions both include regrading activities and installation of a channel through the EWRP. The 'preliminary design' flows and loads were calculated using percolation rates obtained from SRK in 2015 while 'current understanding' flows and loads were calculated using updated percolation rates obtained from SRK in 2016, which correspond to application of coarse textured till cover.
[7]Future loads from the GMT with cover from EcoMetrix Draft Memorandum dated June 25th, 2016.

As seen from Table 4, the groundwater flow rate to the EWRP and the SWRP have been altered slightly based on the current understanding of groundwater flows associated with the Acid Plant and the footprint of the SWRP. Recent studies have shown that the groundwater flow from the Acid Plant reports to the Gunnar Pit and not to the EWRP, so these groundwater flows were removed from the inputs. For the SWRP, the flows were updated to be consistent with the footprint of the waste rock pile and not the sub-catchment area. Additionally, while the estimates completed for the Preliminary Design Report (SRK 2015) did not explicitly consider groundwater loads from the GMT, the calculations have been updated to account for this load component to Zeemel Bay. These changes resulted in minor changes to the uranium and radium-226 loads from the Preliminary Design Report.

If the historic channel is restored, it can be seen that the total load to Zeemel Bay of uranium is reduced by about 53% and the radium-226 load is reduced by 11%.

Predicted future uranium and radium-226 surface water concentrations in Zeemel Bay resulting from remediation (regrading and cover of the SWRP and EWRP, installation of a channel through the EWRP, and cover of the GMT with waste rock and till) are shown in Tables 5 and 6, respectively. Predicted concentrations are shown for a range of waste rock cover options (i.e., coarse, medium, and fine textured till) and also for the effect that pre-remediation groundwater load estimates from the GMT to Catchment 3 have on the future predictions. It should be noted that Appendix U of the 2013 EIS (SRC) estimated future groundwater loads from the GMT to Catchment 3 as 1.1 kg/a for uranium and 5 Bq/a for radium-226; however, Appendix G of the Tailings Remedial Detailed Design Report (O'Kane 2016) provides much higher values of 9.8 kg/a for uranium and 43 Bq/a for radium-226. Both of these loadings were used to calculate the uranium and radium concentrations in Zeemel Bay.

As can be seen from Table 5, surface water uranium concentrations are expected to be reduced to around half of the current levels with remediation using application of a coarse or medium textured till cover, with incremental added benefit seen when looking at finer grades of cover material. Radium-226, however, shows more dependence on initial loading estimates than on selected grade of waste rock cover material. Updated surface water concentration predictions shown in Tables 5 and 6 are similar to those calculated for the preliminary design work, which predicted post-remediation concentrations of 0.008 mg/L for uranium and 0.011 Bq/L for radium-226. In addition, the use of different loadings from the GMT to Catchment 3 does not change the concentrations of uranium and radium-226 significantly.

Table 5: Predicted future uranium surface water concentrations in Zeemel Bay

Scenario	Predicted Post-Remediation Uranium Concentration in Zeemel Bay (mg/L)		
	Coarse Textured Till Cover	Medium Textured Till Cover	Fine Textured Till Cover
Predictions using current GMT loads from Table 10.5, Appendix U of the 2013 Gunnar EIS (SRC)	0.0091	0.0083	0.0064
Predictions using current GMT loads from Appendix G of Tailings Remediation Detailed Design Report (O'Kane 2016)	0.0082	0.0074	0.0055

Note: Current uranium concentrations in Zeemel Bay are approximately 0.018 mg/L (Zeemel Bay geometric mean, as presented in the Preliminary Design Report).

Table 6: Predicted future radium-226 surface water concentrations in Zeemel Bay

Scenario	Predicted Post-Remediation Uranium Concentration in Zeemel Bay (mg/L)		
	Coarse Textured Till Cover	Medium Textured Till Cover	Fine Textured Till Cover
Predictions using current GMT loads from Table 10.5, Appendix U of the 2013 Gunnar EIS (SRC)	0.0111	0.0109	0.0105
Predictions using current GMT loads from Appendix G of Tailings Remediation Detailed Design Report (O'Kane 2016)	0.0074	0.0072	0.0068

Note: Current radium-226 activities in Zeemel Bay are approximately 0.012 Bq/L (Zeemel Bay geometric mean, as presented in the Preliminary Design Report).

Consistent with findings from work performed for the Preliminary Design, the future uranium concentrations in Zeemel Bay are predicted to drop well below the Water Quality Guideline (WQG) of 0.015 mg/L (Saskatchewan Environmental Quality Standard for surface water; Saskachewan Environment 2015) and remain below the site specific remedial objective 0.2 mg/L, which was derived previously from the species sensitivity distribution (SSD). Similarly, radium-226 activities in Zeemel Bay are predicted to remain well below the Canadian Water Quality Guideline (CWQG) of 0.11 Bq/L (CCME 2012).

An assessment of the potential radiological effects on aquatic ecological receptors in Zeemel Bay for both current and future conditions was undertaken; the resulting screening index (SI) values for radiological dose to aquatic ecological receptors in Zeemel Bay are presented in Table 7. The radiological doses to aquatic receptors were estimated using an approach consistent with that taken in Appendix J of the 2013 Gunnar EIS (SRC) and in the Preliminary Design work (SRK 2015). Consistent with the previous approach, a dose rate of 9.6 mGy/d (400 µGy/h) was used to calculate SI values. Additional information on the calculation approach, including transfer factors and dose coefficients required to complete the radiological assessment are presented in the risk assessment (Appendix J) of the 2013 Gunnar EIS (SRC).

As seen in Table 7, all calculated SI values, both those corresponding to current and future conditions, are predicted to be well below the applicable benchmark of 1, indicating that there are no potential radiological effects on the aquatic receptors in Zeemel Bay. While future predictions results in Table 7 correspond to a coarse textured till waste rock cover, the overall conclusion is applicable to any waste rock cover material.

Table 7: Radiological assessment in Zeemel Bay

Scenario	**Calculated Screening Index Values for Radiological Doses**					
	Predator Fish	**Forage Fish**	**Aquatic Plants**	**Phyto-plankton**	**Zoo-plankton**	**Benthic Invertebrates**
Current conditions	0.0005	0.003	0.01	0.03	0.01	0.05
Future conditions using current GMT loads from 2013 EIS (Table 10.5, Appendix U)	0.0004	0.0027	0.01	0.03	0.01	0.04
Future conditions using current GMT loads from the Preliminary Design Report (Appendix G)	0.0004	0.0025	0.01	0.03	0.01	0.04

Note: Future calculations presented for a coarse textured till waste rock cover.

Assessment of Loads and Concentrations in Zeemel Bay – Upper Bound Scenario

While the work performed as part of the Preliminary Design Report (SRK 2015) included evaluation of an upper bound scenario using a 95% Upper Confindence Level of the Mean (UCLM), this evaluation was not reproduced explicitly in the current study as the overall conclusions using the slightly updated flows and loads are expected to be consistent with those from previous calculations. The previous upper bound scenario assessment found that, while the predicted surface water concentrations in Zeemel Bay are higher than those estimated under the expected scenario, there were no expected effects on aquatic receptors on Zeemel Bay. All of the radiological SI values were well below the benchmark of 1 and, while the future uranium surface water concentration was predicted to remain above the WQG of 0.015 mg/L, the uranium SSD curve presented in Appendix J of the 2013 Gunnar EIS (SRC) indicates that at the predicted future concentration all species are protected.

Risk Implications in Zeemel Bay

The current work involved updating the assessment of risks to ecological receptors in Zeemel Bay using the current understanding of the loads/flows as well as updated waste rock cover percolation rates. Results are consistent with those presented in the Preliminary Design Report (SRK 2015) in that there are not expected to be adverse effects to aquatic receptors (e.g., aquatic plants and fish) in Zeemel Bay as a result of re-grading and covering waste rock, restoring the channel through the EWRP, and covering the GMT with waste rock and till. This conclusion is consistent regardless of cover material selected for the waste rock piles.

The Zeemel Bay surface water uranium concentrations are predicted to decrease in both the expected and upper-bound scenarios. In the expected scenario, the uranium concentration is predicted to drop to below the WQG while the upper-bound scenario uranium concentration is predicted to remain above this value. In both cases, however, the uranium SSD curve indicates that, at the predicted future concentrations, all aquatic species are protected. Concentrations of radionuclides are predicted to remain below the CWQGs for all remedial scenarios and timeframes.

Conclusions

This evaluation studied the acceptability of future loads to the Gunnar Pit as a result of remediation of the Acid Plant and Mill Complex areas and found that loads of uranium and radium-226 to the Gunnar Pit are expected to decrease by almost an order of magnitude. However, the changes in loadings to the Gunnar Pit are not expected to reduce the concentrations in the Gunnar Pit for hundreds of years. The overall conclusion for the Gunnar Pit area from a risk perspective is that it is unlikely that small terrestrial animal populations will experience any adverse effects associated with exposure to uranium and radium-226 in the future in the Gunnar Pit if natural attenuation was the chosen option. For St. Mary's Channel, the risk evaluation found that that there will be no adverse effects to fish or other aquatic species associated with the seepage from the Gunnar Pit.

The current work revisited the Zeemel Bay loading and risk evaluation completed for the Preliminary Design Report (SRK 2015) to take into account updated understanding of flows and loads as well as to investigate sensitivity of predictions to waste rock cover material selection. The Catchment 3 remedial measures included re-grading and cover of the waste rock piles, restoration of the channel through the EWRP, and cover of the GMT with waste rock and till. The Zeemel Bay evaluation results indicate that overall conclusions are unchanged from those presented in Preliminary Design Report and that, compared to the benefit of covering the waste rock pile with a coarse textured till material, the additional benefit of moving to a finer textured till material may not provide additional benefit due to erosion issues (Appendix H of Updated Preliminary Remediation Design Report). Overall, the evaluation found that that there are no predicted risks to aquatic ecological species in Zeemel Bay after remedial activities are implemented, regardless of whether expected or upper bound values are used.

This screening-level assessment involved making a number of simplifying assumptions:

- assumed that reduction in loads is proportional to reduction in flow;
- assumed that the flows to Zeemel Bay are associated with the SWRP footprint and not the sub-catchment area:
- assumed that future seep concentrations are based on analysis of current seep data; and
- assumed that future channel water (upstream) quality is consistent with the analysis of Catchment 3 data.

While the use of simplifying assumptions introduces uncertainty into the evaluation, calculations examining the effect of various assumptions provide bounding conditions to ensure that the risk is not underestimated.

References

EcoMetrix 2016. Draft memorandum from Ron Nicholson to D. Chapman and A. Klyashtorin. Comments on Gunnar Loadings Assessment – Refinement of uranium loadings astimates to Catchment 3 (C3) related to the use of waste rock in tailings covers on the Gunnar Main Tailings (GMT). June 25th , 2016.

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SNC Lavalin 2016. Supplemental Gunnar subsurface characterization Program. May.

Saskatchewan Research Council (SRC) 2013a. Gunnar Site Remediation Project EIS, Appendix U,Quantitative Site Loadings Model. October.

Saskatchewan Research Council (SRC) 2013b. Gunnar Site Remediation Project EIS, Appendix J, – Risk Assessment. October.

SRK Consulting 2015. Preliminary Design Report: Gunnar other site aspects.

Appendix C – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Site Hydrology Review and Update

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Memo

To:	Project File	**Client:**	Saskatchewan Research Council (SRC)
From:	Holly Rourke, PEng	**Project No:**	1CS056.003
Cc:		**Date:**	July 12, 2016
Subject:	Gunnar Mine “Other Site Aspects” Update Preliminary Remediation Design – Site Hydrology Review and Update		

1 Introduction

SRK Consulting (Canada) Inc. has been retained by Saskatchewan Research Council (SRC) to undertake the final engineering design for the remediation of the Gunnar Mine Site. As part of this work, SRK has reviewed recent hydrology data made available since undertaking the preliminary design in order to update the hydrological design criteria. This memo provides a summary of the review findings and hydrological recommendations for the designs in the detailed remediation plan.

1.1 Available Information

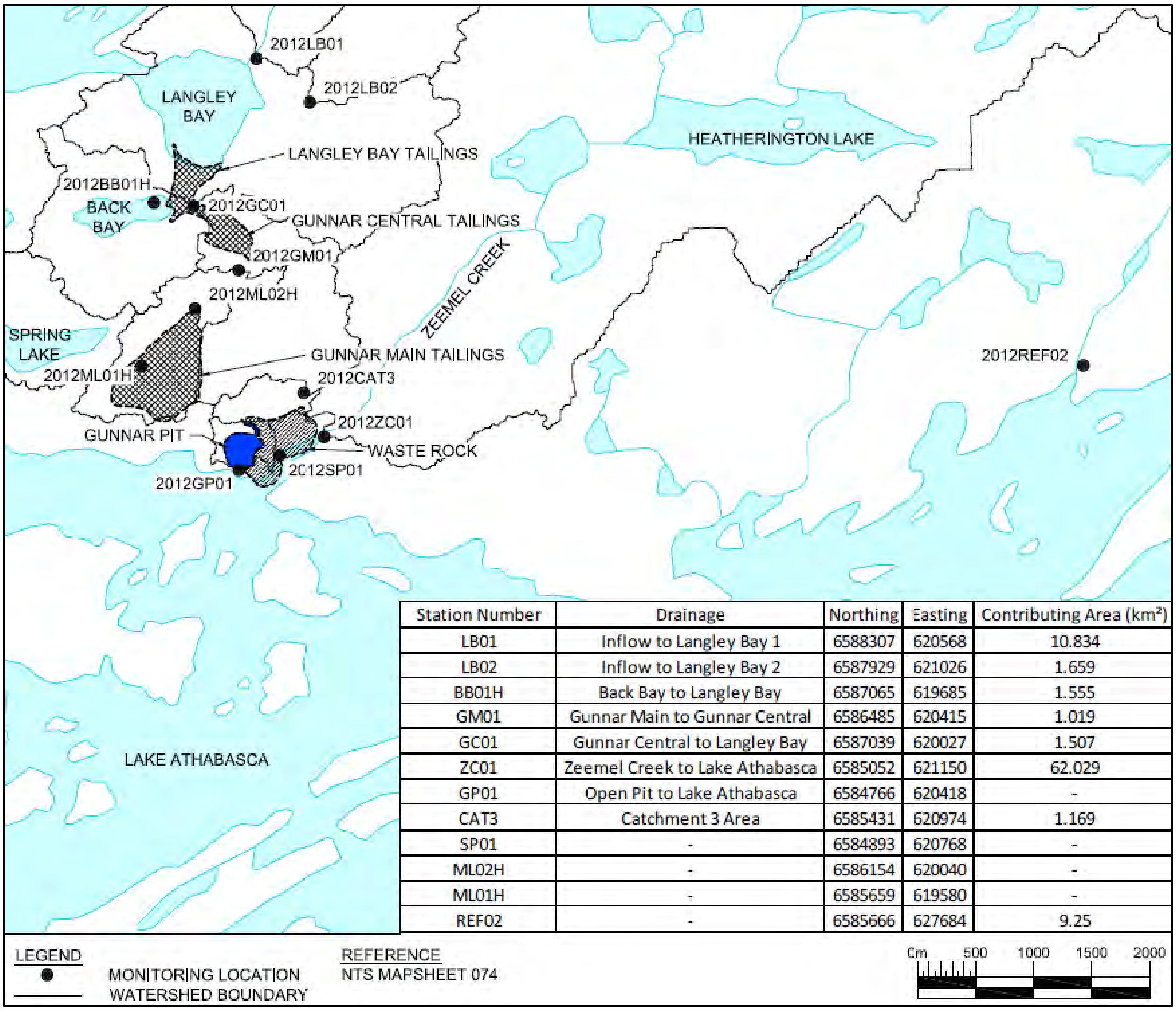
Since SRK undertook a preliminary remediation design for the Gunnar Mine “Other Site Aspects” (SRK, 2015), O’Kane Consultants Inc. (OKC) have prepared a detailed remediation design for the Gunnar tailings areas and McElhanney Consulting Services has collected two years’ worth of hydrometric monitoring data from site stations.

The following information reviewed by SRK includes:

- Design Reports:
  - OKC tailings remediation detailed design report (2016): Gunnar Site Remediation Project – Tailings Remediation Detailed Design Report.pdf
- Hydrological Monitoring Reports:
  - McElhanney 2013 hydrological monitoring report(2014) *McElhanney 2013 Hydrological Monitoring.pdf*
  - McElhanney 2014 hydrological monitoring report (2015)
  - *2711-15002-0 − Final Report − 15 09 22 −2014 Gunnar Hydrometric Monitoring*
  - McElhanney 2015 hydrological monitoring report (2016)
  - *2711-16005-0 − Final Report − 16 03 22 −2014 Gunnar Hydrometric Monitoring*

2 Review of Monitoring Data

SRK reviewed the site monitoring data with the aim of developing a calibration to better assess peak flow estimations. Monitoring site locations are shown in Figure 1, which have been extracted from the McElhanney monitoring report (McElhanney, 2013).



Station Number	Drainage	Northing	Easting	Contributing Area (km²)
LB01	Inflow to Langley Bay 1	6588307	620568	10.834
LB02	Inflow to Langley Bay 2	6587929	621026	1.659
BB01H	Back Bay to Langley Bay	6587065	619685	1.555
GM01	Gunnar Main to Gunnar Central	6586485	620415	1.019
GC01	Gunnar Central to Langley Bay	6587039	620027	1.507
ZC01	Zeemel Creek to Lake Athabasca	6585052	621150	62.029
GP01	Open Pit to Lake Athabasca	6584766	620418	-
CAT3	Catchment 3 Area	6585431	620974	1.169
SP01	-	6584893	620768	-
ML02H	-	6586154	620040	-
ML01H	-	6585659	619580	-
REF02	-	6585666	627684	9.25

Figure 1: Site monitoring station locations (extracted from McElhanney, 2013)

There are eight site stations with recorded flow data and the amount of information available at each station is shown in Figure 1. Red squares represent years where no information has been recorded, and bright green squares represent a full year of data. There are only two stations with at least one full year of data, and just one (Zeemel Creek) with two.

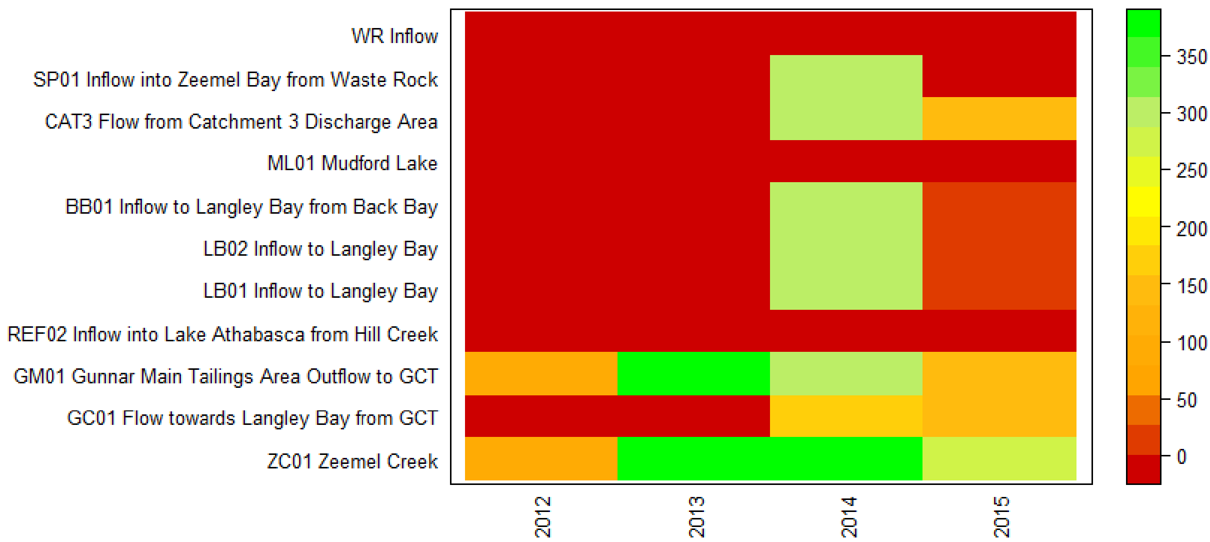


Figure 2: Site monitoring data – available information

2.1 Attempted Calibration to Observed Precipitation

Flow data from the Zeemel Creek gauge station was compared to rainfall records from the nearby Uranium City station (approximately 25 km away). An initial comparison of all data showed that the larger flows recorded at Zeemel Creek did not respond to high rainfall events, but instead are related to seasonal freshet flows. Because recorded winter flows were also affected by the ice thickness, the data was filtered to include just summer months (June, July, and August) where precipitation should directly translate to runoff. The summer months comparison found that recorded flows still do not correlate with precipitation data and that a precipitation-based calibration is not possible with the current data.

2.2 Attempted Calibration to Regional Flow Data

The site station data was also compared to regional flow records. Comparisons of both average daily and average monthly values showed no reasonable correlation with any regional stations (within 600 km). This is likely due to two factors:

- **Large watershed size**: The regional data stations correspond to very large catchments (in the order of 50−5,000 km^2) and their behaviour is not completely representative for smaller catchments (site catchments smaller than 2 km^2). In smaller watersheds, the unit peak flows should tend to be higher and the watershed responses to a precipitation event should be faster than the values at bigger watersheds; and,
- **Limited amount of data**: There is only a limited amount of site data available, which isn't sufficient to establish trends.

Therefore a regional-based calibration is not possible with the current available data.

3 Updates to Preliminary Design

Since there is no correlation between regional and site data, the regional analysis used by SRK to estimate unit peak flows for the preliminary design will no longer be used. Given that it is not possible to refine the peak flow estimate for the site using a calibration to on-site flow measurements, SRK has prepared an updated hydrologic rainfall runoff model to use in the hydrotechnical designs for the Other Site Aspects.

Table 1: Comparison of 2015 Preliminary Design to 2016 Updates

Parameter	SRK 2015 Preliminary Design	2016 Updates	Comments
Design storm - Frequency - Depth (mm)	1 in 200 year event, 24-hr 94.5 mm	1 in 200 year event, 24-hr 118 mm (after climate change)	Storm depth increased to account for climate change.
Peak flow calculation method	Regional analysis, based on observed flows from nearby stations.	TR-55 model, based on an SCS Type II storm distribution and assumed CN values	Conservatively selected since Type II has the most intense storm distribution (OKC, 2016).
Estimated peak flow (converted to unit peak flow)	1 $m^3/s/km^2$	~3 $m^3/s/km^2$	Peak flows are calculated specifically for each area of interest and vary depending on the catchment area, slope, and length. The calculated 2016 calculated peak flows have been converted to an approximate unit peak flow for comparison. The unit peak flow is higher than what had been previously assumed, but is consistent with other studies being undertaken for the site.

3.1 Design Storm

3.1.1 Rainfall Depth

A climate change model was developed as part of the detailed tailings remediation design using intensity duration frequency (IDF) data from the Stony Rapids station instead of Uranium City because of its more recent climate record and higher design values (OKC, 2016). SRK has reviewed the results of the climate change modelling and considers them appropriate for the final engineering design. The adjusted rainfall depths for the 24-hour storm event for return periods ranging from 2 to 1,000 years are provided in Table 2.

Table 2: Previous and Adjusted 24-hour Storm Depths

	Return Period (years)							
	2	**5**	**10**	**25**	**50**	**100**	**200**	**1000**
Previous rainfall depth (mm)	34	48	57	68	76	85	95	115
Depth adjusted for climate change (mm)	39	57	69	83	95	106	118	145

3.1.2 Rainfall Distribution

A Soil Conservation Service (SCS) Type II distribution was conservatively selected to represent the design storm rainfall pattern since it is the most intense of the four distributions (OKC, 2016), with the majority of the rainfall falling in the 12th hour. The cumulative storm distribution and rainfall patterns for the 200 (red) and 1,000-year (green) storm events are shown in Figure 3.

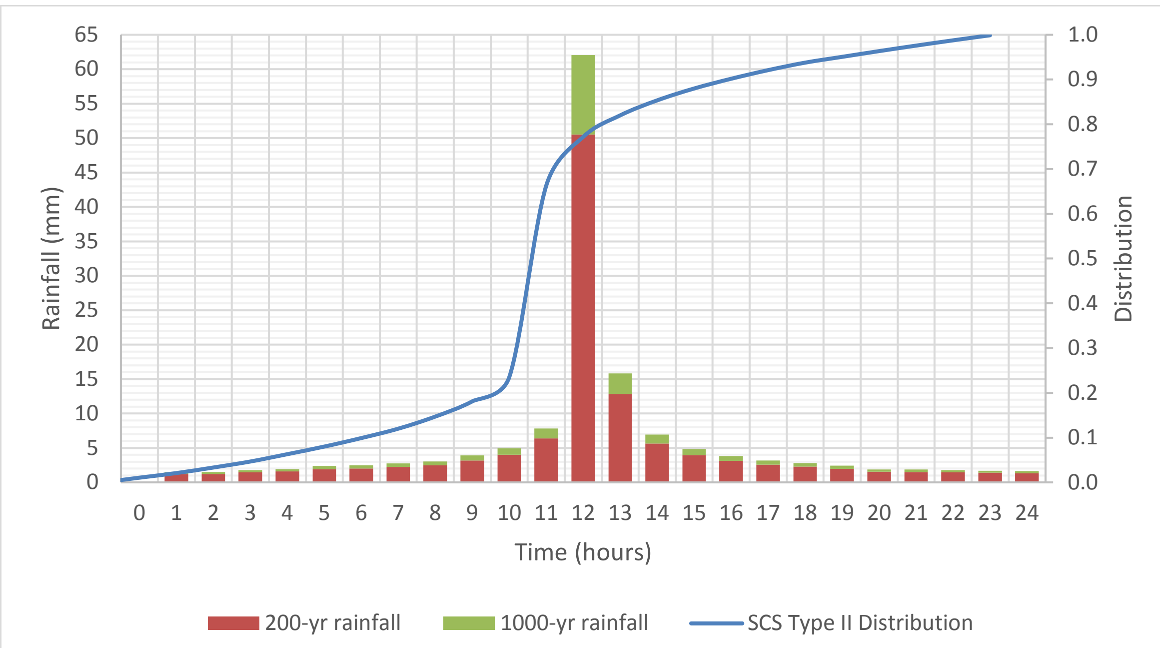


Figure 3: Design storm distribution

3.2 Time of Concentration and Peak Flow

Design peak flows are been calculated using the United States Department of Agriculture (USDA) WinTR-55 model. The main inputs into the model are storm depths, rainfall distribution, runoff curve number (CN) values, and calculated time of concentration (t_c). The design storm depths and rainfall distributions have been described in Sections 3.1.1 and 3.1.2. Typically, the CN value is calibrated to site monitoring data. Because of the lack of knowledge between actual regional data and the site information, a representative CN value of 55 has been selected to represent good vegetation cover simulating natural conditions (Maidment,1993). It is recommended that this assumption should be calibrated to the Site as more monitoring data becomes available.

There are numerous methods for calculating t_c, most of which have been developed for specific regions and/or catchment characteristics and estimations can vary depending on the method selected. For the design, the t_c has been estimated as the average of two methods specifically developed for small catchments: Kerby and Bransby Williams (Maidment,1993).

The Kerby formula is:

$$t_c = \left(\frac{7.216Lr}{S^{0.5}}\right)^{0.324}$$

Where:

- t_c = Time of concentration (mins)
- L = Length (m)
- r = Retardance Coefficient (0.80 for vegetated)
- S = Average catchment slope (m/m)

The Bransby Williams formula is:

$$t_c = \frac{58L}{A^{0.1}S^{0.2}}$$

Where:

- t_c = Time of concentration (mins)
- L = Length (km)
- A = Catchment area (km^2)
- S = Average catchment slope (m/km)

Time of concentrations and peak flows will be calculated specifically for each hydrotechnical feature as each catchment will have a unique area, length, and slope. Example inputs and results are provided in Table 3.

Table 3: Example peak flow calculation for a 1 in 200 year, 24-hour storm event

Catchment Characteristics					Calculations				
Name	Area, A (km^2)	Length, L (m)	Slope, S (m/m)	CN value	t_c (min)	Peak Flow (m^3/s)		Unit Peak Flow ($m^3/s/km^2$)	
						200 years	1,000 years	200 years	1,000 years
Catchment 1	1.5	500	0.02	55	37	4.8	9.3	3.2	6.2

3.3 Summary

It is recognised that the updated approach is conservative and results in a significantly higher unit peak flow estimate than what had been assumed in the preliminary design. At this point, in the absence of available site data to provide a calibration and justification for reducing the flow, SRK has adopted this conservative method for the final engineering design, which is consistent with the method used in the Detailed Tailings Remediation Design (OKC, 2016).

4 Conclusions

The key findings from the site hydrology review are as follows:

- Because site available flow data did not correlated with regional records, it is not possible to calibrate the site peak flows hydrological model; therefore, the regional analysis used by SRK to estimate unit peak flows in the preliminary design of the Other Site Aspects will not be used in detailed design.
- A hydrological rainfall runoff model was developed using conservative parameters. The updated model results tend to present conservative peak flow estimates which are consistent with other studies completed for the Gunnar Mine Remediation Project.
- It is recommended that this updated rainfall runoff model is used for the final engineering design.

5 References

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Appendix D – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Hydrotechnical Design Aspects

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Memo

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From:	Holly Rourke	**Project No:**	1CS056.003
Cc:		**Date:**	July 5, 2016
Subject:	Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design – Hydrotechnical Design Aspects		

1 Introduction

In 2015 SRK Consulting (Canada) Inc. undertook the preliminary design for the remediation of the "Other Site Aspects" at the Gunnar Mine site (the Site) for the Saskatchewan Research Council (SRC). The study identified that the preferred remedial design option for the waste rock areas would involve re-establishing a natural drainage channel between the East Waste Rock Pile (EWRP) and South Waste Rock Pile (SWRP) to manage long-term surface water flows from the Catchment 3 watershed. In addition, the waste rock piles would be regraded to have flatter side slopes and would then be covered with local borrow material. The study also identified the need for an on-site landfill and regrading in other general site areas. Each component of the design requires hydrotechnical features to convey surface water flows.

Since the preliminary design, SRK has been commissioned to undertake the final detailed remediation design. As part of this work, SRK has updated the design of the Re-established Historic Drainage Channel and surface water management structures for the Site.

This document presents the updated design of hydrotechnical features as part of the "Other Site Aspects" detailed remediation design.

2 Hydrology Background

Management of surface water flows is an integral aspect of remediation designs. The areas of interest for the "Other Site Aspects" detailed engineering can be broken into four main catchments, namely: Catchment 3, the Acid Plant area, the Mill Complex / West Gunnar Pit area, and waste rock piles. The catchment areas and general flow directions are shown in Figure 1.

A tracer test conducted in 2014 (SNC Lavalin, 2016) confirmed the location of a seepage flow path running between the EWRP and SWRP. This flow path is believed to correspond to a historic channel underlying the piles that would have received upstream surface water flows from

Catchment 3 and conveyed them toward Zeemel Bay prior to site development. The flow path location and upstream catchment are illustrated in Figure 1.

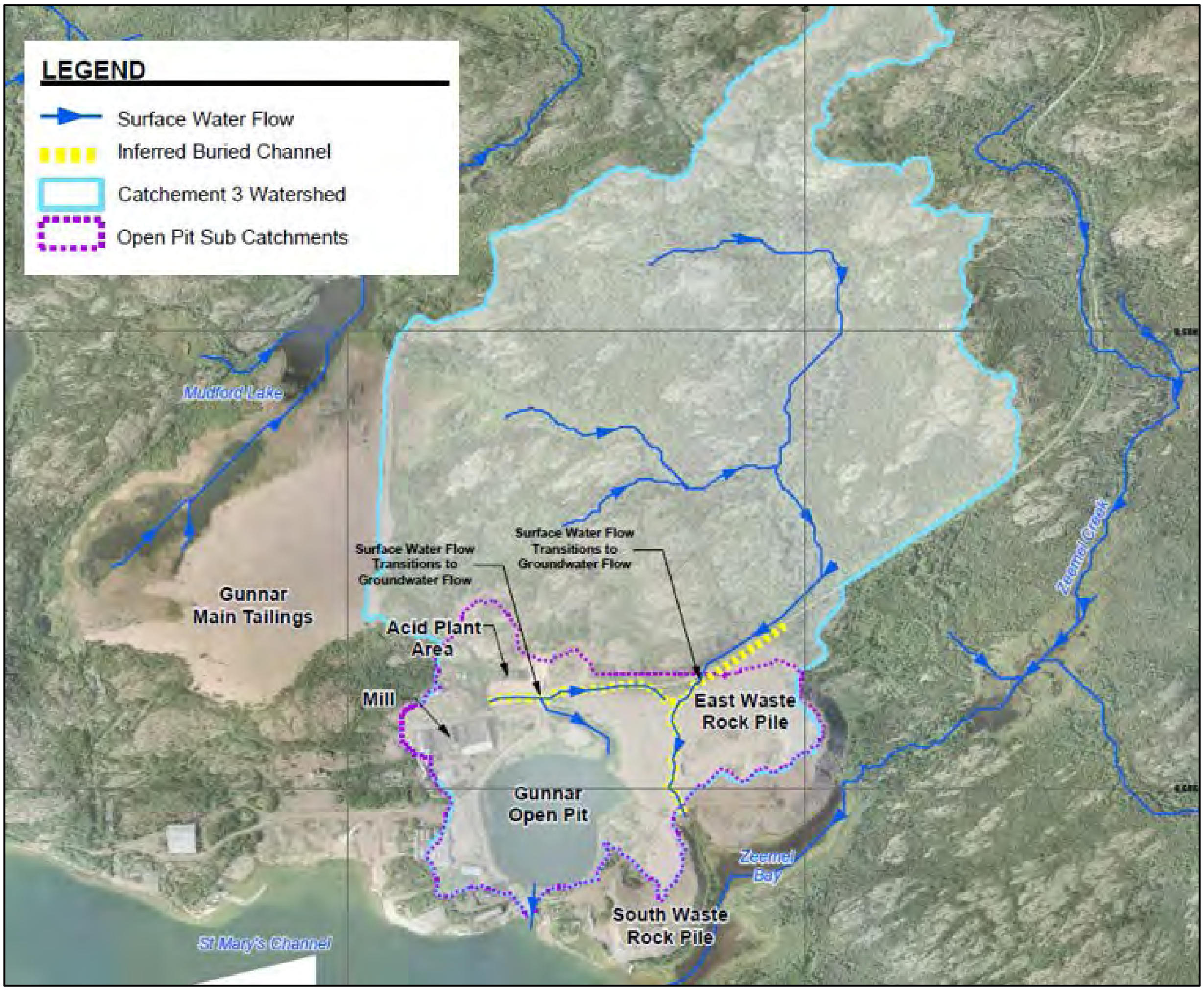


Figure 1: Catchment locations and surface water flows (source: SRK, 2015)

Re-establishment of the Historic Drainage Channel is the preferred remediation strategy because it endeavours to reinstate pre-mining conditions and promotes positive drainage mimicking natural flow conditions rather than diverting surface flows around the waste piles. The Re-established Historic Drainage Channel alignment has been defined using the results of the tracer testing in order to best represent natural flows.

Other Site areas will also be shaped to promote positive drainage, provide geotechnical and hydrotechnical stability, minimise erosion potential, and provide compatibility with the surrounding landscape.

3 Design Criteria

Hydrotechnical features have been designed applying the criteria outlined in Table 1.

Table 1: Hydrotechnical Design Criteria

Parameter	Criteria
Capacity	With the exception of the Re-established Historical Drainage Channel, all hydrotechnical aspects have been designed for the 1 in 200-year design storm event as a minimum requirement.
Peak Flow Estimation	Peak flows have been estimated following the procedure presented in the SRK Hydrology Review Memo (see Appendix B) using the Soil Conservation Service (SCS) method with a Type II rainfall distribution.
Erosion Controls / Lining	Erosion controls have been designed in accordance with relevant engineering guidelines and with the aim of providing multiple layers of protection to allow the channel to accommodate changes over time, providing dynamic stability in the long-term and thereby preventing the need for ongoing maintenance.

Additional design criteria specific to the closure channel is outlined in Table 2.

Table 2: Re-established Historical Drainage Channel Design Criteria

Parameter	Criteria
Capacity	The Re-established Historical Drainage Channel has been sized to convey the 1 in 1,000-year design storm event.
Lining depth	Lining will extend to either the minimum design depth (design water flow level plus freeboard) or to RL 211 m (0.35 m higher than the historical high water mark in Lake Athabasca), whichever is greater.
Seepage	Aim to minimise the potential for seepage by founding the channel within the silt / clay contact underlying the piles

4 Re-established Historical Drainage Channel Design

This section provides an overview of the channel design. Detailed drawings showing the channel design are provided in Attachment 1. .

4.1 Channel Peak Flow

The channel has been conservatively designed with capacity for all surface water runoff flows from Catchment 3, the Acid Plant, and the EWRP areas even though portions of the Acid Plant and EWRP areas will drain elsewhere. The contributing catchment characteristics and the resulting peak flow estimate are shown in Table 3.

Table 3: Contributing Catchment Characteristics and Design Peak Flow

Area (km^2)	Average Slope (%)	Time of Concentration (Minutes)	SCS Runoff Number, CN	1 in 1,000-Year Peak Flow (m^3/s)	Design Channel Peak Flow (m^3/s)
1.55	30	52.4	55	7.5	8.0

4.2 Channel Design Overview

Approximately the first 30 m of the channel has been designed at a gradient steeper than 10% in order to drop the channel into the silt / clay contact as soon as practicable. The channel then transitions to a 1% slope for the remaining length; a small plunge pool will manage turbulence at the transition.

The channel rip rap lining has been designed using the tractive force method (U.S. Department of Transportation, 2005). In this method, a stable channel design is achieved by ensuring the shear resistance of the lining material (rip rap) is greater than the shear stress produced by the design flow. The flow-carrying capacity of the channel is then confirmed using Manning's formula based on the channel geometry and liner surface roughness.

A geotextile filter is also provided beneath the rip rap to prevent the channel foundation soils from being washed out or sucked into the voids of the rip rap in the short-term until long-term equilibrium conditions are established.

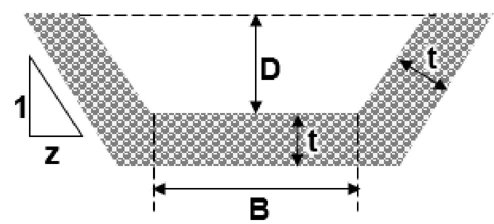
4.2.1 Road and Culvert

There is currently a roadway and culvert at the upstream end of the proposed channel. The road will be kept in place to facilitate access during the required closure monitoring period and then will be decommissioned. SRK has been informed that the current culvert is undersized and is likely damaged. SRK has included a replacement culvert in the design to convey surface runoff under the road during the closure monitoring period. Following the closure monitoring period, decommissioning will involve removing the culvert and excavating the road to the natural ground level at the channel inlet to allow surface water to flow unimpeded into the channel. The culvert decommissioning and roadway cut is not included in this phase of the design.

4.3 Channel Geometry

The entire channel has been designed as a trapezoidal channel with3H:1V side slopes and a 6 m base width, which will facilitate construction. The median size (D_{50}) and lining thickness of the rip rap material differs between the steeper (>10%) and shallower (1%) channel sections. The channel geometries for both sections are provided in Table 4.

Table 4: Channel Design Geometry



Parameter	Channel Section at Steep Slope (>10%)	Channel Section at Shallow Slope (~1%)
Base Width, B (m)	6	6
Side Slope, z (_H:1V)	3	3
Minimum Rip Rap D_{50} (m)	0.5	0.1
Minimum Rip Rap Thickness, t (m)	1.5	0.3
Minimum Channel Depth (inclusive of freeboard), D (m)[1]	1.2	1.2

4.4 Culvert Geometry

The culvert has been designed for the 1 in 50-year design storm (1.63 m^3/s) and features an 800 mm diameter corrugated steel pipe covered by 1 m of borrow material considering a 40t truck as the design vehicle. The flow resulting from a 1 in 50-year storm event was selected as the design flow from a risk perspective since the culvert is a short-term feature that will only be used for the closure monitoring period. There is an approximately 18% risk of a storm event exceeding the design event occurring over the 10-year monitoring timeframe; however, the consequences of such an event will only result in water pooling upstream for a period, and for a very large storm event, the road could be overtopped and require some maintenance. Since the road will mostly consist of waste rock, severe damage to the road structure is unlikely even in the case of a larger storm (i.e. 1 in 100 or 1 in 200 year).

[1] The depth of rip rap lining will extend the minimum channel depth or to an RL of 211 m, whichever is greater.

5 Design of Other Hydrotechnical Features

5.1 Development of a Tool for Ranking Hydrotechnical Features

The key criteria for classifying features is the estimated mean velocity. The U.S. Army Corps of Engineers (1994) provides recommendations for permissible velocities to design non-scouring flood control channels. The ranking tool is used to classify areas based on expected mean velocities as either:

1. Low-velocity (<1 m/s) areas do not required engineered channels or lining designs. These areas can have an earthen base and should be shaped to facilitate drainage.

2. Medium-velocity (>1 m/s, <2 m/s) areas require additional consideration (i.e. erosion control matting or in some cases, rip rap).

3. Higher-velocity (>2 m/s) areas required engineered channel and lining designs, and should be shaped to specific engineering criteria.

5.1.1 Hydraulic Tool Development

SRK has developed a tool for ranking hydrotechnical features to assist in the design of regraded areas. The hydraulic tool has been developed using the statistical computing software, R, which specializes in data manipulation, calculation and graphical display.

Channel velocity is a function of the design peak flow, the channel configuration and slope. The design peak flow can be directly related to the catchment area for a specific design storm event. For simplification, all channels have been assumed to be trapezoidal in shape with base widths of 1 m and side slopes of 3H:1V, and been assumed to have a conservative Manning's roughness value of 0.022 (bare soil). Velocities are calculated for numerous catchment areas, channel slopes, and channel height combinations and then plotted graphically to create the hydrotechnical design tool. The tool has been developed specifically for the 1 in 200-year design storm event using the peak flow estimation methodology as per the design criteria; however, it could be updated for other return periods.

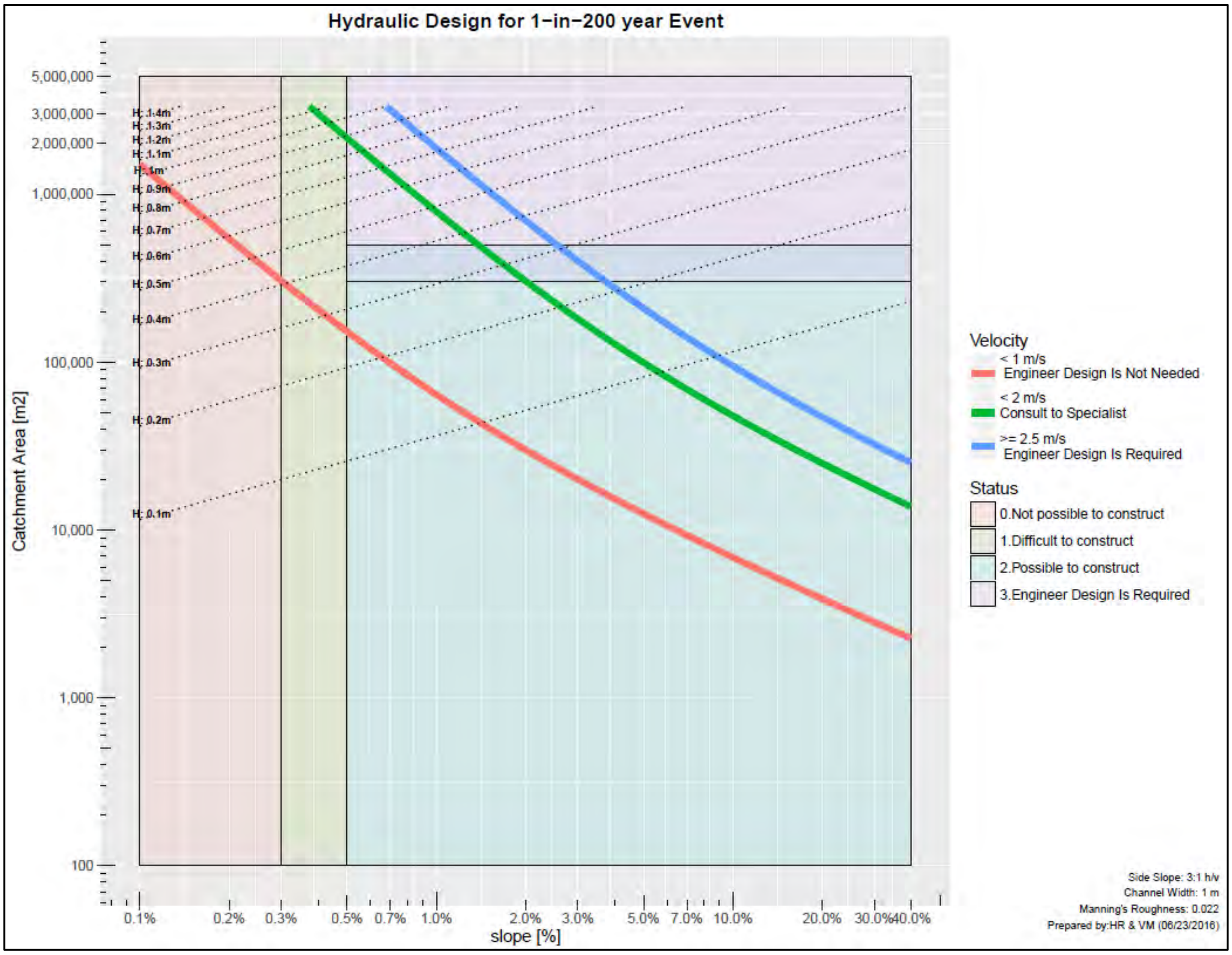


Figure 2: Hydraulic Design Tool for Ranking Channel Features

5.1.2 Use of Hydraulic Design Tool

The tool can be applied to any catchment area and slope to classify hydrotechnical features as "low velocity" (<1 m/s), "medium velocity" (>1 m/s, <2 m/s), or "higher velocity" (>2 m/s) and decide what level of design is required. For example, all features for catchment areas of approximately 50,000 m^2 or less with slopes of up to 1% will have velocities less than 1 m/s and will not require an engineered design or rip rap lining (as indicated by the red shaded area and red dashed lines in Figure 3). Features with areas up to 10,000 m^2 can have slopes up to 5% before requiring engineering and lining (see yellow shaded area and yellow dashed lines in Figure 3).

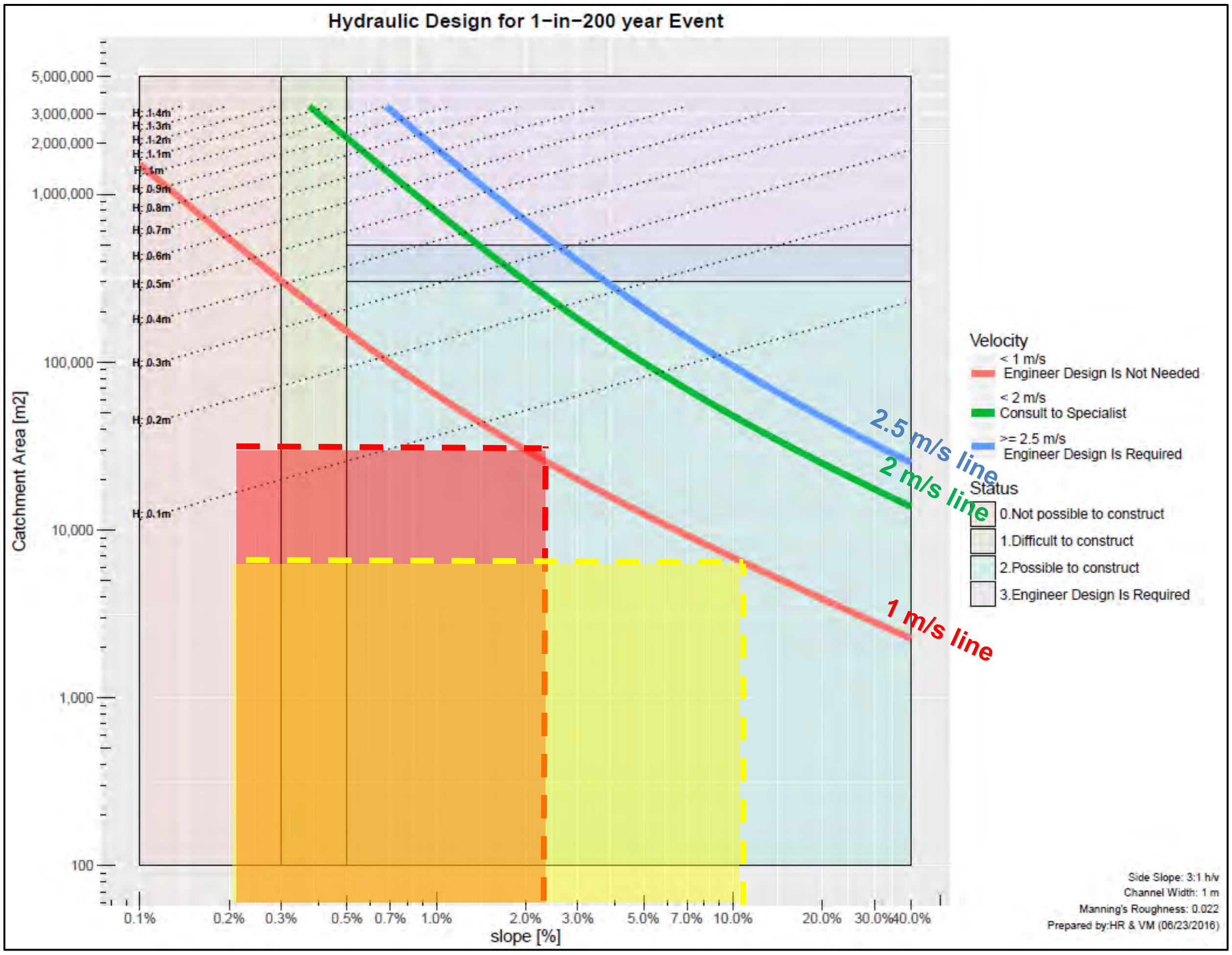


Figure 3: Example Use of the Hydraulic Design Tool

5.2 Site Application of the Hydraulic Design Tool

5.2.1 General Site Areas

Generally, gently sloping swales are the preferred surface water management strategy to facilitate site wide drainage and to limit the development of localised water pools. Soil loss due to erosion is not considered a risk in most gently sloping areas.

5.2.2 Waste Rock Piles

On the waste rock piles, collection channels will be used to convey surface water flows into the Re-established Historic Drainage Channel or toward Zeemel Bay. Where expected velocities are less than or equal to 1 m/s, a vegetated channel is sufficient to convey surface water flows without eroding. In other areas expected to convey a 1 in 200-year design flow at a greater velocity than 1 m/s, coconut matting and/or rip rap will be required for erosion control.

The locations of water conveyance structures on the waste rock piles are shown in Figure 4.

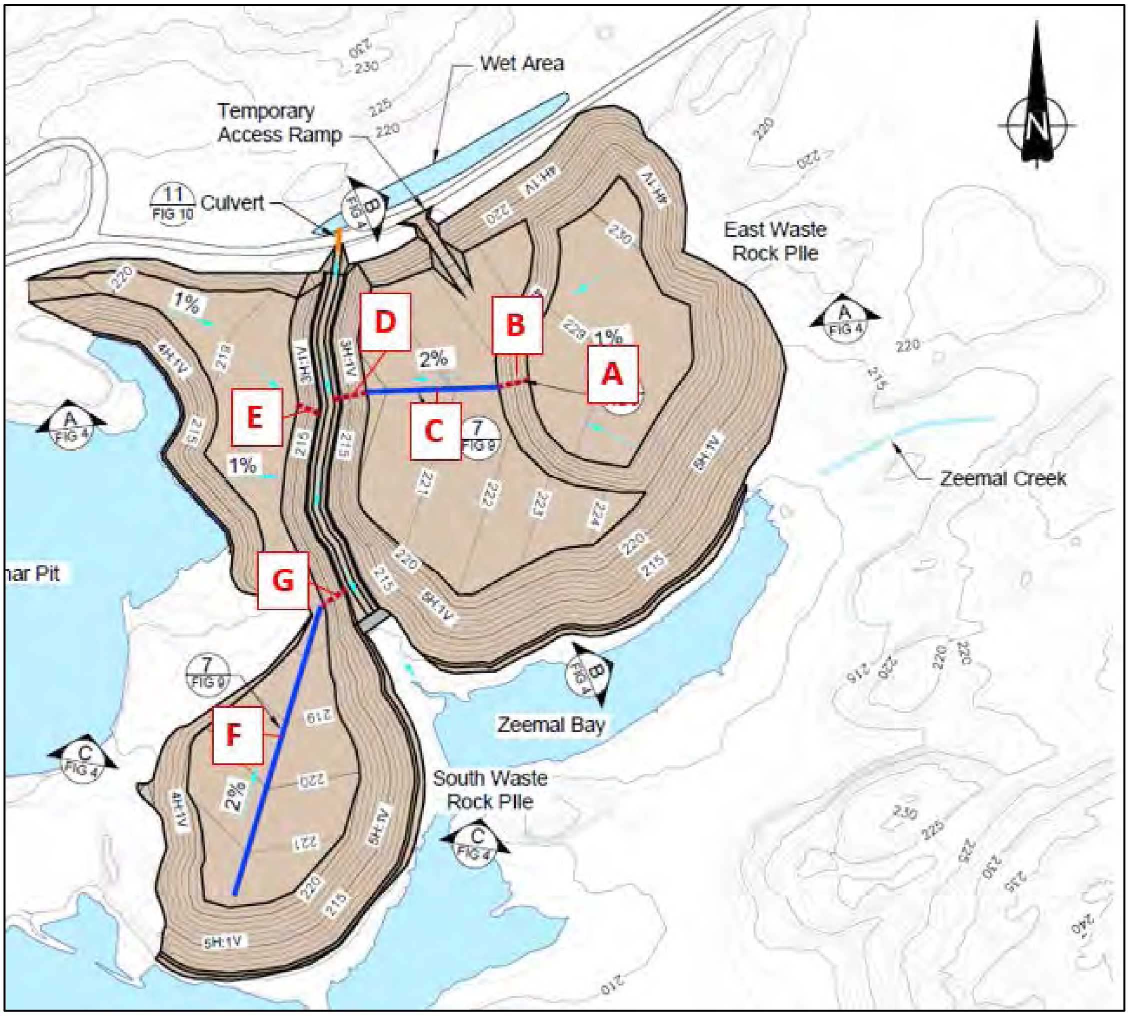


Figure 4: Location of Waste Rock Water Conveyance Structures

Velocities and lining recommendations for the water conveyance structures have been estimated for the 1 in 200-year storm event and are summarised in Table 5.

Table 5: Main Water Conveyance Structures

Feature		Area (m^2)	Slope (%)	Velocity (m/s)	Lining requirement
A	Upper Surface of EWRP	20,000	1%	0.9	Compacted, vegetated ground
B	Upper to Lower Surface of EWRP	20,000	20%	1.7	Rip rap (min D_{50} = 100mm) / Coconut Mat
C	Lower Surface of EWRP	50,000	2%	1.4	Coconut Mat
D	Lower Surface of EWRP to Channel	50,000	33%	2.6	Rip rap (min D_{50} = 150mm)

Feature		Area (m^2)	Slope (%)	Velocity (m/s)	Lining requirement
E	North West Surface to Channel	15,000	33%	1.9	Rip rap (min D_{50} = 100mm) / Coconut Mat
F	SWRP Surface	20,000	2%	1.1	Compacted, vegetated ground / Coconut Mat
G	SWRP Surface to Channel	20,000	33%	2.1	Rip rap (min D_{50} = 100mm)

5.2.3 Mill Area Landfill

A similar methodology was applied to design water conveyance structures for the mill area landfill. The landfill has an area of approximately 37,500 m^2 and is located in a relatively high topographical region, which receives flow from smaller upstream watershed areas. The major contributions are from an unnamed creek with a catchment area of 2.2 ha, followed by other minor flood lines with catchment areas 0.8 and 0.6 ha respectively.

Consistent with other hydrotechnical features, the landfill conveyance channels have been designed with a 1 m base width, 3H:1V side slopes; and a maximum depth of 0.6 m. The hydrotechnical features are shown on Figure 5.

The landfill will capture and convey upstream surface runoff through vegetated ditches on its upper surface which will be re-graded to shallow, non-eroding slopes of 1%. The 25% (4H:1V), landfill side slopes will be protected by riprap with minimum D_{50} of 100 mm. The receiving channel aligned along the toe of the landfill will convey higher velocities and will require coconut matting for erosion protection. Further downstream, when the grades increase to greater than 4%, the channel will be protected by rip rap with a minimum D_{50} of 100 mm. The key hydrotechnical features and geometries for the landfill area are summarized in Table 6.

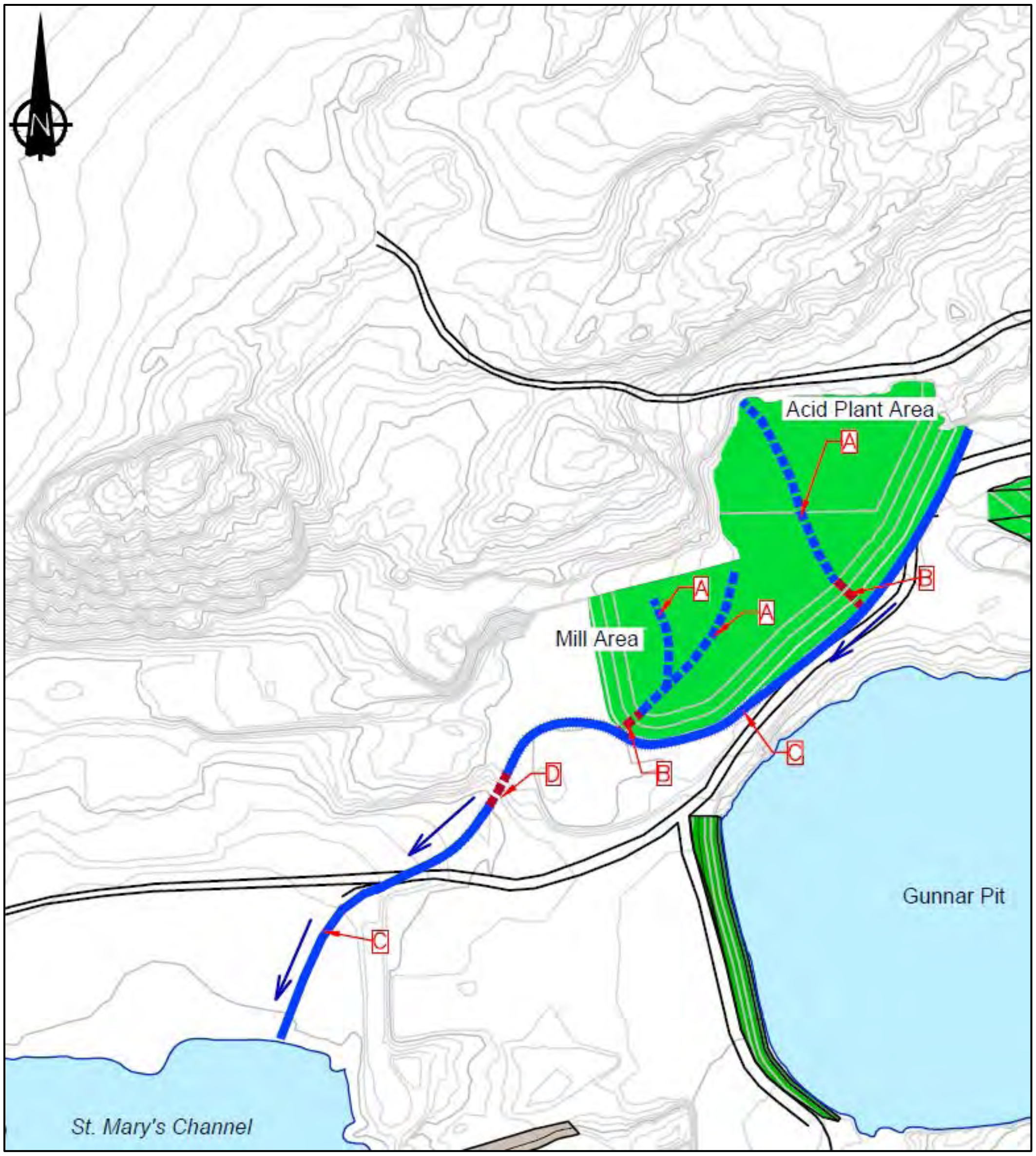


Figure 5: Location of Landfill Water Conveyance Structures

Table 6: Water Conveyance Structures at Site Landfill

Feature		Area (m^2)	Slope (%)	Velocity (m/s)	Lining requirement
A	Upper Surface of Landfill	Variable	1%	< 1.1	Compacted, vegetated ground
B	Landfill side slope	Variable	25%	< 2.2	Rip rap (min D_{50} = 100 mm)
C	Main Conveyance Channel	Variable	< 6%	< 1.8	Coconut Mat
D	Main Conveyance Channel from Landfill to St. Mary's Channel	Variable	> 6%	1.6	Rip rap (min D_{50} = 100 mm)

6 Summary and Conclusions

A Re-established Historical Drainage Channel has been designed to restore the historical surface water flows from Catchment 3 to Zeemel Bay and been designed with capacity for a one in 1,000-year storm event. The key aspects of the channel design are summarized as follows:

- The channel is founded in the silt / clay contact beneath the waste piles;
- The channel initially has a steeper slope (>10%) to tie into the silt / clay contact and then transitions to a shallower slope (1%);
- The channel has a large base width of 6 m to accommodate a one in 1,000-year storm event and to facilitate construction; and
- The channel will be lined with rip rap underlain by non-woven geotextile.

A hydraulic design tool assisted the design of regraded areas by classifying conveyance structures based on expected mean velocities. Unlined channels graded for positive drainage will be used when velocities are less than 1 m/s. Flows that are greater will have engineered designs. Details on recommended lining requirements for engineered designs are been provided in Table 5.

The design values presented in this memo are minimum values and may be adjusted during construction to suit field conditions at the discretion of the responsible engineer.

7 References

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Appendix E – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Stability Assessment

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Memo

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From:	Ryan Williams, Consultant	**Project No:**	1CS056.003
Reviewed By:	Trevor Podaima, Senior Consultant, PEng Maritz Rykaart, Practice Leader, PhD, PEng	**Date:**	July 12, 2016
Subject:	Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design – Stability Assessment		

1 Introduction

In the preliminary design phase of the other site aspects undertaken by SRK Consulting (SRK) (SRK, 2015), it was recommended to complete a stability assessment of the re-graded waste rock piles, the general mine site areas and the waste rock plug situated at the south end of the Gunnar Pit in the next project phase. The Saskatchewan Research Council (SRC) has contracted SRK to undertake the next project phase which involves an update to the Preliminary Remediation Design Report. This memorandum includes a summary of the material properties used and the stability scenarios assessed, as well as the results of the assessment.

2 Stability Assessment Parameters

2.1 Material Properties

There is limited geotechnical strength testing data available for the materials included in this assessment (e.g. waste rock, borrow, shoreline sediments and lake bed sediments). Therefore, SRK used engineering judgement and recommended shear strength parameters from literature to define the material properties. Assumed values have been determined conservatively and a sensitivity check of the assumed values was undertaken to confirm they are appropriate.

Borehole logs from the SNC-Lavalin report, *Supplemental Gunnar Subsurface Characterisation Program* (SNC, 2016), were used to characterise the subsurface geotechnical profile and to gain an understanding of the foundation materials. In select areas, the density of boreholes is high; however in most areas there is only limited boreholes available. Hence a high level of interpretation into the subsurface conditions has been undertaken and SRK has adopted the critical (i.e. most sensitive) subsurface profile in all cases.

The material types encountered in this assessment are as follows:

- Waste rock from run of mine and overburden pre-stripping;

- Shoreline sediments;
- Lake bed sediments;
- Bedrock; and
- Gamma cover material for closure.

2.1.1 Waste Rock

A literature review indicates that waste rock can have a friction angle ranging from 40° to 50°, with the lower range values corresponding to weathered or crushed, fine-grained material, and the higher range values corresponding to fresh, coarse-grained rock (Hustrulid et al., 2000). Large-scale triaxial testing by Leps (Leps, 1970) on rockfill particles up to 200 mm also showed that the friction angle of competent rockfill could be as high as 55° at low stress levels, or at least 50° at moderate stress levels.

Based on SRK's site observations, the waste piles consist of relatively coarse, intact, competent waste rock with angular to sub-angular particles which suggests that the friction angle could be in the order of 50° or higher. However, without material testing, SRK has adopted a conservative value of 45° and a sensitivity check was carried out using the lower (40°) and higher (50°) bounds.

It is important to note that the friction angle is a function of, among other things, the applied stress. The friction angle decreases with increasing stress, resulting in a curved strength envelope passing through the origin (Hustrulid et al., 2000). This phenomenon is also illustrated in the work carried out by Leps (Leps, 1970). The application of a constant friction angle for the entire waste rock pile may be conservative or under-conservative depending on the location within the waste rock pile. Closer to the pile face, stress levels are smaller and hence the friction angle tends to increase. The failure planes considered in this assessment are located close to the pile face; therefore the application of a constant friction angle (which is already a lower-bound value) is considered a conservative assumption.

2.1.2 Shoreline Sediments

Based on Unmanned Aerial Vehicle (UAV) imagery and photos provided by SRC, it appears that the waste rock piles in the Camp Area are situated along the shoreline and are not placed directly on the lake bottom sediments within St. Mary's Channel. There is limited geotechnical information to characterize this material (no boreholes were drilled); however, it appears to consist of a gravelly soil with cobble and boulder sized rocks. Such material is estimated to have a friction angle range of 30 to 50° (Budu 2010), and 35° was chosen for the analysis. This is a conservative assumption since the cobble and boulder sized fractions would likely offer a higher friction angle. Additionally, the cobble and boulder sized material is angular to sub-angular and not rounded. As the assumed friction angle is at the conservative end of the range, a sensitivity check of the friction angle was not deemed necessary.

2.1.3 Lake Bed Sediments

Lake bed sediments (LBS) were encountered within SNC boreholes 49C, 50B, and 51B and show medium to high plasticity clays, firm to stiff, with traces of silt, sand and/or gravel. The locations of the boreholes are provided in Figure 1. Budhu (2010) suggests that for clays, the peak friction angle could range from 20° to 30°. SRK performed a back-analysis of the current East and South Waste Rock Pile slopes and found that for a friction angle of 15° the Factor of Safety (FoS) approaches 1.0, and for a friction angle of 18° the FoS was approximately 1.1. The failure planes considered were for the critical failure surface through the lake bed clay foundation (i.e. surficial ravelling failures of the piles were not considered for the back-analysis).

It is assumed that the FoS for the current slopes is at least 1.1 or higher since the slopes appear to be stable, and has been for at least 50 years. SRK has therefore assumed a friction angle of 18° and zero cohesion for the lake bed clay sediments. It is SRK's opinion that this is conservative and therefore a sensitivity check of a lower-bound value is not required. However, a sensitivity check will be conducted with a higher value of 25° to assess the potential for a higher FoS.

In addition to clay, a sand and gravel layer was found to underlay the clay horizon in SNC borehole 51B at the South Waste Rock Pile (SWRP). A friction angle of 35° is assumed for this material. Since it is sufficiently deep (approximately 20 m below the toe of the pile) it is unlikely to affect the stability analysis and therefore a sensitivity check was not completed.

2.1.4 Bedrock

For the purpose of this assessment the bedrock is assumed to have infinite strength.

2.1.5 Gamma Cover

The gamma cover is expected to be a 0.5 m thick coarse textured borrow material (i.e. sand and gravel with little fines). Peak friction angles for sand range from 32° to 50° (Budhu, 2010) and SRK has assumed a conservative value of 30° in the stability analysis. Since the assumed friction angle is conservative, a sensitivity check of the assumed friction angle is not required. Furthermore, this value is consistent with the gamma cover material properties used for the detailed tailings remediation project undertaken by O'Kane Consultants (O'Kane, 2016).

2.1.6 Summary of Material Properties

A summary of the material properties assumed and the values used for the sensitivity check is provided in Table 1.

Table 1: Material properties

Material	Strength Type	Unit Weight (kN/m^3)	Assumed Values	Sensitivity Check	
				Lower Bound	Upper Bound
Waste rock	Mohr Coulomb	22	$\phi' = 45°, c' = 0$	$\phi' = 40°, c' = 0$	$\phi' = 50°, c' = 0$
Clay lake bed sediments	Mohr Coulomb	20	$\phi' = 18°, c' = 0$	$\phi' = 18°, c' = 0$	$\phi' = 25°, c' = 0$
Sand/gravel shoreline sediments	Mohr Coulomb	21	$\phi' = 35°, c' = 0$	N/A	
Bedrock	Infinite Strength	25	N/A		
Gamma cover	Mohr Coulomb	20	$\phi' = 30°, c' = 0$	N/A	

2.2 Minimum Factors of Safety

The factor of safety is defined as the ratio of the forces tending to resist failure (i.e. the material's shear strength) over the forces tending to cause failure (i.e. the shear stresses) along a given surface. The selection of a design Factor of Safety (FoS) must consider the level of confidence in the factors that will control stability; material properties, analysis methods, and consequences of failure. The British Columbia Mine Waste Rock Pile Research Committee (BCMWRPRC) suggests adopting design safety factors for two cases depending on the level of confidence in the design parameters, consequences of failure, and the analysis method. These safety factors are summarised in Table 2.

Table 2: Recommended Minimum Design FoS for Waste Rock Piles (BCMWRPRC, 1991)

Stability Condition	Factor of Safety	
	Case A	Case B
Stability of Waste Rock Pile Surface		
- Short term (during construction)	1.0	1.0
- Long term (reclamation – abandonment)	1.2	1.1
Overall Stability (Deep Seated Stability)		
- Short term (static)	1.3 – 1.5	1.1 – 1.3
- Long term (static)	1.5	1.3
- Pseudo-static	1.1 – 1.3	1.0
Case A: - Low level of confidence in critical analysis parameters - Possibly unconservative interpretation of conditions, assumptions - Severe consequences of failure - Simplified stability analysis method (charts, simplified method of slices) - Stability analysis method poorly simulates physical conditions - Poor understanding of potential failure mechanism(s)		
Case B: - High level of confidence in critical analysis parameters - Conservative interpretation of conditions, assumptions - Minimal consequences of failure - Rigorous stability analysis method - Stability analysis method simulates physical conditions well - High level of confidence in critical failure mechanism(s)		

Due to the uncertainty in the material properties and to remain conservative, SRK has adopted a FoS of 1.5 for long-term static stability and a FoS of 1.1 for pseudo-static stability.

2.3 Seismic Design Parameters

The Canadian Dam Association provides recommended minimum seismic design criteria as part of their Dam Safety Guidelines (CDA, 2014). For a High dam hazard category, a peak ground acceleration (PGA) of the 1 in 2,475 year average recurrence interval (ARI), or 2% probability of exceedance in 50 years, is specified. The BCMWRPRC suggests that a 10% probability of exceedance in 50 years is appropriate for preliminary pseudo-static analyses (BCMWRPRC, 1991). For the purposes of this assessment, a conservative PGA equal to the 1 in 2,475 year ARI will be utilised.

Site specific seismic parameters for the Project area were obtained from the National Building Code of Canada website (see Attachment 1) which provides ground accelerations and probability of occurrence using the National Building Code Seismic Hazard Calculation (NBC, 2015). Since the Project is located in an area of Canada not considered to be seismically active, this methodology to obtain seismic parameters is deemed suitable.

The corresponding 1 in 2,475 year ARI seismic ground motions are described by spectral acceleration (Sa) values at periods of 0.2, 0.5, 1.0 and 2.0 seconds. The Sa values and PGA value is summarized in Table 3.

Table 3: Seismic Ground Motions for the 1 in 2,475 year ARI Event

Spectral Acceleration	Ground Motion (g)
$Sa_{(0.2)}$	0.0540
$Sa_{(0.5)}$	0.0320
$Sa_{(1.0)}$	0.0160
$Sa_{(2.0)}$	0.0066
PGA	0.0310

3 Model Setup

The commercially available slope stability software package, SLIDE (Version 6.0) developed by Rocscience, was utilised to undertake the modelling. Cross-sections through the highest and steepest waste rock sections were assessed using the Morgenstern-Price limit equilibrium method. The areas that were required for stability modelling are listed below:

- Gunnar open pit waste rock plug;
- Shoreline waste rock piles, including:
    - Camp area; and
    - Fuel tank farm area.

- South waste rock pile;
- East waste rock pile; and
- Surface water channel.

A detailed discussion of each model setup is provided in the following sections. The location of the critical section for each area is illustrated in Figure 1.

3.1 Gunnar Open Pit – Waste Rock Plug

The stability of the waste rock plug that acts as a barrier between the Gunnar Open Pit and St. Mary's Channel was assessed and both upstream and downstream slopes were analysed. The model geometry from previous seepage modelling of the plug undertaken by McElhanney Resources Services Ltd. (McElhanney, 2013) was assumed to be unchanged and re-created in SLIDE. Two base cases for the seepage modelling were assumed by McElhanney:

- Scenario 1 – pit lake at Elevation (Elev.) 211.5 m and Lake Athabasca at Elev. 208.5 m
- Scenario 2 – pit lake at Elev. 211.0 m and Lake Athabasca at Elev. 209.5 m

SRK has conservatively assumed the higher of the two pit lake elevations for the stability assessment. Material permeabilities are assumed to be as per the base case defined by McElhanney. SRK conducted a steady-state seepage model using the groundwater component in SLIDE to establish the phreatic surface for the stability assessment.

A rapid drawdown analysis was not considered for the plug as it is assumed that the pit lake elevation has reached equilibrium and will not significantly change. Furthermore, such conditions would have a negligible impact to the plug stability as the slopes are comprised of permeable rockfill.

3.2 Shoreline Waste Rock Piles

Waste rock has been placed at the shoreline of St. Mary's Channel in two areas to form platforms for previous mining infrastructure. The two areas are located at the former fuel tank farm area (immediately southwest of the Gunnar Pit) and the former school area (now the location of the camp and further west of the Gunnar Pit). These areas are termed the Fuel Farm Area and the Camp Area respectively. The heights and slopes of several sections were checked and found to range from 5 to 12 m high and slopes varied from 1.4 Horizontal to 1.0 Vertical (H:V) (36°) to 3.0H:1.0V (18°). SRK has assessed the stability of the highest and steepest section of each area to provide recommendations for flattening these slopes to achieve a long-term static stability FoS of 1.5 or greater.

SRK used SNC boreholes 55A, 62A and 63A located at the Fuel Farm Area to characterise the subsurface profile. Of the boreholes listed above, only borehole 62A showed possible lake bed sediments beneath the waste rock; the remaining boreholes showed waste rock founded on bedrock. The lake bed sediments encountered were sand and sand with gravel. Since these boreholes are approximately 20 to 30 m from the toe of the rock piles, there is a possibility that the boreholes failed to identify clay lake sediments in the foundation. SRK has therefore assumed a 1 m thick layer of clay lake bed sediments at the toe of the Fuel Farm Area pile. This is a conservative assumption as the FoS will be lower than compared to a waste rock pile completely founded on bedrock.

No boreholes were conducted at the Camp Area, located approximately 600 m west of the Fuel Farm Area. The subsurface conditions here are assumed to be similar to that of the Fuel Farm Area. Based on site photos provided by SNC, it is clear that the waste rock piles here are founded on shoreline sediments and not clay lake bed sediments. Therefore the assumed model geometry does not include a clay layer in the foundation.

3.3 South Waste Rock Pile (SWRP)

A review of a number of sections through the SWRP found the steepest section to be at a slope of 1.7H:1.0V (31°) and a height of 19 m. SNC borehole 51B was used to characterise the subsurface profile for the analysed section. This borehole indicated that the waste rock pile is founded on approximately 17.5 m of clay lake bed sediments overlaying 5 m of sand and gravel before encountering bedrock. A similar idealised section is shown in Cross-Section F-F' in the SNC-Lavalin report, *Supplemental Gunnar Subsurface Characterisation Program* (SNC, 2016).

To remediate the SWRP, the pile will be flattened to 5.0H:1.0V (11°) and reduced in elevation from approximately Elev. 228 m to Elev. 225 m. A 0.5 m thick gamma cover, consisting of coarse textured borrow material, will be placed on the final slope. For the purposes of the stability assessment the gamma cover was assumed to be fully saturated. SRK has included a water table through the SWRP in the event frozen pore water (if present), is to melt. Two water tables were considered; an assumed depressed water table and an elevated water table for conservatism.

3.4 East Waste Rock Pile (EWRP)

The EWRP was reviewed and the steepest section was found to have a 1.4H:1.0V (36°) slope and a height of 30 m. SNC borehole 67A was used to characterise the subsurface profile for the analysed section. This borehole shows waste rock founded on bedrock and that no lake bed sediments were encountered. However, this borehole is approximately 60 m from the waste pile toe and therefore SRK has conservatively assumed that some clay lake bed sediments are present.

The EWRP will be flattened to 5.0H:1.0V (11°) and reduced in elevation from approximately Elev. 240 m to Elev. 230 m/225 m. A 0.5 m gamma cover, consisting of coarse textured borrow material will also be placed on the final slope. Two water tables through the waste rock pile, a depressed water table and an elevated water table, will be assessed much the same as per the water tables considered for the South Waste Rock Pile.

3.5 Surface Water Channel (Re-established Historic Channel)

A surface water channel (i.e. re-establishment of historic drainage channel prior to mine development) to divert runoff from north to south into the Zeemal Bay is to be constructed between the East and South Waste Rock Piles. The channel will be cut into the existing waste piles at a slope of 3H:1V (18°) and will be up to 10 m deep. Rip-rap lining will be installed along the base of the channel; however this is expected to provide little buttressing effect.

Boreholes in the vicinity of the channel include 49B, 49C, 49D, and 50B. Boreholes 49B and 49D indicate that the waste rock is founded directly onto bedrock, while borehole 49C shows a thin 1.4 m thick layer of clay, silt and sand between the waste rock and bedrock. Further downstream of the channel, borehole 50B shows approximately 2.6 m of clay and silt between the waste rock and bedrock. As the channel will be excavated into the foundation, SRK has assumed a 1 m layer of lake bed sediments beneath the channel base as the critical scenario.

3.6 Summary of Assessment Scenarios

A summary of the assessment Scenarios is provided in Table 4.

Table 4: Stability Assessment Scenarios

Model No.	Scenario
Model 1 - Gunnar Open Pit Waste Rock Plug	
1.1	Elevated pit lake, base case material properties, upstream slope
1.2	Elevated pit lake, base case material properties, downstream slope
1.3	Elevated pit lake, critical slope, waste rock ϕ' = 40° (lower bound sensitivity check)
1.4	Elevated pit lake, critical slope, waste rock ϕ' = 50° (upper bound sensitivity check)
Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area	
2.1	Current slope, bedrock foundation, base case material properties
2.2	Current slope, 1 m thick LBS foundation, base case material properties
2.3	2.0H:1.0V slope, 1 m thick LBS foundation, base case material properties
2.4	2.5H:1.0V slope, 1 m thick LBS foundation, base case material properties
2.5	2.5H:1.0V slope, 1 m thick LBS foundation, LBS ϕ' = 25° (upper bound sensitivity check for LBS)
Model 3 - Shoreline Waste Rock Piles – Camp Area	
3.1	Current slope, 1 m thick shoreline sediments foundation, base case material properties
3.2	2.0H:1.0V slope, 1 m thick shoreline sediments foundation, base case material properties
Model 4 - South Waste Rock Pile	
4.1	Current slope, base case material properties
4.2	Current slope, LBS ϕ' = 15° (lower bound sensitivity check)
4.3	5.0H:1.0V slope, depressed water table, base case material properties
4.4	5.0H:1.0V slope, elevated water table, base case material properties
4.5	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)

4.6	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)
4.7	5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check)
Model 5 - East Waste Rock Pile	
5.1	Current slope, base case material properties
5.2	Current slope, LBS ϕ' = 15° (lower bound sensitivity check)
5.3	5.0H:1.0V slope, depressed water table, base case material properties
5.4	5.0H:1.0V slope, elevated water table, base case material properties
5.5	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)
5.6	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)
5.7	5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check)
Model 6 – Re-establishment of Historic Channel	
6.1	3.0H:1.0V slope, base case material properties
6.2	3.0H:1.0V slope, elevated water table, base case material properties
6.3	3.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)
6.4	3.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)

4 Results

The results of each scenario under long-term static and seismic conditions are presented in Table 5 and Table 6, respectively and the slide output figures are included in Attachments 2 and 3, respectively. All potential failure surfaces such as shallow/surficial failures and deep-seated failures were considered. Only the FoS for the critical failure surface, i.e. critical to the stability of the cover or to the global waste pile stability, has been reported. Note that the critical failure surface for the SWRP was a global deep-seated foundation failure surface since the foundation is assumed to comprise of weaker lake bed sediments. However, for the EWRP and surface water channel, the critical failure surface is a shallow toe failure along the foundation and not a deep-seated foundation failure. This is due to a bedrock foundation for these areas where the bedrock is assumed to have infinite strength.

Table 5: Stability Assessment Results – Long Term Static

Model No.	Scenario	FofS	Failure Type	Recommended Minimum FoS
Model 1 - Gunnar Open Pit Waste Rock Plug				
1.1	Elevated pit lake, base case material properties, upstream slope	1.54	Global	1.5
1.2	Elevated pit lake, base case material properties, downstream slope	3.11	Global	1.5
1.3	Elevated pit lake, critical slope, waste rock ϕ’ = 40° (lower bound sensitivity check)	1.29	Global	1.5
1.4	Elevated pit lake, critical slope, waste rock ϕ’ = 50° (upper bound sensitivity check)	1.84	Global	1.5
Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area				
2.1	Current slope, bedrock foundation, base case material properties	1.42	Surficial	-
2.2	Current slope, 1 m thick LBS foundation, base case material properties	1.11	Toe	-
2.3	2.0H:1.0V slope, 1 m thick LBS foundation, base case material properties	1.35	Toe	1.5
2.4	2.5H:1.0V slope, 1 m thick LBS foundation, base case material properties	1.53	Toe	1.5
2.5	2.5H:1.0V slope, 1 m thick LBS foundation, LBS ϕ’ = 25° (upper bound sensitivity check for LBS)	1.93	Toe	1.5
Model 3 - Shoreline Waste Rock Piles – Camp Area				
3.1	Current slope, 1 m thick shoreline sediments foundation, base case material properties	1.42	Surficial	-
3.2	2.0H:1.0V slope, 1 m thick shoreline sediments foundation, base case material properties	2.0	Toe	1.5
Model 4 - South Waste Rock Pile				
4.1	Current slope, base case material properties	1.13	Global	-
4.2	Current slope, LBS ϕ’ = 15° (lower bound sensitivity check)	0.97	Global	-
4.3	5.0H:1.0V slope, depressed water table, base case material properties	1.80	Global	1.5
4.4	5.0H:1.0V slope, elevated water table, base case material properties	1.64	Global	1.5
4.5	5.0H:1.0V slope, elevated water table, waste rock ϕ’ = 40° (lower bound sensitivity check)	1.60	Global	1.5
4.6	5.0H:1.0V slope, elevated water table, waste rock ϕ’ = 50° (upper bound sensitivity check)	1.67	Global	1.5
4.7	5.0H:1.0V slope, elevated water table, LBS ϕ’ = 25° (upper bound sensitivity check)	2.24	Global	1.5
Model 5 - East Waste Rock Pile				
5.1	Current slope, base case material properties	1.30	Toe	-

5.2	Current slope, LBS ϕ' = 15° (lower bound sensitivity check)	1.25	Toe	-
5.3	5.0H:1.0V slope, depressed water table, base case material properties	1.80	Toe	1.5
5.4	5.0H:1.0V slope, elevated water table, base case material properties	1.80	Toe	1.5
5.5	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)	1.74	Toe	1.5
5.6	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)	1.87	Toe	1.5
5.7	5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check)	2.48	Toe	1.5
Model 6 – Re-establishment of Historic Channel				
6.1	3.0H:1.0V slope, base case material properties	1.64	Toe	1.5
6.2	3.0H:1.0V slope, elevated water table, base case material properties	1.50	Toe	1.5
6.3	3.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)	1.38	Toe	1.5
6.4	3.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)	1.52	Toe	1.5

Table 6: Stability Assessment Results – Seismic

Model No.	Scenario	Factor of Safety	Failure Type	Recommended Minimum Factor of Safety
Model 1 - Gunnar Open Pit Waste Rock Plug				
1.1	Elevated pit lake, base case material properties, upstream slope	1.46	Global	1.1
1.2	Elevated pit lake, base case material properties, downstream slope	2.60	Global	1.1
1.3	Elevated pit lake, critical slope, waste rock ϕ' = 40° (lower bound sensitivity check)	1.22	Global	1.1
1.4	Elevated pit lake, critical slope, waste rock ϕ' = 50° (upper bound sensitivity check)	1.74	Global	1.1
Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area				
2.4	2.5H:1.0V slope, 1 m thick LBS foundation, base case material properties	1.39	Toe	1.1
2.5	2.5H:1.0V slope, 1 m thick LBS foundation, LBS ϕ' = 25° (upper bound sensitivity check for LBS)	1.76	Toe	1.1
Model 3 - Shoreline Waste Rock Piles – Camp Area				
3.2	2.0H:1.0V slope, 1 m thick shoreline sediments foundation, base case material properties	1.86	Toe	1.1

Model 4 - South Waste Rock Pile				
4.3	5.0H:1.0V slope, depressed water table, base case material properties	1.52	Global	1.1
4.4	5.0H:1.0V slope, elevated water table, base case material properties	1.39	Global	1.1
4.5	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)	1.36	Global	1.1
4.6	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)	1.40	Global	1.1
4.7	5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check)	1.91	Global	1.1
Model 5 - East Waste Rock Pile				
5.3	5.0H:1.0V slope, depressed water table, base case material properties	1.52	Toe	1.1
5.4	5.0H:1.0V slope, elevated water table, base case material properties	1.52	Toe	1.1
5.5	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)	1.48	Toe	1.1
5.6	5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)	1.57	Toe	1.1
5.7	5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check)	2.11	Toe	1.1
Model 6 – Re-establishment of Historic Channel				
6.1	3.0H:1.0V slope, base case material properties	1.40	Toe	1.1
6.2	3.0H:1.0V slope, elevated water table, base case material properties	1.25	Toe	1.1
6.3	3.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check)	1.19	Toe	1.1
6.4	3.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)	1.44	Toe	1.1

5 Conclusions

A stability assessment has been conducted for the Gunnar Open pit plug, shoreline waste rock piles, the South and East Waste Rock Piles and the Surface Water Channel. It is noted that Model 1.3 for the Open Pit Plug and Model 6.3 for the Surface Water Channel did not meet the minimum recommended Static FoS (1.5) when reducing the waste rock friction angle to 40°, which in the sensitivity analysis is the lower bound for the waste rock friction angle. The calculated factors of safety were 1.29 and 1.38, respectively. However, because these results are based on the lower bound sensitivity value for both the waste rock and the lake bottom sediments, they represent conservative conditions within the ranges modelled. In addition, past experience supports that the waste rock will have a friction angle of 45° or higher and that the lake bed sediments will have a friction angle greater than 18º. Therefore a FoS of approximately 1.3 for such conservative conditions is considered to be acceptable.

In general, the results of the assessment reveal the following:

- The Gunnar Open pit plug is stable under both long-term static and seismic conditions;
- The shoreline waste rock piles at the Fuel Farm and Camp areas meet the minimum FoS at a slope of 2.5H:1.0V and 2.0H:1.0V, respectively
- The South Waste Rock Pile is stable under both long-term static and seismic conditions at a slope of 5.0H:1.0V
- The East Waste Rock Pile is stable under both long-term static and seismic conditions at a slope of 5.0H:1.0V
- The waste rock slopes at the Surface Water Channel are stable under both long-term static and seismic conditions at a slope of 3.0H:1.0V.

6 References

Budhu, M., 2010. Soil Mechanics and Foundations, 3rd Edition, p. 724 (Budhu, 2010).

Hustrulid, W.A., McCarter, M., Van Zyl, D., 2000. Slope Stability in Surface Mining, Section 30.3, p. 276 (Hustrulid et al., 2000).

Leps, T., 1970. Review of shearing strength of rockfill. Journal of Soil Mechanics and Foundation Division, ASCE. Vol. 96, SM4, p. 1159-1170 (Leps, 1970).

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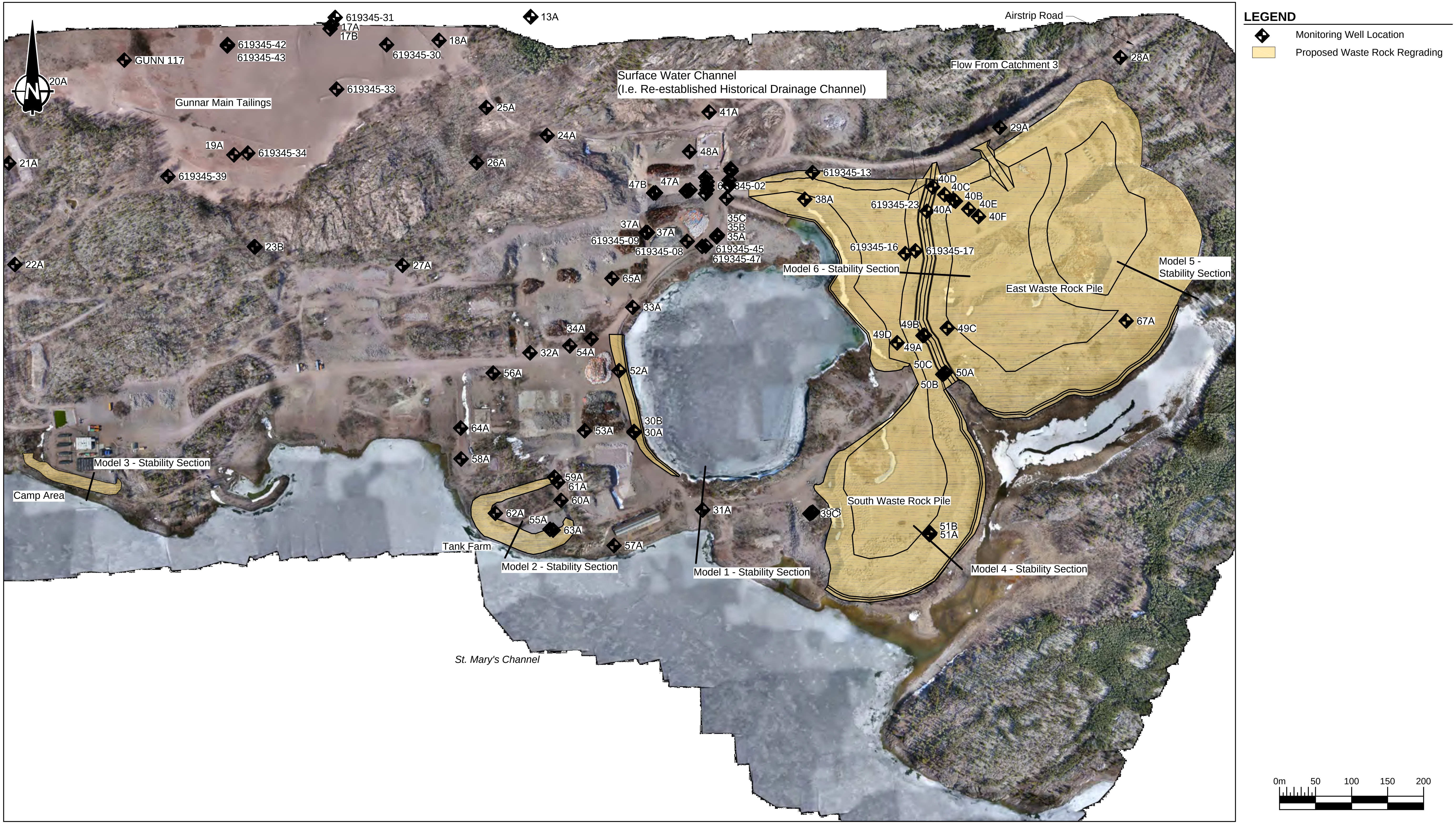
Figures



srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

UPDATED PRELIMINARY REMEDIATION DESIGN

PLAN MAP
STABILITY SECTIONS

SRK JOB NO.: 1CS056.003

FILE NAME: 1CS056.003 - PM Stability Sections.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

DATE: 2016/07/11

APPROVED:

FIGURE: 1

Attachment 1: Site Specific Seismic Parameters

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

June 06, 2016

Site: 59.3876 N, 108.8824 W User File Reference: Gunnar Mine

Requested by: , SRK Consulting

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)**
0.042	0.058	**0.054**	0.043	**0.032**	**0.016**	**0.0066**	**0.0013**	**0.0007**	**0.031**	**0.022**

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)	0.0019	0.010	0.019
Sa(0.1)	0.0034	0.016	0.029
Sa(0.2)	0.0040	0.017	0.029
Sa(0.3)	0.0036	0.015	0.024
Sa(0.5)	0.0026	0.011	0.018
Sa(1.0)	0.0011	0.0051	0.0092
Sa(2.0)	0.0005	0.0020	0.0037
Sa(5.0)	0.0002	0.0005	0.0008
Sa(10.0)	0.0002	0.0003	0.0005
PGA	0.0018	0.0085	0.016
PGV	0.0013	0.0063	0.012

References

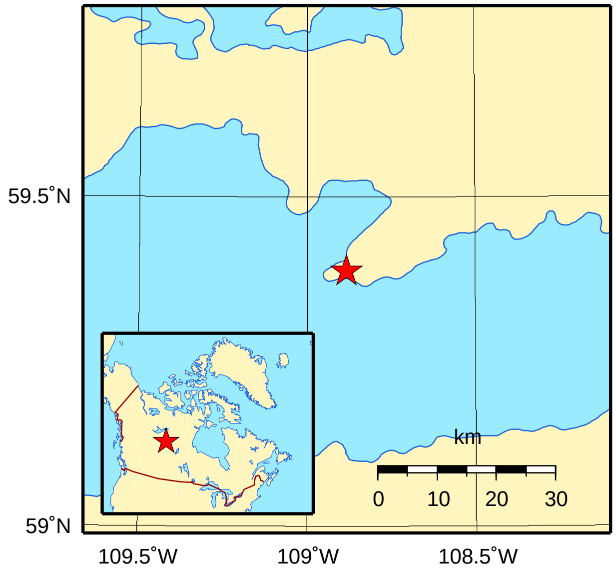
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



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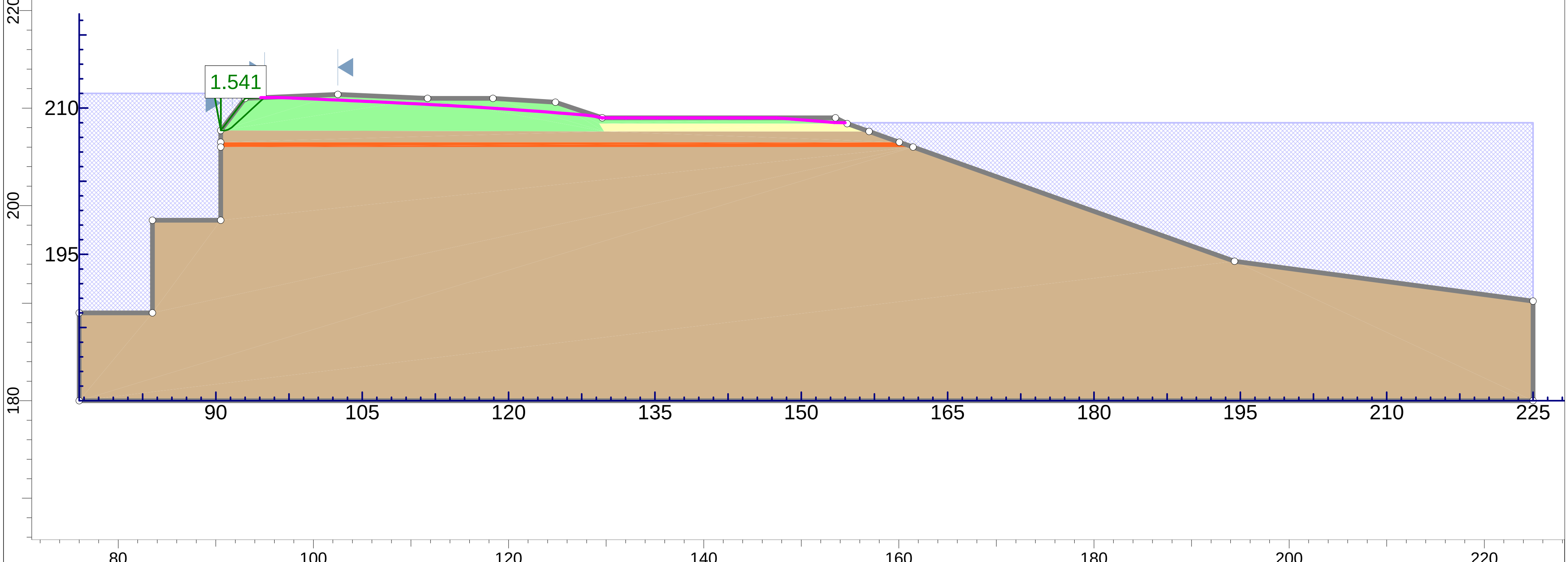
Attachment 2: Long-term Term Static Stability Results

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	45
Bedrock		25	Infinite strength		

Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0

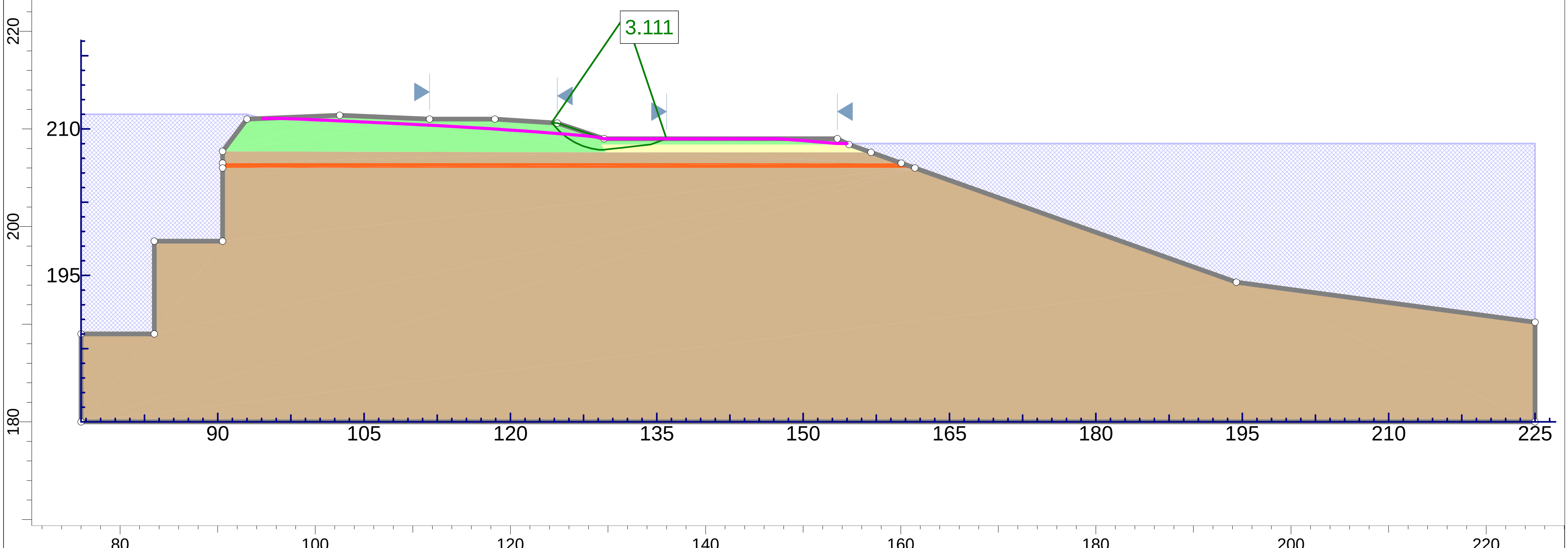


Project	Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)
Analysis Description	1.1 Elevated pit lake, base case material properties, upstream slope (Long-term Static)
Drawn By	R Williams
Scale	1:600
Company	SRK Consulting
Date	6/21/2016, 8:36:03 AM
File Name	1.1.slim

SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	45
Bedrock		25	Infinite strength		

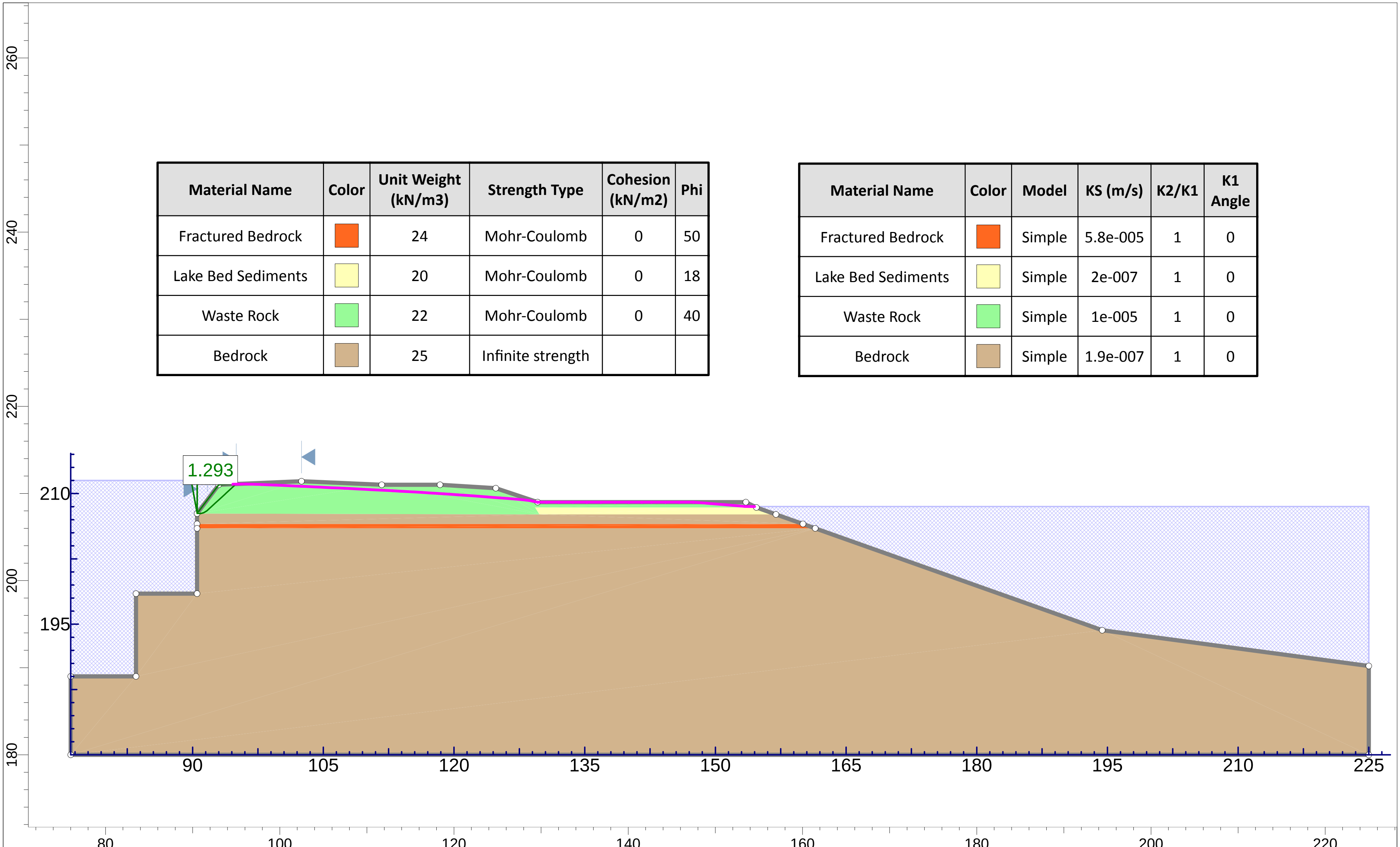
Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0



rocscience	*Project* Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)		
	Analysis Description 1.2 Elevated pit lake, base case material properties, downstream slope (Long-term Static)		
	Drawn By R Williams	*Scale* 1:600	*Company* SRK Consulting
SLIDEINTERPRET 6.014	*Date* 6/21/2016, 8:36:03 AM		*File Name* 1.2.slim

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	40
Bedrock		25	Infinite strength		

Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0

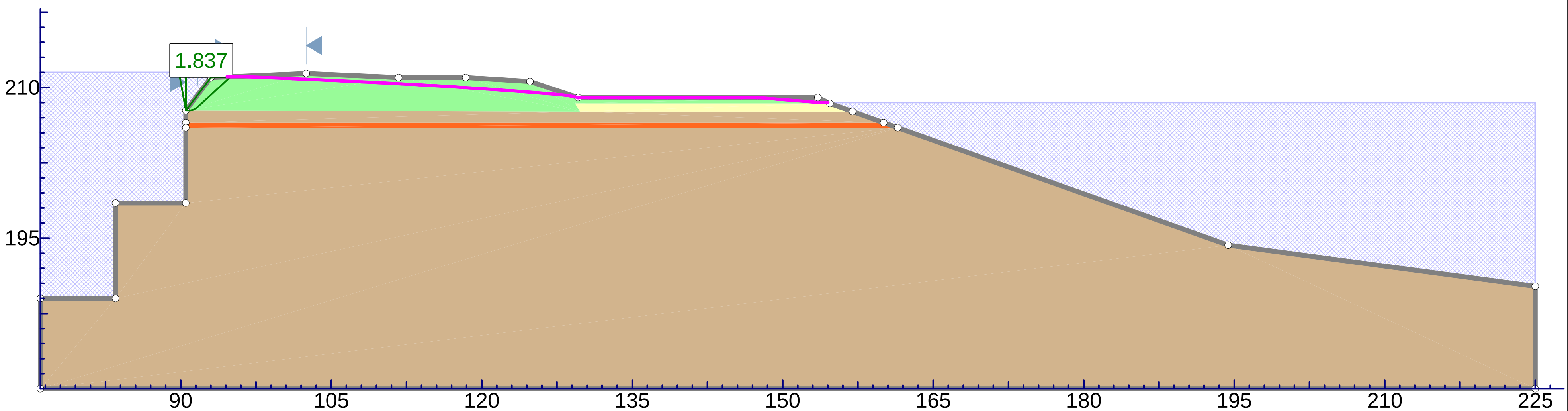


SLIDEINTERPRET 6.014

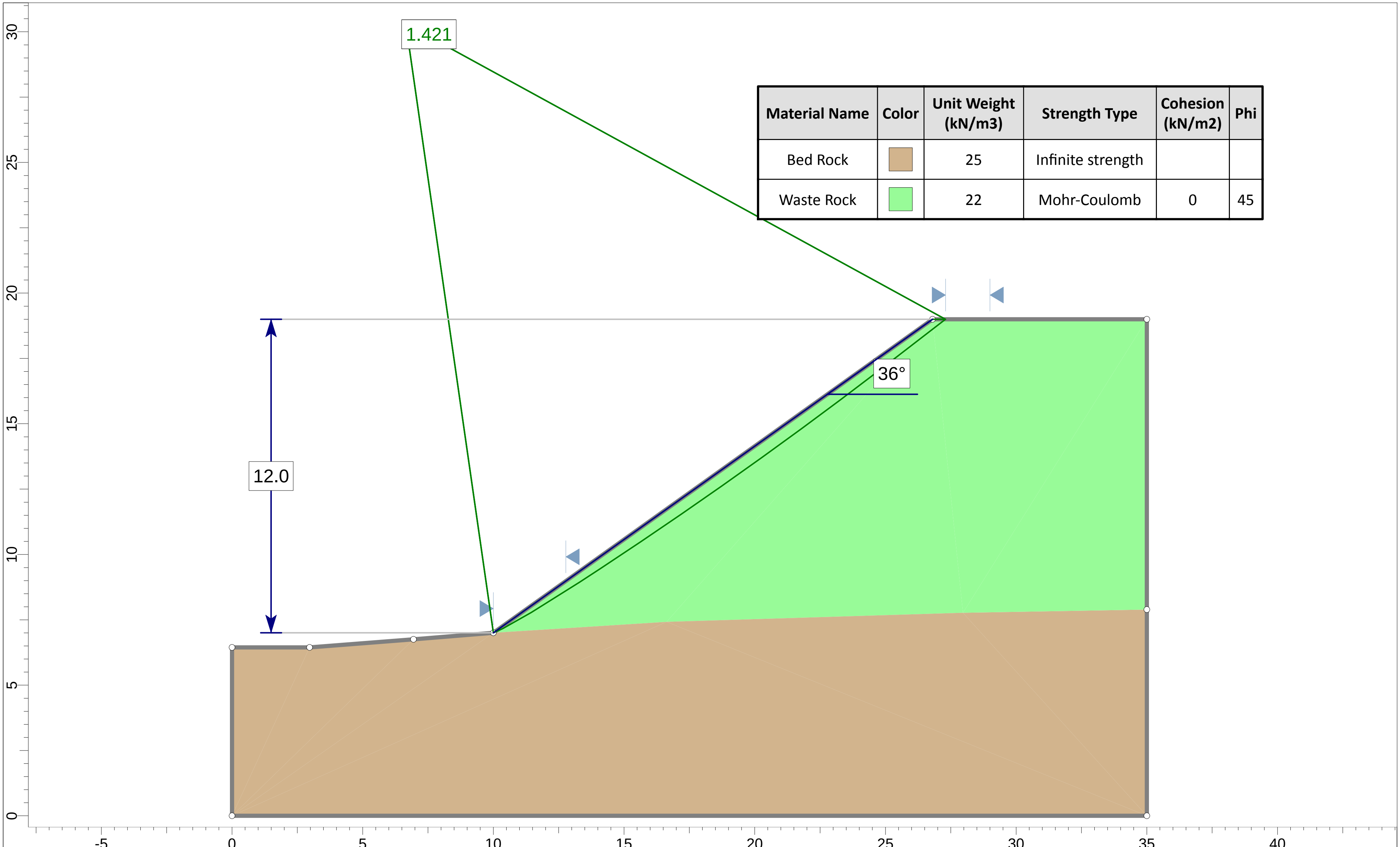
Project	Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)
Analysis Description	1.3 Elevated pit lake, critical slope, waste rock $\phi' = 40°$ (lower bound sensitivity check) (Long-term Static)
Drawn By	R Williams
Scale	1:600
Company	SRK Consulting
Date	6/21/2016, 8:36:03 AM
File Name	1.3.slim

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	50
Bedrock		25	Infinite strength		

Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0



rocscience	*Project* Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)
	Analysis Description 1.4 Elevated pit lake, critical slope, waste rock ϕ' = 50° (upper bound sensitivity check) (Long-term Static)
	Drawn By R Williams · *Scale* 1:600 · *Company* SRK Consulting
SLIDEINTERPRET 6.014	*Date* 6/21/2016, 8:36:03 AM · *File Name* 1.4.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Bed Rock		25	Infinite strength		
Waste Rock		22	Mohr-Coulomb	0	45

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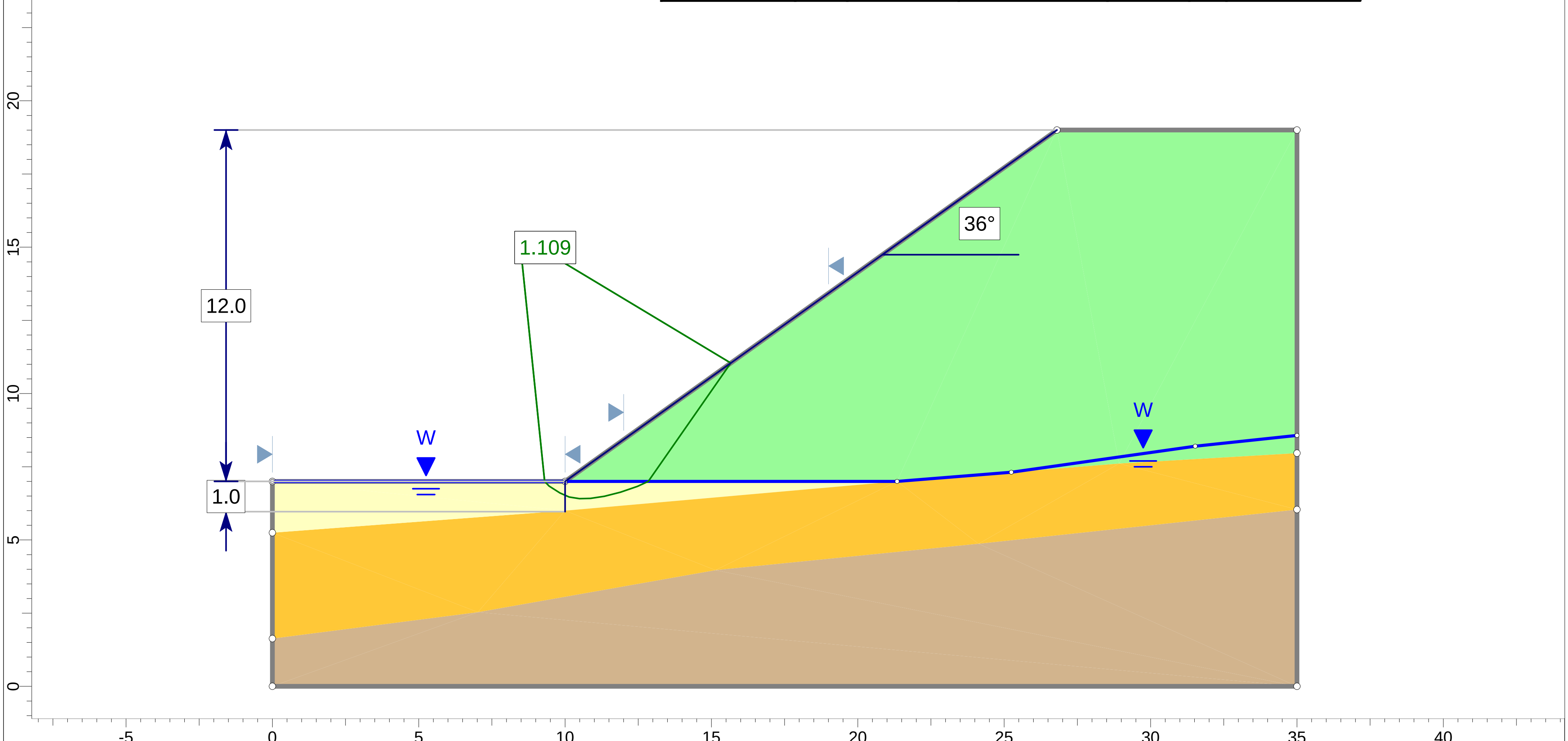
SLIDEINTERPRET 6.014

Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project)		
Analysis Description	2.1 Current slope, bedrock foundation, base case material properties (Long-term Static)		
Drawn By R Williams	*Scale* 1:200	*Company*	SRK Consulting
Date	6/15/2016, 1:00:13 PM	*File Name*	2.1.slim

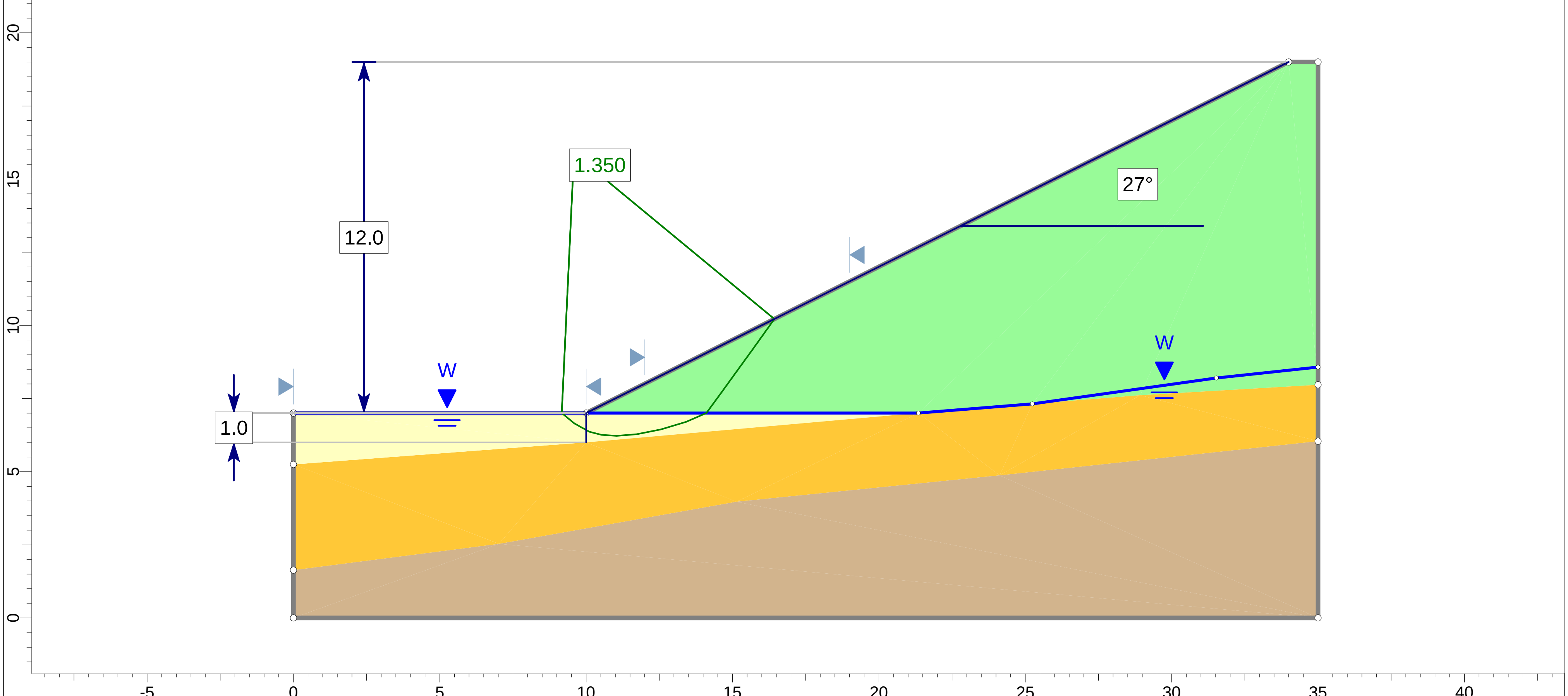
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface



Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project)
Analysis Description	2.2 Current slope, 1 m thick LBS foundation, base case material properties
Drawn By	R Williams
Scale	1:200
Company	SRK Consulting
Date	6/15/2016, 1:00:13 PM
File Name	2.2.slim

SLIDEINTERPRET 6.014

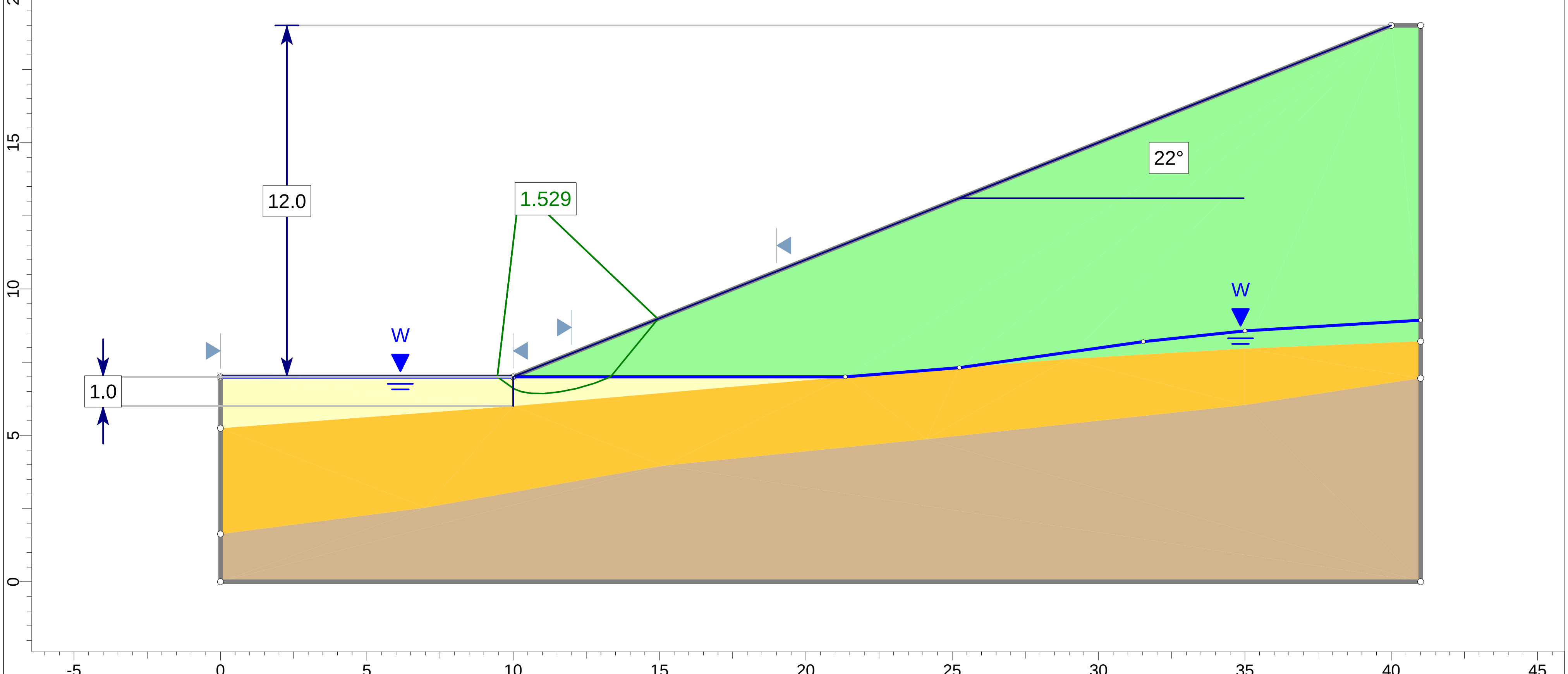
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Bed Rock		25	Infinite strength		
Waste Rock		22	Mohr-Coulomb	0	45



Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project_
Analysis Description	2.3 2.0H:1.0V slope, 1 m thick LBS foundation, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:200
Company	SRK Consulting
Date	6/15/2016, 1:00:13 PM
File Name	2.3.slim

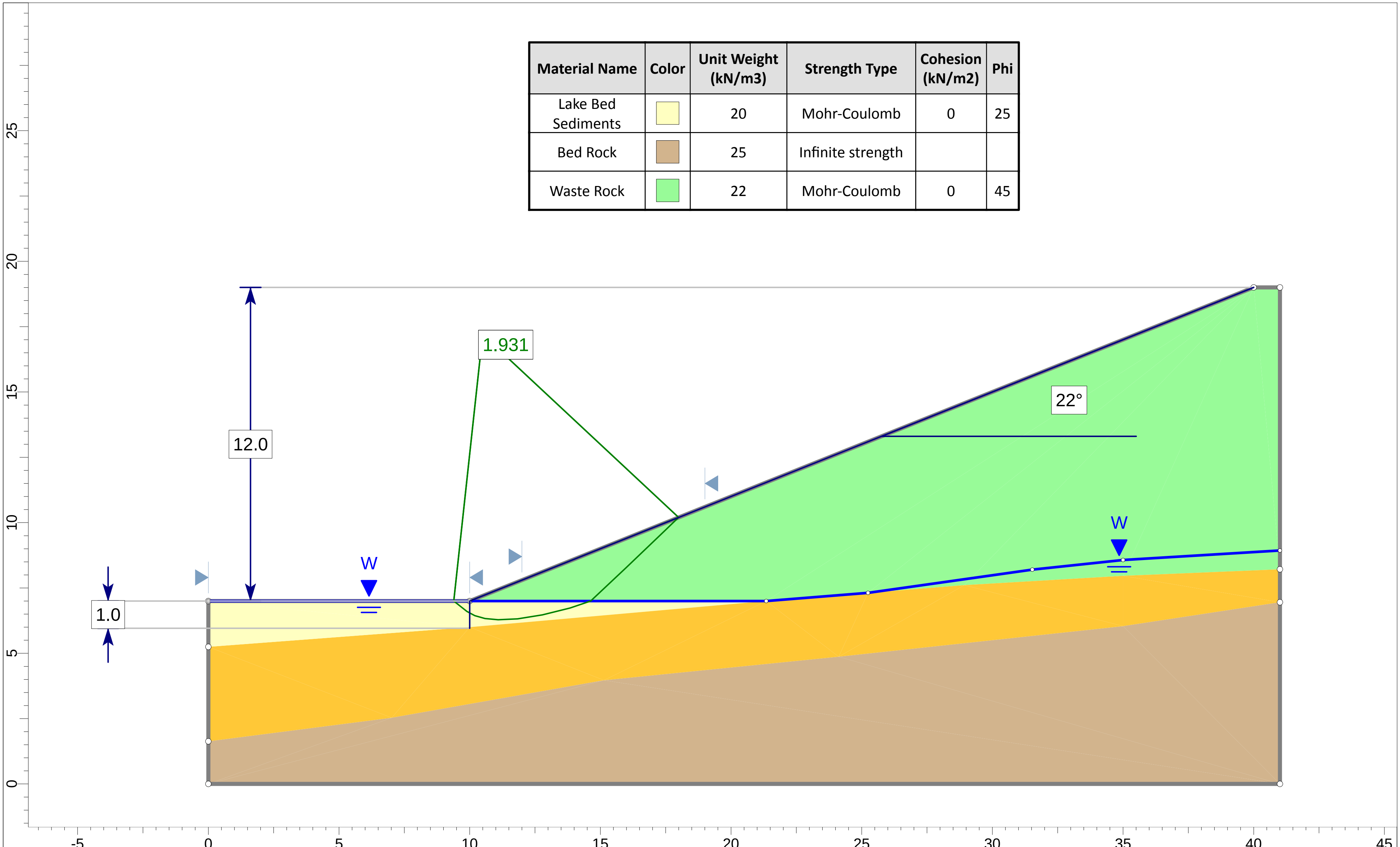
SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface



Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project)
Analysis Description	2.4, 2.5H:1.0V slope, 1 m thick LBS foundation, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:200
Company	SRK Consulting
Date	6/15/2016, 1:00:13 PM
File Name	2.4.slim

SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Lake Bed Sediments		20	Mohr-Coulomb	0	25
Bed Rock		25	Infinite strength		
Waste Rock		22	Mohr-Coulomb	0	45

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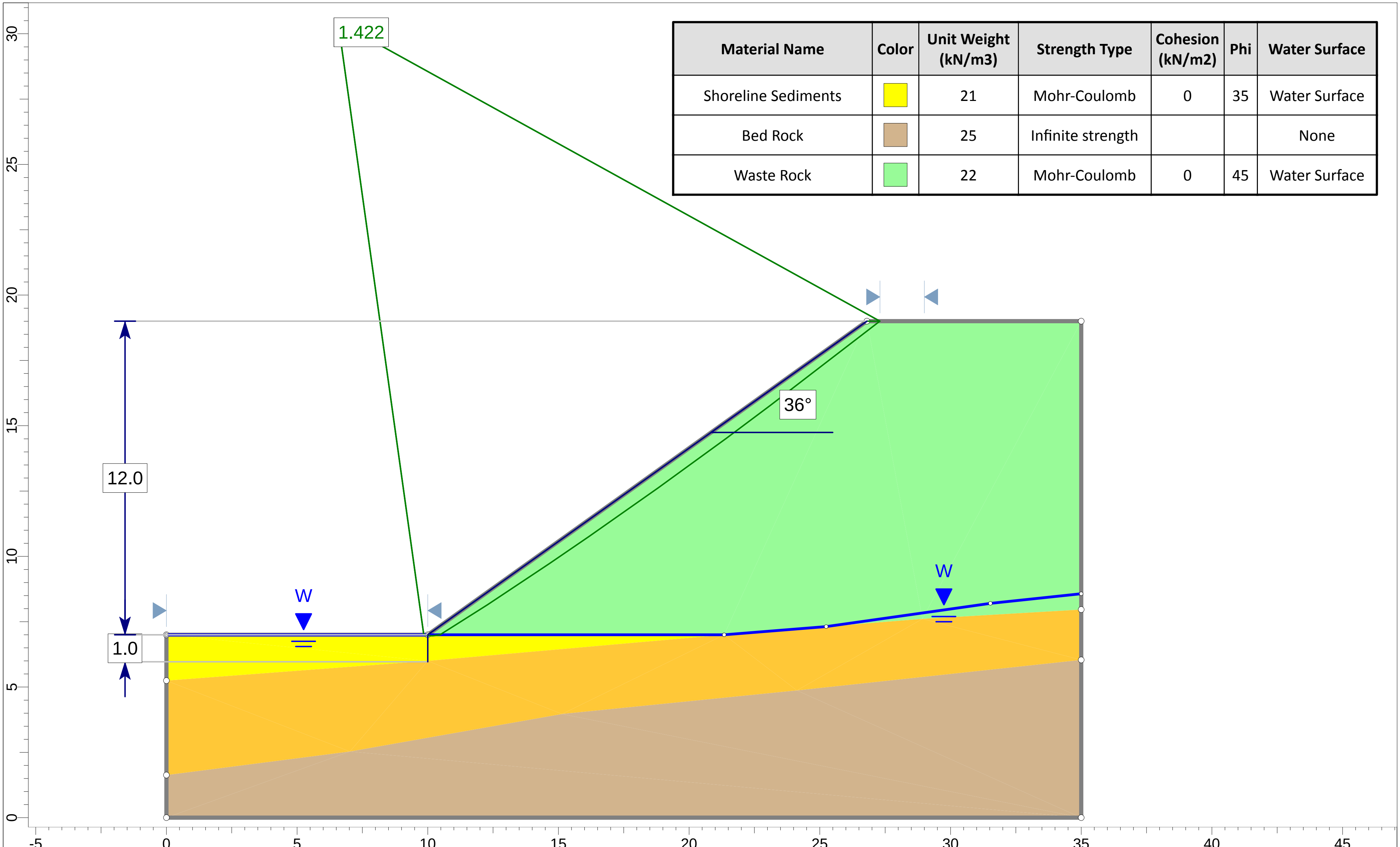
Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project)		
Analysis Description	2.5, 2.5H:1.0V slope, 1 m thick LBS foundation, LBS ϕ' = 25° (upper bound sensitivity check for LBS) (Long-term Static)		
Drawn By R Williams	*Scale* 1:200	*Company*	SRK Consulting
Date	6/15/2016, 1:00:13 PM	*File Name*	2.5.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Shoreline Sediments		21	Mohr-Coulomb	0	35	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface

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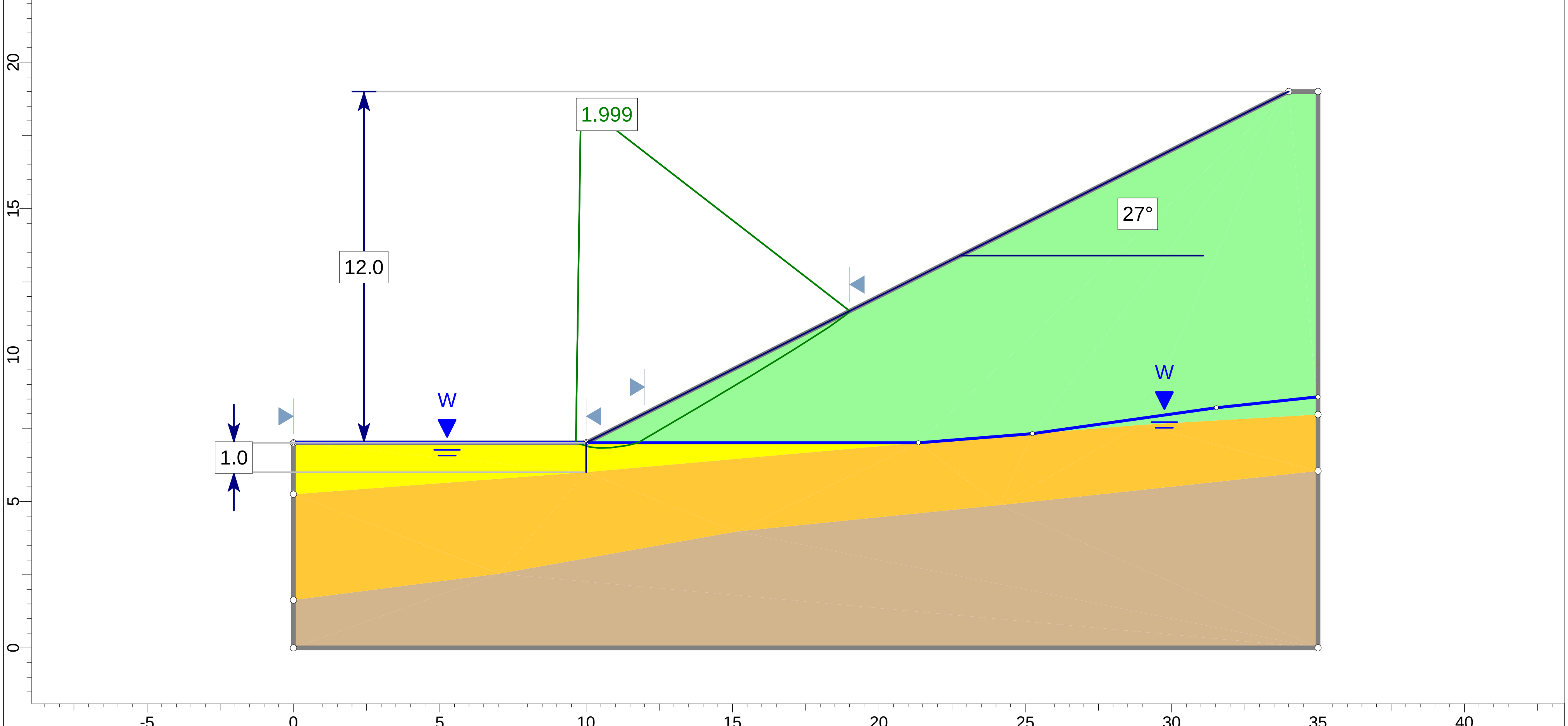
SLIDEINTERPRET 6.014

Project	Model 3 - Shoreline Waste Rock Piles – Camp Area (Gunnar Mine Site Remediation Project)
Analysis Description	3.1 Current slope, 1 m thick shoreline sediments foundation, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:200
Company	SRK Consulting
Date	6/15/2016, 1:00:13 PM
File Name	Camp Area_Current Slope - 3.1_revised.slim

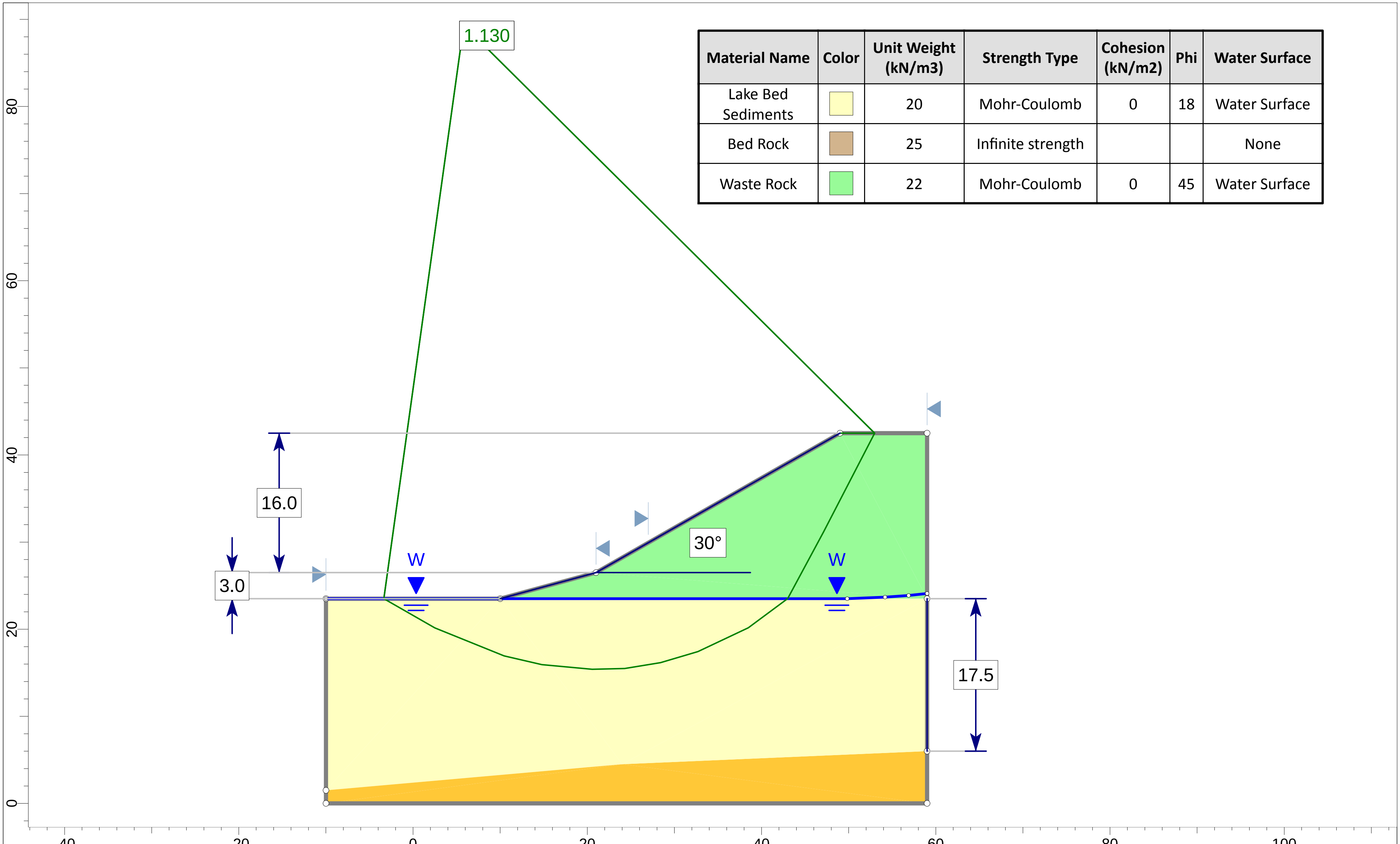
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Shoreline Sediements		21	Mohr-Coulomb	0	35
Bed Rock		25	Infinite strength		
Waste Rock		22	Mohr-Coulomb	0	45



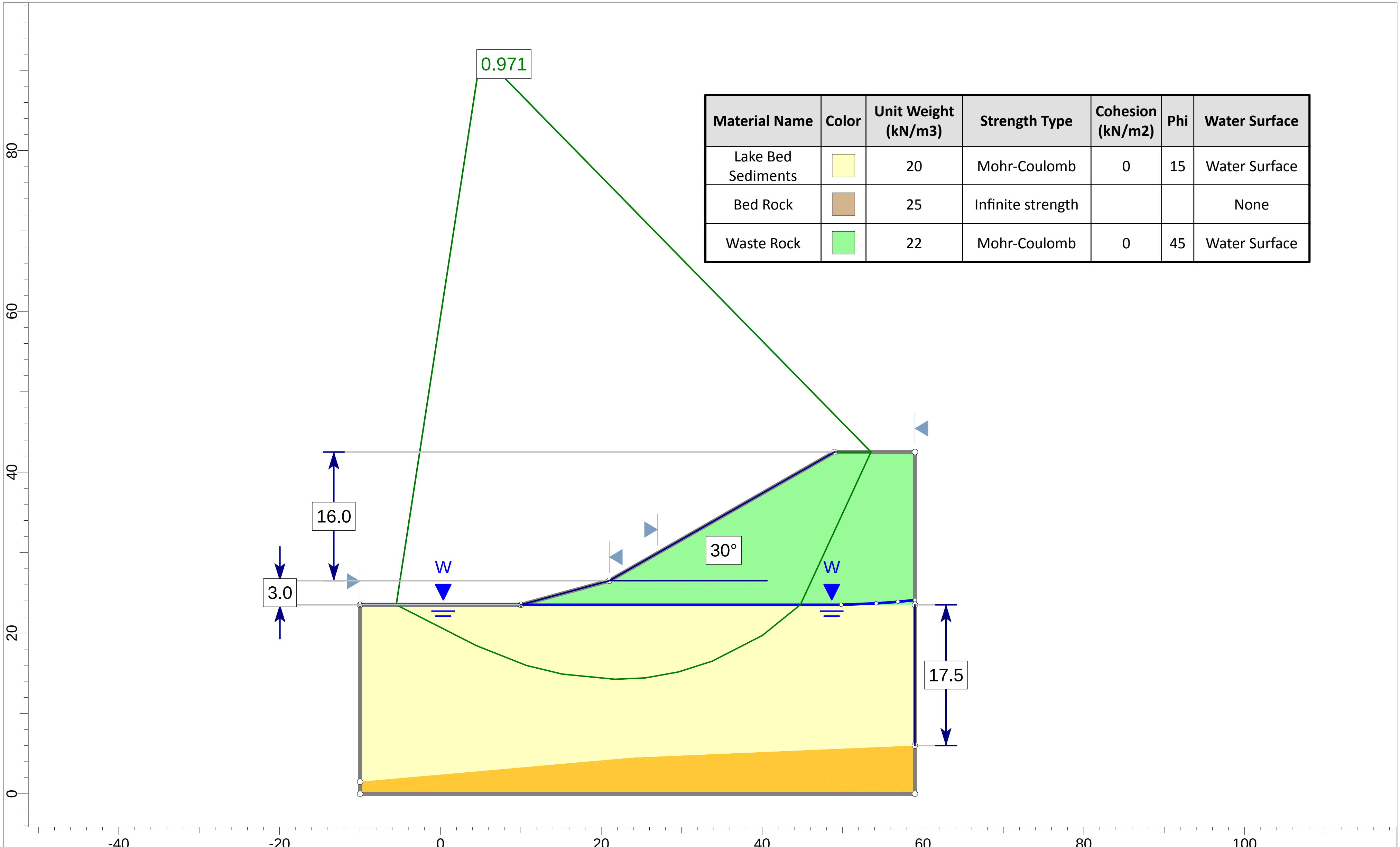
Project	Model 3 - Shoreline Waste Rock Piles – Camp Area (Gunnar Mine Site Remediation Project)
Analysis Description	3.2 2.0H:1.0V slope, 1 m thick shoreline sediments foundation, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:200
Company	SRK Consulting
Date	6/15/2016, 1:00:13 PM
File Name	Camp Area_1V to 2H - 3.2.slim

SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface



SLIDEINTERPRET 6.014	Project: Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)		
	Analysis Description: 4.1 Current slope, base case material properties (Long-term Static)		
	Drawn By: R Williams	Scale: 1:600	Company: SRK Consulting
	Date: 6/15/2016, 3:52:16 PM		File Name: 4.1.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	15	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface

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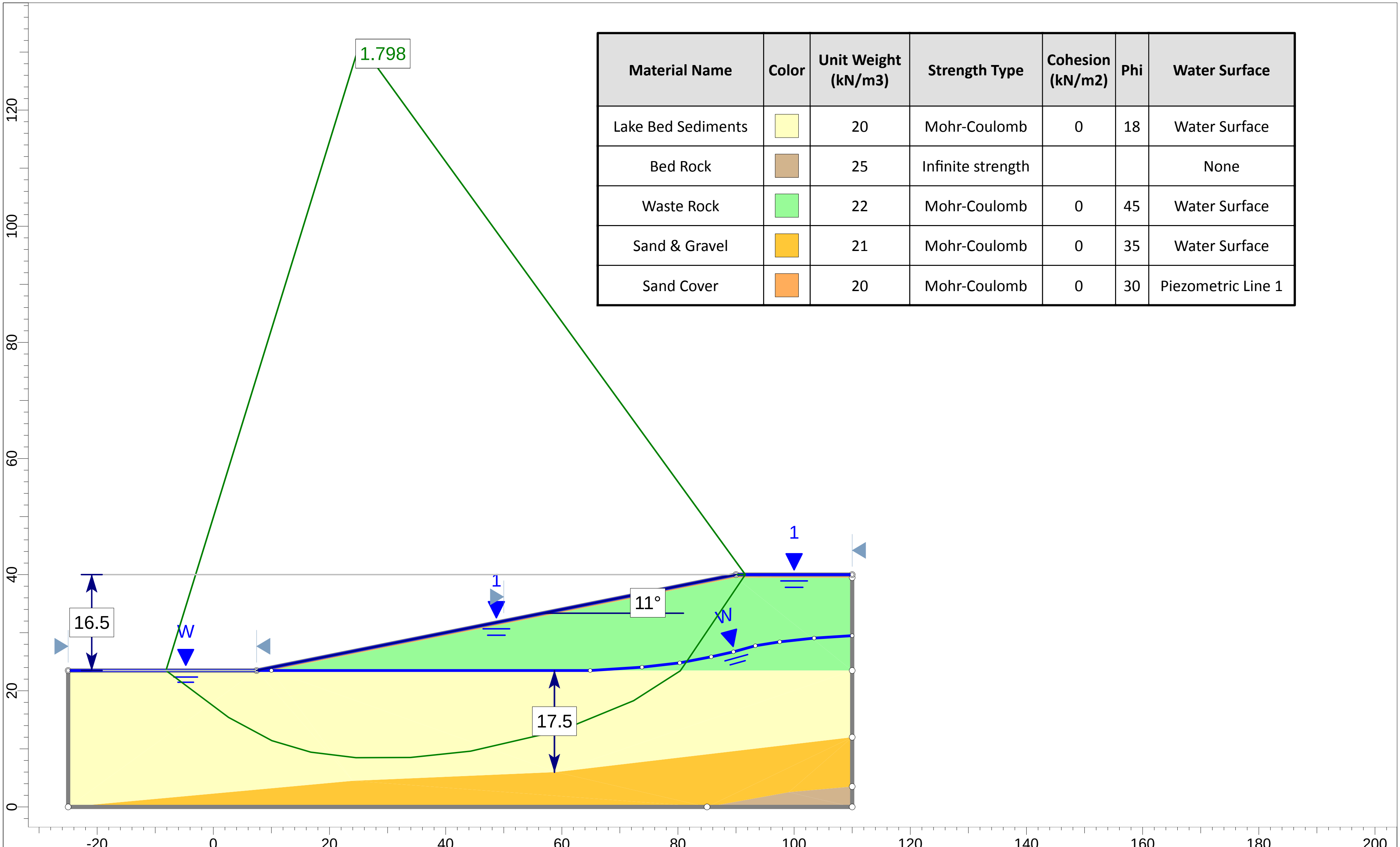
SLIDEINTERPRET 6.014

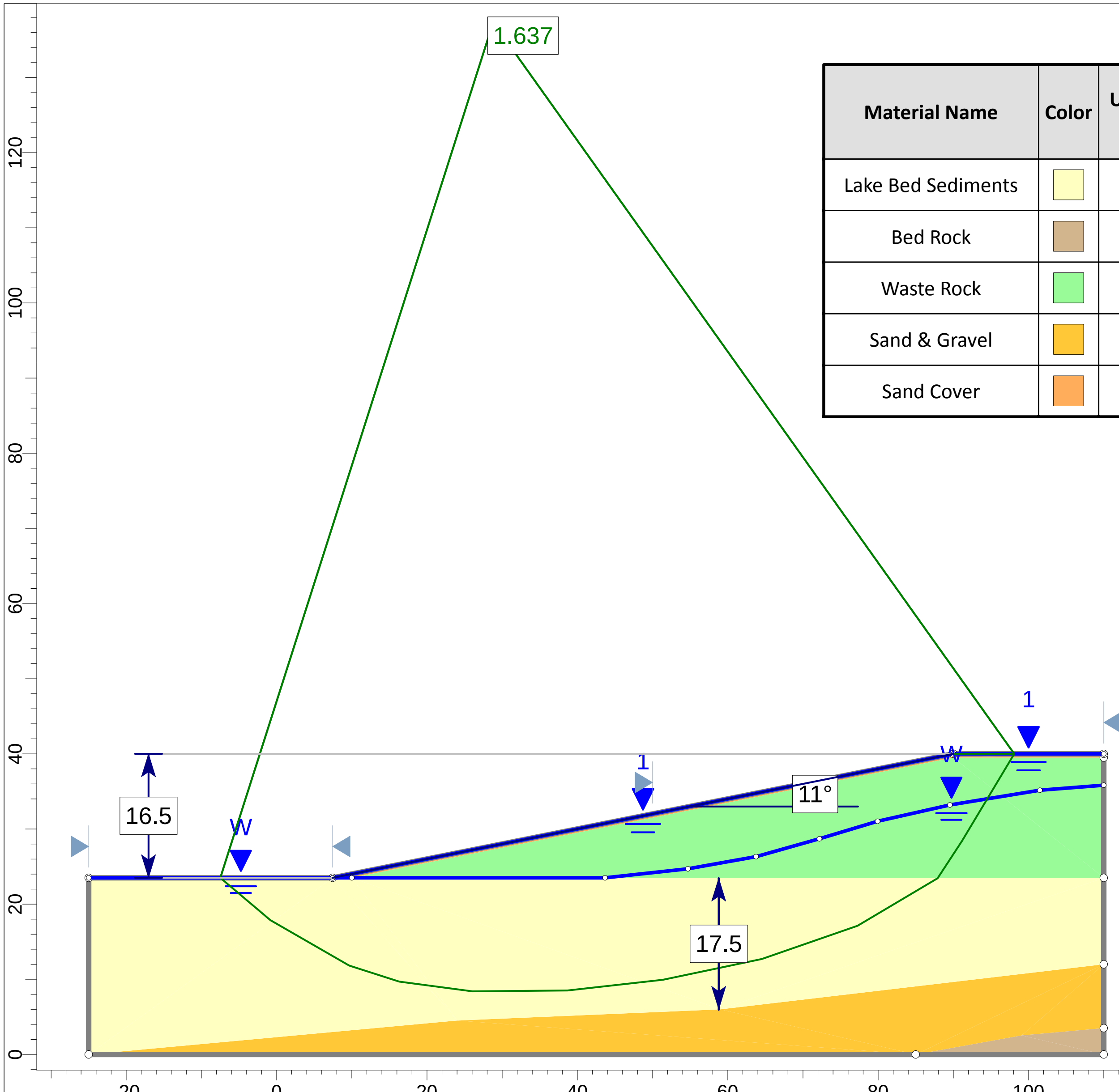
Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	4.2 Current slope, LBS ϕ' = 15° (lower bound sensitivity check) (Long-term Static)		
Drawn By R Williams	*Scale* 1:650	*Company*	SRK Consulting
Date	6/15/2016, 3:52:16 PM	*File Name*	4.2.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.3 5.0H:1.0V slope, depressed water table, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:900
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.3.slim

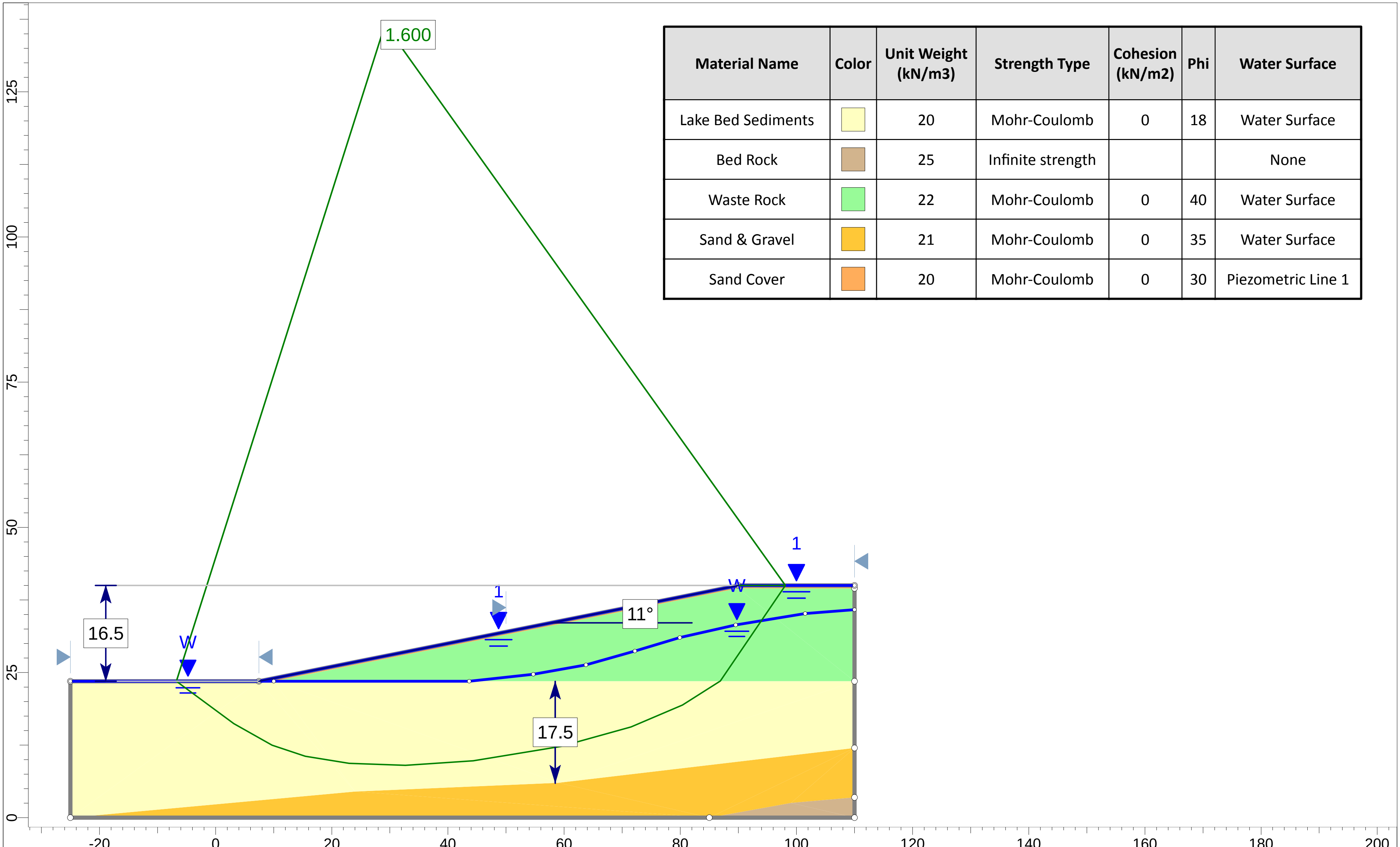
SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	4.4 5.0H:1.0V slope, elevated water table, base case material properties (Long-term Static)		
Drawn By	R Williams	Scale	1:900
Company	SRK Consulting		
Date	6/15/2016, 3:52:16 PM	File Name	4.4.slim

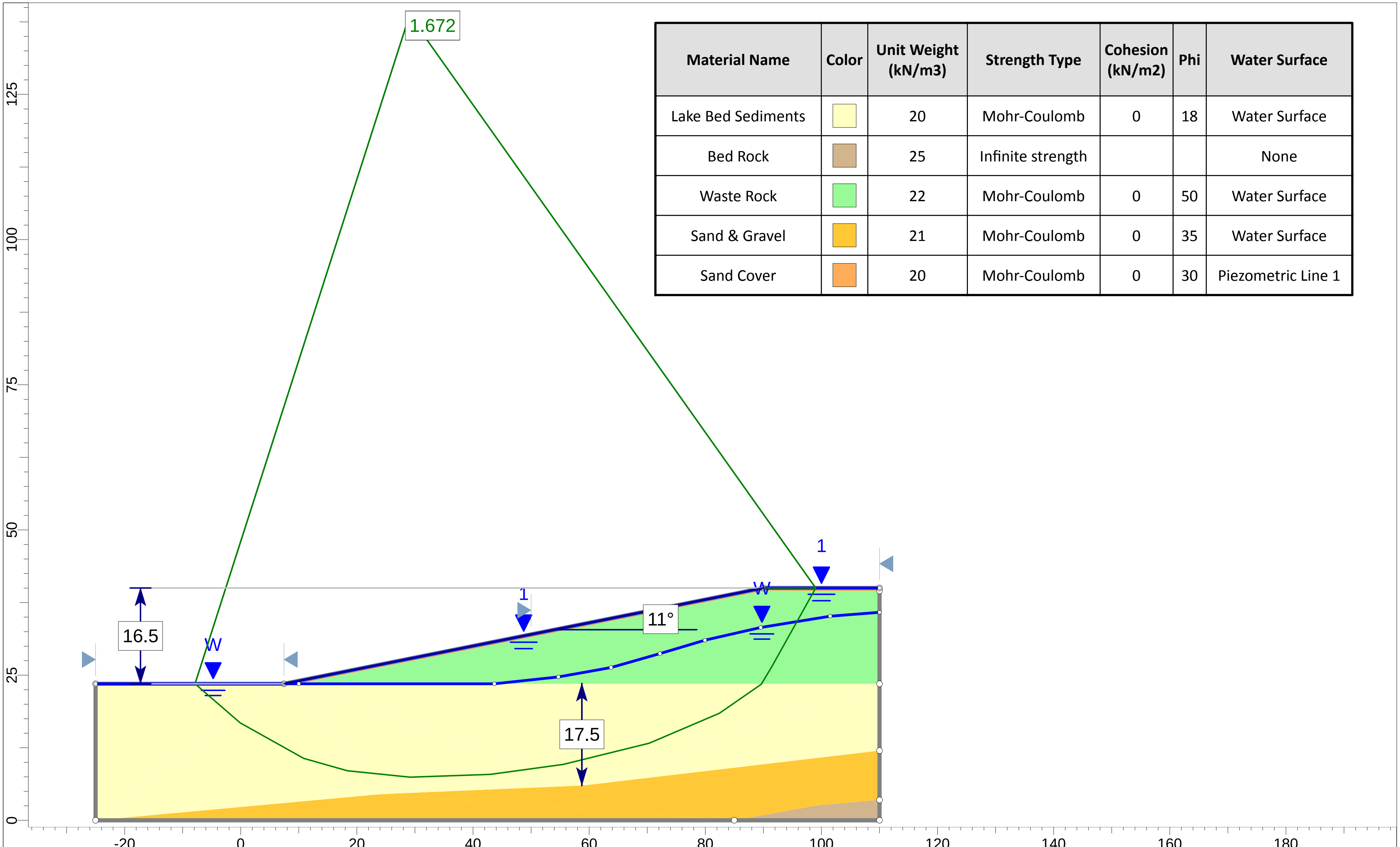
SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	40	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.5 5.0H:1.0V slope, elevated water table, waste rock φ′ = 40° (lower bound sensitivity check) (Long-term Static)
Drawn By	R Williams
Scale	1:900
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.5.slim

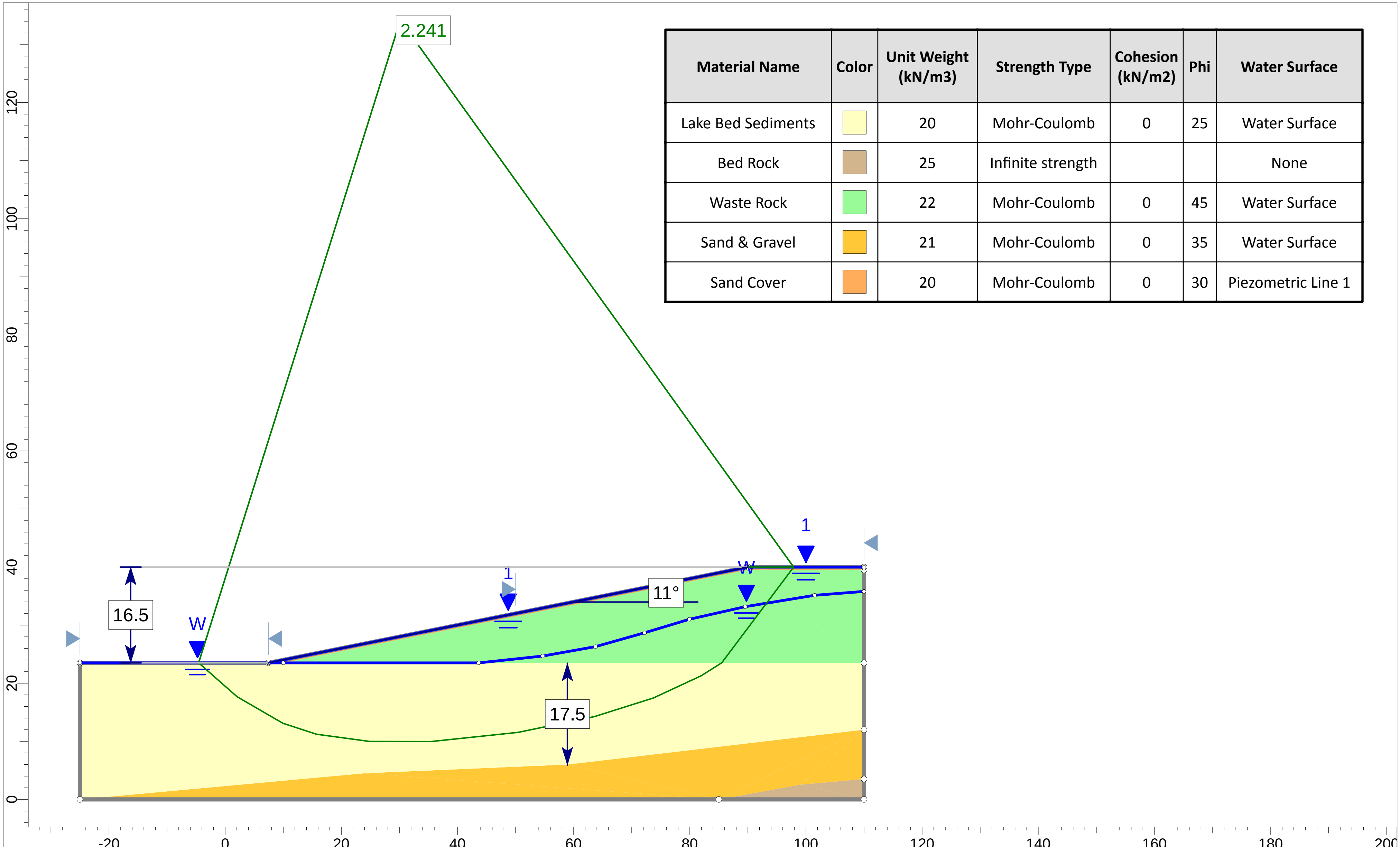
SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

SLIDEINTERPRET 6.014

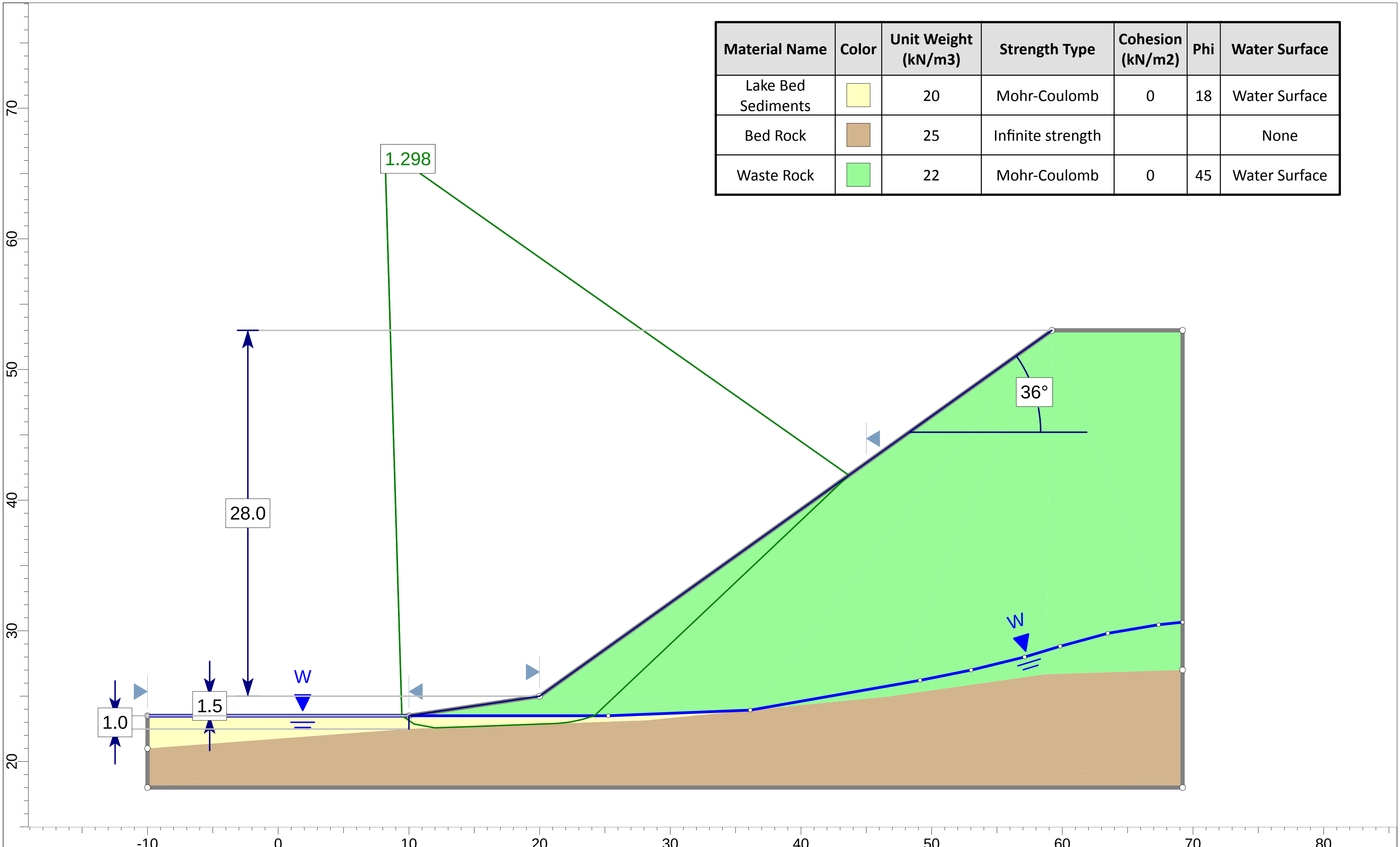
Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.6 5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check) (Long-term Static)
Drawn By	R Williams
Scale	1:900
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.6.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	25	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.7 5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check) (Long-term Static)
Drawn By	R Williams
Scale	1:900
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.7.slim

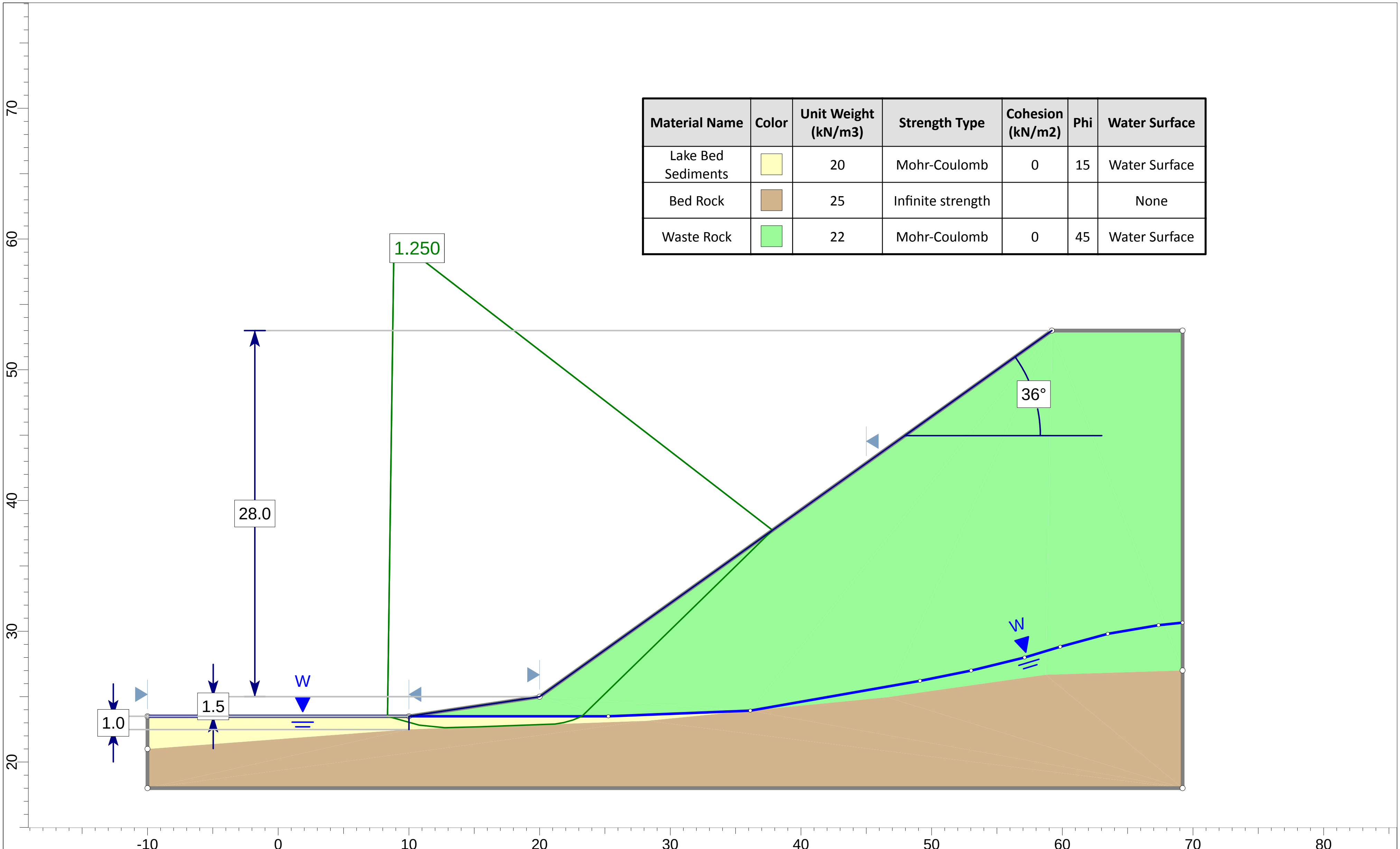
SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface

SLIDEINTERPRET 6.014

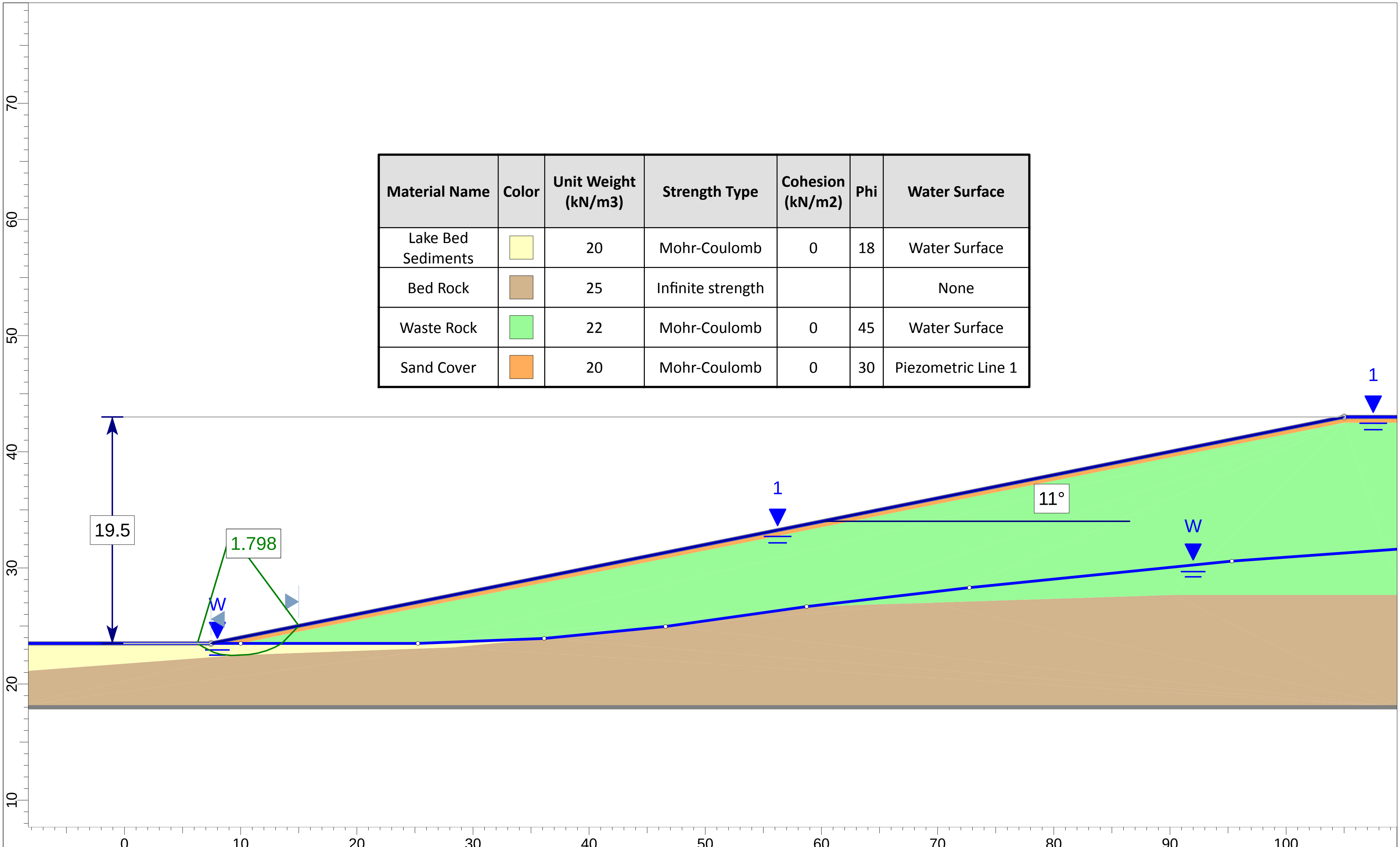
Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.1 Current slope, base case material properties (Long-term Static)		
Drawn By	R Williams	*Scale* 1:400	*Company* SRK Consulting
Date	6/15/2016, 3:52:16 PM		*File Name* 5.1.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	15	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface

Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.2 Current slope, LBS ϕ' = 15° (lower bound sensitivity check) (Long-term Static)		
Drawn By	R Williams	*Scale*	1:400
Company	SRK Consulting		
Date	6/15/2016, 3:52:16 PM	*File Name*	5.2.slim

SLIDEINTERPRET 6.014

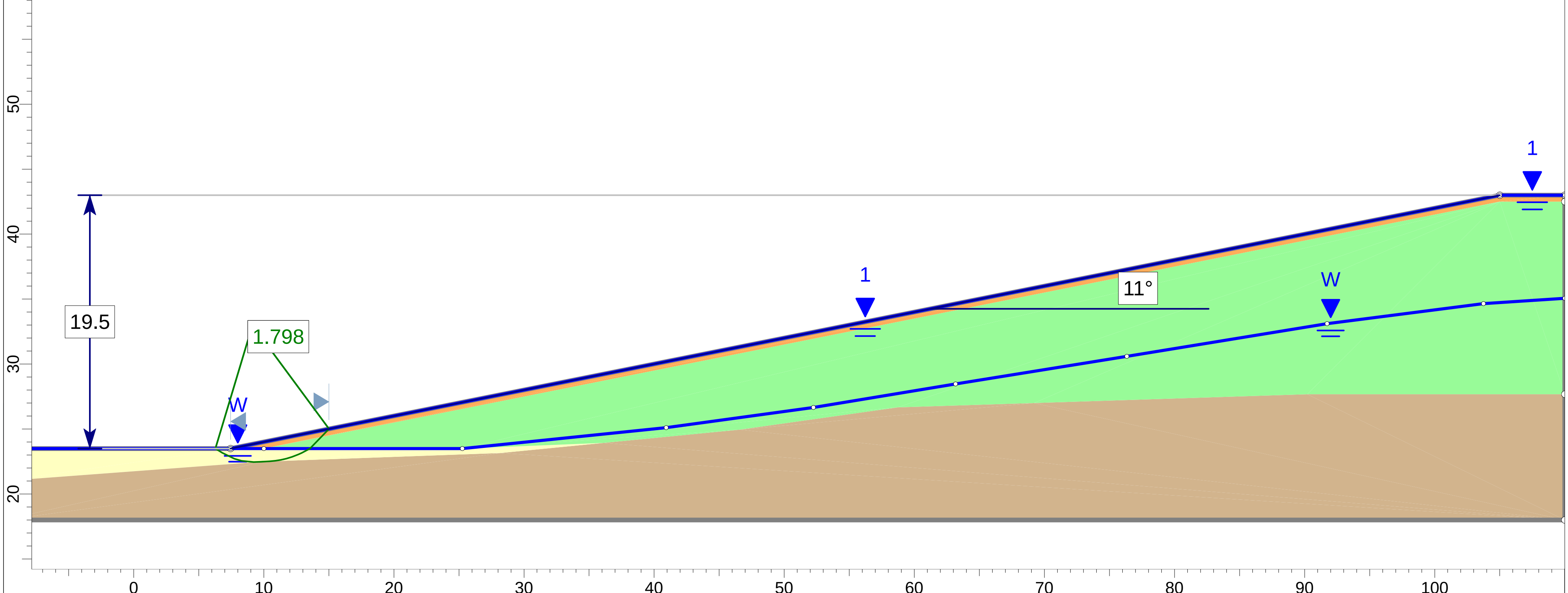


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	5.3 5.0H:1.0V slope, depressed water table, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:450
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	5.3.slim

SLIDEINTERPRET 6.014

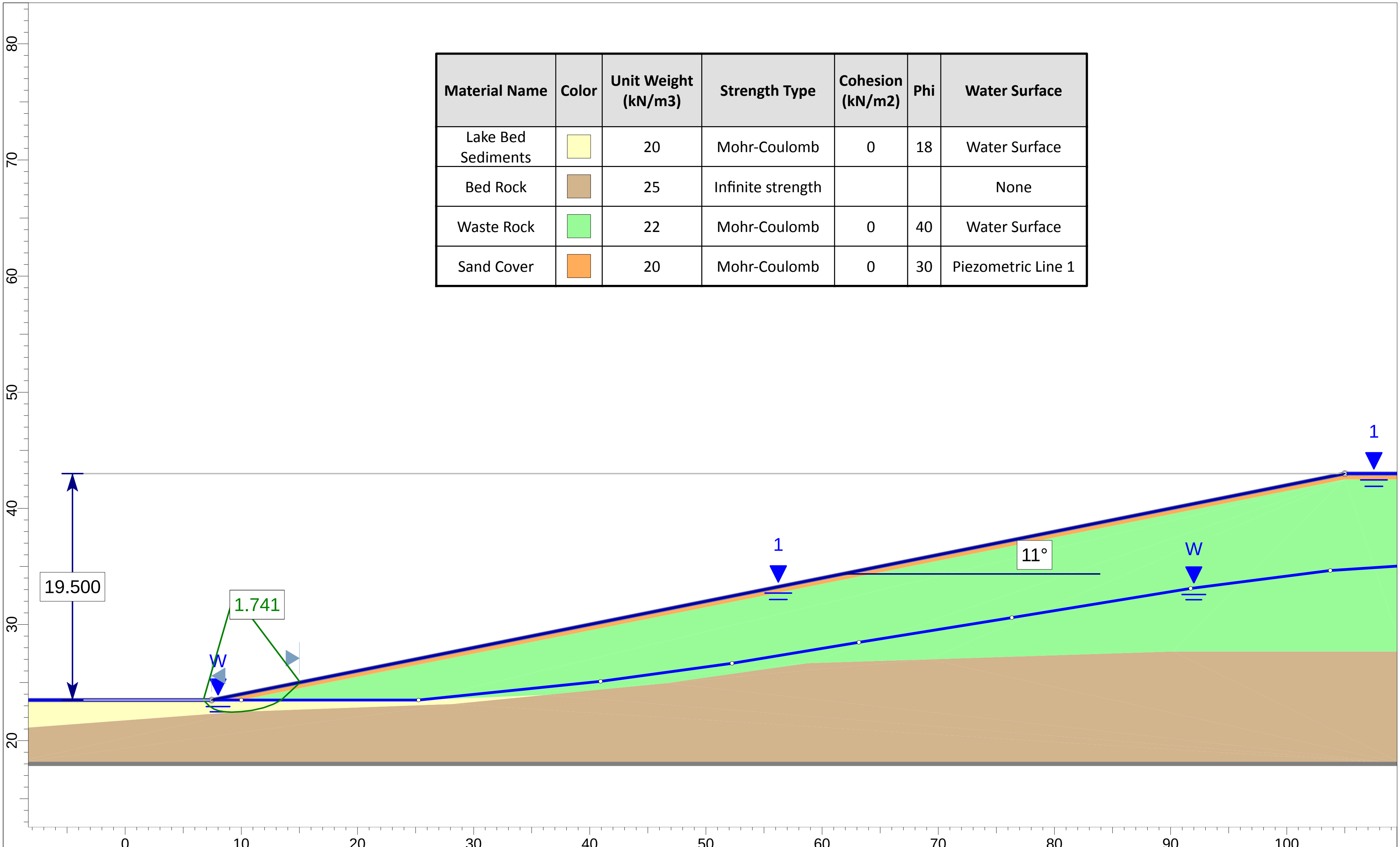
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1



Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.4 5.0H:1.0V slope, elevated water table, base case material properties (Long-term Static)		
Drawn By	R Williams	*Scale*	1:450
Company	SRK Consulting		
Date	6/15/2016, 3:52:16 PM	*File Name*	5.4.slim

rocscience

SLIDEINTERPRET 6.014

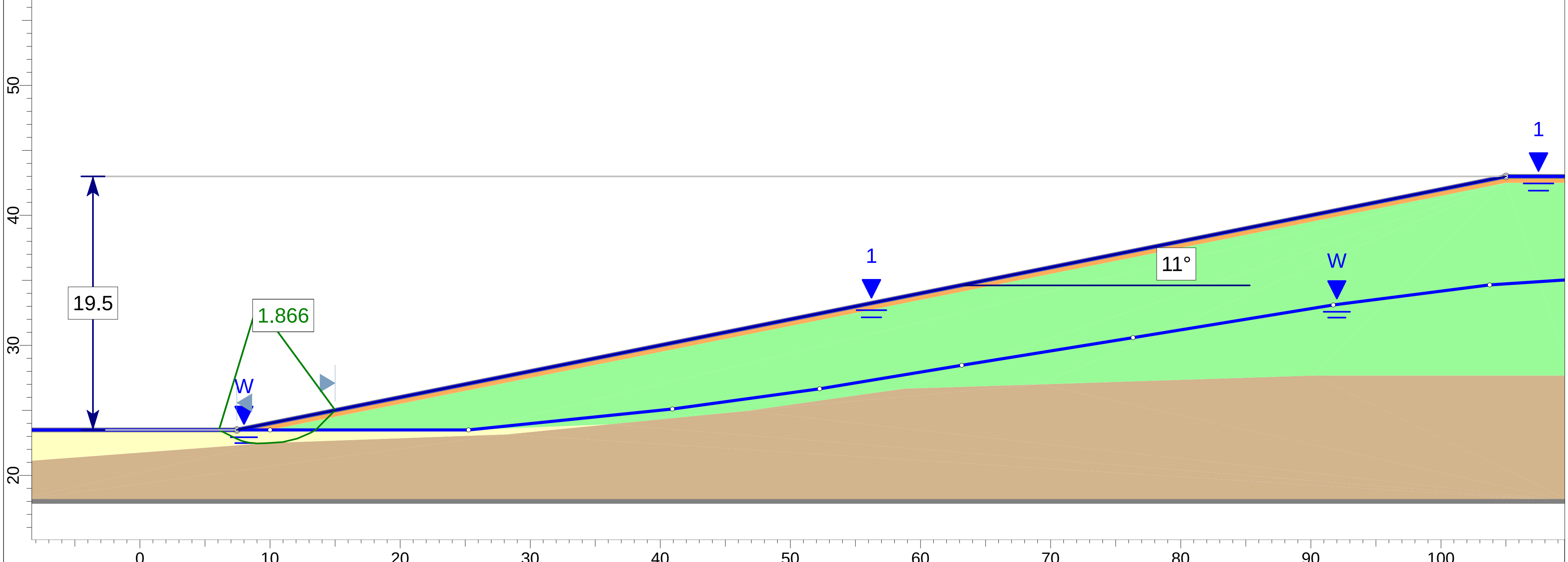


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	40	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.5 5.0H:1.0V slope, elevated water table, waste rock ϕ′ = 40° (lower bound sensitivity check)		
Drawn By	R Williams	*Scale*	1:450
Company	SRK Consulting		
Date	6/15/2016, 3:52:16 PM	*File Name*	5.5.slim

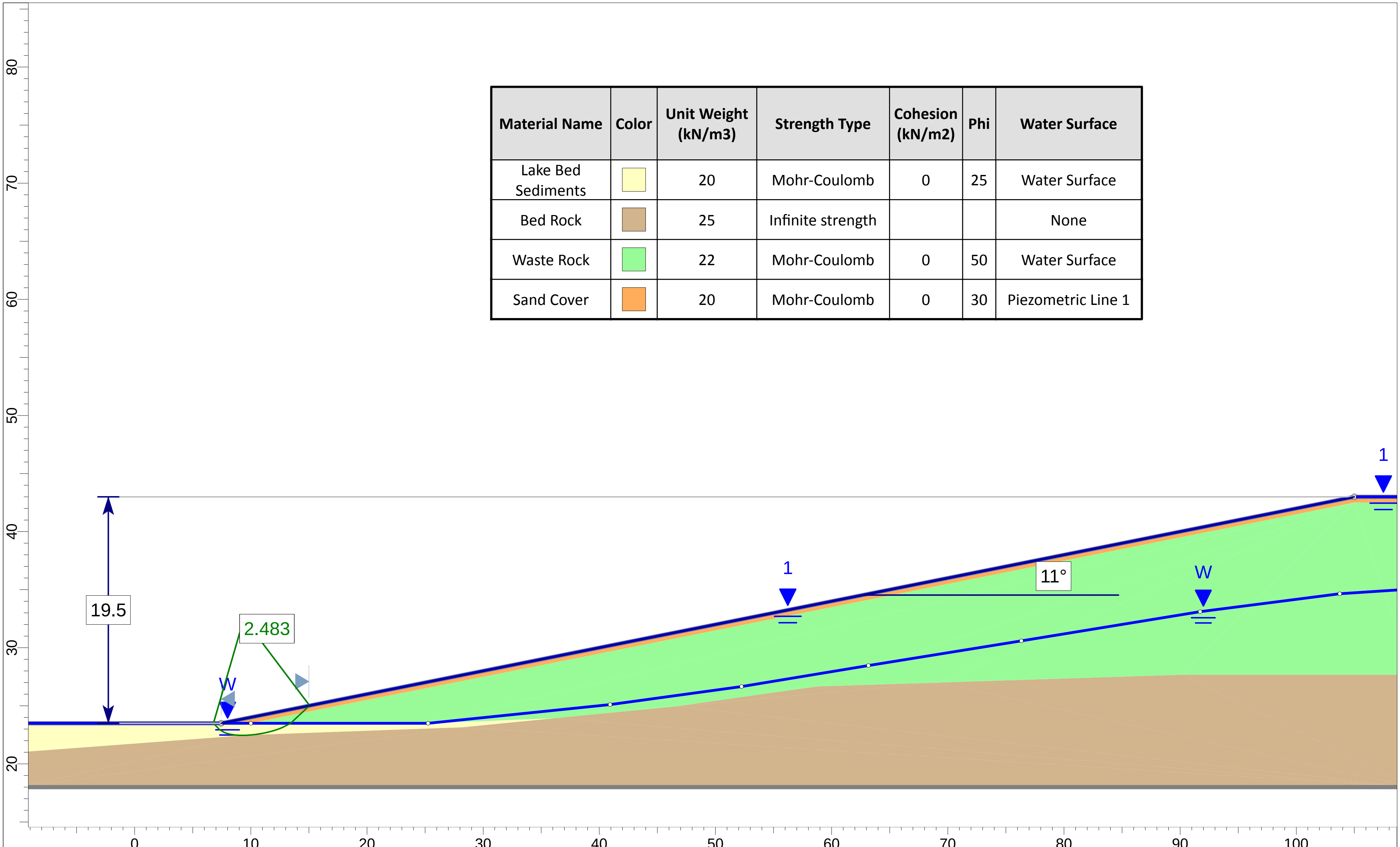
SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1



Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	5.6 5.0H:1.0V slope, elevated water table, waste rock $\phi' = 50°$ (upper bound sensitivity check) (Long-term Static)
Drawn By	R Williams
Scale	1:450
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	5.6.slim

SLIDEINTERPRET 6.014

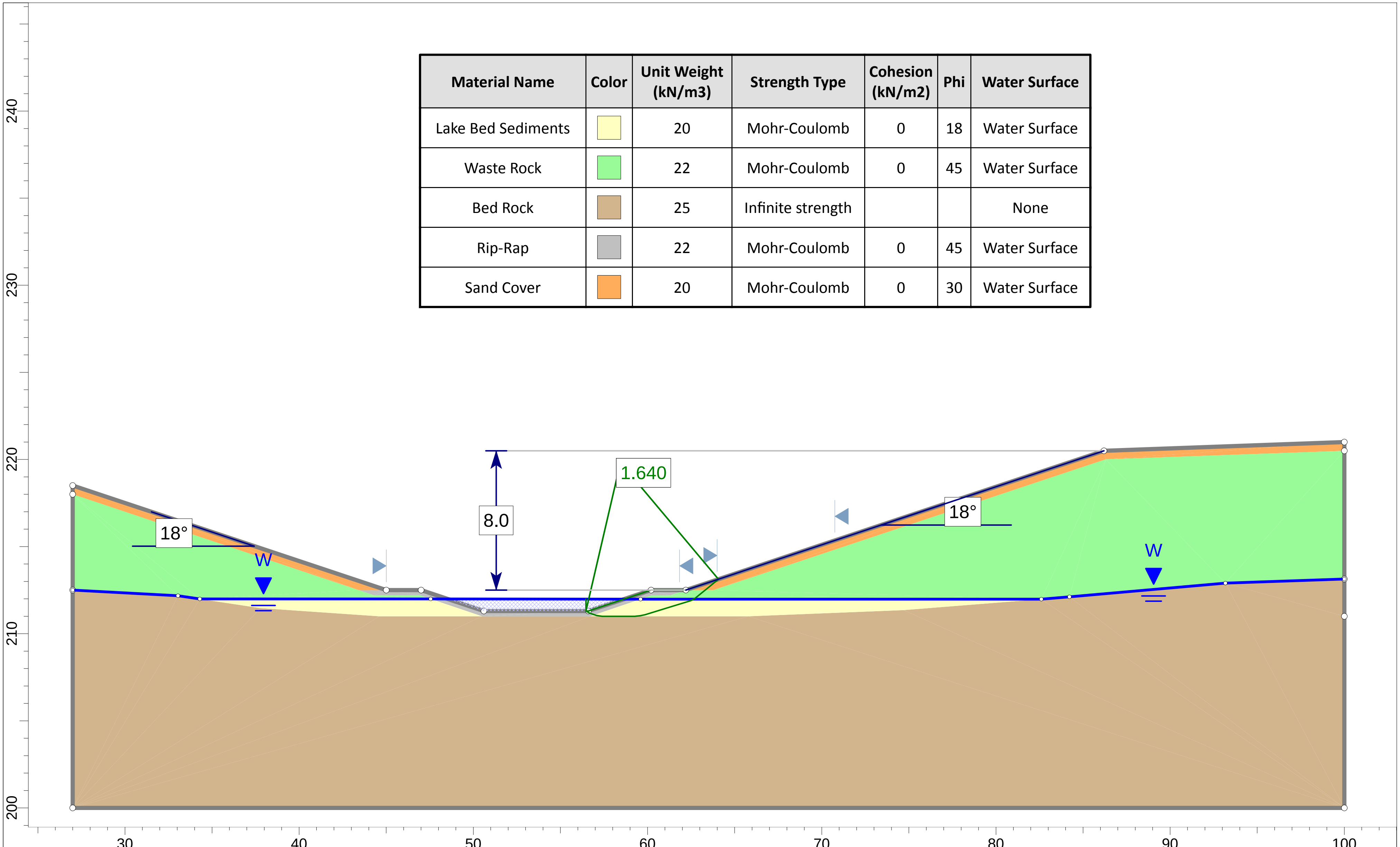


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	25	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

SLIDEINTERPRET 6.014

Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.7 5.0H:1.0V slope, elevated water table, LBS ϕ' = 25° (upper bound sensitivity check) (Long-term Static)		
Drawn By	R Williams	*Scale* 1:450	*Company* SRK Consulting
Date	6/15/2016, 3:52:16 PM	*File Name*	5.7.slim

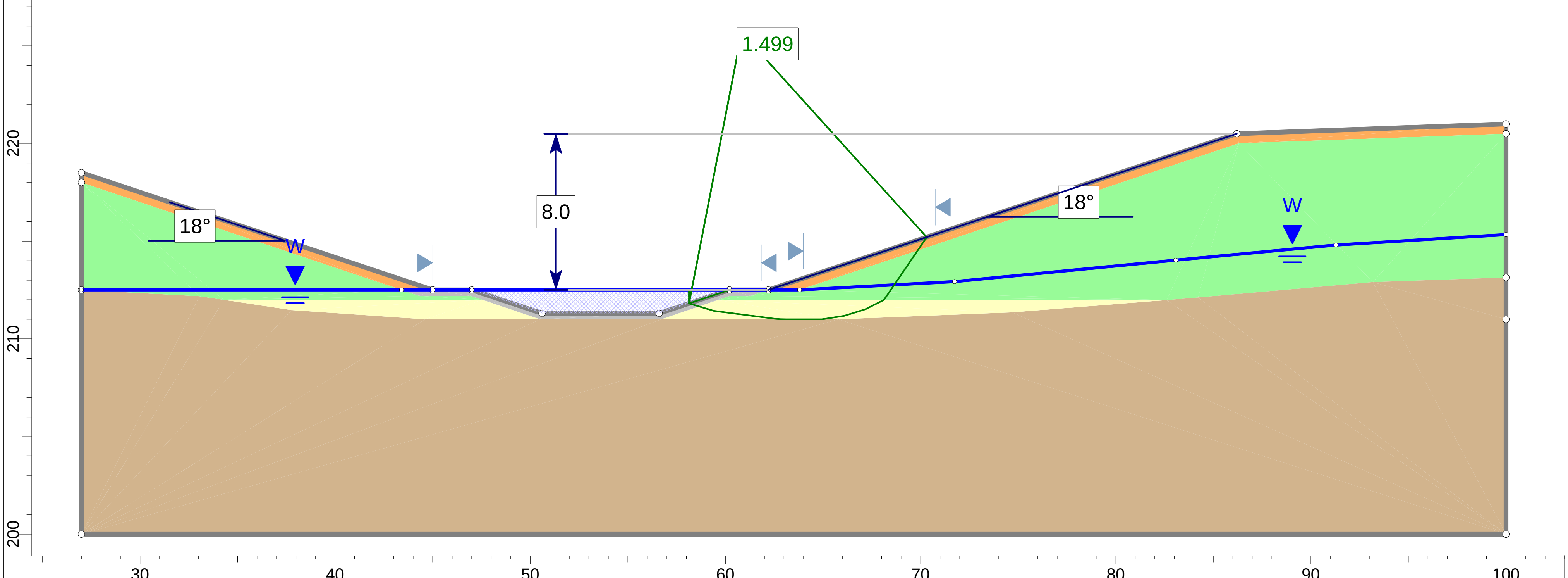
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface



SLIDEINTERPRET 6.014

Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)
Analysis Description	6.1 3.0H:1.0V slope, base case material properties (Long-term Static)
Drawn By	R Williams
Scale	1:300
Company	SRK Consulting
Date	7/6/2016, 7:52:10 PM
File Name	Surface Water Channel - 6.1.slim

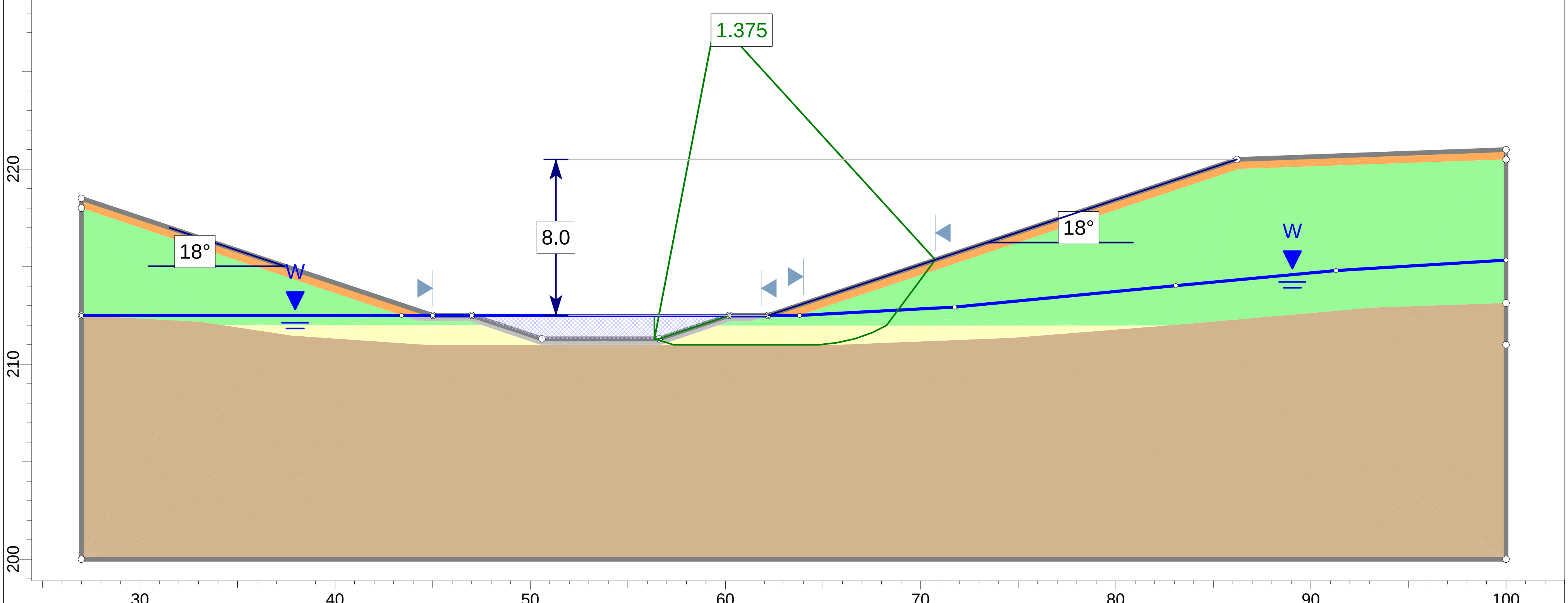
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface



Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)		
Analysis Description	6.2 3.0H:1.0V slope, elevated water table, base case material properties (Long-term Static)		
Drawn By R Williams	*Scale* 1:300	*Company*	SRK Consulting
Date	7/6/2016, 7:52:10 PM	*File Name*	Surface Water Channel - 6.2.slim

SLIDEINTERPRET 6.014

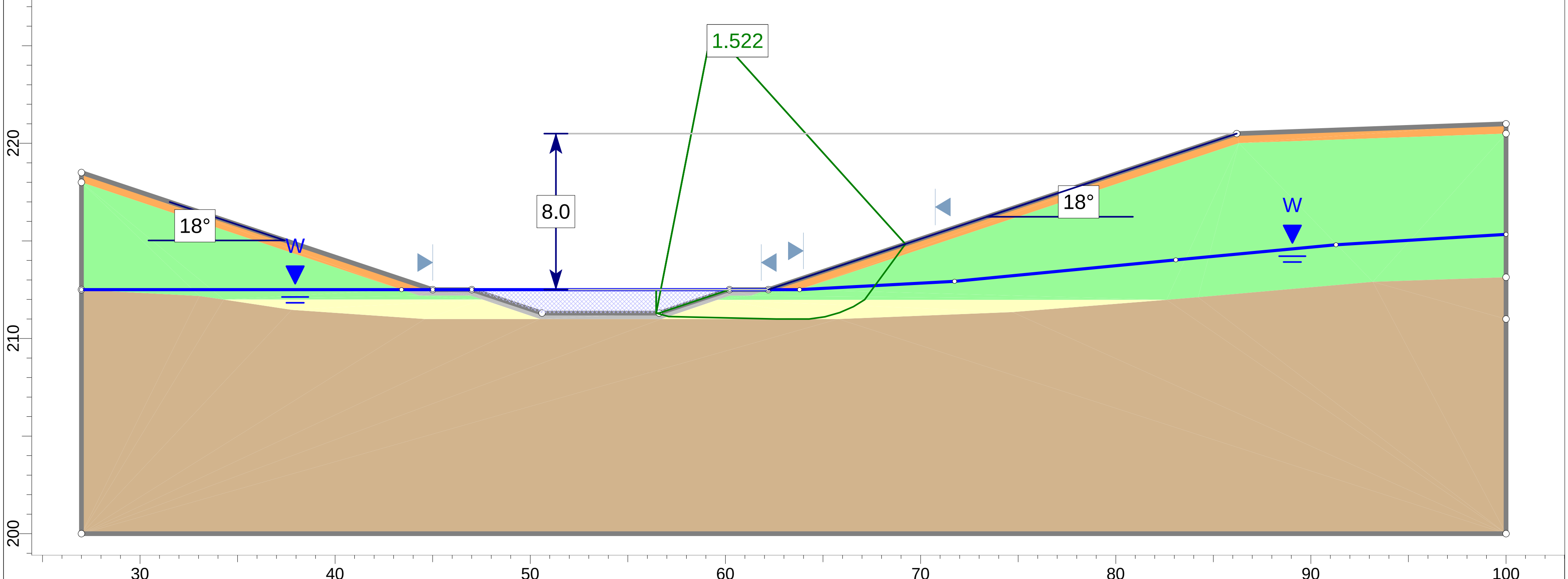
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	40	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface



Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)
Analysis Description	6.3 3.0H:1.0V slope, elevated water table, waste rock $\phi' = 40°$ (lower bound sensitivity check) (Long-term Static)
Drawn By	R Williams
Scale	1:300
Company	SRK Consulting
Date	7/6/2016, 7:52:10 PM
File Name	Surface Water Channel - 6.3.slim

SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface



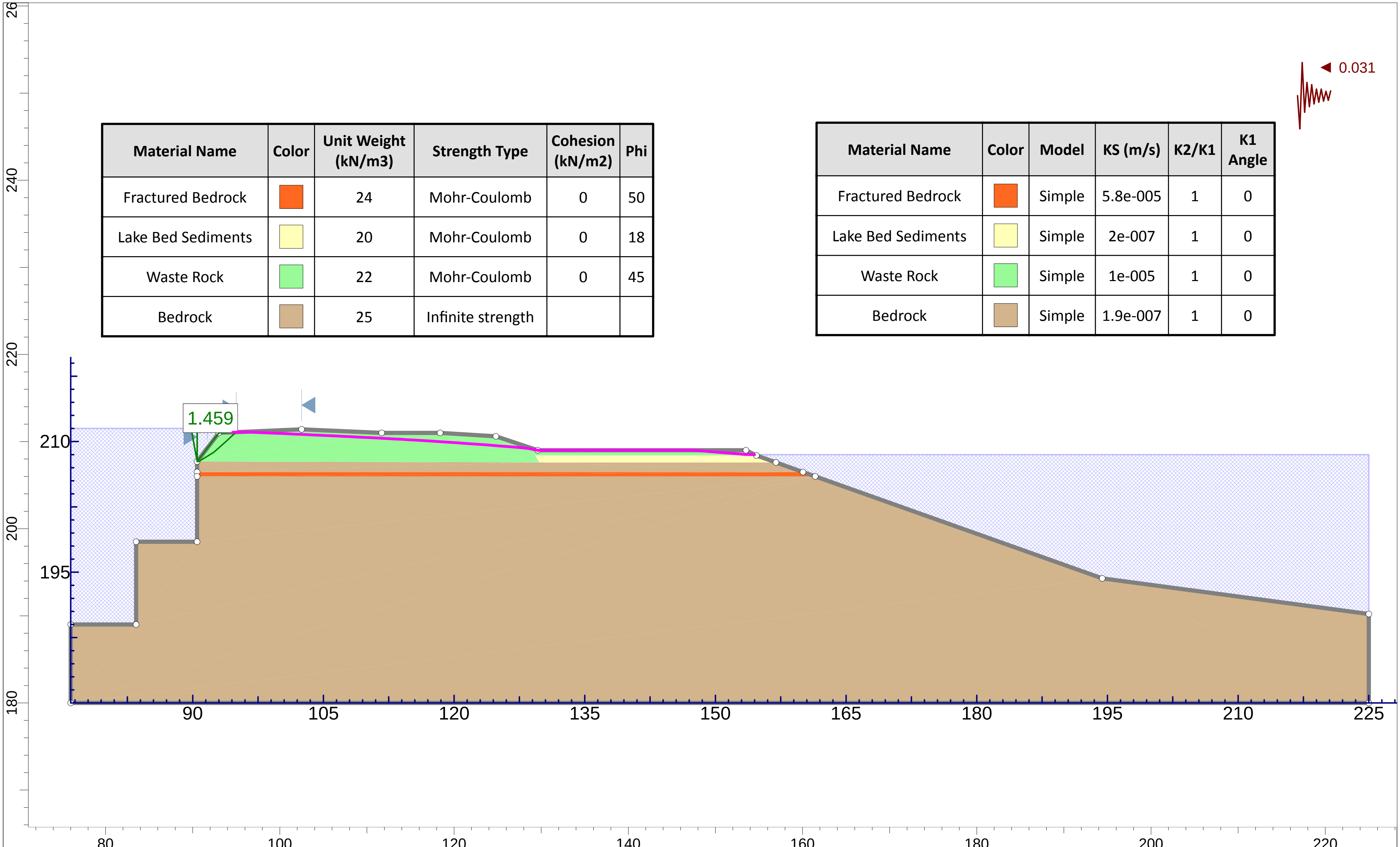
Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)		
Analysis Description	6.4 3.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check) (Long-term Static)		
Drawn By	R Williams	*Scale* 1:300	*Company* SRK Consulting
Date	7/6/2016, 7:52:10 PM		*File Name* Surface Water Channel - 6.4.slim

SLIDEINTERPRET 6.014

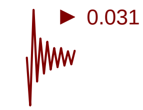
Attachment 3: Seismic Stability Results

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	45
Bedrock		25	Infinite strength		

Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0

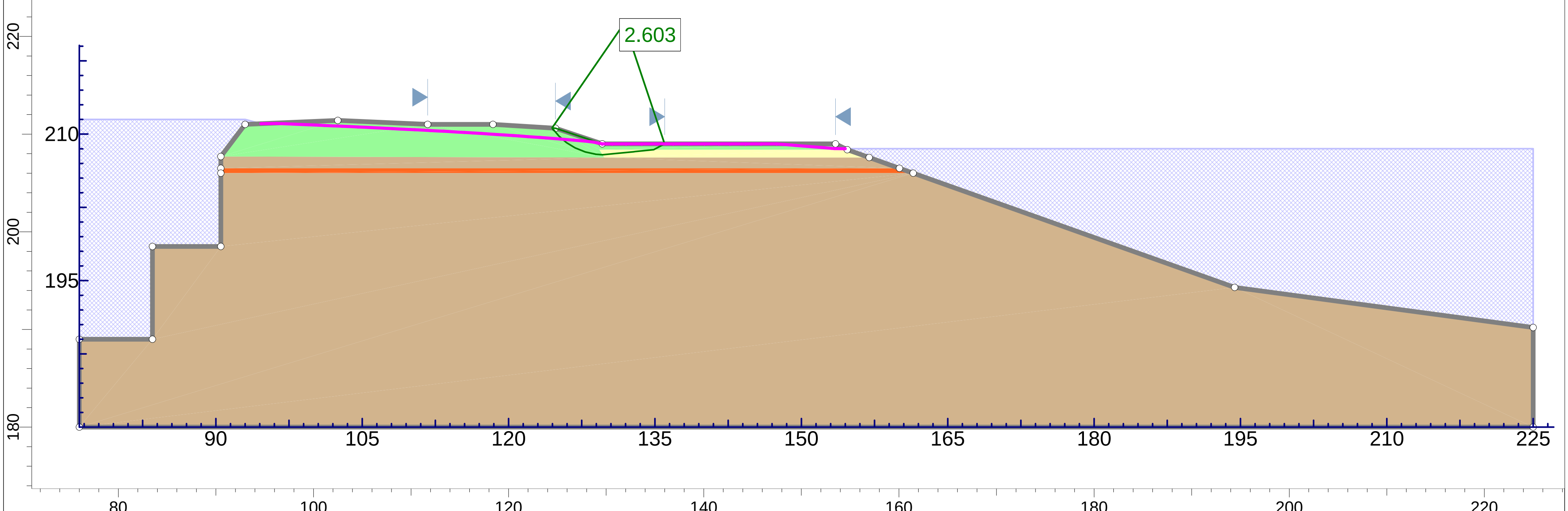


	Project Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)		
	Analysis Description 1.1 Elevated pit lake, base case material properties, upstream slope (Pseudo-static - PGA = 0.031)		
	Drawn By R Williams	*Scale* 1:600	*Company* SRK Consulting
SLIDEINTERPRET 6.014	*Date* 6/21/2016, 8:36:03 AM		*File Name* 1.1 - Seismic.slim



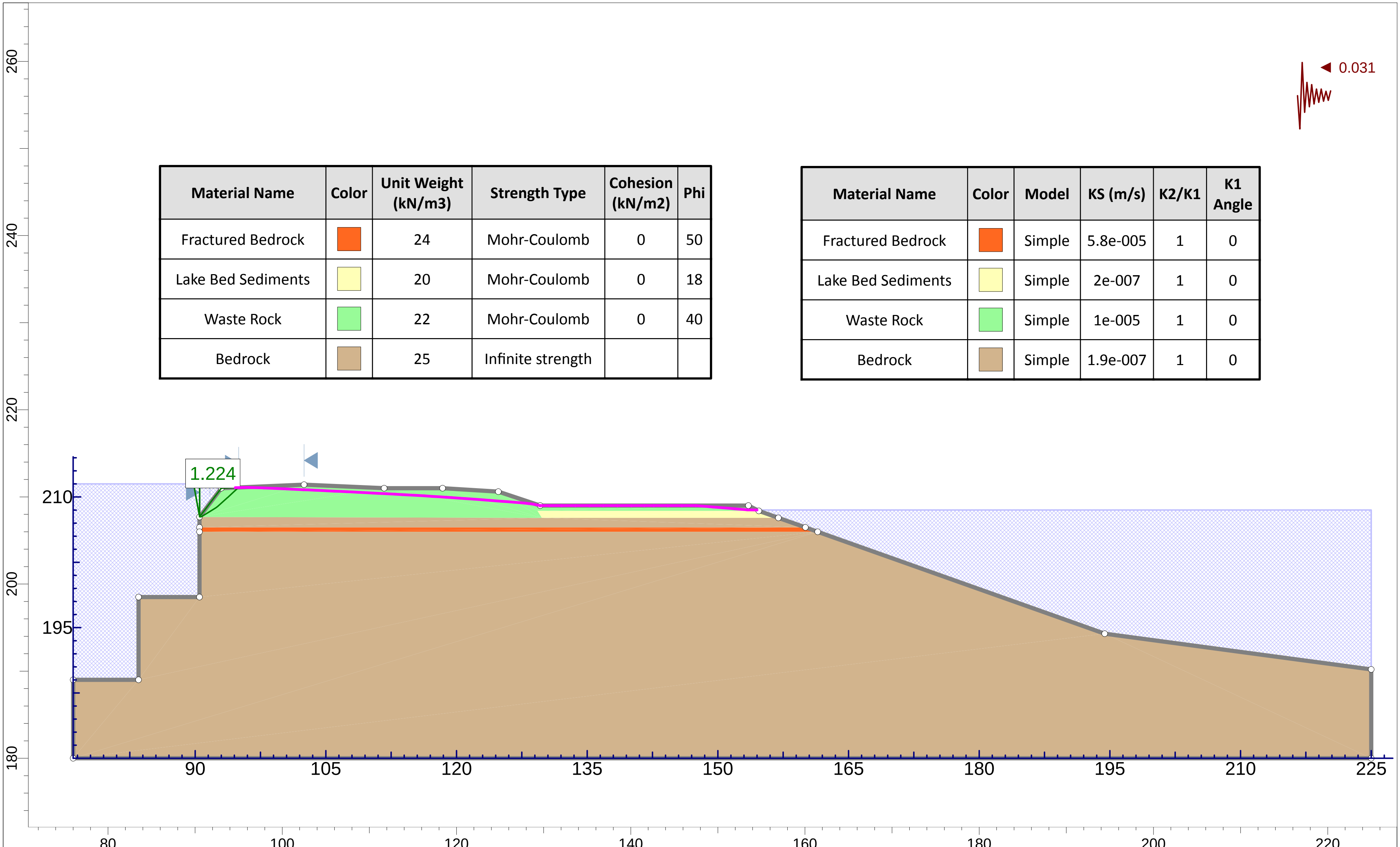
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	45
Bedrock		25	Infinite strength		

Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0



Project	Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)
Analysis Description	1.2 Elevated pit lake, base case material properties, downstream slope (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:600
Company	SRK Consulting
Date	6/21/2016, 8:36:03 AM
File Name	1.2 - Seismic.slim

SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	40
Bedrock		25	Infinite strength		

Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0

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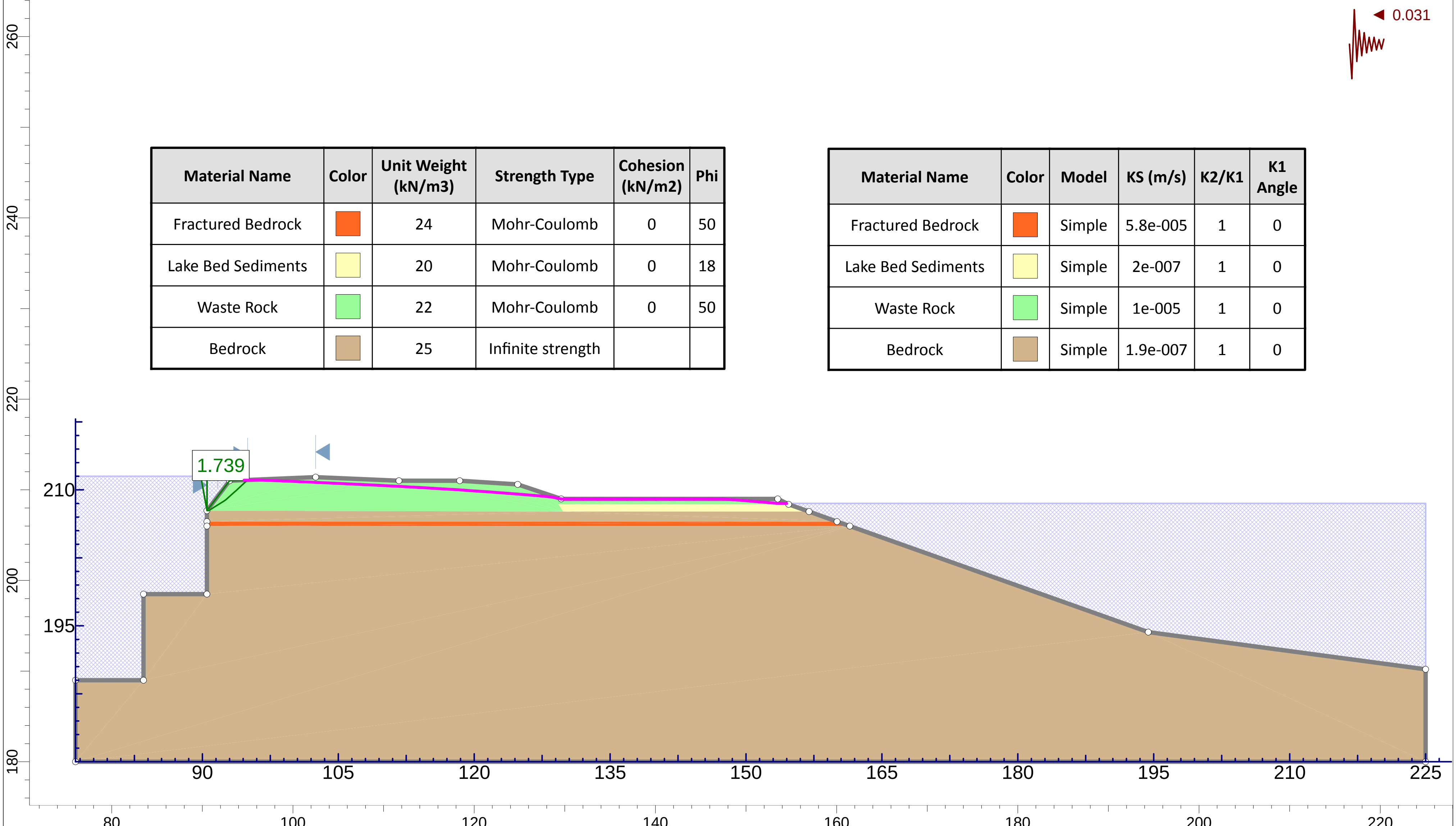
Project	Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)		
Analysis Description	1.3 Elevated pit lake, critical slope, waste rock ϕ' = 40° (lower bound sensitivity check) (Pseudo-static - PGA = 0.031)		
Drawn By R Williams	*Scale* 1:600	*Company*	SRK Consulting
Date	6/21/2016, 8:36:03 AM	*File Name*	1.3 - Seismic.slim

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Fractured Bedrock		24	Mohr-Coulomb	0	50
Lake Bed Sediments		20	Mohr-Coulomb	0	18
Waste Rock		22	Mohr-Coulomb	0	50
Bedrock		25	Infinite strength		

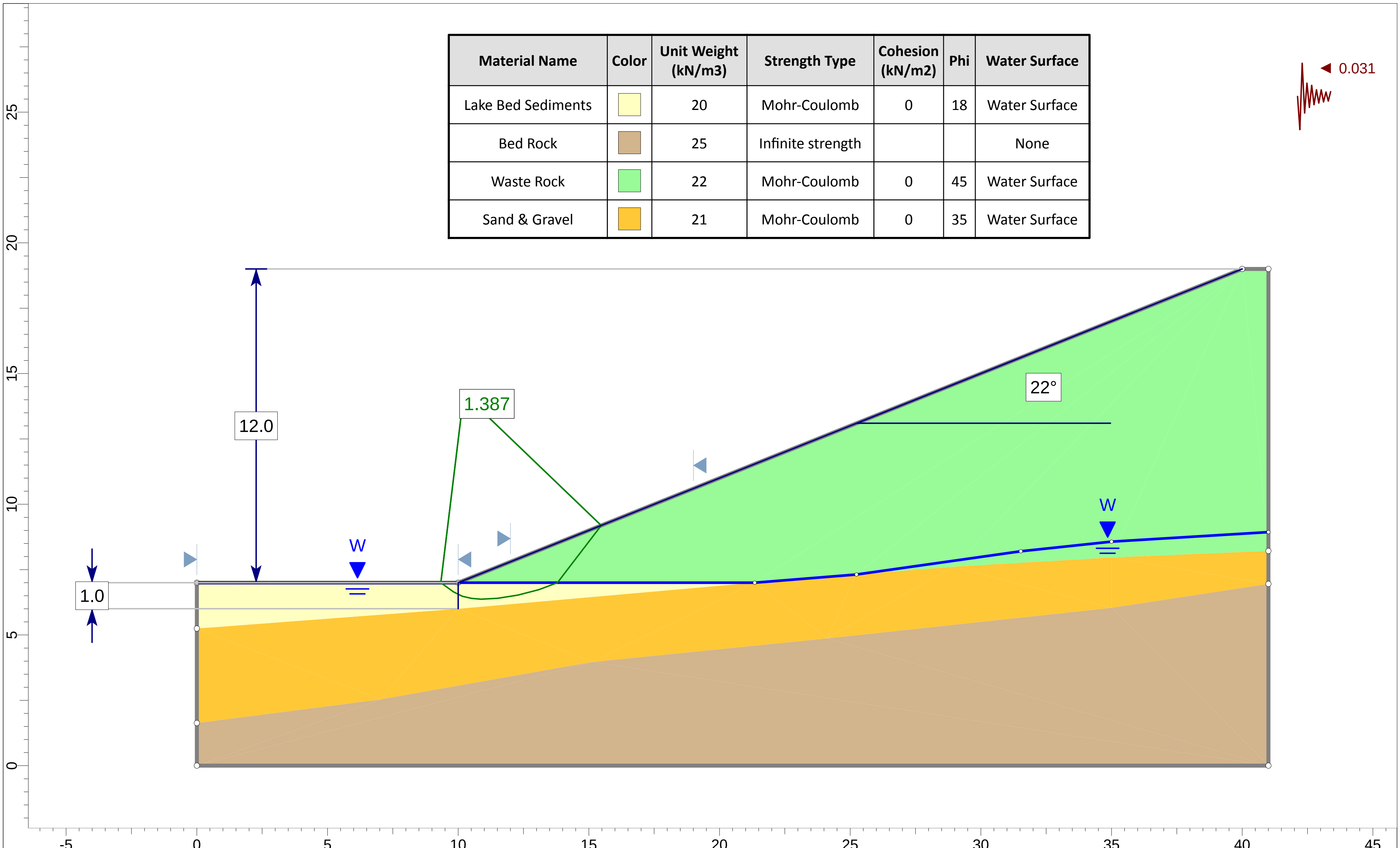
Material Name	Color	Model	KS (m/s)	K2/K1	K1 Angle
Fractured Bedrock		Simple	5.8e-005	1	0
Lake Bed Sediments		Simple	2e-007	1	0
Waste Rock		Simple	1e-005	1	0
Bedrock		Simple	1.9e-007	1	0



Project	Model 1 - Gunnar Open Pit Waste Rock Plug (Gunnar Mine Site Remediation Project)
Analysis Description	1.4 Elevated pit lake, critical slope, waste rock ϕ' = 50° (upper bound sensitivity check) (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:600
Company	SRK Consulting
Date	6/21/2016, 8:36:03 AM
File Name	1.4 - Seismic.slim

SLIDEINTERPRET 6.014

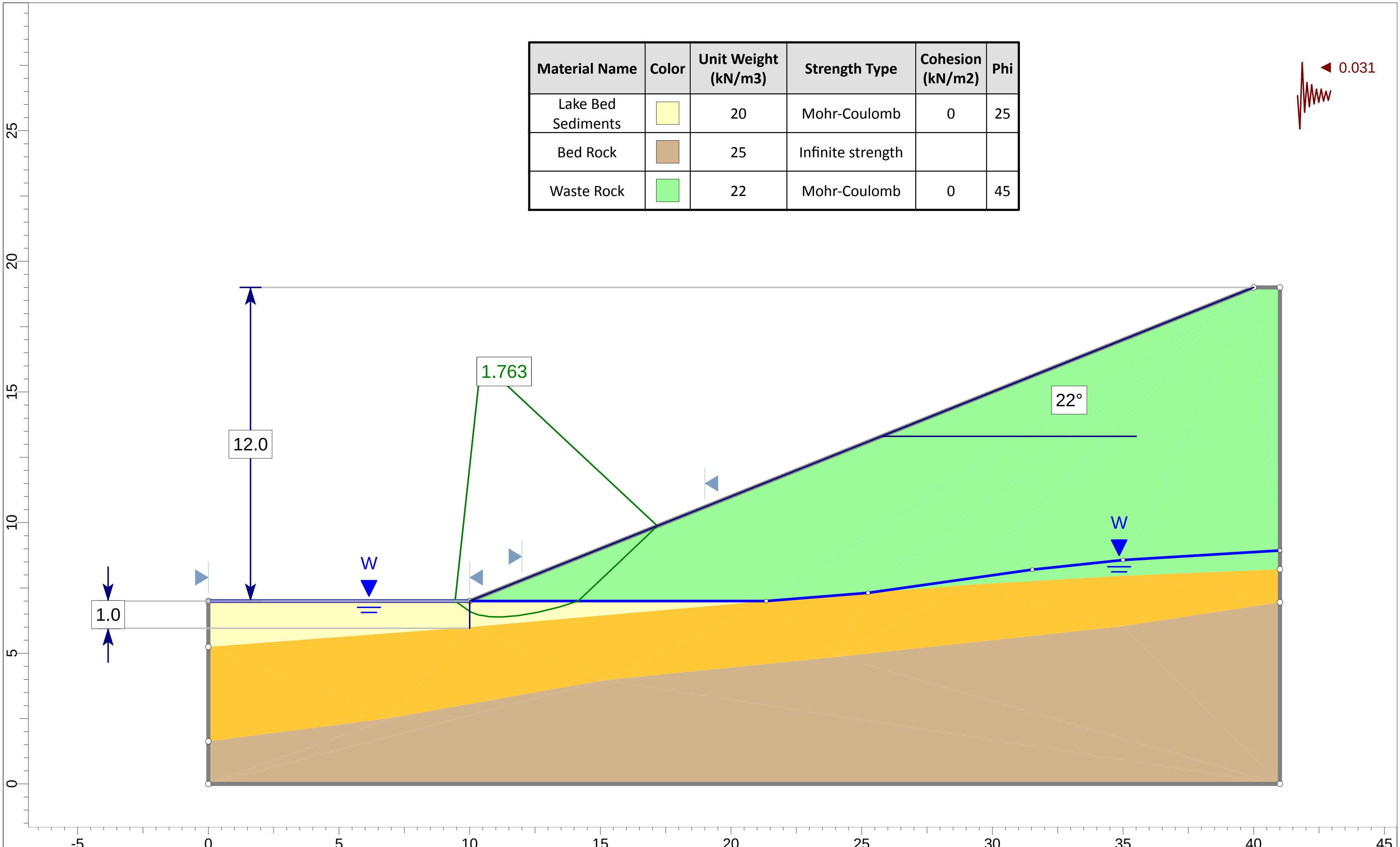
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface



Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project)
Analysis Description	2.4 2.5H:1.0V slope, 1 m thick LBS foundation, base case material properties (Pseudo-static - PGA = 0.031
Drawn By	R Williams
Scale	1:200
Company	SRK Consulting
Date	6/15/2016, 1:00:13 PM
File Name	2.5 - Seismic.slim

SLIDEINTERPRET 6.014

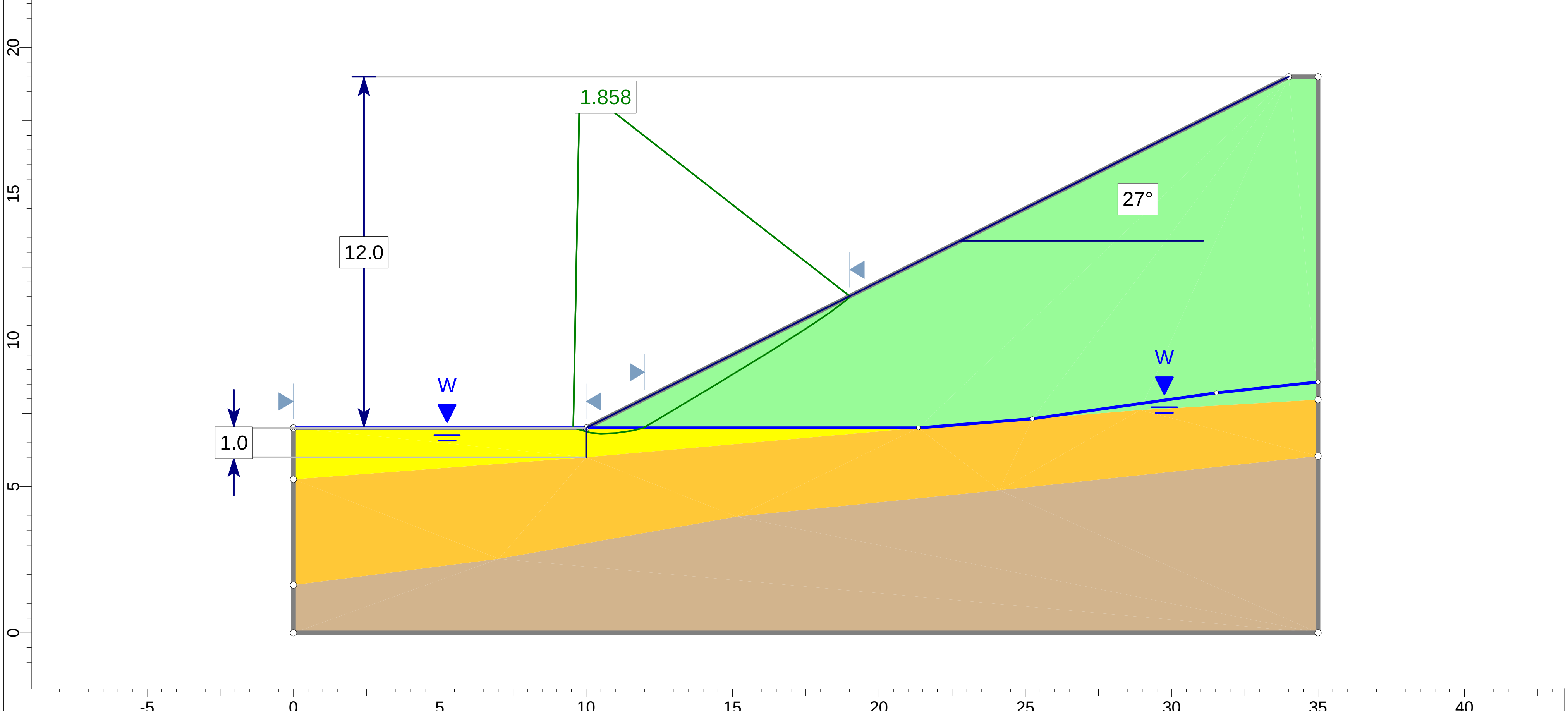
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Lake Bed Sediments		20	Mohr-Coulomb	0	25
Bed Rock		25	Infinite strength		
Waste Rock		22	Mohr-Coulomb	0	45



Project	Model 2 - Shoreline Waste Rock Piles – Fuel Farm Area (Gunnar Mine Site Remediation Project)		
Analysis Description	2.5 2.5H:1.0V slope, 1 m thick LBS foundation, LBS ϕ' = 25° (upper bound sensitivity check for LBS) (Pseudo-static - PGA = 0.031)		
Drawn By	R Williams	*Scale*	1:200
Company	SRK Consulting		
Date	6/15/2016, 1:00:13 PM	*File Name*	2.6 - Seismic.slim

SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi
Shoreline Sediements		21	Mohr-Coulomb	0	35
Bed Rock		25	Infinite strength		
Waste Rock		22	Mohr-Coulomb	0	45



Project	Model 3 - Shoreline Waste Rock Piles – Camp Area (Gunnar Mine Site Remediation Project)		
Analysis Description	3.2 2.0H:1.0V slope, 1 m thick shoreline sediments foundation, base case material properties		
Drawn By R Williams	*Scale* 1:200	*Company*	SRK Consulting
Date 6/15/2016, 1:00:13 PM		*File Name*	Camp Area_1V to 2H - 3.2.slim

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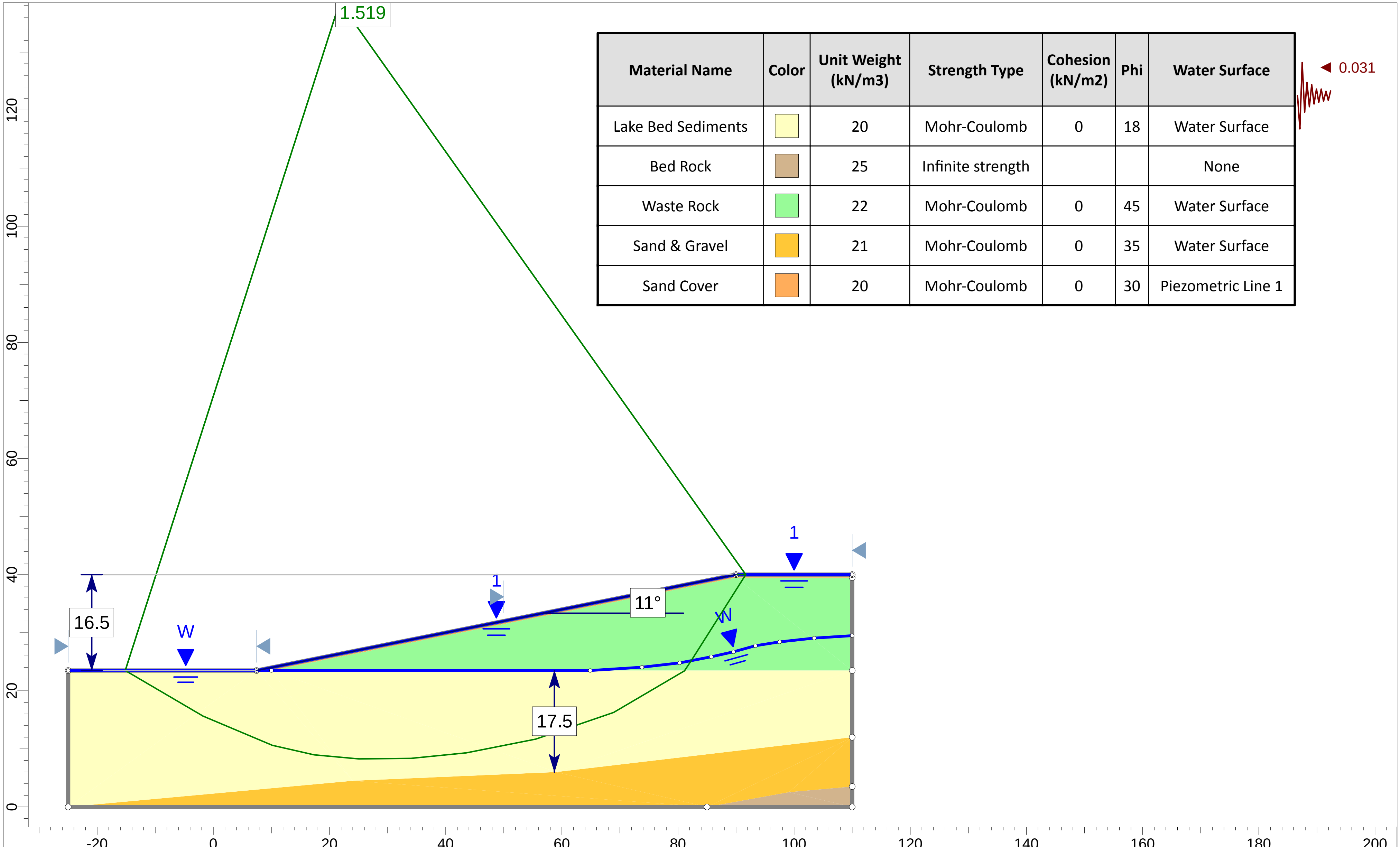
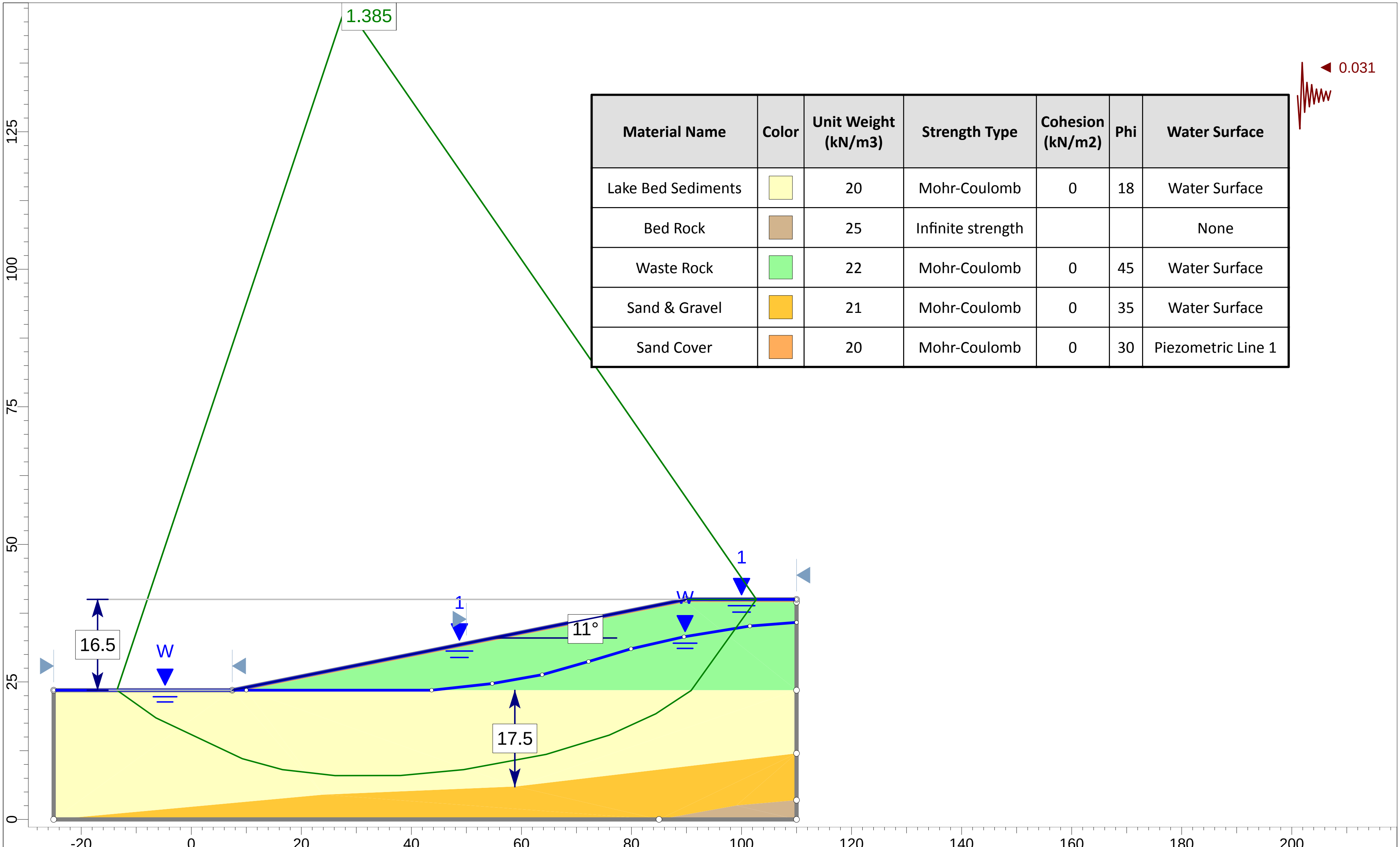


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile(Gunnar Mine Site Remediation Project)		
Analysis Description	4.3 5.0H:1.0V slope, depressed water table, base case material properties (Pseudo-static - PGA = 0.031)		
Drawn By	R Williams	*Scale*	1:900
Company	SRK Consulting		
Date	6/15/2016, 3:52:16 PM	*File Name*	4.3 - Seismic.slim

SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

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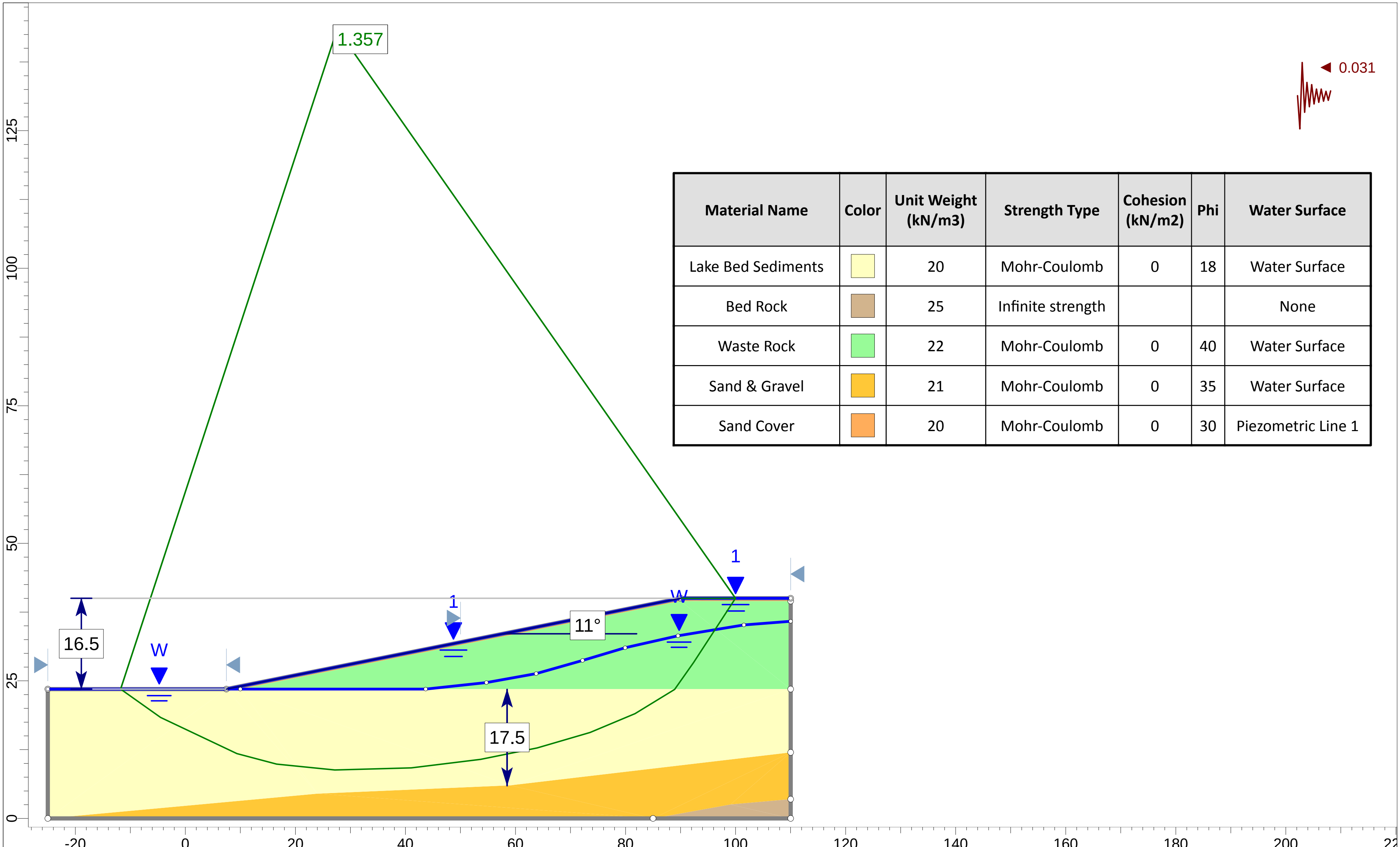
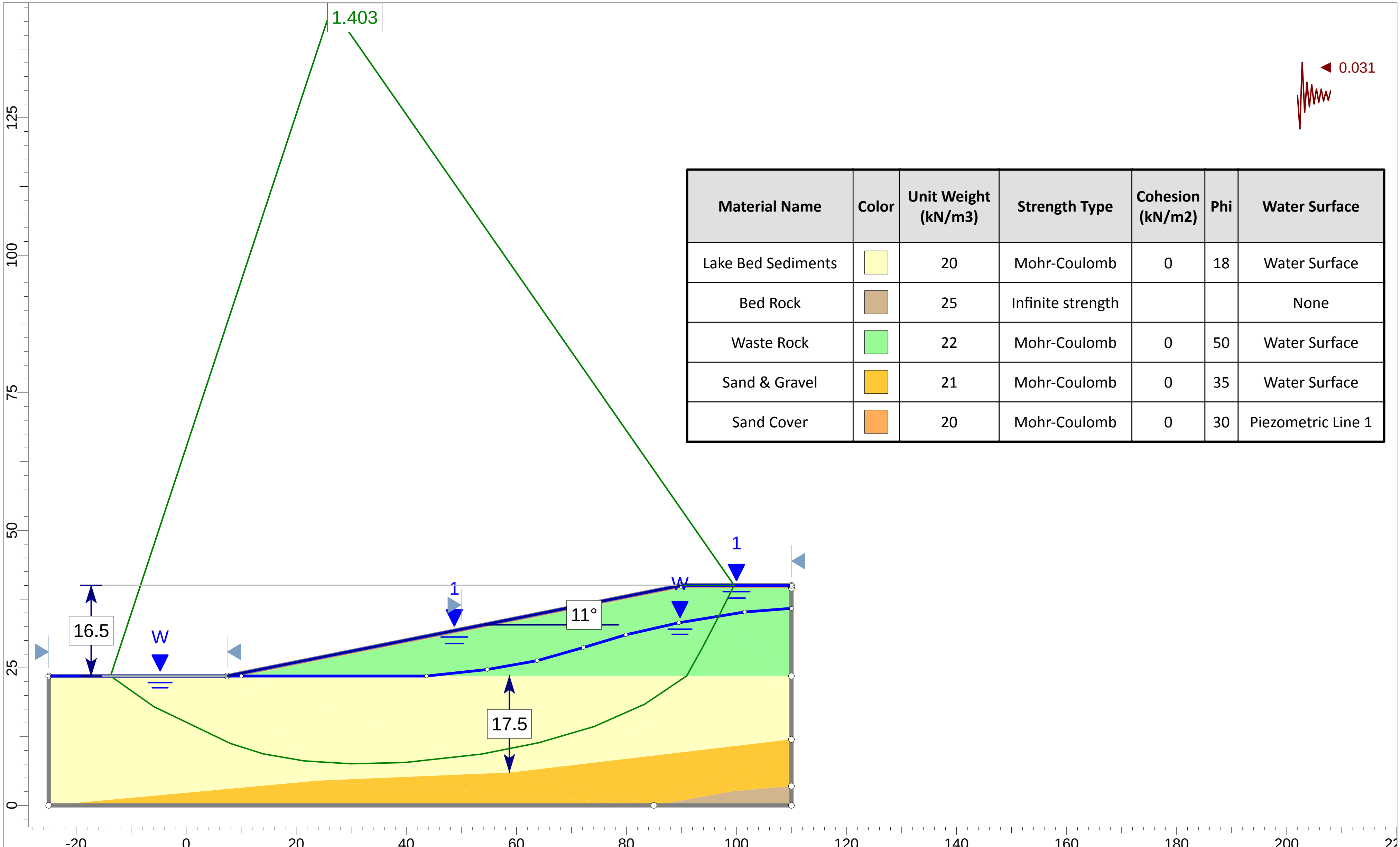
Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.4, 5.0H:1.0V slope, elevated water table, base case material properties (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:950
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.4 - Seismic.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	40	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.5, 5.0H:1.0V slope, elevated water table, waste rock ϕ= 40° (lower bound sensitivity check) (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:950
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.5 - Seismic.slim

SLIDEINTERPRET 6.014



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	4.6 5.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check) (Pseudo-static - PGA = 0.031)		
Drawn By	R Williams	*Scale*	1:950
Company	SRK Consulting		
Date	6/15/2016, 3:52:16 PM	*File Name*	4.6 - Seismic.slim

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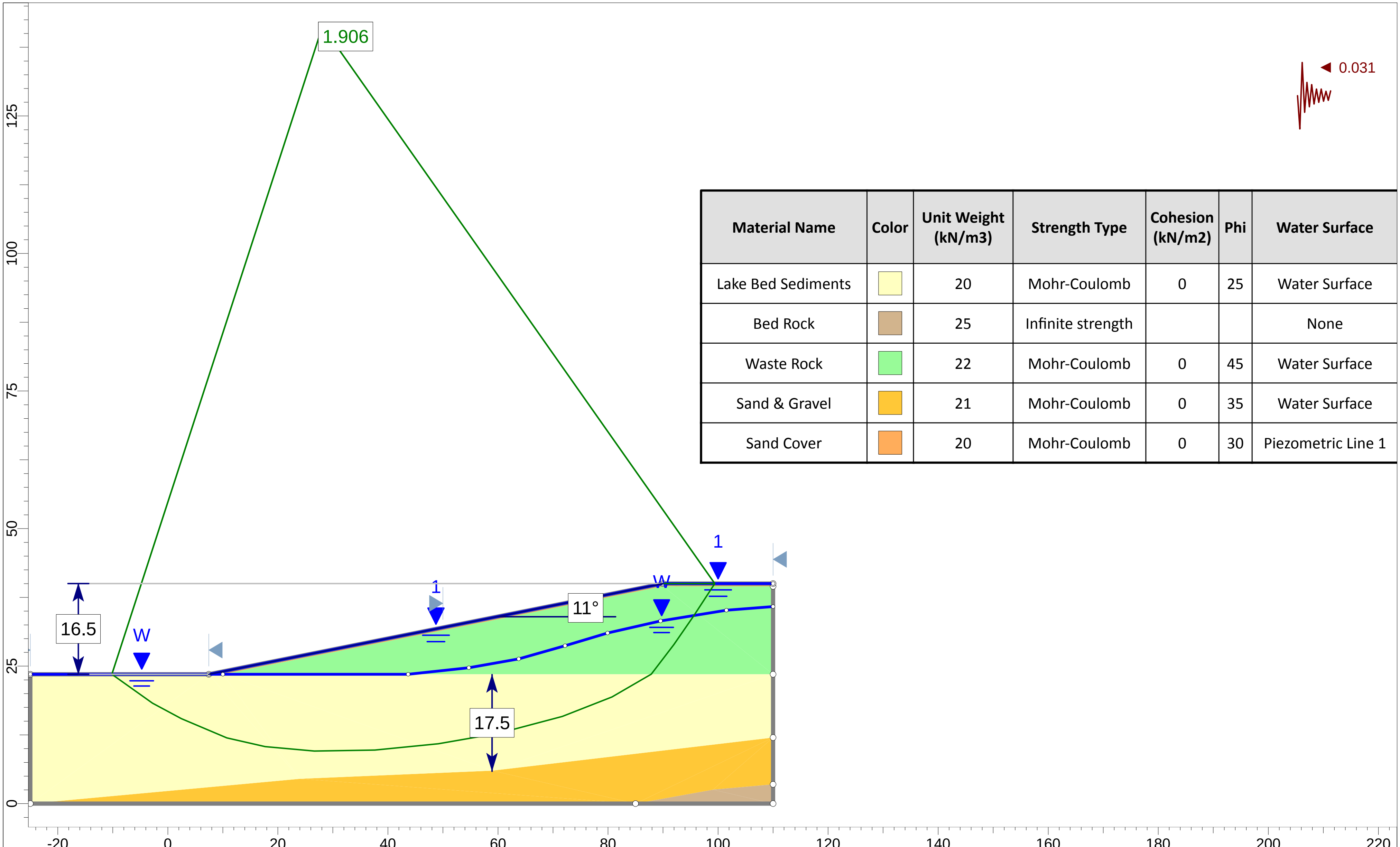

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	25	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand & Gravel		21	Mohr-Coulomb	0	35	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

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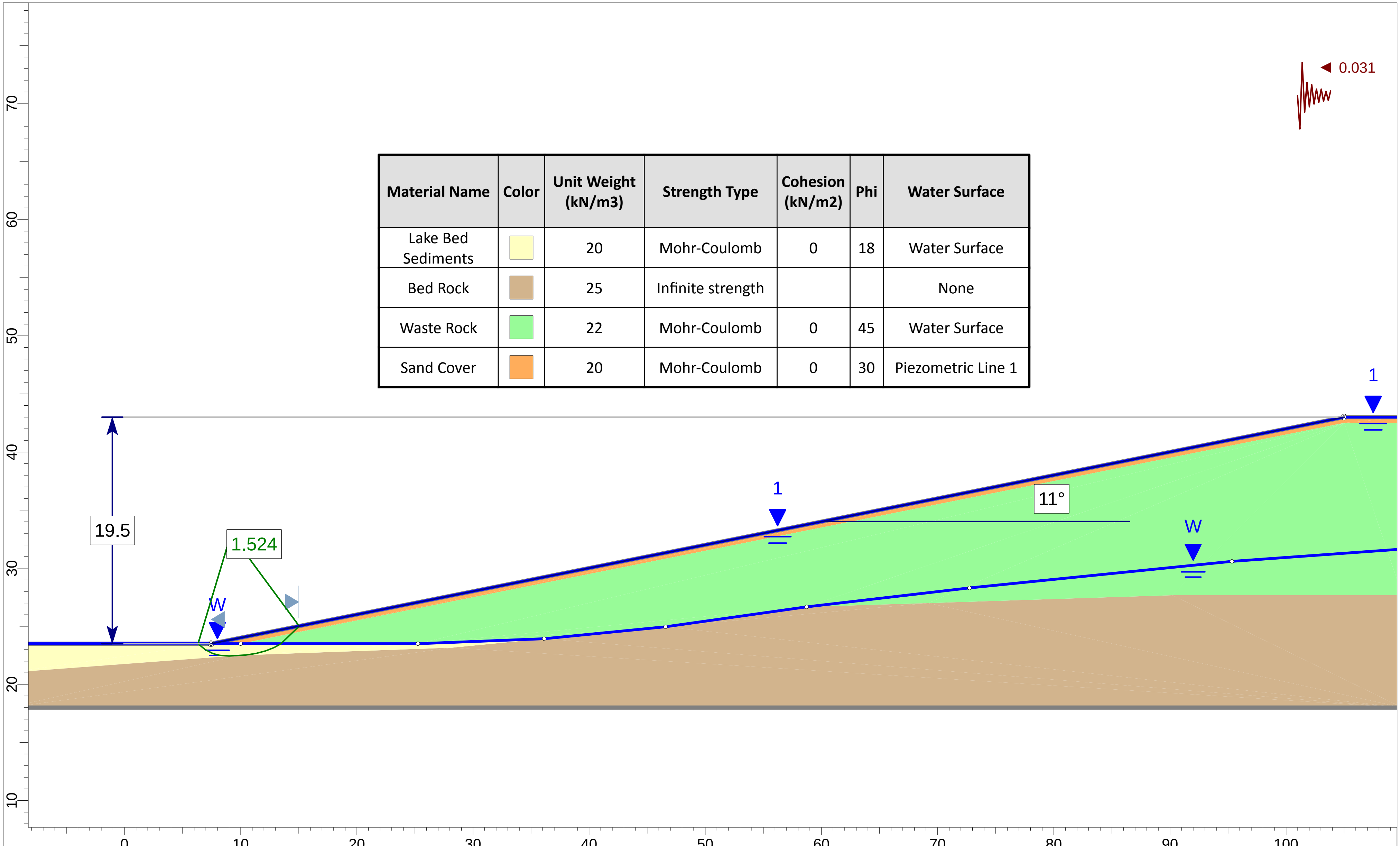
Project	Model 4 - South Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	4.7 5.0H:1.0V slope, elevated water table, LBS ϕ′ = 25° (upper bound sensitivity check) (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:950
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	4.7 - Seismic.slim

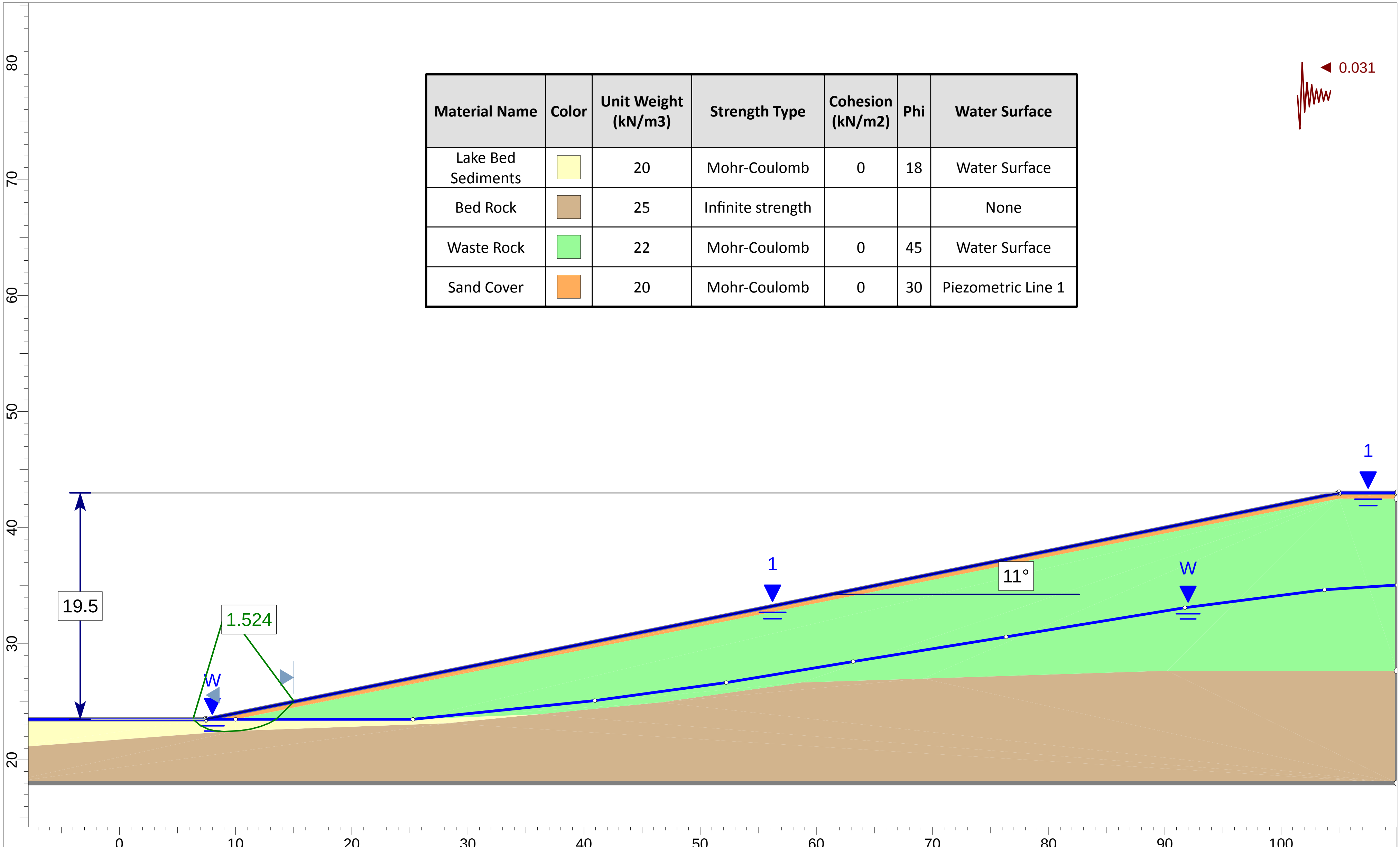


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.3, 5.0H:1.0V slope, depressed water table, base case material properties (Pseudo-static - PGA = 0.031)		
Drawn By	R Williams	*Scale* 1:450	*Company* SRK Consulting
Date	6/15/2016, 3:52:16 PM	*File Name*	5.3 - Seismic.slim

SLIDEINTERPRET 6.014

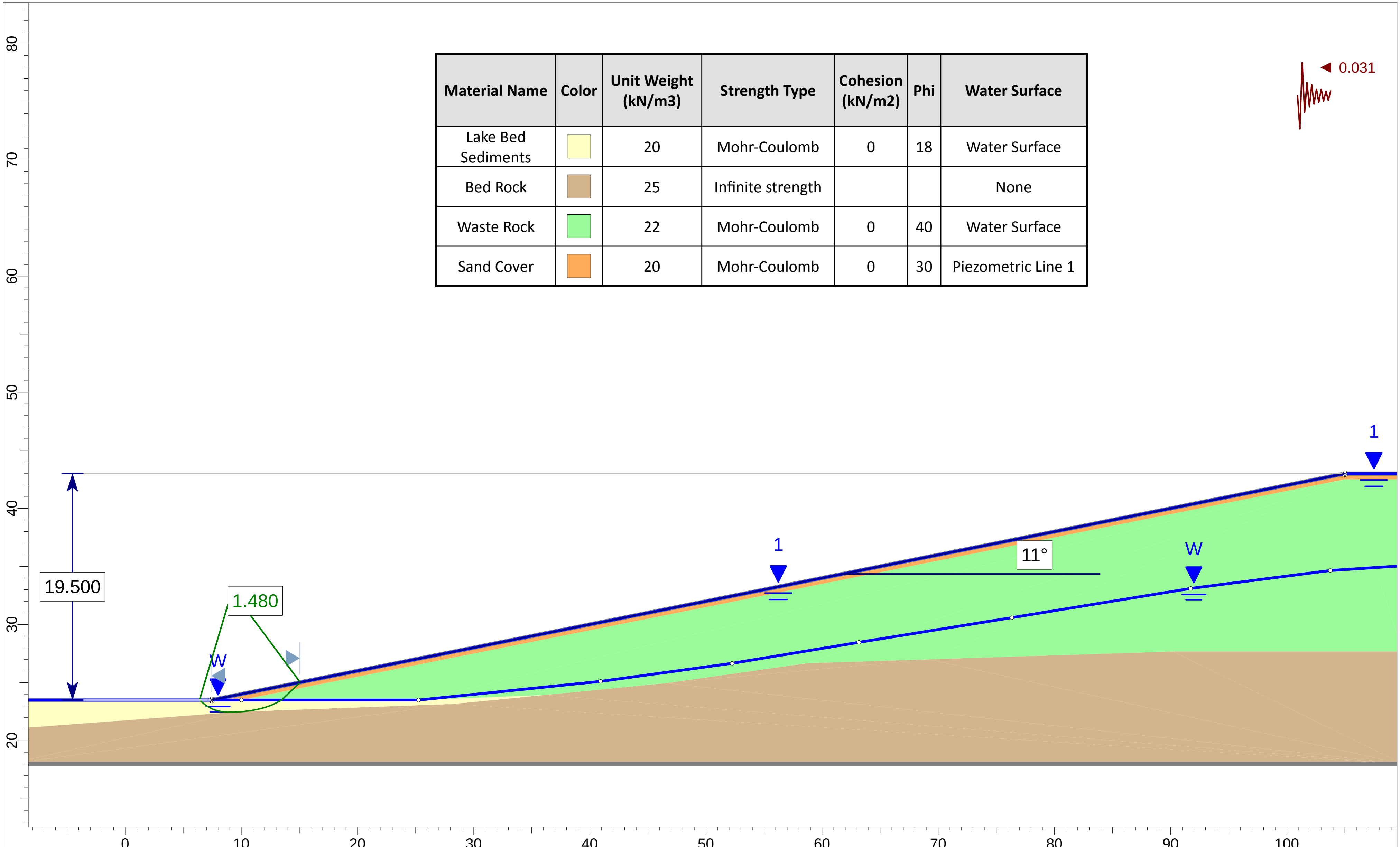
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1



Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	5.4, 5.0H:1.0V slope, elevated water table, base case material properties (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:450
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	5.4 - Seismic.slim

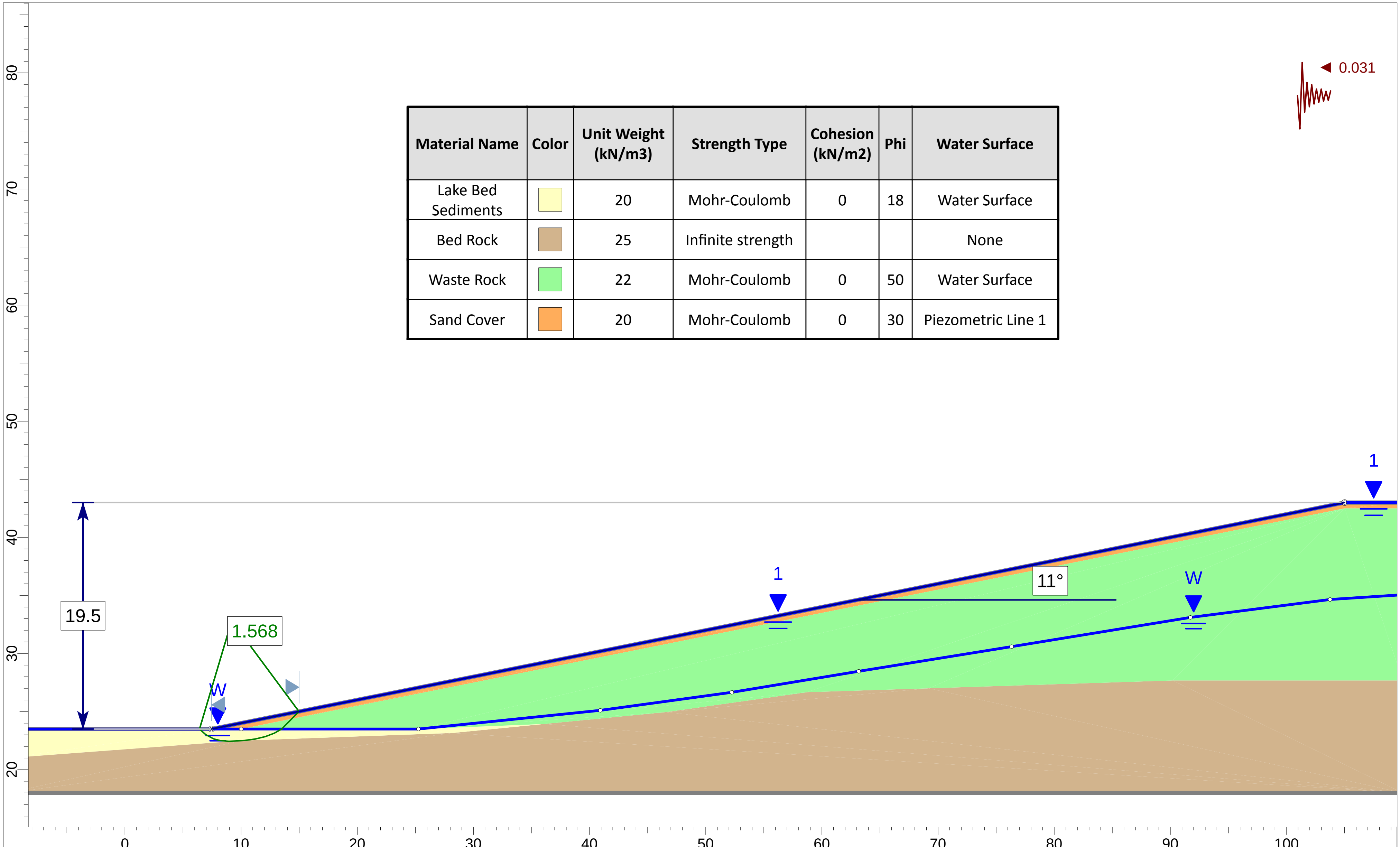
SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	40	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1



Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)
Analysis Description	5.5 5.0H:1.0V slope, elevated water table, waste rock ϕ' = 40° (lower bound sensitivity check) (Pseudo-static - PGA = 0.031)
Drawn By	R Williams
Scale	1:450
Company	SRK Consulting
Date	6/15/2016, 3:52:16 PM
File Name	5.5 - Seismic.slim

SLIDEINTERPRET 6.014



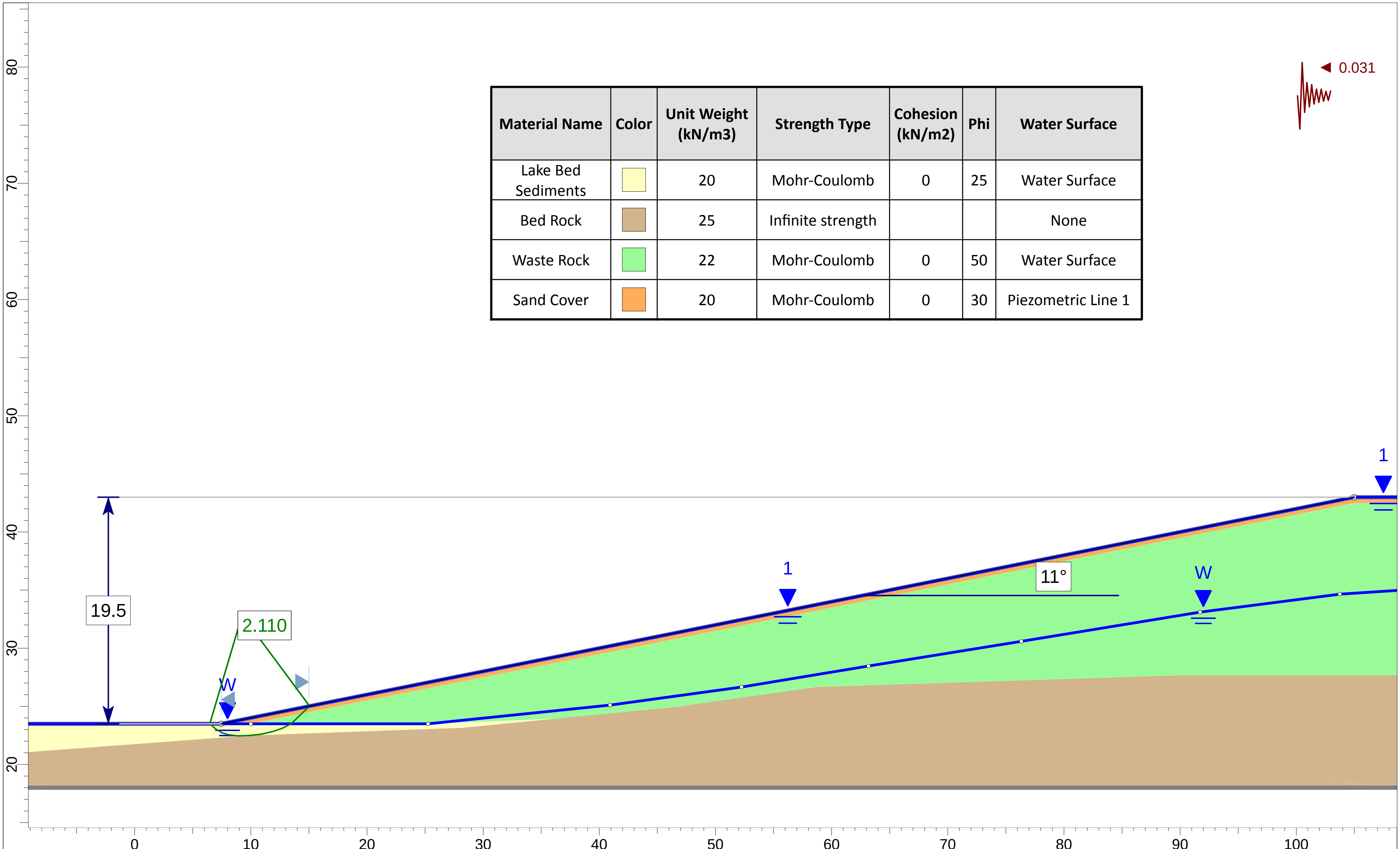
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

SLIDEINTERPRET 6.014

Project: Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)

Analysis Description: 5.6 5.0H:1.0V slope, elevated water table, waste rock ϕ′ = 50° (upper bound sensitivity check) (Pseudo-static - PGA = 0.031)

Drawn By R Williams	*Scale* 1:450	*Company* SRK Consulting	
Date 6/15/2016, 3:52:16 PM		*File Name* 5.6 - Seismic.slim	



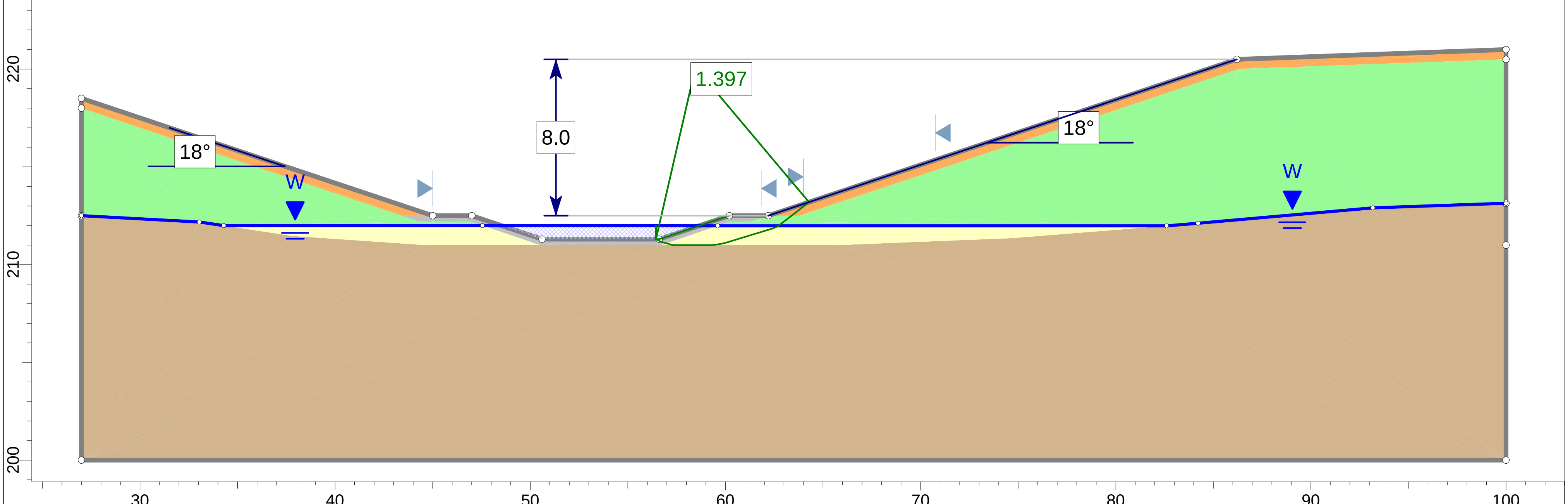
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	25	Water Surface
Bed Rock		25	Infinite strength			None
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Piezometric Line 1

SLIDEINTERPRET 6.014

Project	Model 5 - East Waste Rock Pile (Gunnar Mine Site Remediation Project)		
Analysis Description	5.7 5.0H:1.0V slope, elevated water table, LBS ϕ′ = 25° (upper bound sensitivity check) (Pseudo-static - PGA = 0.031)		
Drawn By	R Williams	*Scale* 1:450	*Company* SRK Consulting
Date	6/15/2016, 3:52:16 PM		*File Name* 5.7 - Seismic.slim

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface

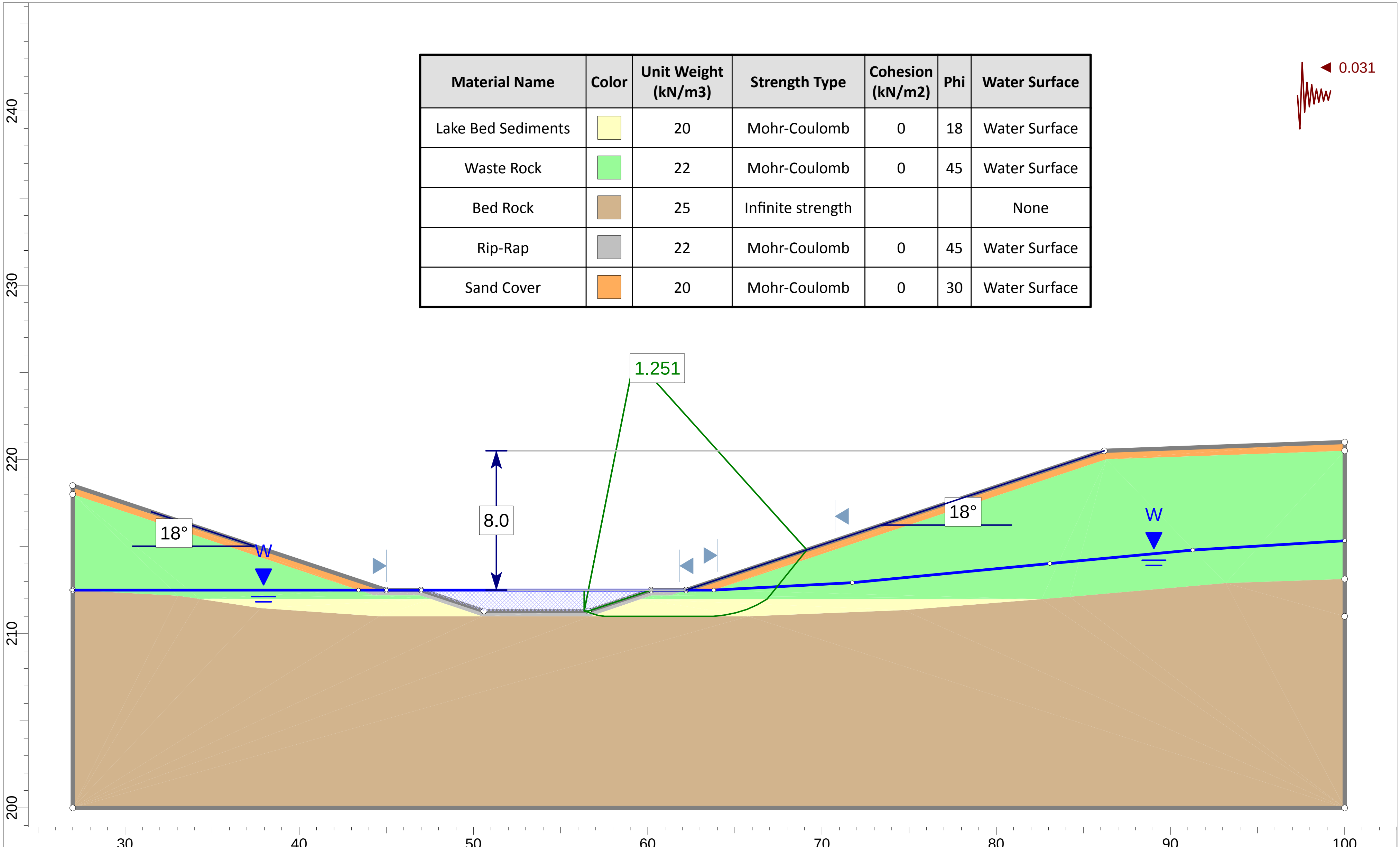
0.031



SLIDEINTERPRET 6.014

Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)
Analysis Description	6.1 3.0H:1.0V slope, base case material properties
Drawn By	R Williams
Scale	1:300
Company	SRK Consulting
Date	7/6/2016, 7:52:10 PM
File Name	Surface Water Channel - 6.1.slim

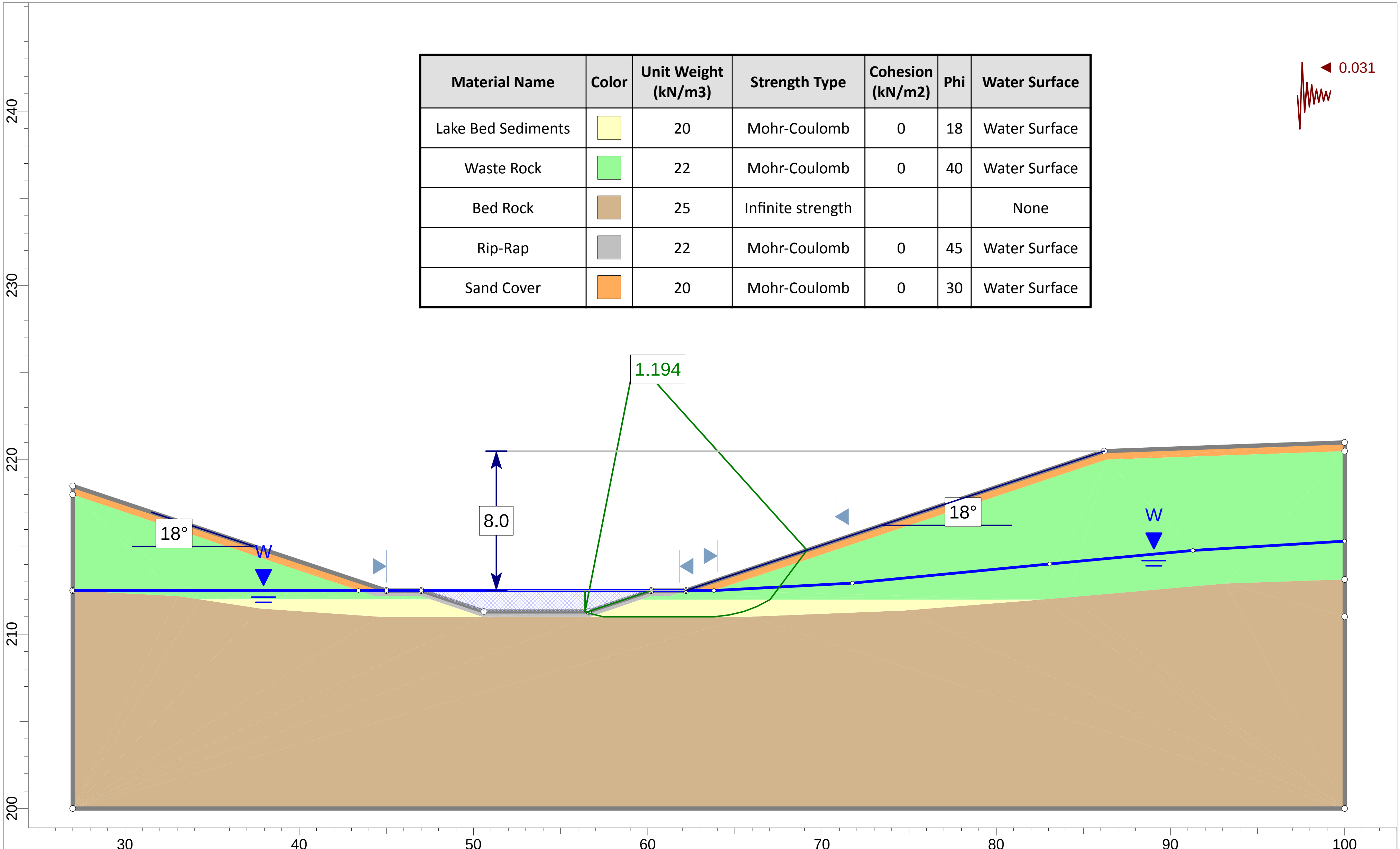
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	45	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface



Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)
Analysis Description	6.2 3.0H:1.0V slope, elevated water table, base case material properties
Drawn By	R Williams
Scale	1:300
Company	SRK Consulting
Date	7/6/2016, 7:52:10 PM
File Name	Surface Water Channel - 6.2.slim

SLIDEINTERPRET 6.014

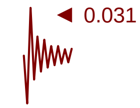
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	40	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface

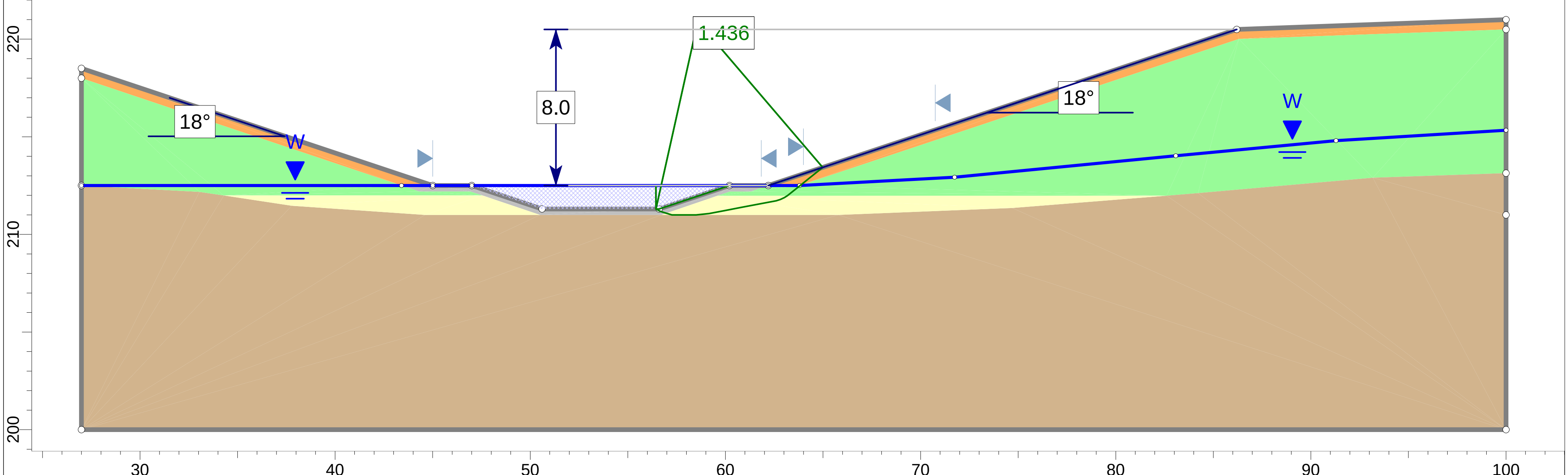


Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)
Analysis Description	6.3 3.0H:1.0V slope, elevated water table, waste rock $\phi' = 40°$ (lower bound sensitivity check)
Drawn By	R Williams
Scale	1:300
Company	SRK Consulting
Date	7/6/2016, 7:52:10 PM
File Name	Surface Water Channel - 6.3.slim

SLIDEINTERPRET 6.014

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface
Lake Bed Sediments		20	Mohr-Coulomb	0	18	Water Surface
Waste Rock		22	Mohr-Coulomb	0	50	Water Surface
Bed Rock		25	Infinite strength			None
Rip-Rap		22	Mohr-Coulomb	0	45	Water Surface
Sand Cover		20	Mohr-Coulomb	0	30	Water Surface





SLIDEINTERPRET 6.014

Project	Model 6 – Re-establishment of Historic Channel (Gunnar Mine Site Remediation Project)
Analysis Description	6.4 3.0H:1.0V slope, elevated water table, waste rock ϕ' = 50° (upper bound sensitivity check)
Drawn By	R Williams
Scale	1:300
Company	SRK Consulting
Date	7/6/2016, 7:52:10 PM
File Name	Surface Water Channel - 6.4.slim

Appendix F – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Treatment & Handling of Potentially Petroleum Hydrocarbon Contaminated Soil

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Memo

To:	Project File	**Client:**	Saskatchewan Research Council (SRC)
From:	Arlene Laudrum, PGeo	**Project No:**	1CS056.003
Reviewed By:	Jordan Graham EIT, Mark Liskowich PGeo	**Date:**	July 4, 2016
Subject:	Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design - Treatment and Handling of Potentially Petroleum Hydrocarbon Contaminated Soil		

1 Objectives

This memo provides information pertaining to the methodology used to segregate the petroleum hydrocarbon (PHC) contaminated soil from the non-contaminated soil at the former Gunnar Mine, Saskatchewan. It also outlines the soil sampling/analysis procedures to be implemented to confirm that the remediation objectives are being met in ex-situ soil.

A corrective action plan (CAP) that summarizes the results of the detailed site assessment, lists the applicable PHC standards for the site and describes what remediation techniques have been chosen is required. The memo provides information about how the ex-situ soil is to be managed during reclamation activities at the former Gunnar Mine.

2 Soil Excavation

Detailed delineation of the areas of petroleum hydrocarbon (PHC) contamination has not been undertaken (SRK, 2015a). The Canadian Standards Association (CSA) provides direction on how to conduct a detailed site assessment to determine the limits of the PHC contamination. The CAN/CSA-Z769-00 (R2013) *Phase II Environmental Site Assessment Standard* provides a framework for developing a sampling plan, preparing for and undertaking the investigation and interpreting and reporting the information gathered. The *Saskatchewan Ministry of Environment Guidance Document: Impacted Sites* (SMOE, 2015) advises the reader that strict adherence to the CSA standard is mandatory under the new regulatory framework. The CAP is to provide direction on excavation measures.

3 Processing of Excavated Soil

In order to improve the efficiency of the remediation, all excavated PHC contaminated soil will be processed using a screen to separate stones and boulders with a particle size larger than 5 cm from the contaminated soil fines. A vibrating screen, such as the Scalper 107D portable screening plant, is to be used. Given the larger surface area by volume of the silt, sand and gravel fractions (< 5 cm), a negligible portion of the PHC contaminants will be attached to the screened oversize materials. Additionally, because of the low clay and moisture content of the soil, the finer PHC contaminated soil particles are expected to readily separate from the stones and boulders during the screening. The screening and removal of coarse fractions is standard practice in the treatment of contaminated soil and has been applied at numerous remediation projects in Canada and elsewhere. SRK has successfully implemented the use of a vibrating screener to remediate PHC contaminated soil at the Nanisivik Mine, Nunavut (SRK 2014). It brings key advantages in terms of improving homogeneity, reducing the volume of the material requiring further treatment, aerating the soil, and allowing for the bulk segregation of soil by PCH concentrations as indicated using field tests.

3.1 Management of Oversize Material

The screened large size materials (> 5 cm) will be visually inspected for evidence of hydrocarbon sheen and the adhesion of finer grain particles. Should the fines not be separated from the oversize, the material will be allowed to dry out and rerun through the plant. Separated stones and boulders (> 5 cm) that do not show signs of PHC impact will be considered “clean” and will not be subject to further treatment. Impacted oversize materials will be placed in the landfill.

3.2 Management of Undersized Material

The fines (< 5 cm) passing through the plant are to be transferred into temporary stockpiles using a 2.5 m to 4 m front end loader. The stockpiles are to be no more than 25 m^3 in size. Five discrete samples for field testing are to be collected while the stockpile is being built (i.e. a sample is collected from every second bucket load placed in the pile if a 2.5 m loader is used). The temporary stockpile is to be identified and the unique sample number for each discrete sample collected from the stockpile recorded. The field test methodology is described in Section 3.2.1.

Based on the interpretation of the field test results the soil is to be separated into “potentially clean” or “likely contaminated” stockpiles and the potentially clean soil sampled. Measures needed to be undertaken to interpret the field test results are described in Section 3.2.2. Upon receipt of confirmatory laboratory results the clean material may be used as fill for the remediation of the site (i.e. landfill cover/fill). The remediation confirmatory sample plan and quality assurance/quality control (QA/QC) plan are described in Sections 3.2.3 and 3.2.4. The likely contaminated soil may be placed into the lined landfill with no further testing.

3.2.1 Field Testing Methodology

Potentially PHC impacted soil is to be field tested on site using a bag-headspace method with a portable gas detector and/or a photo-ionization detector (PID), and olfactory indications. The results of the field test combined with the visual appearance of the soil and olfactory indications are then used on-site to guide the segregation of soil by the indicated level of PHC contamination.

The bag-headspace method involves placing soil in a large Ziploc® freezer bag, sealing the bag, disaggregating the soil in the bag and allowing organic vapours to accumulate in the bag’s headspace. The samples sit in a warm environment (in the sun or near a heater) for one to two hours prior to encourage the longer chain hydrocarbons (F2, F3) to volatilize. The concentration of organic vapour is then measured using a portable gas monitor or PID.

The readings from the portable gas detector and PID provide an indication of the PHC concentrations; however, the method is susceptible to errors when the sample preparation environment cannot be controlled (i.e. when samples are not warmed at a constant temperature over a consistent length of time and when there is interference from PHC vapours emitted from equipment operating nearby in the sample preparation area). Confirmation that the soil quality remediation objectives are met requires laboratory analyses of samples.

3.2.2 Field Test Result Interpretation

A comparison of field test results to laboratory analyses is needed to determine if a field test result can be expected to either meet or exceed the applicable PHC standards for the site. An indeterminate range is to be expected upon comparison of the field tests results and the laboratory analyses. For example, at the Nanisivik site, a comparison of field test results and laboratory analyses indicated that: soil with vapour readings of 20 ppm or less will meet the Site's remediation objectives; and soil with vapour readings greater than 70 ppm will exceed the Site's remediation objectives (SRK, 2015b).

3.2.3 Soil Quality Remediation Confirmatory Samples

Soil samples are to be collected based on the volume of soil in a given stockpile and the homogeneity of the soil in the pile. In accordance with the The *Saskatchewan Ministry of Environment Guidance Document: Impacted Sites* (SMOE, 2015) the sampling plan must include the methods (grid, composite) and frequency (number of samples per surface area). The samples are analyzed for contaminates of interest and compared with the remediation objectives presented in the CAP. All remediation confirmatory soil samples are analyzed at a laboratory accredited by the Canadian Association for Environmental Analytical Laboratories.

A composite sample to characterize the stockpiled clean soil is to be created by combining five discrete samples. Discrete samples are to be collected during the placement of soil into a stockpile. The volume of soil represented by each composite sample should typically range from 50 m^3 to 150 m^3, with no discrete sample representing more than 50 m^3. Discrete samples are to be analyzed by the laboratory as part of QA/QC measures. Each discrete sample is to be field tested. Should the field test results indicate that the material sampled is likely contaminated it should be relocated to the lined landfill.

This laboratory analytical sampling procedure takes into consideration the improved homogeneous nature of the soil created by passing it through a vibrating screener and the use of the field testing results to manage the soil.

3.2.4 Quality Assurance and Quality Control

QA/QC measures associated with the collection and analysis of the soil samples included the comparison of field screening results with laboratory data and laboratory analysis of blind duplicates and discrete QA/QC samples. Blind field duplicate samples monitor a combination of the precision of the laboratory analyses, sample preparation errors, sample collection errors and genuine short scale variations in soil geochemistry. Discrete samples monitor the homogeneity of composite sample areas.

The QA/QC plan requires one duplicate and five discrete samples from one of the composite sample area for every ten composite samples submitted for laboratory analysis.

4 References

[CSA] Canada Standards Association (CSA International). 2013. Phase II Environmental Site Assessment Standard. CAN/CSA-Z769-00 (R2013).

[SOME] Saskatchewan Ministry of Environment. 2015. Guidance Document: Impacted Sites. Version 1.0. May 2015.

SRK Consulting (Canada) Inc. 2014. Nanisivik Mine Contaminated Soil Remediation 2013 Progress Report. Prepared for CanZinco Ltd. February 2014. Filed on the Nunavut Water Board public registry at ftp://ftp.nwb-oen.ca/registry/1 INDUSTRIAL/1A/1AR - Remediation/1AR-AN1419/3 TECH/1 20GENERAL (B)/2 20ANNUAL RPT/2013/.

SRK Consulting (Canada) Inc. 2015a. Gunnar Mine “Other Site Aspects” Preliminary Remediation Design. Prepared for Saskatchewan Research Council. August 2015.

SRK Consulting (Canada) Inc. 2015b. Nanisivik Mine Contaminated Soil Remediation 2014 Progress Report. Prepared for CanZinco Ltd. March 2015. Filed on the Nunavut Water Board public registry at ftp://ftp.nwb-oen.ca/registry/1 INDUSTRIAL/1A/1AR - Remediation/1AR-NAN1419/3 TECH/1 GENERAL (B)/2 ANNUAL RPT/2015/.

Appendix G – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Hazardous Landfill Design Elements

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Memo

To:	Project File	**Client:**	Saskatchewan Research Council
From:	Erik Ketilson, MEng, PEng.	**Project No:**	1CS056.003
Cc:		**Date:**	July 6, 2016
Subject:	Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design - Hazardous Landfill Design Elements		

1 Introduction

SRK Consulting (Canada) Inc. is currently undertaking the detailed design of the "other site aspects" at the former Gunnar Mine, located near Uranium City, Saskatchewan. SRK's scope includes the design of a suitable containment facility for the hazardous waste materials on-site. This technical memorandum outlines the evaluation used determine the proposed cover configuration for the facility. Landfill components aside from the cover are not discussed in detail in this memo, but are included in the design report (SRK 2016).

The hazardous material on-site consists of an estimated 3,000 m^3 of hydrocarbon impacted soils. A contingency of 1,000 m^3 (33%) has been applied to this quantity on the basis that during excavation additional material may be identified. The hazardous material landfill has therefore been sized to store approximately 4,000 m^3 of soil.

A landfill is proposed to occupy the former sulphur storage area, located directly east of the former acid plant. This area consists of a concrete floor, and concrete side-walls, with an open area to the southwest that previously served as a load-out area for the sulphur. The preliminary design for the landfill consists of filling and repairing the concrete surface and wall joints to create a low permeability base and side-wall. A low-permeability cover is proposed over the waste to limit infiltration, with the intent of creating a "dry-tomb" (Section 3).

2 Remedial Objectives and Design Criteria

The hazardous waste design option must meet the remedial objectives of the site and the proposed design criteria (SRK 2016). The relevant objectives to the hazardous waste facility include consolidation and permanent disposal of contaminated earthen and industrial materials following the Saskatchewan Environmental Code for landfills. The relevant design criteria for the facility are provided in Table 2-1.

Table 2-1: Gunnar Other Site Aspects Overall Remediation Design Criteria

Parameter	Criteria
Design Life	The remediation of the Other Site Aspects is expected to be effective in perpetuity. However, it is not credible to suggest the design criteria listed in this table can be met in geological timeframes. Therefore, a 100-year design life has been adopted similar to that of the Lorado Remedial Project (SRK 2014). A design life longer than 100 years is achievable provided proper monitoring and maintenance is performed.
Land Use	General wilderness area use includes large and small terrestrial animals, birds and aquatic life will be present. (Flora and fauna adjacent to and within the site must not be significantly impacted.) Humans could also travel through the area infrequently, but maintain traditional land use adjacent to and within the site. Special measures to preclude access are not required.
Landform	Promote use of landforms consistent with current landscape. Cover to promote sustainable vegetation, ensure positive drainage and reduce erosion potential.
Physical Exposure	As far as practicable, no visible signs of hazardous materials or demolition debris. Includes weathering due to repeated wetting/drying and/or freeze/thaw cycles, forest fires and burrowing animals.
Groundwater Quality	Remediation designs developed attempted to improve groundwater quality in an effort to meet the Environment Canada 2010 Interim Tier 2 commercial / industrial guidelines at receiving environments.
Covers	Must be able to support self-sustaining vegetation and reduce erosion. For landfills, covers must adhere to landfill cover standards.
Slope Stability	Stable under static and dynamic loading conditions.
Overland Flow and Surface Water Erosion	Maximum permissible velocity for surface flow on cover material prior to establishing vegetation is 1 m/s. No visible damage over cover for 24-hour duration precipitation event less than 1-in-200 year recurrence interval. Short-term ponding on remediated surface permitted. Prolonged ponding resulting in vegetation dieback should be discouraged.
Landfill Design (If required)	As far as practical meet the objectives of the Saskatchewan Environmental Code (EMPA 2010). Reduce the potential for frost heave of landfill debris. Up to 0.3 m differential settlement expected and acceptable.
Vegetation	Promote establishment of self-sustaining vegetation cover endemic to the region. No requirement to preclude specific species from establishing on cover areas.

The draft environmental code (EMPA 2010) is structured such that prescribed designs considered acceptable by the Saskatchewan Ministry of Environment can be implemented or alternate designs can be proposed and evaluated on a case-by-case basis. Due to the remoteness of the site and one-time placement of material within the landfill prior to covering, an alternative design is proposed for the hazardous waste landfill consisting of:

- a low permeability base of concrete overlying bedrock,
- no leachate collection system, and
- a low-permeability cover as described in Section 3.

3 Landfill Cover Design Considerations

The prescribed cover (EMPA 2010) is a compacted clay liner (CCL) with a thickness of 1.0 m and a minimum of 10% fines. In the context of attempting to achieve a dry-tomb, SRK suggests the hydraulic conductivity should approximate an average of $1x10^{-9}$ m/s, which is a lower hydraulic conductivity as compared to the guideline. There are other low permeability geosynthetic barriers capable of reducing the hydraulic flux into the landfill to a similar or greater degree than that of the CCL prescribed by the EMPA (2010). The following options assessed as part of this memo include:

- Compacted material cover constructed of native fine grained borrow analogous to the CCL base layer described in EMPA (2010), with a minimum thickness of 1.0 m
- High density polyethylene geomembrane (HDPE) with suitable protective cover
- Linear low density polyethylene geomembrane (LLDPE) with suitable protective cover
- Bituminous geomembrane (BGM) with suitable protective cover
- Geosynthetic clay liner (GCL) with suitable protective cover

In the cold climate of the Gunnar Site, ground frost penetration could negatively impact the performance of some low permeability layers. With the exception of the CCL, all of the low-permeability cover options discussed in this analysis are resistant to the effects of freeze-thaw (i.e. where freeze-thaw does not cause an increase to the hydraulic conductivity). The CCL would likely be damaged by freeze-thaw (i.e. ice lensing causing an increased hydraulic conductivity by orders of magnitude); therefore, a frost penetration analysis was completed to understand what design modifications would be required to protect the CCL, and then to determine whether those modifications are feasible. Section 3.2 outlines the frost penetration analysis.

The options previously discussed in this section plus a variation on the CCL option were assessed. The options required different combinations of the following components: a frost protection layer and an overlying non-woven geotextile to protect the membrane or a prepared subgrade. The requirements of each option are displayed in Table 3-1.

Table 3-1: Cover Option Requirements

Low Permeability Option	Frost Protection Layer	Membrane Protection Layer	Prepared Subgrade	Non-Woven Geotextile
CCL	Yes	No	No	No
CCL & Non-Haz Waste	Yes (Non-Haz Waste)	No	No	No
HDPE	No	Yes	Yes	Yes (above)
LLDPE	No	Yes	Yes	Yes (above)

BGM	No	Yes	Yes	No
GCL	No	Yes	Yes	No

As indicated in Table 3-1, the CCL and non-hazardous waste option includes a frost protection layer that consisted of non-hazardous waste. This material will consist of concrete from the site demolition debris.

3.1 Compacted Clay Liner Design Assumptions

Description and characterization of the fine-grained borrow is presented by O'Kane (2016). O'Kane characterized the overall borrow into four general classifications: finer-textured (clay and silt), medium-textured (fine sand to coarse sand), coarser-textured (sand and gravel or coarser), and waste rock. For the purposes of designing and constructing a CCL, the finer textured material would be most suitable. The finer-textured (clay and silt) material consists of 80 to 100% clay and silt (O'Kane 2016).

Golder (2013) also characterized the on-site borrow. In Borrow Area 6, the finer-textured materials have greater than 30% clay. The materials characterized by both O'Kane and Golder should be capable of meeting a hydraulic conductivity of $1x10^{-9}$ m/s. It is proposed that suitable material for the CCL be obtained from Borrow Area 6 and stockpiled until the construction activities for the hazardous waste landfill occur.

Should a compacted clay liner be selected, the hydraulic conductivity of the fine grained borrow material should be confirmed through laboratory testing.

3.2 Frost Penetration Depth

A frost penetration analysis was completed to determine the required thickness of the frost protection layer. The analysis used the modified Berrgren equation as described in the Canadian Foundation Engineering Manual, 4th Edition (CGS 2006). The equation produces a design depth, which accounts for a substantially colder than normal winter that has 30% more freezing degree days than average. The analysis was completed based on two material cover types, the first was the fine grained borrow material from Borrow Area 6 (Golder 2013) and the second was based on material properties of concrete or waste rock in an effort to replicate the material properties of non-hazardous waste. Proposed non-hazardous waste that could be used as a frost protection layer would consist of concrete and/or waste rock, with other waste (e.g. steel) not being considered suitable for use in this application.

The calculated design frost protection layer thicknesses are presented in Table 3-2.

Table 3-2: Frost Protection Layer Thickness

Borrow Material Type	Frost Protection Layer Thickness
Fine grained borrow material	3.0 m
Non-hazardous waste (e.g. concrete / wasterock)	3.3 m

3.3 Differential Settlement

The hazardous waste consists of contaminated soil composed of rock and some coarse grained soils. The material will be placed within the landfill in lifts, and expected settlement and consolidation of the soils will be minimal. Differential settlement of the waste is not expected to impact the cover performance.

3.4 Comparative Cost Evaluation

Conceptual level cost estimates were calculated to compare the low permeability cover options based on estimated material quantities and assumed unit costs. The costs only include the direct costs of the barrier layer and do not include costs relating to the preparation of the concrete floor or transporting and processing waste materials.

The landfill design cost components pertinent to the comparison are presented in Table 3-3, the unit costs for the cover materials are included in Table 3-4. Table 3-5 illustrates the comparative quantities to complete each option, based on different surface areas. Two surface areas were compared in the event that the detailed design is modified to include a reduced thickness of waste, and a larger footprint, as the costs vary depending on surface area of the cover.

Table 3-3: Landfill Design Parameters

Item	Quantity	Units	Comments
Total Landfill Surface Area	1950	m²	Based on minimal footprint design that utilizes the entire concrete base.
Frost Protection Layer	3.0	m	Based on fine grained soils.
Frost Protection Layer	3.3	m	Based on concrete / waste rock

Source: LandfillCoverComparison_1CS056-003_REV0-ek.xlsx

Table 3-4: Cover Unit Costs

Item	Cost	Units
Geosynthetic Mobilization[1]	$29,000.00	LS
Prepared Subgrade[2]	$1.00	per m²
Protective Soil Cover[2]	$8.50	per m³
Geotextile[1]	$4.40	per m²
Compacted Clay Liner[2]	$20.00	per m³
HDPE[1]	$8.95	per m²
LLDPE[1]	$7.05	per m²
Bituminmous Geomembrane	$20.00	per m²
GCL[1]	$11.45	per m²

Source: LandfillCoverComparison_1CS056-003_REV0-ek.xlsx

Notes:

1. Unit costs based on a comparative level quote from Nilex (2016).
2. Unit costs based SRK's past project experience.

Table 3-5: Cover Quantities – 1950 m^2 Surface Area

Description		Option – 1950 m^2 Surface Area					
		CCL	CCL & Non-Haz	HDPE	LLDPE	BGM	GCL
Quantities	Frost Protection Layer or Cover Layer Thickness (m)	3.0	0.5	0.5	0.5	0.5	0.5
	Frost Protection Layer or Cover Layer Volume (m^3)	5755	975	975	975	975	975
	CCL Thickness (m)	1	1	0	0	0	0
	CCL Volume (m^3) / Geosynthetic Area (m^2)	1950	1950	1950	1950	1950	1950
	Non-wove geotextile protection layer (m^2)	0	0	1950	1950	0	0
	Prepared Subgrade (m^2)	0	0	1950	1950	1950	1950

Source: LandfillCoverComparison_1CS056-003_REV0-ek.xlsx

A comparative cost estimate was completed, based on surface area and quantities / unit costs as described above. The comparative cost estimate indicated that the lowest cost option was the construction of a CCL, and the frost-protection layer being constructed of non-hazardous waste materials (e.g. concrete or waste rock). This option is the lowest cost because the cost of handling and placing the non-hazardous waste must occur and be incorporated into a non-hazardous landfill. Therefore, this option has a lower cost than utilizing clean borrow to construct a frost protection layer. Figure 1 illustrates the percent difference in cost relative to the lowest cost option versus the landfill cover surface area. The cost to construct a frost protection layer of clean borrow would be approximately 85% more. The figure also demonstrates that cover construction using geosynthetics is not cost competitive at low surface areas due to the mobilization cost, but if the surface area of the landfill were to be greater, geosynthetic covers may be more appropriate to consider.

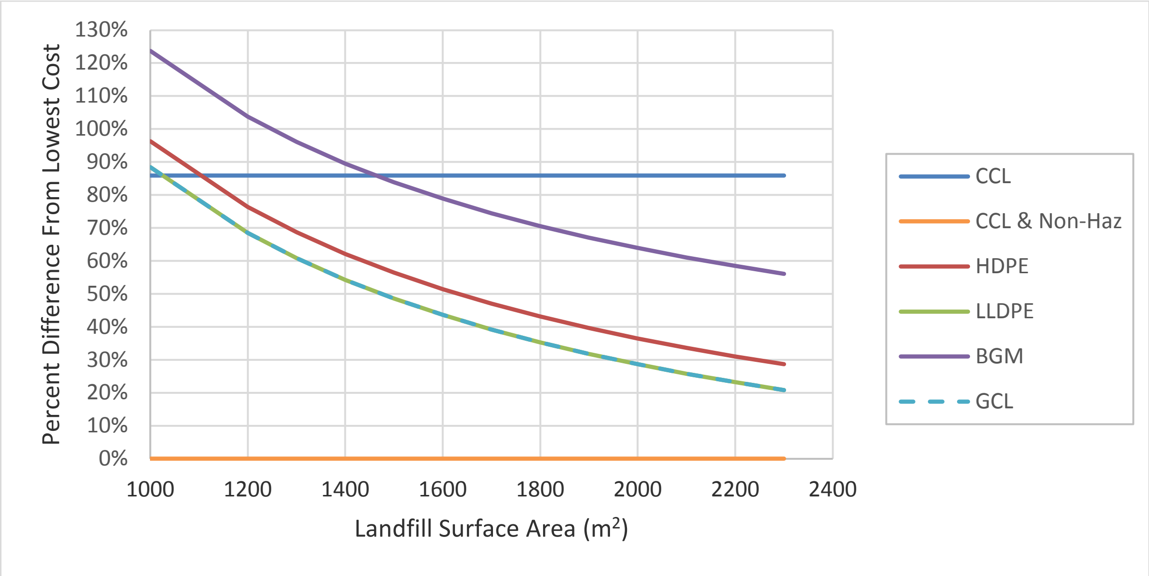

Figure 1: Comparative Cover Cost versus landfill surface area.

4 Conclusion

The hazardous materials landfill cover is recommended to be a compacted clay liner constructed of finer-textured (clay and silt) materials from Borrow Area 6, with non-hazardous waste materials consisting of a 3.3 m thick layer of concrete and waste rock placed over the compacted clay liner as a frost protection layer. The compacted clay liner is proposed to be 1.0 m thick, and is expected to be able to achieve an in situ hydraulic conductivity of $1x10^{-9}$ m/s. The upper 0.5 m of the frost protection layer should consist of a coarser textured borrow material to meet the long-term erosion targets on-site and to achieve the re-vegetation targets.

Construction of a CCL cover also meets the project design intent by utilizing the local borrow materials, and reducing the need for specialty contractors, which may be required if a geosynthetic barrier was used.

Further testing of the finer-textured materials should be completed to confirm the hydraulic conductivity will meet the specified target of $1x10^{-9}$ m/s. Should laboratory testing indicate that the material is not capable of meeting $1x10^{-9}$ m/s, the design will be modified to include a geosynthetic barrier to cover the waste.

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Appendix H – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Optimization of Waste Rock Grading and Gamma Cover

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Memo

To:	Skye Ketilson, Project Manager, Environment Division	**Client:**	Saskatchewan Research Council (SRC)
From:	Trevor Podaima, PEng and Jordan Graham, EIT	**Project No:**	1CS056.003
Reviewed By:	Mark Liskowich, PGeo	**Date:**	July 11, 2016
Subject:	Gunnar Project “Other Site Aspects” Updated Preliminary Remediation Design Optimization of Waste Rock Grading and Gamma Cover (Revision 1)		

1 Introduction

SRK Consulting (Canada) Inc. was requested by the Saskatchewan Research Council (SRC) to provide a summary of the detailed remediation plan for the Gunnar Mine site waste rock grading and gamma cover. The intent of this summary is to present the design changes associated with the waste rock grading subsequent to the preliminary remediation design, demonstrate that the 0.5 m thick gamma cover along the waste rock slopes will be stable for the long term (i.e. low susceptibility to erosion), and meet the project design criteria. In essence, this memo further addresses Comment #5 from the Canadian Nuclear Safety Commission (CNSC), discussed below.

The analysis included herein are prepared in support of the *Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design* report (SRK, 2016).

1.1 Context

The Preliminary Remediation Design Report for the Gunnar Mine “Other Site Aspects”, was completed August 2015 and was subsequently reviewed by the Canadian Nuclear Safety Commission (CNSC). In general, the CNSC found that the Preliminary Remediation Design Report met the requirements of the environmental assessment (CNSC, 2014) to reduce radiation exposure, minimize contaminant loadings to the environment, consolidate and stabilize the waste, and promote vegetative growth at the overall site. However, the review identified areas that require further supporting information and clarification prior to acceptance of the remediation plan and comments were sent to the SRC on December 18, 2015. Responses were submitted to the CNSC, and are included in Appendix A, (SRK, 2016). For reference, Comment #5 and the SRC/SRK responses are provided below.

CNSC Comment #5:

The landform design of Gunnar other site aspects remediation is to promote use of a landform consistent with current landscape, promote sustainable vegetation, ensure positive drainage, and *reduce erosion potential. The landform designed should not only be stable geotechnically, but should also maintain the long-term integrity of the remediated features such as the waste rock pile and the landfill. The side slopes of the landfill containment structures for non-contaminated demolition debris and for contaminated and hazardous materials, and the side slopes of waste rock piles are designed with a gradient of 1V:3H without sufficient justification for their long term integrity. The experience from mine reclamation in northern Saskatchewan such as the Cluff Lake waste rock pile reclamation and the Rabbit Lake waste rock pile reclamation implies that a gentler landform slope is needed in order to ensure the integrity of waste disposal structures (i.e., landform and waste rock piles). SRC is expected to justify the side slope gradient of the waste disposal structures to ensure their long-term integrity or otherwise to provide sufficient information to demonstrate the integrity of the designed structures is in the long term, should the proposed options be justified adequately by addressing other comments.*

SRC/SRK Response:

Both landfill and waste rock pile configurations, that include 3.0 Horizontal to 1.0 Vertical (H:V) slopes, were designed to be stable geotechnically and for the long term.

<u>Waste Rock Piles</u>
Preliminary engineering included access ramps to facilitate construction and to provide access should adaptive management measures for unforeseen events be required. Drainage channels were positioned along the 3.0H:1.0V slopes at a frequency where each channel will accommodate flow from a 1 ha area and the top surface of the waste rock piles and benches have a 1.0 % grade towards the drainage channels. The intent of this configuration was to reduce, surface flow velocities to below 1.0 m/s, the potential of surface erosion and to promote sustainable vegetation that will intern uphold the long-term integrity of the remediated waste rock piles.

The waste rock pile configurations include a series of 3.0H:1.0V slopes that are 6 m in height and are separated by benches that are 8 to 10 m in width. Such configuration results in an overall average slope angle of 4.0H:1.0V to 5.0H:1.0V. Therefore the benches could be excavated to form a gentler landform and the volumetrics will be the same. Landform design will be considered in the next phase of engineering, which will include a review of historical reclamation designs in Northern Saskatchewan, a trade-off study (benches vs. flatter uniform slope), and a FMEA to assess the consequences of erosion. This exercise will ultimately determine the final landform configuration for the waste rock piles.

<u>Waste Disposal Structures</u>
Both non-contaminated and contaminated landfill designs include surface/slope water management features that will promote sustainable vegetation, reduce the potential of erosion and thus facilitate the long-term integrity of the structure. Specifically, the crest of the non-contaminated landfill will be graded at 1.0% to form a swale-like feature towards the center of the crest, which will ultimately drain towards the Open Pit via an armored drainage channel situated along the 3.0H:1.0V slope.

The crest of the contaminated landfill is much smaller and will therefore be graded at 1.0% towards the exterior slope. Water bars comprised of riprap will be situated along the 3.0H:1.0V slope of the landfill to manage sheet flow and to reduce the potential of erosion from runoff. Runoff from surrounding watersheds will be diverted around both landfills and towards the Open Pit.

The proposed landfill slopes were also designed using guidelines from the Saskatchewan Environmental Code for Landfills (EMPA, 2010) where the recommended landfill slopes for Type I and Type II waste range from 3.0H:1.0V and 4.0H:1.0V.

Landform design will be included in the next phase of engineering as well as a FMEA and if required, the slopes may be flattened to support the final landform configuration.

Vegetation and Landform Design
One of the key components in reducing short term erosion potential is the establishment of sustainable vegetation species native to the Gunnar site. SRC's vegetation study will be utilized in the next phase of engineering to confirm the re-vegetation potential and to develop a re-vegetation plan.

2 Optimization of Preliminary Remediation Landform

Multiple design aspects were considered in order to optimize the waste rock and landfill landform designs after the cover criteria had been satisfied. These design aspects include soil loss due to erosion, borrow material suitability in consideration of loading reduction performance, a volumetric assessment, and hydrotechnical analysis. The erosion analysis of the available cover materials was completed to determine which borrow materials can be used as cover for various slope geometries and site conditions. Coarse and fine textured borrow materials were evaluated in consideration of their loading reduction performance, and their overall suitability as a waste rock gamma cover. The volumetric assessment was completed to determine where to excavate waste rock to accommodate the tailings remediation design as well as minimizing material movement to achieve the final landform. The final evaluation included a hydrotechnical assessment to determine the types of structures required to accommodate areas of the landform where concentrated flow may occur.

2.1 Cover Criteria

A remediation performance criterion for gamma radiation was established as part of the EIA (SRC, 2013) and SRK completed an evaluation of the cover thickness (Attachment H1). The primary criterion of the cover system is to reduce the sum of gamma radiation and radon gas exposure measured 1 m above an impacted area to no greater than 2.64 μSv/hr (2.5 μSv/hr above background) as a spot reading and no higher than 1.14 μSv/hr (1.0 μSv/hr above background) as an average measured over 1 ha. The background gamma dose rate over 1 ha is 0.14 μSv/hr (SRC, 2013).

Several gamma radiation surveys have been completed at the Gunnar Mine site that range from 1986 to 2009. The results of the most recent gamma survey completed in 2009 and 2011 indicate gamma dose rates ranged from 0.3 to 6.0 μSv/h with an average value of 1.2 μSv/h (SRC, 2013). O'Kane Consultants Inc. (OKC) completed a gamma shield assessment as part of the detailed tailings remediation design, which revealed that a cover system 0.2 m thick will be sufficient to bring the average gamma radiation of the tailings below the target of 1.14 μSv/h and the maximum value below the 2.64 μSv/h. Unlike the tailings, which have a higher gamma signature, the waste rock piles do not require the same level of protection (i.e. cover thickness) as the average and maximum gamma signature of the waste rock piles are 70% and 50% lower than the tailings, respectively. Therefore, the proposed minimum cover thickness of 0.5 m over the waste rock piles will provide more than adequate protection from gamma radiation and a contingency should there be loss due to erosion.

There is no requirement for infiltration reduction or oxygen reduction and the cover material must be able to support self-sustaining vegetation. For landfills, covers must adhere to landfill cover standards.

2.2 Erosion Analysis

The following sections are based on the results of the cover erosion analysis (Attachment 2).

2.2.1 Scope and Purpose of the Erosion Analysis

The effects of wind and water erosion on the cover were analyzed for short and long term performance. In the water erosion assessment, only sheet and rill erosion were considered. Sheet and rill erosion occur as a result of overland flows that are not concentrated into a particular flow path. The design of the waste rock pile landform will include channels where concentrated flow is expected to occur. These areas will be armoured with non-woven geotextile or coconut matting and rip rap, which will mitigate erosion along these concentrated flow areas.

Wind erosion was estimated using the Wind Erosion Model presented by Skidmore (1994). Wind erosion should occur relatively uniformly over an erodible surface, which is reflected in the model.

All calculated erosion estimates are presented as "soil loss". Soil loss is a mass or depth of eroded material that leaves the slope entirely. Material that is detached and deposited on the slope is not included in the estimates for soil loss.

2.2.2 Soil Loss Criteria

The Revised Universal Soil Loss Equation for application in Canada (RUSLEFAC) was used to determine the effects of sheet and rill erosion on site. The RUSLEFAC is accompanied by soil loss classifications. Class 1 soil loss, also considered tolerable soil loss, is defined as the "maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected." The value of tolerable soil loss considered by RUSLEFAC is 6 T/ha/year. This value should be achieved on site, as one of the design objectives is to establish and then maintain a vegetated cover surface. Although this value was presented in the RUSLEFAC, which only takes water erosion into account, the target of 6 T/ha/year applies to the sum of soil loss due to both water and wind erosion. The 6 T/ha/year target was used to assess the short term stability of the cover system against erosion.

The remediation of the other site aspects is expected to be effective in perpetuity; however, it is not credible to suggest this design criteria can be met in geological timeframes. Therefore a 100-year design life has been adopted similar to that of the Lorado Remedial Project (SRK, 2014). Annual soil loss quantities determined by the RUSLEFAC were multiplied by 100 years to determine the total soil loss over the project design life (i.e. long term stability against erosion). The target value of 6 T/ha/year would then equal 600 T/ha/100years. To visualize this loss, the mass of soil was converted to an average depth over the eroded surface using a dry soil density of 1.7 T/m^3. The corresponding depth was 3.5 cm over the course of the design life, which will not impact the objective of the cover system to reduce gamma signatures.

2.2.3 Factors Affecting Soil Loss Due to Water Erosion

Slope Length

Slope lengths ranging from 10 m to 200 m were assessed, which were based on the existing topography of the waste rock piles. The results of the analysis indicated that soil loss increases as the slope length increases.

Slope Steepness and Shape

Soil losses for straight, complex and benched slopes were assessed. Complex slopes (i.e. concave) and benched slopes were assessed as they are both occasionally implemented as landform designs in the mining industry. In practice, complex slopes are intended to appear more natural by imitating the shapes of surrounding landforms, and also to cause a reduction in velocity as flow progresses down the slope. Benches are intended to reduce flow velocities and to create a flat area where soil deposition can occur.

The results revealed that complex slopes and benched slopes yield less soil loss than an equivalent straight slope (i.e. straight slope of 4H:1V vs. a complex slope with an overall slope of 4H:1V), approximately 9% and 15% less, respectively. Although the analysis indicates these slopes may perform somewhat better, other issues may arise with complex and benched slopes. It has been shown that, while benches can reduce flow energy if the design storm is not exceeded, standing water on terraces and benches can increase erosion (Sawatsky and Beersing, 2014). Benches have led to many different types of erosion degradation such as subsidence, piping, rilling and differential settling, which are costly to repair and create liability concerns (Clark, 2008). For these reasons, benches are no longer being considered as part of the waste rock design as previously proposed (SRK, 2015). Complex slopes tend to be difficult to construct and they require that a greater quantity of material to be displaced, which offsets the marginal reduction in soil loss.

Due to constructability and potential performance issues with complex and benched slopes, respectively, straight slopes were selected for the waste rock grading plan. The steepness of the straight slopes that were analyzed ranged from 2H:1V to 6H:1V. Slopes flatter than 6H:1V were deemed to be impractical due to the quantity of waste rock excavation that would be required. The results of the analysis showed that soil loss increases with increasing slope grade (Attachment 2).

Soil Type

Four different soils were compared in the erosion analysis, which were based on the material types available in Borrow Areas 5 and 6W. These two borrow areas will be utilized for the remediation of both the tailings and other site aspects. The soil parameters used in the analysis were based on the borrow investigations completed by Golder Associates (EIS, 2013) and OKC (2016) at the Gunnar Mine site.

The results of the analysis indicated that the material from Borrow Area 6W is the least erodible material (at least 55% less erodible than the next least erodible material). Furthermore, this material is not as susceptible to freeze thaw action and ice lensing. Based on the borrow investigation completed by OKC (2016), it is understood that there is enough material in Borrow Area 6W to complete the cover systems for the other site aspects (Section 2.2 provides more detailed discussion regarding borrow quantities). Therefore, the cover systems for the other site aspects will utilize the material from Borrow Area 6W.

Vegetation and Surface Cover

Two surface cover scenarios were considered in this analysis: undisturbed soil with no surface vegetation (assessed for short term stability), and undisturbed soil with 40% surface coverage of small, short-rooted vegetation (for long term stability). SRC indicated that establishing this degree of surface coverage is achievable based on the revegetation trials that have been undertaken at the Gunnar Mine site (Petelina, 2013a & b).

The results indicated that soil loss is significantly reduced as more vegetation is established. The reduction from no vegetation to 40% coverage with small, short-rooted vegetation is generally greater than 65%. Hence the importance of establishing vegetation as soon as possible.

Climate and Storm Events

Soil loss due to water erosion was assessed on an annual basis as a result of average precipitation, and on an event basis as a result of single storms. Erosion was assessed as a result of three storm events: a 1 in 100 year 24-hour event, a 1 in 200 year 24-hour event, and a 1 in 200 year 24-hour event that accounts for an increase in precipitation due to the potential effects of climate change. These events were chosen as the project design events based on the consequence classification for surface water management throughout the site.

The results of the analysis for 4H:1V slopes that are 100 m in length, indicated that each of the events exceed the soil loss target of 6 T/ha/year for non-vegetated slopes covered with material from Borrow Area 6W. However, if vegetated (small, short-rooted plants, 40% coverage), each of the events result in less soil loss than the target value.

Attachment 2, Figure 1 reveals that each storm event can generate more than a years' worth of erosion. The soil loss target is for an entire year, and if added to the average annual soil loss, each of the storm events would contribute to a loss of greater than 6 T/ha/year in the year that the storm occurred. However, tolerable soil loss is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected (Section 2.1.3). Therefore, if total soil loss marginally exceeds the target in a single year, it will not necessarily adversely affect the natural soil productivity of the hill slope. These results indicate that, prior to establishment of vegetation, microtopography should be utilized to reduce potential soil loss due to storm events.

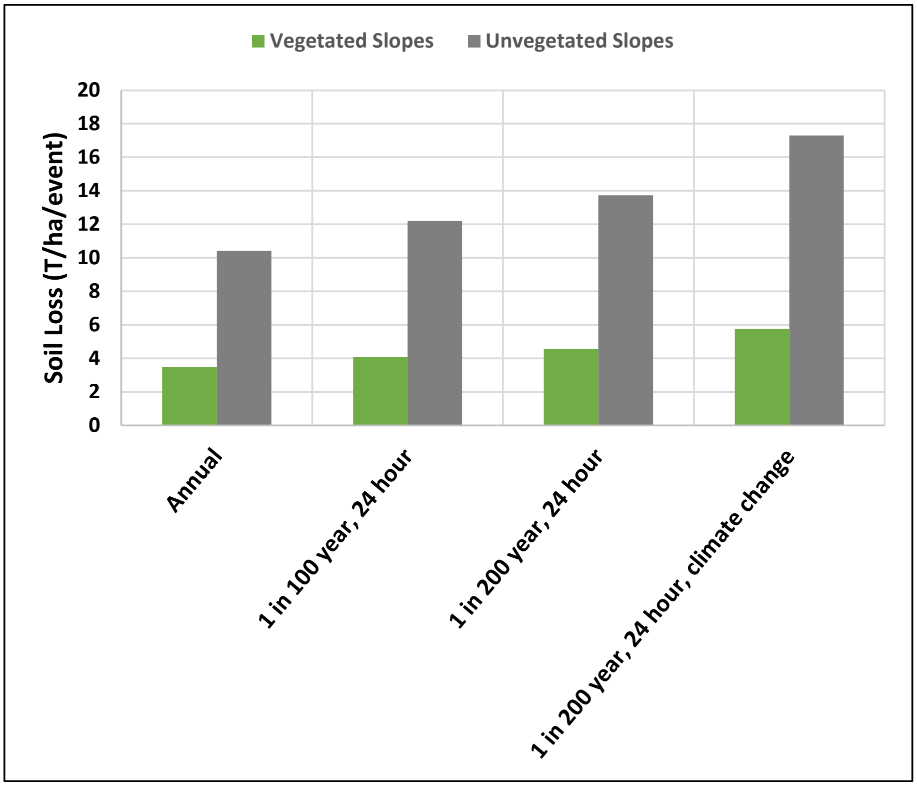

Figure 1: Soil Loss on an Annual Basis and for Storm Events (Vegetated and Non-vegetated)

Microtopography

Another limitation of the RUSLEFAC is that it does not account for erosion in concentrated flow paths where gullies may begin to form. The RUSLEFAC provides an estimate of the average amount of erosion that will occur over the entire erodible surface.

To mitigate the potential for flow to concentrate in certain areas causing channel or gulley erosion, microtopography features have been incorporated in the design. Within RUSLEFAC documentation, these features are referred to as support practice factors. These measures include slope texturing, installation of organic fiber rolls / wattles, installation of rolled erosion control products, installation of sediment fencing, and seeding. These features, when placed strategically, can also help to reduce sheet, rill and wind erosion. Based on the analysis (Attachment 2), slope texturing alone is not sufficient to reduce the soil loss values to 6 T/ha/year or less; however, the use of microtopography features that reduce flow velocity are capable of reducing the rate of soil loss to acceptable levels. The use of rolled erosion control products (RECP) can reduce soil loss values to approximately 1 T/ha/year. Additional details related to the placement of the microtopography is provided in Attachment 3. Brief descriptions of each method are provided below in the following paragraphs.

Slope texturing includes techniques such as imprinting, ripping, or surface tracking to decrease erosion rates, and effectively trap seeds, sediment, and runoff. Slope texturing is typically completed prior to seeding, and is intended to create roughness elements that could be between 50 mm and 150 mm in height across the slope.

Organic fibre rolls/wattles are used to reduce the effective slope length, thereby reducing the erosion potential associated with a slope. Organic fibre rolls/wattles are installed immediately adjacent to one another to provide continuous contouring across a slope.

RECP provide immediate and long-term erosion protection. The form close contact to the underlying soil, and direct overland flow over manufactured surfaces. The primary purpose of an RECP is to provide a stable surface that is able to support the development of vegetation.

Sediment fencing decreases the effective slope length providing an area for sediment deposition. They are typically used near waterbodies to restrict the deposition of sediment into a waterbody.

The final cover slopes are intended to be broadcast seeded, however hydroseeding and/or hydromulching will be considered in the next phase of engineering.

2.2.4 Soil Loss Due to Wind Erosion

Soil loss due to wind erosion is driven by the following parameters: climate (specifically wind, precipitation and temperature), soil type, vegetative cover, microtopography and roughness, and the size of the erodible area. Generally, soil loss increases on a unit area basis with higher wind speeds, higher fines content of the soil, and larger erodible areas that do not contain a wind break. Soil loss generally decreases with an increase in surface roughness, an increase in microtopography features, and increased vegetative cover.

The impacts of wind erosion were only assessed for material from Borrow Area 6W. The results of the analysis indicated that one of the soil samples from Borrow Area 6W was significantly more susceptible to wind erosion than the other. However, the analysis also indicated that soil losses due to wind erosion from either material are insignificant once the areas are vegetated. In the shorter term (non-vegetated), substantial amounts of erosion could occur from the material that is more susceptible to wind erosion if no microtopography features are included in the design (similar quantities of soil loss to that of water erosion may occur). With the inclusion of microtopography features, soil loss caused by wind of either material is nearly eliminated on all areas of the site.

2.2.5 Erosion Analysis Summary

The waste rock cover system for the other site aspects was assessed for both short term and long term stability against erosion. The results of the assessment were used to optimize the preliminary grading design for the waste rock piles. The series of 3H:1V slopes and benches initially proposed (SRK, 2015) have been modified to a straight slope with an overall grade of 5H:1V. The overall grade was selected based on the maximum slope length of the re-graded waste rock piles, approximately 80 m, which is located at the north east flank of the east waste rock pile. Microtopgraphy features are required to limit soil loss along unvegetated slopes in support of providing a successful environment to establish a vegetated cover.

2.3 Borrow Suitability Considering Loading Reduction Performance

A comparative evaluation of borrow materials was completed in support of confirming the appropriate cover material. The comparative evaluation was completed based considerations of borrow availability; erosion susceptibility; loading reduction performance; constructability; borrow area footprint; and cost. The comparative evaluation is provided in Attachment 1.

Due to the tailings cover remediation design (OKC, 2016), the material balance indicates that there is insufficient medium textured borrow, and therefore it was not considered in the comparative evaluation. The assessment considered the fine textured, and coarse textured borrow materials.

The erosion susceptibility of both borrow materials is discussed in Section 2.2, and a detailed evaluation of the erosion analysis completed is provided in Attachment 2. The erosion analysis concluded that the fine textured borrow material is classified as highly erodible with sever soil loss, while the coarse textured borrow material is considered to have a very low to low soil loss.

The coarse textured and fine textured materials were evaluated based on loading reduction performance. Net percolation analyses were completed based on coarse textured and finer textured cover materials, and the Uranium and Radium-226 reductions were estimated versus existing conditions. Although the loadings reduction indicated that a finer-textured cover material would reduce the loadings 5% more than the coarse textured cover material, the loadings reduction does not consider the impact of freeze-thaw on the performance of the finer-textured material. The coarser textured material is not considered susceptible to freeze-thaw cycling; and therefore, the freeze-thaw cycling is not anticipated to influence the performance of the coarse textured material.

The constructability and cost of the cover using coarse textured borrow versus fine textured was considered to be better. A fine textured cover was deemed to be more difficult to manage during construction due to sediment migration issues and the likelihood that moisture conditioning would be required. A substantially more complex landform design would also be required for a fine textured cover system to accommodate the erosion issues mentioned above and adaptive management would be greater to address potential long-term performance issues.

Lastly, the tailings remediation design does not call for fine textured borrow and a new borrow area would need to be developed for such material, increasing land disturbance.

In summary, the comparative evaluation concluded that the coarse textured material is recommended for use as the gamma cover system for the other site aspects.

2.4 Volumetric Assessment

Based on the results of the erosion analysis, the volumetric assessment initially considered a conservative approach by excavating all slopes of the east and south waste rock piles and the perimeter of open pit to 5H:1V. Such excavation resulted in approximately 1.1 Mm^3 of waste rock, which is significantly more than the 851,000 m^3 that is required for the tailings remediation design. Therefore, to reduce the amount of excavation, the erosion analysis was used to assess short and long term soil erosion for various slope lengths and angles. Based on the topography and height of the existing waste rock piles, it was determined that the assessment consider slope lengths and angles of 30 m at 3H:1V, 50 m at 4H:1V and 100 m at 5H:1V. The results of the assessment are provided in Table 1.

Table 1: Summary of Soil Loss for 30 m, 50 m and 100 m Long Slopes

Slope Configuration Length and Angle	Non-vegetated – Short Term Stability (T/ha/year)[1]	Vegetated – Long Term Stability	
		(T/ha/year)	(cm/100 years)
30 m (3H:1V)	7.9	2.6	1.6
50 m (4H:1V)	7.5	2.5	1.5
100 m (5H:1V)	7.8	2.6	1.5

Each of the three slope configurations will be stable under long term erosion conditions (Table 1). For short term conditions where vegetation has not yet been established, the annual soil losses marginally exceed the target value of 6 T/ha/year. However, soil loss below 11 T/ha/year is still classified as a low soil loss (Class 2, RUSLEFAC). Microtopography will be incorporated in the design and is expected to reduce short term soil loss to below the target value (Section 2.1.4). Once vegetation is established, soil losses on all of the proposed slopes will be substantially below the target value. Therefore, the following criteria was used to further optimize the grading plan for the waste rock piles:

- Waste rock slopes > 50 m in length will be graded to 5H:1.0V;
- Waste rock slopes ≤ 50 m in length will be graded to 4H:1V; and
- The channel slopes through the east waste rock pile will be ≤ 30 m in length and will be graded 3H:1V.

Several grading iterations were carried out to satisfy the 851,000 m^3 waste rock requirement for the tailings remediation design and to limit the amount of grading to achieve a landform that would conform to the above criteria. The proposed configuration of both waste rock piles and area surrounding the perimeter of the open pit is shown in Figure 16, SRK 2016.

2.5 Hydrotechnical Design and Microtopography

There are three areas along the waste rock piles where concentrated flow will occur (Figure 2). To determine the type of hydrotechnical design required for these areas, SRK has reviewed recent hydrology data (Appendix C, SRK 2016) and has updated the hydrological design criteria (Appendix D, SRK 2016). In summary three rip rap drainage channels and two channels lined with a RECP will be required to accommodate channelized flow (Figure 16, SRK 2016). Details of the rip rap drainage channels are shown in Figures 22 and 23, SRK 2016.

The main channel design to route Catchment 3 flow to Zeemel Bay is relatively consistent with the design proposed in the preliminary design (SRK, 2015), which in general, consists of a trapezoidal excavation that has a 6 m wide base and 3H:1V side slopes. Non-woven geotextile will be placed along the bottom of the excavated channel and keyed-in to an anchor trench. The non-woven geotextile will reduce migration of fine particles from the foundation excavation, which will be covered with a layer of rip rap. The upper portion of the channel side slopes above the rip rap will be protected with a RECP to stabilize the cover material until vegetation is established. The bench situated at the top of the rip rap armoring will act as a temporary sediment trap subsequent to construction until vegetation is established along the slopes. Details of the channel are shown in Figure 3. This channel configuration will safely convey the 1-in-1,000 year design storm event.

Microtopography features such as slope texturing, organic fibre rolls/wattles, sediment fences, RECPs, and seeding will be incorporated into the detailed plan for the waste rock piles (Section 2.2.3). These features will significantly reduce erosion during the most sensitive stage of the remediation, which is immediately after construction and prior to establishment of a self-sustaining vegetation over the cover system. The proposed layout of the microtopography is presented in Attachment 3.

3 Summary of Optimized Grading and Cover Design

In follow up to the response to CNSC Comment #5, the waste rock slope and cover design has been optimized as part of the detailed plan for the Gunnar Mine other site aspects in the following manner:

- Gamma cover thickness will be 0.5 m thick, and constructed with the coarse textured borrow;
- Waste rock slopes > 50 m in length will be graded to 5H:1V;
- Waste rock slopes ≤ 50 m in length will be graded to 4H:1V;
- The channel slopes through the east waste rock pile will be ≤ 30 m in length and will be graded 3H:1V, which is consistent with the configuration (SRK, 2015); and
- Microtopography features such as slope texturing, organic fibre rolls/wattles, sediment fences, RECPs, and seeding will be incorporated into the detailed plan for the waste rock piles.

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Attachment 1: Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Waste Rock Gamma Cover Trade-Off Study

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Memo

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Reviewed By:	Mark Liskowich, PGeo	**Date:**	July 8, 2016
Subject:	Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design - Waste Rock Gamma Cover Trade-Off Study		

1 Introduction

1.1 Context

The Preliminary Remediation Design Report for the Gunnar Mine "Other Site Aspects" (SRK, 2015), was reviewed by the Canadian Nuclear Safety Commission (CNSC) and identified areas of the design that required further supporting information. Comments were sent to the Saskatchewan Research Council (SRC) on December 18, 2015 and preliminary responses were subsequently submitted to the CNSC, which are included in Appendix A, (SRK, 2016a). This memo further addresses Comment #6 from the CNSC, which stated the following:

Comment 6:
"*One of the remediation objectives is to minimize contaminant loadings to St. Mary's Channel and Zeemel Bay. In order to achieve this objective, the cover system should be designed to limit the net infiltration and ensure its long term integrity. The current cover design of 0.5 m medium to coarse borrow materials seems not well justified to support achieving this objective. Based on the site investigation, a significant amount of fine-grained borrow material are available and should be used to enhance the cover design. SRC is expected to justify the current design of cover thickness. The fine-grained borrow materials should be considered to enhance the cover design and its performance."*

1.2 Scope and Purpose

In the preliminary design of the "Other Site Aspects" (SRK, 2015), medium to coarse grained borrow was proposed over fine grained borrow for the cover systems associated with the waste rock piles and peripheral areas, as these materials are less susceptible to frost and erosion. This cover system provided a conservative uranium load reduction estimate for Zeemel Bay (56% reduction) that was confirmed in the human health and ecological risk assessment (HHERA) to have no adverse effects on humans and aquatic environment. However, since there is an abundance of fine textured borrow, the intent of this comparative assessment is to determine if utilizing fine-textured borrow can further reduce infiltration, and to provide a comparative evaluation of the available borrow materials in consideration of erosion susceptibility, constructability, performance, footprint of borrow areas and cost.

2 Waste Rock Cover

2.1 Gunnar Project "Remediation Objectives"

The purpose of remediating the Gunnar Mine site (the Site) is to reduce the risks that the Site poses to human health, safety of the public, and integrity of the environment (SRC, 2013). The remediation objectives that pertain to the "other site aspects" are to:

- Stabilize waste rock slopes;
- Minimize human health risks posed by gamma dose rates;
- Consolidate and permanently dispose of demolition debris following the Saskatchewan Environmental Code for landfills;
- Consolidate and permanently dispose of contaminated earthen and industrial materials following the Saskatchewan Environmental Code for landfills;
- Minimize contaminant loadings to St. Mary's Channel and Zeemel Bay; and
- Take measures to ensure public and environmental health and safety during and after the remediation activities through appropriate monitoring.

2.2 Cover System Criteria

To achieve the site objectives listed above, the following criteria was established for the cover systems for the other site aspects (SRK, 2015):

1. The primary function of the cover system is to reduce gamma radiation and radon gas exposure in accordance with the performance criteria established in the Environmental Impact Statement (EIS) (SRC, 2013). This includes: "The sum of gamma radiation and radon gas exposure measured 1 m above impacted area must be no greater than 2.64 μSv/hr (2.5 μSv/hr above background) as a spot reading and no higher than 1.14 μSv/hr (1.0 μSv/hr above background) as an average measured over 1 ha.";
2. The cover system must be able to support self-sustaining vegetation; and
3. The cover system must be stable geotechnically, and provide long term stability against erosion.

There is no requirement for infiltration reduction or oxygen reduction; however, the design of the cover system will be completed in accordance with the ALARA principle ('As Low as Reasonably Achievable').

2.3 Cover System Thickness

Several gamma radiation surveys have been completed at the Site that range from 1986 to 2009. The results of the most recent gamma survey completed in 2009 and 2011 (exclusive of tailings areas) indicated that the average gamma dose rate was approximately 1.73 μSv/h and that the maximum spot check dose rate was 11.63 μSv/h, which was situated at the East Waste Rock Pile (EWRP). The next highest spot check was at the mill yard, which had a value of 4.44 μSv/h. It is understood that the maximum spot check and values that measured above 2.5 μSv/h were almost all associated with materials that had been hauled and placed on the east waste rock pile and were not actually waste rock material (OKC, 2016).

A gamma shield assessment for the areas associated with the other site aspects was completed, which considered source gamma rays that ranged from 2.64 to 11.63 µSv/h (SRK, 2016a). These values are consistent with the 75th percentile and maximum spot gamma readings, respectively, taken 1 m above the surface of the waste rock piles, as presented in the EIS (SRC, 2013). The results of the assessment revealed that a cover system 0.2 m thick with soil and/or waste rock borrow will be sufficient to bring the 75th percentile gamma radiation readings below the “average” target of 1.14 µSv/h and the maximum spot check value below the 2.64 µSv/h.

SRK completed a long term erosion analysis (SRK, 2016b), which determined design life soil loss. This was estimated to be as high as 0.086 m for a non-vegetated, 100 m, 3H:1V slope. This was considered conservative as the proposed design slopes are 4H:1V, or flatter, and are generally shorter in length. In maintaining a conservative approach to soil loss, a thickness of 0.1 m was considered appropriate to protect against long-term erosion.

Based on the revegetation plan for the other site aspects (SRC, 2016), it is understood that approximately 0.3 to 0.4 m of borrow is required to support vegetation. Therefore the proposed minimum cover thickness of 0.5 m over the waste rock piles and general site areas will provide an adequate growth medium for vegetation, more than adequate protection from gamma radiation (minimum 0.2 m thick), and will also provide a contingency should there be loss due to erosion (estimated to be less than 0.1 m thick).

2.4 Borrow Material and Design Quantities

2.4.1 Borrow Material Characterization

In general, there are three borrow material types that are available for use in the cover system, which are characterized as follows (OKC, 2016):

1. Finer-textured Borrow (clay and silt)
   - 80 to 100% clay and silt, 0 to 30% sand, less than 20% cobble and gravel;
2. Medium-textured Borrow (fine sand to coarse sand)
   - less than 70% clay and silt, 30 to 100% sand, less than 20% gravel and cobble; and
3. Coarser-textured Borrow (sand and gravel or coarser)
   - less than 40% clay and silt, 30 to 80% sand, 20 to 40% gravel and cobble.

2.4.2 Borrow Availability

A borrow material investigation was completed by O’Kane Consultants Inc. (OKC) in 2015 to further refine borrow source volumes available for the proposed remediation designs. Previous studies focused on Borrow Areas 6, 13 and the airstrip while the OKC investigation targeted Borrow Areas 1, 2, 5, 11 and 12. The investigation consisted of excavating test pits for visual inspection, soil sample collection and to log and predict the depth of borrow. In summary, Borrow Areas 1, 2, 11, 12 and 13 consisted of fine textured borrow and Borrow Areas 5 and 6 consisted primarily of medium to coarse textured borrow. Borrow Areas investigated by OKC and others are shown in Figure 1. The estimated borrow material volumes above the water table are summarized in Table 1 and details on how the volumes were estimated are provided in OKC (2016).

Table 1: Estimated Borrow Material Volumes (Above Water Table) (OKC, 2016)

Borrow Area	Area (m^2)	Fine Textured (m^3)	Medium Textured (m^3)	Coarse Textured (m^3)
1	59,150	125,210	-	-
2	97,930	310,950	-	-
5	277,120	587,850	194,190	47,940
6S, 6V & 6W	246,500	-	124,100	686,470
6U	76,630	-	108,230	-
6 Contingency	96,860	75,590	46,800	-
11	118,610	278,430	-	-
12	152,540	383,100	-	-
13	296,000	646,100	-	-
West Airstrip	54,450	-	-	80,930
Totals		**2,407,230**	**473,320**	**815,340**

Estimated material volumes that remain after the Tailings Remediation Project is complete are provided in Table 2 (OKC, 2016).

Table 2: Estimated Borrow Material Volumes for Other Site Aspects (OKC, 2016)

Fine Textured (m^3)	Medium Textured (m^3)	Coarse Textured (m^3)
2,407,230	51,320	533,340

2.4.3 Borrow Remediation Design Quantities for the Other Site Aspects

The volume of borrow to meet the gamma cover requirements for the remediation of the other site aspects is estimated at approximately 245,000 m^3 (SRK, 2016a). There is sufficient fine or coarse textured borrow to accommodate the gamma cover requirements should either material type be used. The medium textured borrow will be nearly depleted as part of the Tailings Remediation Project and for that reason this material was not considered in the comparative assessment.

3 Comparative Assessment

3.1.1 Erosion Susceptibility

An erosion analysis was completed as part of the updated preliminary remediation design (SRK, 2016a). Both short and long term stability against wind and water erosion was assessed and considered the following factors: slope length, slope steepness and shape, soil type, vegetation and surface cover, climate and storm events. As expected the erosion susceptibility of the fine textured borrow is significantly higher than the coarse textured borrow material. The coarse textured borrow would have a very low to low soil loss “Class 1 and 2, RUSLEFAC” (Wall, 2002) and the fine textured borrow is highly erodible and would result in severe soil loss “Class 5, RUSLEFAC” (Wall, 2002). The coarse textured borrow material is approximately 11 times less erodible than the fine grained borrow material (SRK, 2016b). Erosion susceptibility is a primary consideration in the success of the cover system and the successful establishment of vegetation. Therefore because the fine textured borrow material is classified as highly erodible with severe soil loss, it is a less desirable material for use in the cover system as compared to the coarse textured borrow material.

3.1.2 Performance – Reduction in Uranium and Radium Loading

In the Gunnar loadings memo for the other site (CanNorth, 2016a), the three borrow material types (i.e. cover options) were evaluated to assess the reduction in surface water concentrations in Zeemel Bay as net percolation varied for each material type. The net percolation for each material type was estimated based on the sensitivity analysis completed in the cover system alternatives memo, Appendix K of the EIS (SRC, 2013). Estimated percolation values as well as Uranium and Radium-226 reductions from existing conditions (i.e. base case) are provided in Table 3.

Table 3: Summary of Net Percolation and Future Uranium and Radium Surface Water Concentrations for Different Cover Options

Cover Material	Net Percolation		Predicted Post-Remediation			
	(mm/yr)	% Change	Uranium Concentration in Zeemel Bay (mg/L)	% Change	Radium-226 Activities in Zeemel Bay (Bq/L)	% Change
Bare Waste Rock (Base Case)	176	-	0.0180	-	0.0120	-
Coarse Textured Till Cover	118	-33%	0.0082	-54%	0.0074	-38%
Medium Textured Till Cover	101	-43%	0.0074	-59%	0.0072	-40%
Fine Textured Till Cover	61	-65%	0.0055	-69%	0.0068	-43%

Notes: 1) % Changes were calculated versus the base case.
2) Concentrations provided by CanNorth (CanNorth, 2016a)

As seen in Table 3, the use of various coarse, medium, or fine textured borrow material results in net percolation reductions of 33%, 43%, and 65%, respectively, as compared to the base case, which influences the reduction in Uranium and Radium-226 concentrations post-remediation. The base case is the current, unpremeditated condition of the site. The percent change in Uranium and Radium-226 concentration between the coarse textured and the fine textured till, as compared to the base case is approximately 33% and 8%, respectively.

Although the fine textured till has a larger percent reduction in Uranium and Radium-226 concentrations, these reductions consider the integrity of the cover is maintained over the design life of the facility, and a target hydraulic conductivity of approximately $1X10^{-7}$ m/s or less is maintained. Literature indicates that materials with properties such as the fine textured borrow can increase in hydraulic conductivity by several orders of magnitude due to freeze/thaw cycling affects (MEND, 2012). This increase in hydraulic conductivity would increase percolation through the fine borrow cover to values that could be higher than the coarse textured borrow. The coarse textured material is not as susceptible to freeze-thaw affects and ice lensing. Unless a frost protection layer were added to the cover design, the reduced hydraulic conductivity of the fine grained borrow would result in loadings that would be at least similar, if not worse to that of the coarse textured borrow. Therefore the benefit of reduced percolation/loading would only be time dependent for a borrow cover system with fine textured material and thus performance in regards to loading is deemed the same between the two material types.

3.1.3 Constructability

In general, a cover system using fine textured borrow versus coarser textured borrow would be more difficult to manage during construction as it is likely that some degree of moisture conditioning would be required.

A cover system option that consists of 0.25 m of fine grained borrow followed by 0.25 m of coarse grained borrow was considered. However, this would be very difficult to construct as there would be a high likelihood of cross contamination/mixing of the borrow materials, especially along waste rock and landfill slopes. Cross contamination is considered a high risk as once the materials are mixed, the fines component will dominate and the cover system will become more susceptible to erosion. Even with a stringent QA/QC program, this risk would outweigh the potential benefits of such a system. Furthermore, placing in such small lifts may result in over compaction of the material, which could impact vegetation growth.

3.1.4 Footprint of Borrow Areas

The tailings remediation design (OKC, 2016) does not call for fine textured borrow and a new borrow area would need to be developed increasing land disturbance to accommodate the required volume. Borrow Area 6 comprised of coarse textured material will be developed as part of the tailings remediation design, which will have a sufficient amount of borrow to complete remediation designs for the other site aspects.

3.1.5 Cost

Typically, due to moisture requirements, the handling and placement costs associated with fine textured materials is higher than coarse textured materials. A more robust microtopography design (if achievable) would be required to lessen the erosion related issues discussed in the sections above. It is also likely that adaptive management would be required to address long term erosion of the fine textured material. For these reasons, a coarse textured cover system was deemed to be more cost effective.

3.1.6 Evaluation

The two borrow material types were rated on a comparative scale for each of the evaluation components discussed above. The evaluation components were rated based on “same”, “better”, or “worse”. The results are presented in Table 4.

Table 4: Results of Comparative Evaluation

Evaluation Components	Cover System		Comments
	Coarse Textured Borrow	Fine Textured Borrow	
Erosion Susceptibility	better	worse	Coarse Textured Borrow has very low to low erodibility while fine textured borrow is highly erodible.
Performance – Reduction in Uranium and Radium Loading	same	same	Fine textured borrow may initially perform better but would only be time dependent. Erosion and effects from freeze thaw would impact long term performance of a fine textured cover system.
Constructability	better	worse	Construction efficiency more favorable for coarse textured borrow cover system.
Footprint of Borrow Area (land disturbance)	better	worse	Increased land disturbance for fine textured borrow cover system.
Cost	better	worse	Handling and placement of fine textured materials is typically higher due to moisture conditioning. Adaptive management would likely be required to address long term erosion issues, which may result in more complex landform design (and higher cost to implement).

4 Conclusion and Recommendations

Based on this comparative assessment, the coarse textured borrow material placed 0.5 m thick is recommended for the gamma cover system for the other site aspects.

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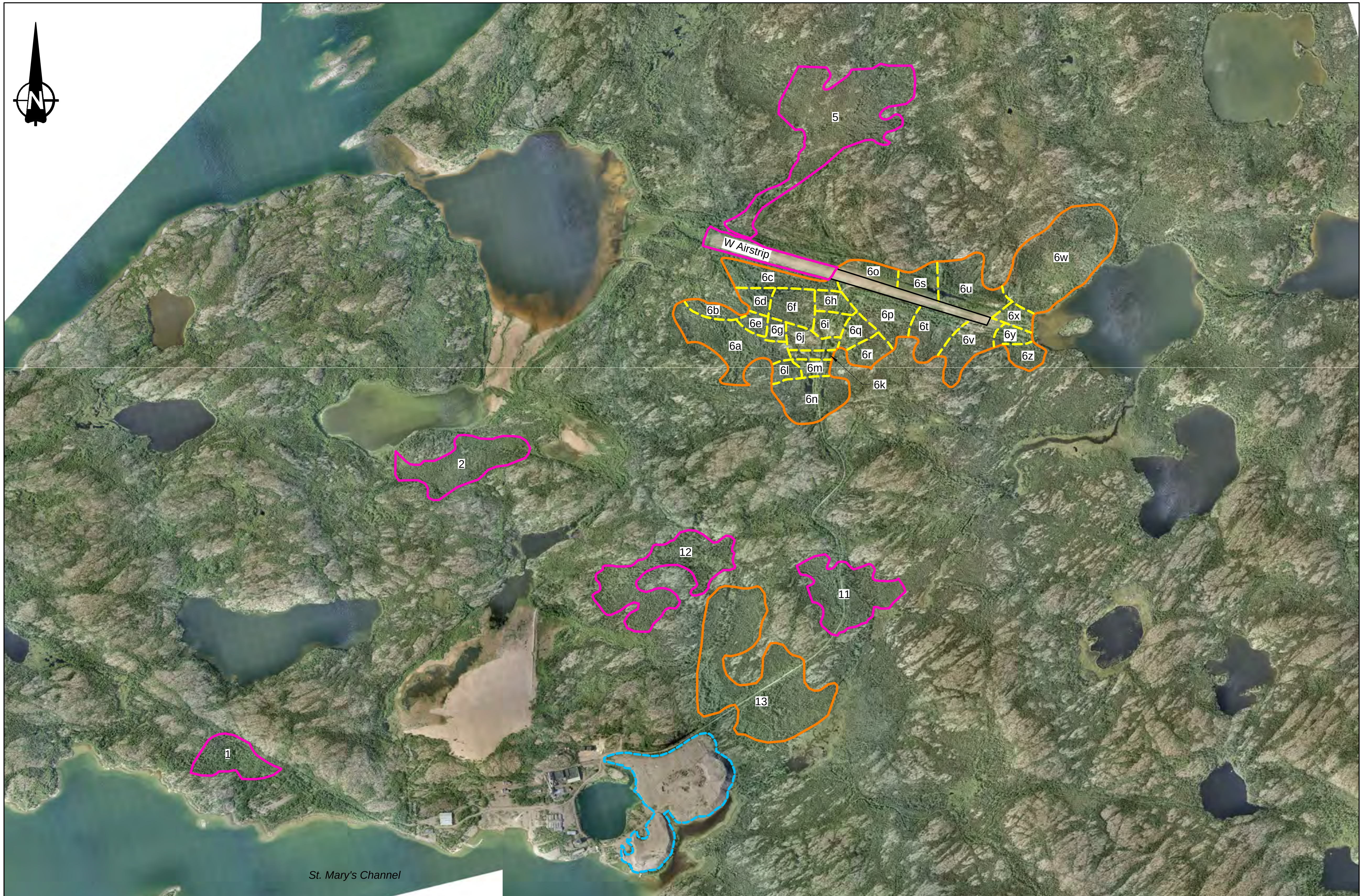
Figures



LEGEND

- Sub Area Section Boundary
- Waste Rock Pile Footprint
- Current Borrow Investigation (OKC 2015)
- Previous Borrow Investigation (By others)

NOTES

Imagery provided by SRC.

REFERENCE

NAD83 UTM Zone 12.

Borrow investigation areas adapted from dwg no. 963/1-020, Gunnar Borrow and Waste Rock Investigation - Plan. Provided by O'Kane Consultants Inc.

Borrow Area 6 sub areas adapted from figure 4, Borrow Area 6 Sub Areas. Provided by Golder Associates.

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srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

UPDATED PRELIMINARY REMEDIATION DESIGN

BORROW LOCATION PLAN

GUNNAR MINE "OTHER SITE ASPECTS"

SRK JOB NO.:	1CS056.003
FILE NAME:	1CS056.003 - Borrow Zones.dwg

DATE:	APPROVED:	FIGURE:
2016/07/08		1

Attachment 2: Gunnar Project "Other Site Aspects" Updated Preliminary Remediation Design – Cover System Erosion Analysis

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Memo

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From:	Jordan Graham, EIT, Erik Ketilson, PEng	**Project No:**	1CS056.003
Reviewed by:	Trevor Podaima, PEng, Maritz Rykaart, PEng	**Date:**	July 12, 2016
Subject:	Gunnar Project "Other Site Aspects" Updated Preliminary Remediation Design - Cover System Erosion Analysis		

1 Introduction

SRK Consulting (Canada) Inc. is currently undertaking the detailed design plan for the "other site aspects" at the former Gunnar Mine Site (the Site), located near Uranium City, SK. SRK's scope includes the reclamation and detailed design planning for the waste rock piles, and proposed hazardous and non-hazardous landfills.

Determining the potential impacts of water and wind erosion is an important aspect in closure planning particularly when considering the long-term performance of proposed landform designs, as erosion can significantly alter an engineered landscape. Several areas at the former Site require landform design including the waste rock piles and landfills. SRK is considering methods of mitigating water and wind erosion during construction, during the post-construction monitoring period, and into long-term passive closure stages. The purpose of this memo is to present the potential loss of soil due to sheet and rill water erosion, as well as wind erosion that could occur on the engineered slopes over short-term and long-term periods at the Site. The intent then is to determine methods of protection sufficient to reduce erosion to acceptable levels, and to characterize (if any) sacrificial thickness should be added to the cover to account for erosion without impacting the performance objectives for the cover of a particular area.

In the water erosion assessment, only sheet and rill erosion were considered. Sheet and rill erosion occur as a result of flows that are not concentrated into a particular flow path. Erosion that may occur within channel flow, and the necessary armouring will be discussed as part of the hydrotechnical design of the defined channels as a separate 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 wind or water. Material that is detached and deposited on the slope is not included in the estimates for soil loss. The results presented are therefore conservative.

2 Soil Loss Estimation Methods

There are several methods available for estimating water erosion including the Universal Soil Loss Equation (USLE), the Revised Universal Soil Loss Equation (RUSLE) Versions 1 and 2, the Revised Universal Soil Loss Equation for Use in Canada (RUSLEFAC), the Water Erosion Prediction Project (WEPP), Community Surface Dynamics Modeling System's SIBERIA, 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). The RUSLEFAC uses metric units and input parameters that apply to Canadian conditions. RUSLE Version 2 is one of the most current soil loss estimation methods and is an update of the RUSLE. RUSLE Version 2 is available only as a computer program, whereas the earlier versions were available as summary documents from which one could learn to calculate soil loss manually. WEPP and SIBERIA are also only available as computer programs.

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 of each of the input parameters can be thoroughly understood.

3 RUSLEFAC Scope and Limitations

The RUSLEFAC (Wall et al., 2002) is a tool for calculating sheet flow erosion and rill erosion and 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:

- 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 lenses typically form in finer grained material with sufficient capillary action. The borrow material that will be proposed in this analysis is relatively coarse material and is not considered susceptible to ice lensing.

4 Design Criteria

Based on the RUSLEFAC, acceptable rates of erosion for the site have been preliminarily estimated at approximately 6 tonnes per hectare per year. 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

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).

Although 6 tonnes per hectare per year is considered an acceptable rate of erosion, landform designs at the Site should yield the least amount of erosion possible. Establishing long term vegetation on the engineered landforms should be one of the primary objectives of the design. Recommendations for short-term (i.e. during construction) management practices will be provided as part of the detailed remediation plan to limit erosion and provide a suitable substrate for the vegetation to establish.

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 are 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: 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: 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 precipitation energy that causes soil loss over the course of an average year. The annual erosivity value should be used to determine the cumulative soil loss over a long period of time.

Storm event erosivity should be used to determine short term soil loss. The degree of accuracy of soil loss predictions for single storm events is relatively low (Section 3).

6.1.1 Annual Erosivity

Annual R values are not shown on the Canadian Isoerodent Maps in Northern Saskatchewan near the Site. The farthest north that the maps extend is near Island Falls, Saskatchewan: the R value in this area is 400 MJmm/hah. Values in northern BC, Ontario and Quebec that have similar latitude and climate (and in the case of Ontario and Quebec, are also in the Canadian Shield) to that of the site are also shown on the isoerodent maps. Values in these areas are also similar to 400 MJmm/hah. Therefore, an annual R value of 400 MJmm/hah was used for the Site.

6.1.2 Storm Event Erosivity

Erosivity was calculated for single storm events using the method described in Wischmeier and Smith, 1978. The storm events were determined using intensity-duration-frequency curves for Stoney Rapids (Environment Canada, 2014). Single storm distributions are not available from Environment Canada and were estimated using a second quartile Huff distribution (Huff, 1990). The storm events erosivity values are presented in Table 6-1.

Table 6-1: Storm Event Erosivity Values

Storm Event	Total Precipitation (mm)*	Erosivity (MJmm/hah)
1 in 100 year, 24 hour	85	469
1 in 200 year, 24 hour	95	528
1 in 200 year, 24 hour (adjusted for estimated effects of climate change)	118	665

*Total precipitation for the 1 in 200 year climate change event was obtained from the Site Hydrology Review and Update Memorandum (SRK, 2016).

6.2 Soil Erodibility Factor (K)

SRK understands that Borrow Area 6W will be available for use on the landfills, waste rock piles, and other areas included in the “other site aspects” that require cover (Figure 1). Two test pits were excavated and sampled in Borrow Area 6W (Golder, 2013). The material in this area primarily consists of sand and gravel, with little silt or clay. This material was evaluated using the soil erodibility nomograph (Wall et al., 2002); the resulting K value was 0.09 (the two samples yielded very similar results).

Three representative soils from the August, 2015 field sample program (O’Kane, 2015) were also evaluated separately using the soil erodibility nomograph: a coarse textured soil, a medium-coarse textured soil, and a medium-fine textured soil, all from Borrow Area 5. SRK understands that it is unlikely that this material will be used for the “other site aspects”; however, the soils were assessed to determine how borrow from a different area would compare to that of Borrow Area 6W. The K values were 0.027, 0.038 and 0.099, respectively.

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SRC SASKATCHEWAN RESEARCH COUNCIL

GUNNAR MINE "OTHER SITE ASPECTS"

DETAILED REMEDIATION PLAN

BORROW AREA LOCATIONS FOR EROSION ANALYSIS

Date:	Approved:	Figure:
June 2016	JG	1

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, 3H: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 m bench, and a straight slope with two 10 m 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 drawing indicates the horizontal to vertical slopes, but it is not drawn to scale.

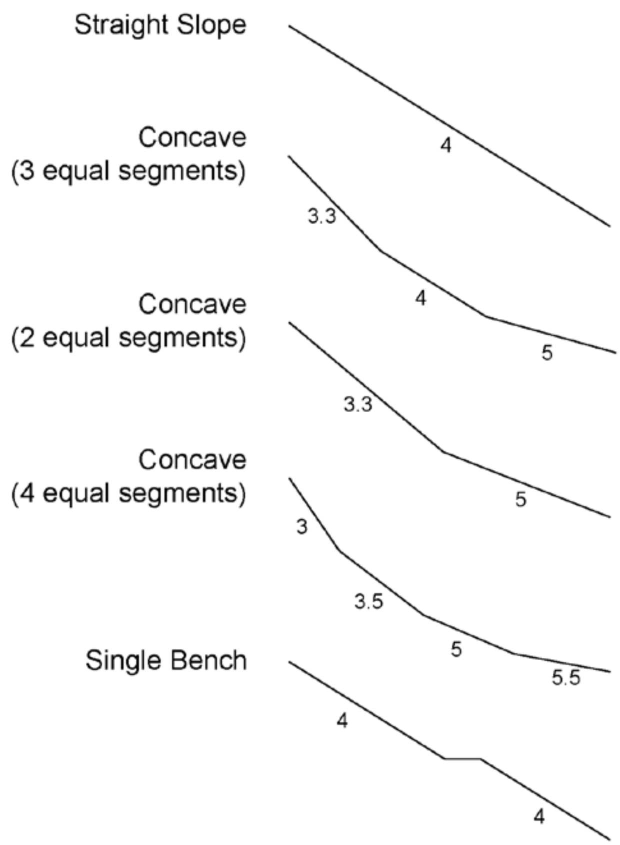

Figure 2: Types of slopes assessed

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 are likely to be incorporated into the design in support of the successful establishment of vegetation on the re-contoured surfaces. The support practices are likely to include slope texturing, sediment fencing, and/or the use of rolled erosion control products. The support practice factors are 0.9, 0.6, and 0.1 respectively (Alberta, 2011).

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 1.7 T/m³. The depth represents the average depth of soil loss over the entire erodible surface area. The guideline values 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 if no vegetative cover is established. For slope lengths shorter than 50 m, slopes as steep as 5H:1V will meet the guideline of 6 T/ha/year. If 4H:1V slopes are used for 50 m slope length, the expected soil loss will approach 10 T/ha/year.

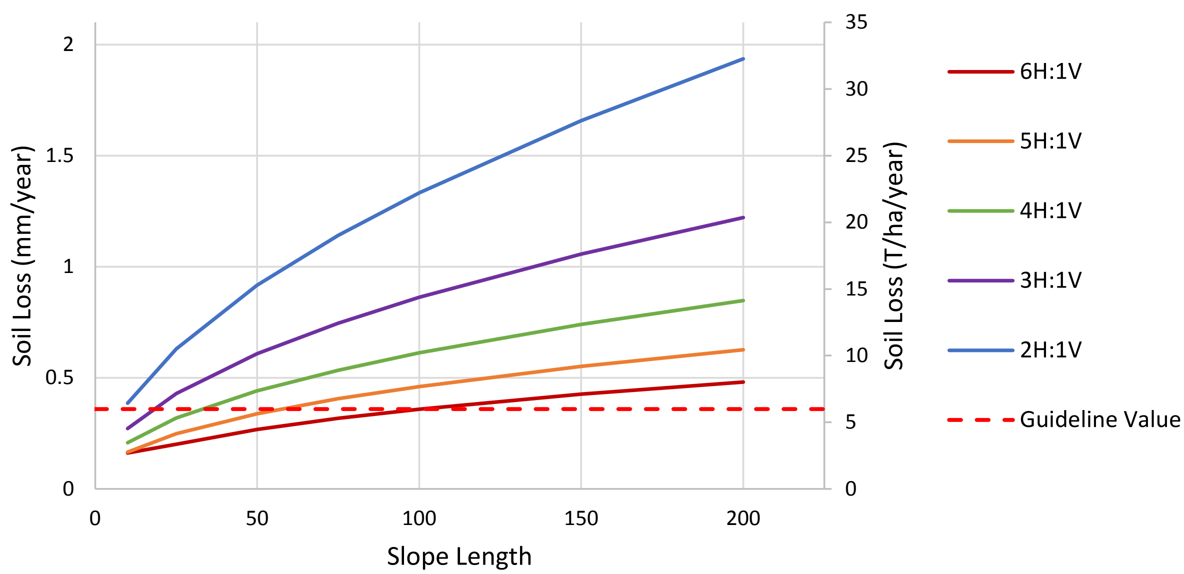

Figure 3: Straight slopes using Borrow Area 6W Material with no vegetative cover

7.2 Effects of Vegetation

Figure 4 illustrates the expected straight slope soil loss with 40% small, short-rooted plant coverage and no vegetative canopy. For slope lengths shorter than 100 m, slopes as steep as 3H:1V will meet the guideline value. Comparing Figure 3 and Figure 4 shows that established vegetation significantly reduces soil loss due to water erosion.

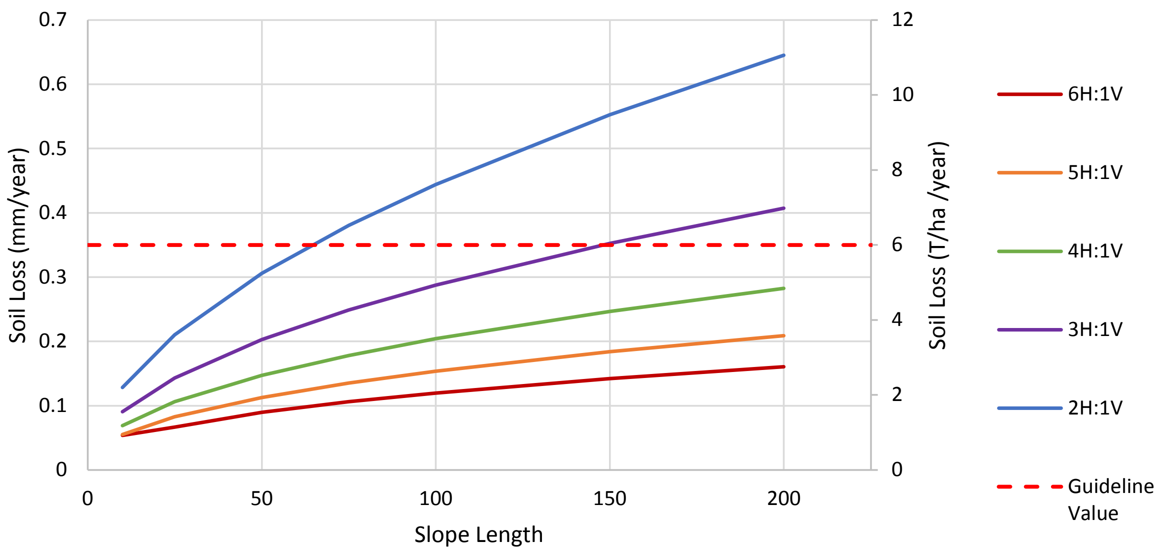

Figure 4: Straight slopes using Borrow Area 6W Material with 40% small, short-rooted plant coverage and no vegetative canopy

7.3 Effects of Complex Slopes

The soil losses for 100 m long complex slopes at 4H:1V are shown in Figure 5. The figure indicates that each of the complex slopes yields less soil loss than an equivalent straight slope. A slope with two 10 m benches sloped outwards at a 1% grade yielded the least soil loss in this analysis; soil loss was reduced by 15% from that of a 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. The values in Figure 5 are representative of a surface consisting of material from Borrow Area 6W with no vegetative cover.

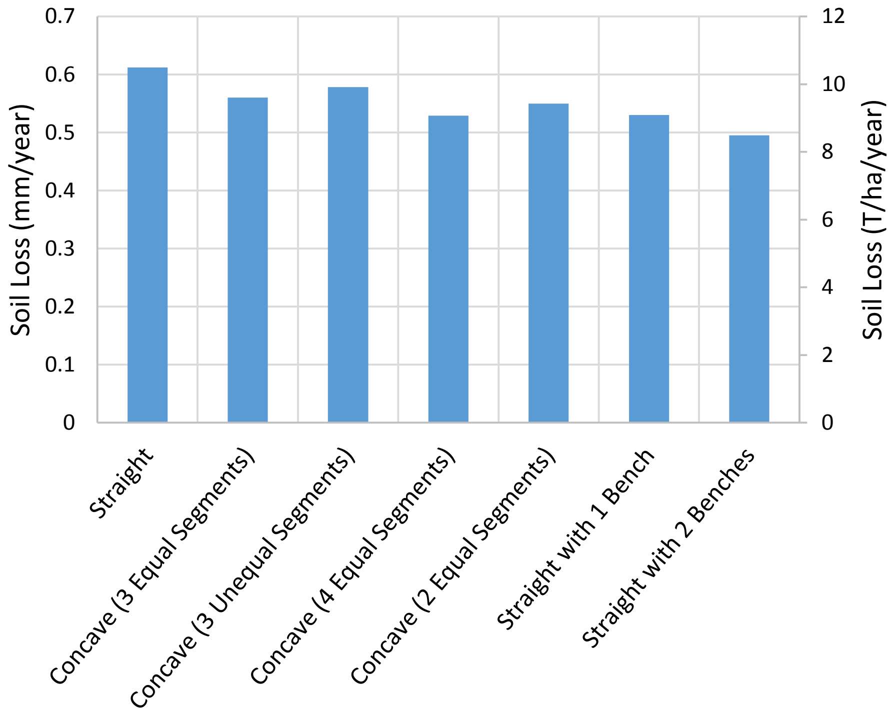

Figure 5: Complex slope comparison (100 m long at 4H:1V and no vegetative cover)

7.4 Effects of Soil Type

The effects of soil type are presented in Figure 6. Each of the soil loss estimates are based on 100 m long 4H:1V straight slopes, and no vegetative cover. The figure indicates that the material from Borrow Area 6W will erode less than the other materials that were assessed. The coarse and medium-coarse material could potentially be used with different slopes, slope lengths, and vegetative cover. The medium-fine material is highly erodible and should not be used for the “other site aspects”.

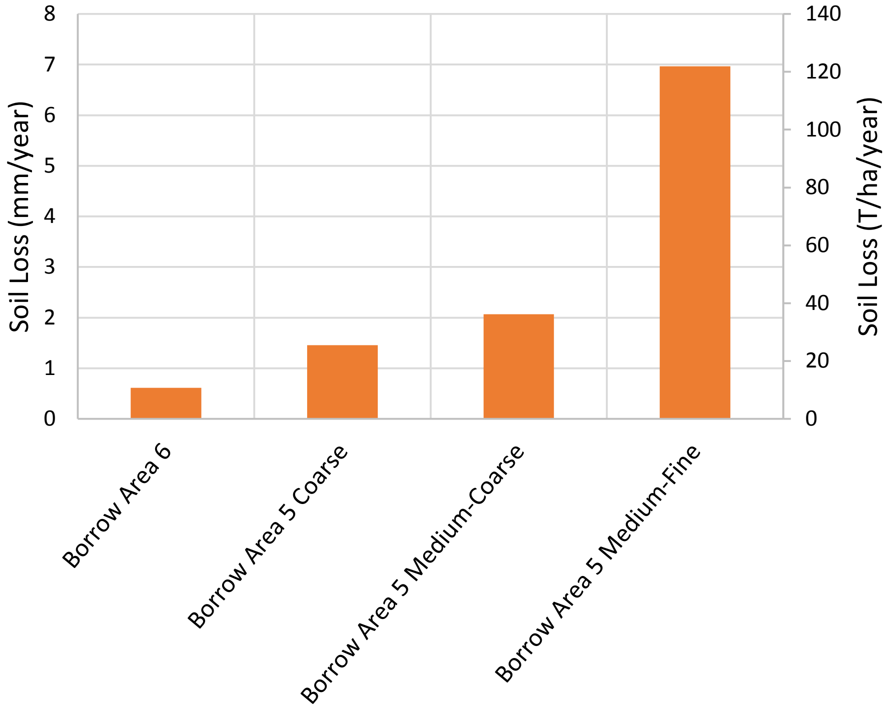

Figure 6: Soil Type Comparison (based on 100 m long 4H:1V straight slopes)

7.5 Effects of a Storm Event

The effects of erosivity resulting from major storm events are presented in Figure 7. Each of the soil loss estimates are based on 100 m long 4H:1V straight slopes, with material from Borrow Area 6W and no vegetative cover. Annual soil loss is included in blue as a relative reference. The figure shows that major storms have a greater impact than the average erosion that is expected to occur over the course of an entire year. However, based on this analysis, only the 1 in 200 year, 24 hour, storm that accounts for climate change caused greater than an average depth of one millimeter of soil loss.

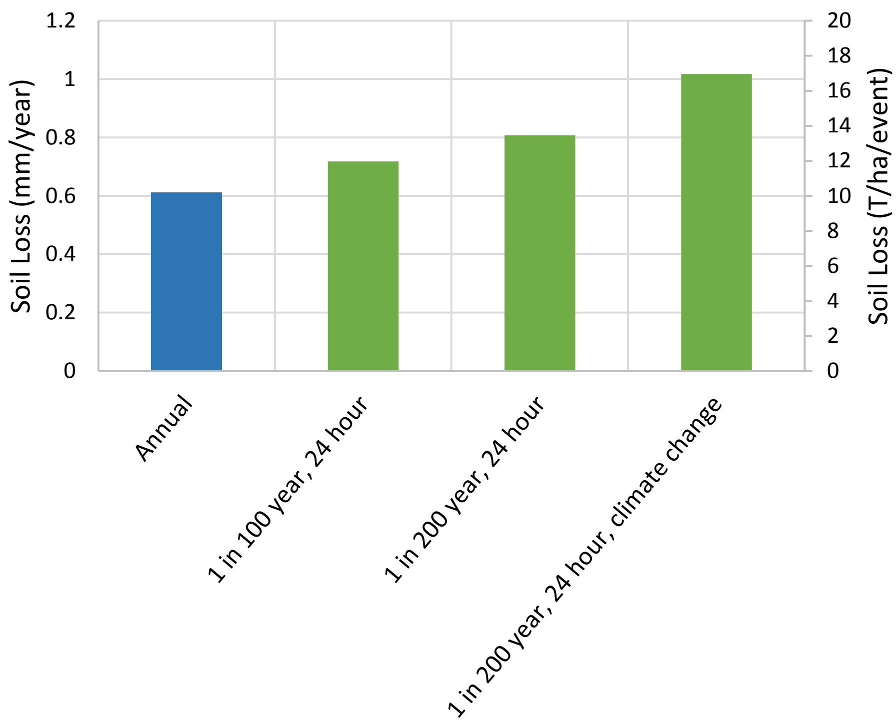

Figure 7: Storm Impacts Comparison (no vegetation)

7.6 Effects of Support Practice Factor

The effects of the support practice factor were evaluated on a non-vegetated, 100 m long, 4H:1V slope, covered with material from Borrow Area 6W, while considering average climatic conditions. 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. The results also show that the use of soil texturing alone will not reduce the rate of erosion to the target. Rolled erosion control products reduce the rate of erosion to nearly negligible levels. Sediment fencing is grouped together with wattles, as their effectiveness in reducing erosion is very similar.

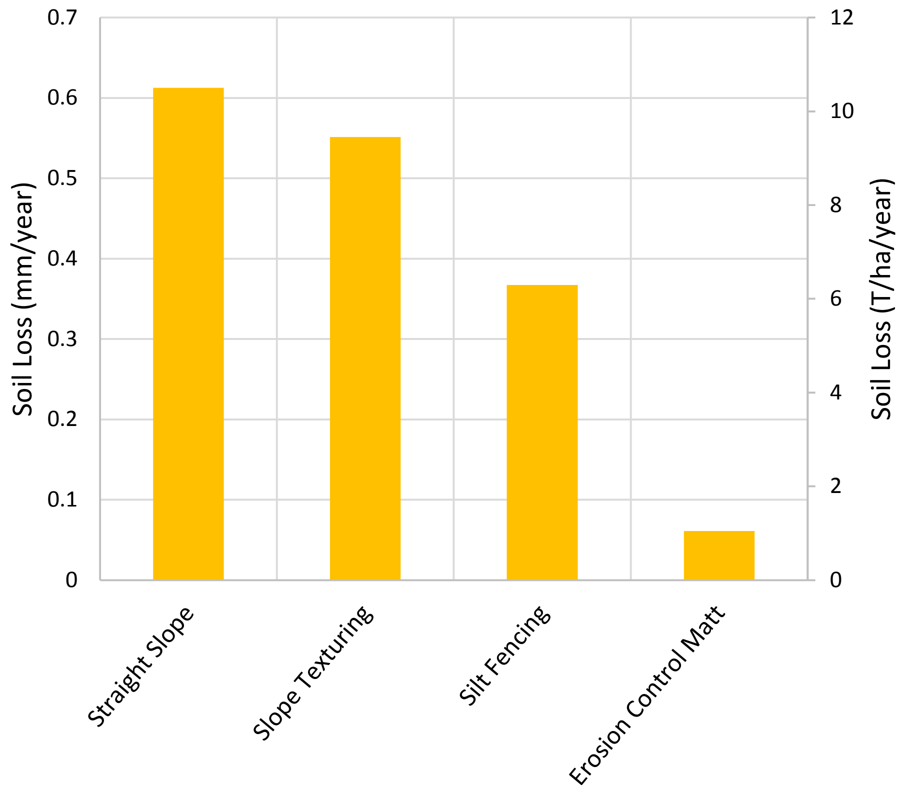

Figure 8: Support Practice Comparison (no vegetation)

8 Wind Erosion

Wind erosion was estimated using the Wind Erosion Model presented by Skidmore (1994). Wind erosion is a function of the soil's erodibility, inflection points on the slope, ridges that may be present on the slope (tilled ridges), surface roughness, the local climate, the size of the exposed surface, and the vegetative cover. Wind speed, temperature and precipitation values from the 1961-1990 Climate Normals for Uranium City were used as inputs to the model.

8.1 Effects of Vegetation

The effects of vegetation on erosion are significant. In this analysis using the material from Borrow Area 6W, the addition of the same vegetation coverage in that of the water erosion analysis (40% small, short-rooted plant coverage, no canopy) reduces soil loss due to wind erosion to an insignificant quantity relative to loss due to water erosion. Therefore, the wind erosion estimates presented in the following sections are for bare soil with no vegetation.

8.2 Effects of Soil Type and Surface Area

Soil from Borrow Area 6W (Golder, 2013) was used in the wind erosion analysis. Two areas within Borrow Area 6W were test pitted and analyzed for grain size, one test has shown to be more susceptible to wind erosion than the other. Wind erodibility was assessed for both samples.

The size of the exposed area is somewhat proportional to soil loss. Table 8-1 presents high and low soil loss estimates (based on soil type) for different sized areas.

The slope inflection points, tilled ridges, and surface roughness were all held constant in the computations that produced the values in Table 8-1, and were set to standard values (i.e. a flat surface with no ridges and minimal roughness) that would not significantly influence the model.

Table 8-1: Soil Loss Due to Wind Erosion (no ridges or roughness)

Area		More wind erosion susceptible material		Less wind erosion susceptible material	
Site Area	**Approximate Size**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**
Mill Area Landfill	70m x 70m	5.5	0.32	0.0	0.00
Acid Plant Area Landfill	150m x 50m	6.4	0.38	0.1	0.01
South Waste Rock Pile	300m x 250m	14.9	0.88	1.8	0.11
East Waste Rock Pile	400m x 300m	15.1	0.89	1.8	0.11

Soil losses from wind erosion increase with increasing size of the exposed area and with the erodibility of the material (Table 8-1).

8.3 Effects of Surficial Ridges and Roughness

Ridges and surficial roughness can substantially reduce wind erosion. The values in Table 8-2 were computed by adding ridges that were 15 cm high, spaced 2 m apart, and perpendicular to the predominant wind direction; a moderate increase in surface roughness was also made. An increase in surface roughness can be achieved if the material is not compacted with a flat roller. All other parameters that were used in Table 8-1 were held constant.

Table 8-2: Soil Loss Due to Wind Erosion (ridges and roughness accounted for)

Area		More wind erosion susceptible material		Less wind erosion susceptible material	
Site Area	**Approximate Size**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**
Mill Area Landfill	70m x 70m	0.3	0.02	0.0	0.0
Acid Plant Area Landfill	150m x 50m	0.5	0.03	0	0.0
South Waste Rock Pile	300m x 250m	3.0	0.18	0.1	0.0
East Waste Rock Pile	400m x 300m	3.6	0.21	0.2	0.0

In all cases assessed at the site, the addition of ridges and surface roughness reduce soil loss due to wind erosion by greater than 75%.

9 Design Life 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 cover thickness required for gamma radiation reduction. 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 9-1. Material from Borrow Area 6W was used to calculate the design life soil loss. The total loss varies from 8 mm to 86 mm depending on the slope grade, the slope length, and the vegetative cover.

Table 9-1: Calculated Water Erosion Design Life Soil Loss

Slope Condition		Design Life Soil Loss (mm) per Slope Length			
		25 m	**50 m**	**75 m**	**100 m**
Non-Vegetated	**3H:1V**	43	61	75	86
	4H:1V	32	44	53	61
	5H:1V	25	34	41	46
Vegetated (40% Short-Rooted Plant Coverage, No Canopy)	**3H:1V**	14	20	25	29
	4H:1V	11	15	18	20
	5H:1V	8	11	14	15

Design life soil loss was also calculated for the wind erosion scenarios presented in Section 8. Design life soil loss due to wind erosion with no ridges and little surface roughness is shown in Table 9-2, while design life soil loss in the scenario that includes ridges and moderate surface roughness is included shown in Table 9-3.

Table 9-2: Calculated Wind Erosion Design Life Soil Loss (no vegetation, no ridges, flat surface)

Area		Design Life Soil Loss (mm)	
Site Area	**Approximate Size**	**Borrow Area 6W (More wind erosion susceptible material)**	**Borrow Area 6W (Less wind erosion susceptible material)**
Mill Area Landfill	70 m x 70 m	32	0
Acid Plant Area Landfill	150 m x 50 m	38	1
South Waste Rock Pile	300 m x 250 m	88	11
East Waste Rock Pile	400 m x 300 m	89	11

Table 9-3: Calculated Wind Erosion Design Life Soil Loss (vegetation, ridges, moderate roughness)

Area		Design Life Soil Loss (mm)	
Site Area	**Approximate Size**	**Borrow Area 6W (More wind erosion susceptible material)**	**Borrow Area 6W (Less wind erosion susceptible material)**
Mill Area Landfill	70 m x 70 m	2	0
Acid Plant Area Landfill	150 m x 50 m	3	0
South Waste Rock Pile	300 m x 250 m	18	1
East Waste Rock Pile	400 m x 300 m	21	2

Appropriate values from Table 9-1 and Table 9-2 or Table 9-3 can be summed to determine the total soil loss for a particular area and slope condition.

10 References

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Attachment 3: Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Supporting Erosion and Sediment Controls.

CanNorth
Canada North Environmental Services Limited Partnership
A First Nation Environmental Services Company

TECHNICAL MEMORANDUM

Date: **July 11, 2016**

To: **SRK Consulting**

From: **Kendra Purton**
Canada North Environmental Services

Subject: **Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design – Supporting Erosion and Sediment Controls**

CanNorth Project No. 2397

Introduction

The engineering design and planned revegetation specifications for each of the Gunnar Mine other site aspects was assessed to determine erosion and sediment control recommendations to support the establishment of a self-sustaining vegetation cover of species endemic to the region and to help maintain the integrity of remediated features. The purpose of this memo is to present those recommendations as environmental support for the Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Plan (SRK, 2016).

Justification of Need for Erosion and Sediment Controls

Saskatchewan's *Environmental Management and Protection Act* (EMPA) prohibits the discharge of any substance into the environment in any amount, concentration or level or at a rate of release that may cause or is causing an adverse effect unless expressly authorized (GS, 2010). Substances are defined as: any solid, liquid, particulate, or gas capable of becoming dispersed in or discharged into the environment, and thus includes the erosion of soil particles resulting from construction activities. Such discharges are to be reported, and there is a duty to take immediate action "to repair or remedy any undue risk; or to reduce or mitigate danger to life, health, property or the environment that results or that may reasonably be expected to result from the discharge of the substance" (GS, 2010). As such, there is a clear need to develop an erosion and sediment control management strategy to support the remediation activities at the Gunnar Mine Site to prevent contravention of EMPA.

Additionally, one of the overarching remediation design criteria for the other site aspects is the establishment of a self-sustaining vegetation cover endemic to the region (SRK, 2016). This, in turn, will aid in ensuring that the cover systems, which will be put in place in areas exhibiting gamma radiation 1.0 μSv/h above background (SRK, 2016), will remain intact and continue to meet the project design objectives.

Erosion and Sediment Control Management Strategy

Soil erosion is controlled by numerous factors, including climate, topography, soil properties, soil cover (e.g., vegetation and residue), and land use practices (Wall et al., 2002). Generally, intense rainfall and runoff, steep and long convex slopes, and sparse soil cover increase the potential for erosion. Soils with a large proportion of silt and very fine sand particles, low soil organic matter content, poor structure, and very low permeability are the most susceptible to erosion.

This erosion and sediment control management strategy is as a component of the Gunnar Mine "Other Site Aspects" Updated Preliminary Remediation Design (SRK 2016). It outlines the recommended location, and types of erosion and sediment controls to be implemented at the site to effectively mitigate risks associated with erosion of the soil cover system. It is informed by SRC's revegetation plan for the Gunnar Mine "Other Site Aspects" Remediation Project (Petelina, 2016), as well as findings from revegetation research conducted at the Gunnar Mine Site (Petelina, 2013a, b; Petelina, 2014). For each site aspect, this document determines erosion and sedimentation risk qualitatively and provides site-specific recommendations of erosion and sediment control measures recommended for implementation to support the engineering design and promote revegetation. This document is a part of the preliminary design stage of the project, and should be modified to incorporate any updates to the design, information obtained during construction, and observations of performance after implementation and/or installation of recommended erosion and sediment controls.

Physical Geography

The Gunnar Mine Site is located in the Tazin Lake Upland Ecoregion of the Taiga Shield Ecozone. This ecoregion is largely comprised of ridged to hummocky bedrock formations, which are typically covered by a thin veneer of ground moraine where bedrock outcrops do not occur (Acton, 1998). The climate is subarctic.

The site is located in the Uranium City Upland Landscape Area. Terrain is rugged and local relief can range by up to 100 m (Acton, 1998). Steep bedrock ridges dominate the area, and slopes vary from 10% to 30% (AAFC 1996). Morainal Dystric Brunisols occur between bedrock outcrops (AAFC, 1996) and isolated areas of Organic and Crysolic soils occur in low-lying areas (Acton, 1998). Jack pine (*Pinus banksiana*) and black spruce (*Picea mariana*) dominate forest canopies, with white spruce (*Picea glauca*) occurring near the margins of fens and marshes and trembling aspen (*Populus tremuloides*) present in sheltered areas (Acton, 1998). Additionally, the Gunnar Mine Site is adjacent to Lake Athabasca, which is part of the Peace-Athabasca Delta.

Site Assessment

Design of Site Components for Revegetation

Following cover placement, the following aspects of the Gunnar Mine Site will be revegetated:

- Non-Hazardous Landfill;
- Hazardous Landfill;
- Waste rock piles; and
- General site areas.

Details of the cover designs are found in SRK (2016).

Borrow Material Characteristics

Borrow materials to be used as growth medium in the soil cover systems for the Gunnar site aspects have previously been characterized in Appendix B of OKC (2016). These borrow materials range from medium to coarse-textured. Fine-textured borrow material is also available, but was determined by both OKC and SRK to be unsuitable for use as a growth medium due to the relatively high potential for erosion (OKC, 2016, SRK, 2016). The medium-textured borrow material is predominantly fine to coarse sand. It contains less than 70% clay and silt, 30% to 100% sand, and less than 20% gravel and cobbles. Coarse-textured borrow material consists of sand, gravel, and cobbles. It contains less than 40% clay and silt, 30% to 80% sand, and 20% to 40% gravel and cobbles.

Of the borrow materials, very coarse-grained materials such as gravel and rock are unlikely to be eroded due to their mass, which allows them to resist detachment. Finer particles are generally easier to erode; though clay particles are also somewhat resistant to detachment due to cohesion, among other factors. Silt-sized particles are at the highest risk for detachment, as they have relatively little mass and do not exhibit cohesion. The relatively low organic matter content of the borrow materials and probable poor structure also increase their susceptibility to erosion.

Site Erosion Potential and Evaluation

Due to the lower erosion potential of the coarse-textured borrow material, it was selected as the preferred material for use in the Gunnar Mine other site aspects cover system. Anticipated rates of soil loss due to water erosion for the coarse-textured borrow material range from approximately three to eight tonnes/hectare/year for the longest designed slope, depending on the percentage of vegetation cover assumed and assuming no microtopography features are included (SRK 2016). Accounting for wind erosion would increase these values slightly. However, as the long-term goal is to establish a self-sustaining vegetation cover, erosion rates will decline over time as this cover is established. The implementation of effective soil erosion controls will further diminish soil losses by increasing cover and reducing effective slope lengths.

The above rates suggest that the soil erosion class for all areas of the site are either low or very low (Wall et al., 2002). Additionally, few of the site aspects are directly connected to a waterbody or watercourse where water quality or aquatic resources are a concern (e.g., Zeemel Bay and St. Mary's Channel). As such, degradation of water quality and fish habitat (the most damaging consequence of erosion), would be prevented in these areas if erosion were to occur. Where impacts of erosion are anticipated to be more severe (e.g., where the site drains directly to the re-established historical channel), additional measures to mitigate erosion have been incorporated into the design. The recommended erosion and sediment control measures to be implemented for each of the Gunnar Mine other site aspects are discussed in the following section.

Erosion and Sediment Control Measures

The recommended erosion and sediment control measures for each of the other site aspects are summarized in Table 1 and Figure 1. A more detailed discussion of the engineering designs for each site aspect is provided in the Main Report (SRK 2016). The following sections provide additional measures to be implemented to enhance the microtopographies of the covers specific to each site aspect. Briefly, these measures include slope texturing, installation of organic fibre rolls/wattles, installation of rolled erosion control products (RECP), installation of sediment fencing, and seeding. Details of how each of these features will reduce erosion as well as installation and/or construction methods are discussed below.

Slope Texturing

Slope texturing using techniques such as imprinting, ripping, or surface tracking should be used to decrease erosion rates and effectively trap seeds, sediment, and runoff. Slope texturing should be completed immediately prior to seeding, and should aim to create roughness elements between 50 mm and 100 mm in height. If surface tracking is to be used, the number of passes across the slopes should be limited to reduce the degree of soil compaction while still creating beneficial microtopography. The design density to be achieved during compaction will be determined during subsequent design stages.

Organic Fibre Rolls/Wattles

Organic fibre rolls/wattles can be used to temporarily reduce effective slope length, thereby reducing the erosion potential associated with a slope. The details for organic fibre roll/wattle installation are provided in Figure 2. Briefly, organic fibre rolls/wattles should be installed immediately adjacent to one another to provide a continuous contour along slopes. Spacing between contours should vary with slope gradient, with spacing between organic fibre rolls/wattles varying from 12 m to 25 m apart between contours. Additionally, fibre roll diameters and material types will be determined during the next stage of design to provide the appropriate erosion protection and longevity required.

Rolled Erosion Control Products (RECP)

RECP provide immediate protection against erosion as well as longer term erosion control by reinforcing the erosion resistance plants once they are established. These products additionally support vegetation establishment by increasing and preserving soil moisture, moderating soil temperature, and preventing seed displacement. Details for typical RECP installation are provided in Figure 3. Briefly, slopes to be covered with RECP should be relatively smooth (e.g., no large depressions or mounds), and should be seeded with an appropriate mix prior to installation. Products should be installed to maximize contact with the underlying soil, which will serve to reduce erosion.

Sediment Fences

Sediment fencing prevents the deposition of sediment in natural waterbodies by creating a low energy environment that promotes sedimentation of soil particles before they are transported to nearby waters. Sediment fences should be installed where there is potential for sedimentation into adjacent natural waterbodies (e.g., Zeemel Bay/St. Mary's Channel). Fences should be located approximately 2 m from the base of slopes with a consistent elevation from corner to corner.

Seeding

The revegetation plan for the Gunnar Mine "Other Site Aspects" Remediation Project (Petelina, 2016) states that broadcast seeding will be used where suitable (e.g., areas with relatively low slopes). This technique includes preparation of the soil cover using decompaction/soil scarification prior to fall seeding at rates between 1,000 and 4,000 pure live seeds per square meter. Following seed placement, shallow harrowing and recompaction will be used to ensure close contact between seeds and the soil. Wherever possible, vegetation and topsoil will be salvaged and used to facilitate revegetation. Hydroseeding and/or hydromulching is more robust seeding process that would facilitate germination and vegetation establishment and will be considered in the next phase of engineering via a trade-off study.

Maintenance of Erosion and Sediment Controls

Maintenance of erosion and sediment controls is important to ensure their effectiveness, and should continue until the controls are no longer required and are properly removed, if applicable. Controls not designed to deteriorate in place (e.g., sediment fences) can be removed when revegetation is successful and there is no evidence of erosion or sedimentation. Erosion and sediment controls designed to degrade over time should be left in-situ. During the first year, inspection and maintenance of erosion and sediment controls should occur in the fall to evaluate whether installed controls will persist throughout winter conditions, as well as prior to, during, and after freshet. After the first year, inspection and maintenance should occur at least twice annually to ensure any issues are remedied promptly, ideally after freshet and after major precipitation and/or wind events. The need for erosion and sediment control maintenance is anticipated to decrease over time, as establishment of the vegetation cover will serve to protect soil from wind and water erosion.

Summary

In addition to the engineering design elements outlined in SRK (2016) aimed to reduce soil erosion, a variety of erosion and sediment controls will be implemented at the site to ensure successful establishment of a self-sustaining endemic vegetation cover and to prevent degradation of nearby natural waterbodies and associated fish and fish habitat. These controls include slope texturing, installation of organic fibre rolls/wattles, rolled erosion control products, sediment fences, and seeding will be accompanied by procedural measures aimed to further reduce the likelihood and intensity of erosion.

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Tables

TABLE 1

Evaluation of site erosion potential of Gunnar Mine "Other Site Aspects" and recommended erosion and sediment controls.

Site Aspect	Soil Erosion Class[1]	Connectivity to Aquatic Resources[2]	Erosion and Sedimentation Control Measures		
			Procedural	Permanent	Temporary
Non-Hazardous Landfill					
Slopes: <50 m long; 4.0H:1.0V	Very low	No connectivity	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding. • Texture slopes by trackwalking or imprinting.	• Seed the area with an appropriate seed mix; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• Install organic fibre rolls/wattles on slopes to reduce effective slope length.
Minimal graded surface: 1% slope	Very low	No connectivity	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding.	• Seed the area with an appropriate seed mix; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• RECP will be used in concentrated flow areas.
Hazardous Landfill					
Slopes: <50 m long; 4.0H:1.0V	Very low	No connectivity	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding. • Texture slopes by trackwalking or imprinting.	• Seed the area with an appropriate seed mix; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• Install organic fibre rolls/wattles on slopes to reduce effective slope length.
Minimal graded surface: 1% slope	Very low	No connectivity	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding.	• Seed the area with an appropriate seed mix; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• RECP will be used in concentrated flow areas.
Waste Rock Piles					
Reestablished historical channel	-	Direct	• Any in-water work near Zeemel Bay should follow the Saskatchewan Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013).	• Seed the channel slopes with an appropriate seed mix prior to installation of turf reinforcement matting; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• Channel slopes will be covered with turf reinforcement matting.
Slopes: >50 m long; 5.0H:1.0V	Low	Indirect	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding. • Texture slopes by trackwalking or imprinting.	• Seed the area with an appropriate seed mix prior to installation of turf reinforcement matting; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• Install organic fibre rolls/wattles on slopes to reduce effective slope length. • Install sediment fencing approximately 2 m from the base of slopes where deposition to natural waterbodies may occur.
Slopes: <50 m long; 4.0H:1.0V	Very low	Indirect	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding. • Texture slopes by trackwalking or imprinting.	• Seed the area with an appropriate seed mix prior to installation of turf reinforcement mats; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• Install organic fibre rolls/wattles on slopes to reduce effective slope length. • Install sediment fencing approximately 2 m from the base of slopes where deposition to natural waterbodies may occur.
Minimal graded surface: 1% slope	Very low	Indirect	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding.	• Seed the area with an appropriate seed mix; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	• RECP will be used in concentrated flow areas.
General Site Areas					
Minimal graded surface	Very low	Direct	• Install erosion and sediment controls as early as possible. • Minimize time between construction and seeding.	• Seed the area with an appropriate seed mix; see the Gunnar Mine "Other Site Aspects" revegetation plan for details.	-

[1]Hazard classes: <6 tonnes/hectare/year = very low; 6 to 11 tonnes/hectare/year = low; 11 to 22 tonnes/hectare/year = moderate; 22 to 33 tonnes/hectare/year = high; >33 tonnes/hectare/year = severe (Wall et al. 2002).

[2]Connectivity to aquatic resources: no connectivity = sediment-laden runoff flows into a non-significant waterbody and sediment is trapped where water quality or aquatic resources are not a concern, or must terminate before connecting with any stream that has water quality or aquatic resource values; indirect = sediment-laden runoff flows into a non fish-bearing secondary watercourse (i.e., stream or ditch) before connecting with any stream with water quality or aquatic resource values; direct = sediment-laden runoff is transported directly downstream to locations where it may result in adverse effects to water quality or aquatic resources (Alberta Transportation 2011).

Figures

NOTES:

1. SEEDING APPLIED
2. SEEDING AND SLOPE TEXTURING APPLIED. INSTALL ORGANIC FIBRE ROLLS/WATTLES.
3. SEEDING APPLIED. INSTALL ROLLED EROSION CONTROL PRODUCT.
4. SEEDING AND SLOPE TEXTURING APPLIED. INSTALL ORGANIC FIBRE ROLLS/WATTLES. INSTALL SEDIMENT FENCING WHERE SLOPES ARE ADJACENT TO NATURAL WATERBODIES (E.G., ZEEMEL BAY/ST. MARY'S CHANNEL).

LEGEND

- Proposed Re-grading (No Vegetated Borrow Cover
- Proposed Re-grading (Vegetated Borrow Cover)
- Non-Hazardous Landfill (Vegetated Borrow Cover)
- Hazardous Landfill (Vegetated Borrow Cover)
- Suface Flow

Reference:
NAD83 UTM Zone12
Orthophoto provided by SRC

srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

GUNNAR MINE "OTHER SITE ASPECTS"

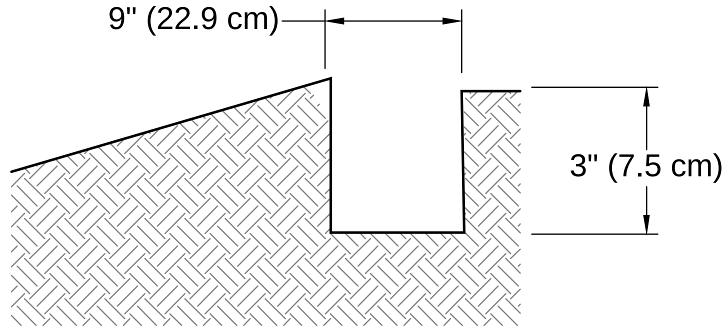
UPDATED PRELIMINARY REMEDIATION DESIGN

GENERAL SITE PLAN

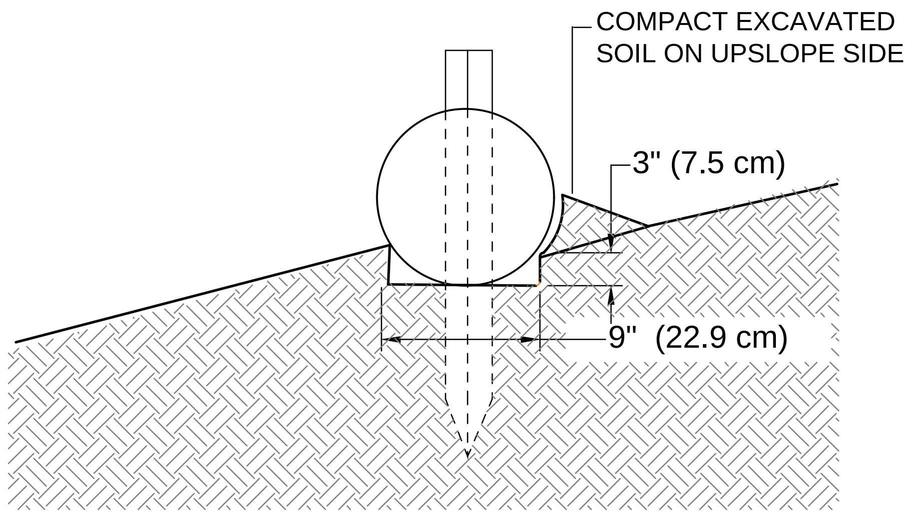
SRK JOB NO.: 1CS058.003

FILE NAME: 1CS058.003 -FIGURE 1 JUNE2018 CANMORE.dwg

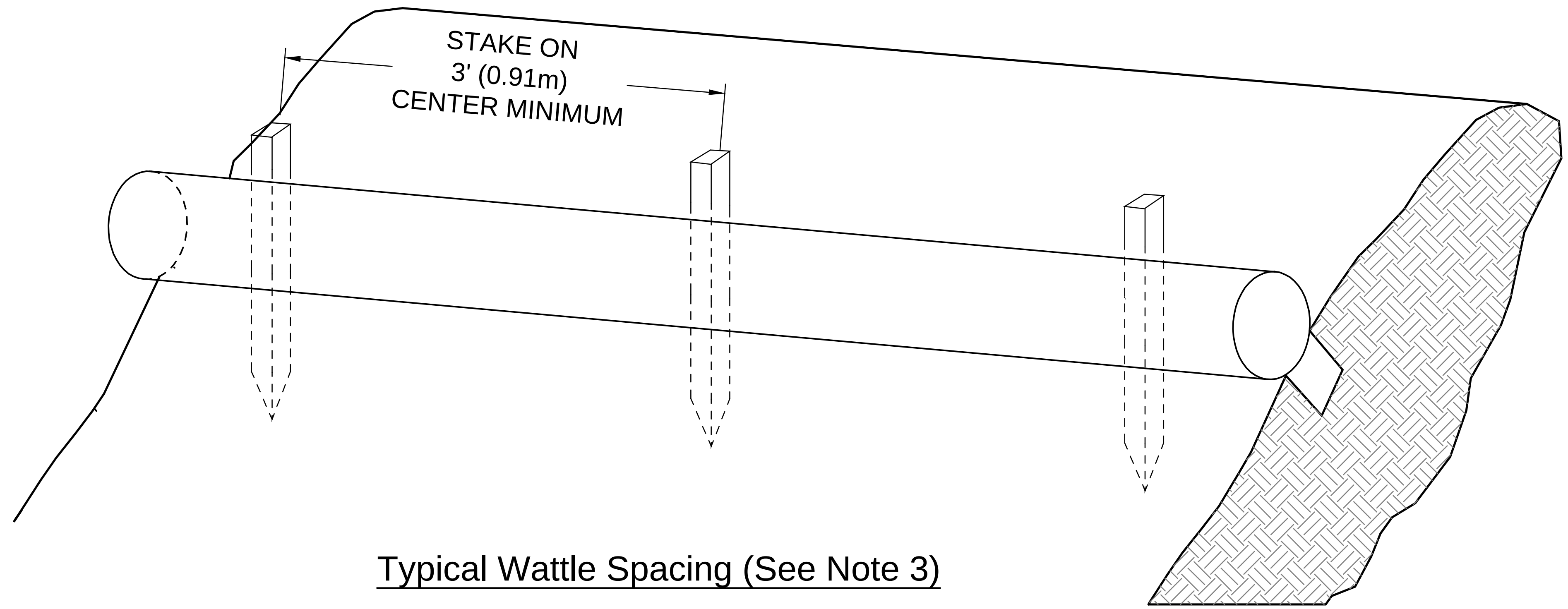
DATE: JUNE 2018 | APPROVED: TPP/MWL | FIGURE: 1



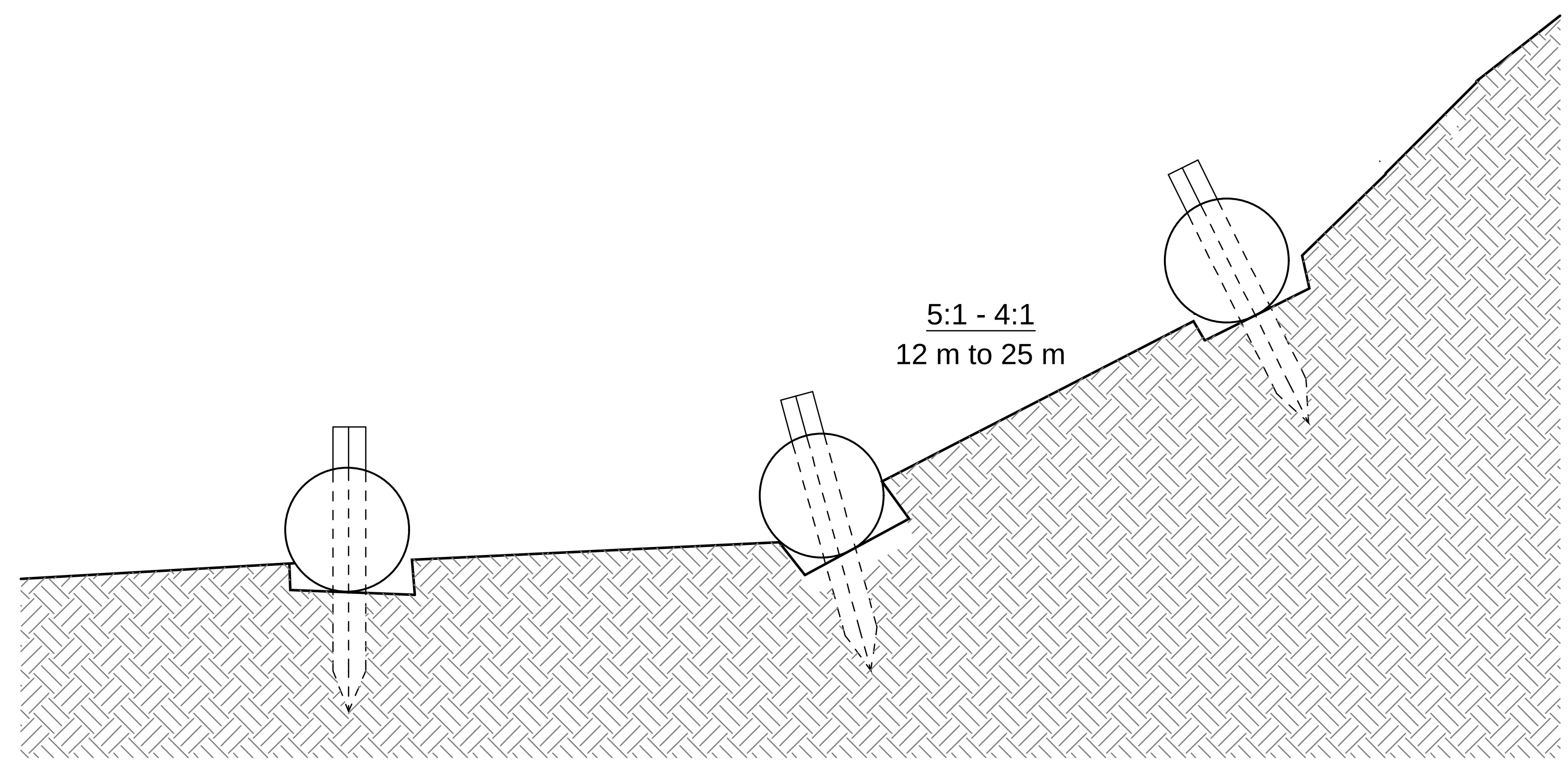
Typical Trench (See Note 1)



Typical Wattle Installation (See Note 2)



Typical Wattle Spacing (See Note 3)



Typical Wattle Spacing (See Note 3)

NOTES:

1. Begin at the location where the wattle is to be installed by excavating a 2-3" (5-7.5 cm) deep x 9" (22.9 cm) wide trench along the contour of the slope. Excavated soil should be placed upslope from the anchor trench.

2. Place the wattle in the trench so that it contours to the soil surface. Compact soil from the excavated trench against the wattle on the uphill side. Adjacent wattles should tightly abut.

3. Secure the wattle with 18-24" (45.7-61 cm) stakes every 3-4' (0.9 -1.2 m) and with a stake on each end. Stakes should be driven through the middle of the wattle leaving at least 2-3" (5-7.5 cm) of stake extending above the wattle. Stakes should be driven perpendicular to the slope face.

ISSUED FOR REVIEW

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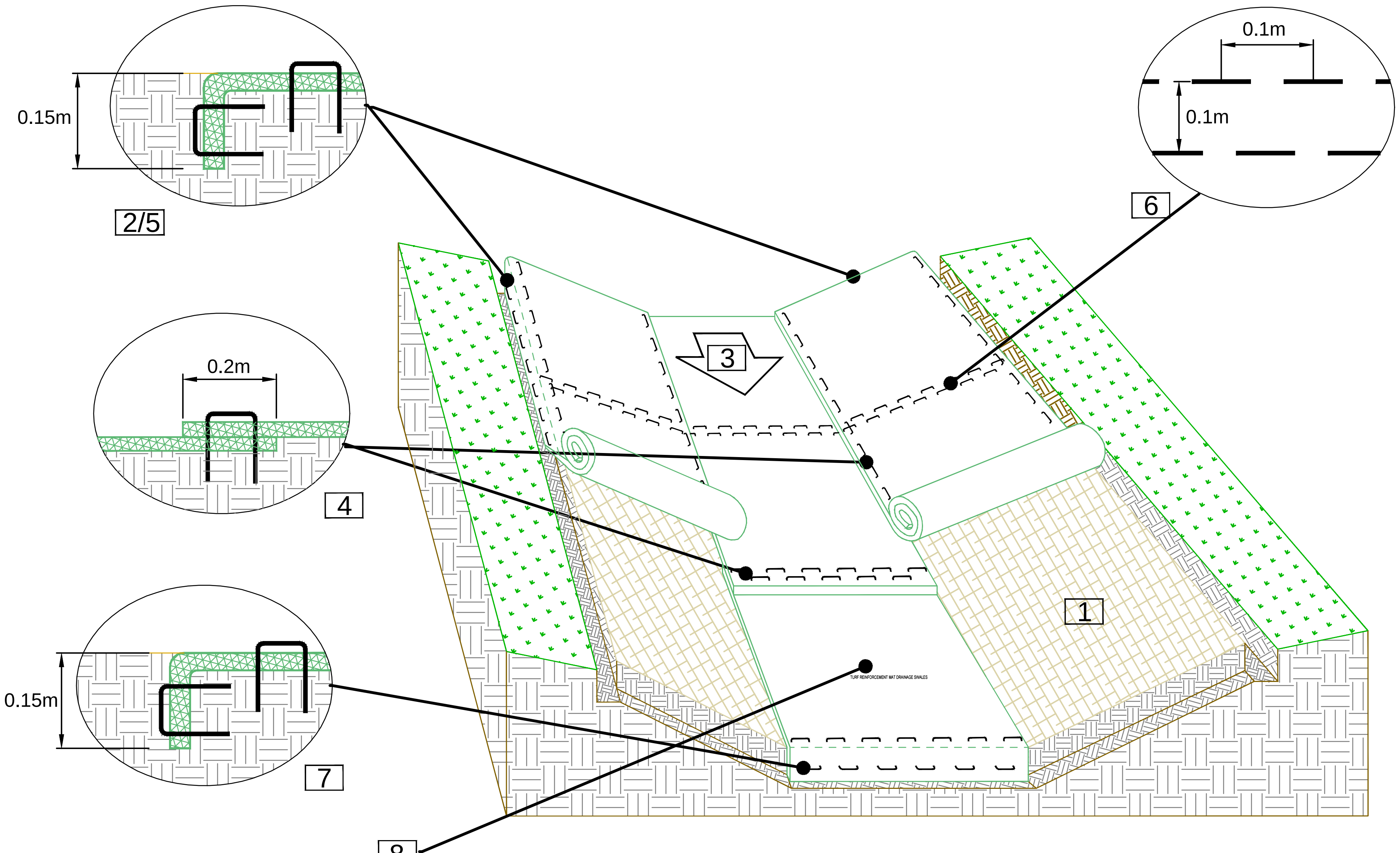
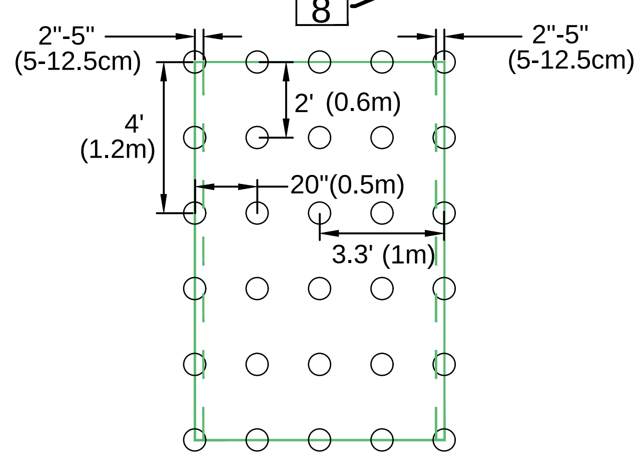
UPDATED PRELIMINARY REMEDIATION DESIGN

STRAW WATTLE INSTALLATION DETAILS

SRK JOB NO.: 1CS056.003	GUNNAR MINE "OTHER SITE ASPECTS"	DATE: JULY 2016	APPROVED: TPP/MWL	FIGURE: 2
FILE NAME: 1CS056.003- FIGURE 2_3 JUNE2016 CANMORE.dwg				





3.4 Staples per SQ.YD.

NOTES:
*Horizontal staple spacing should be altered if necessary to allow staples to secure the critical points along the channel surface.

**In loose soil conditions, the use of staple or stake lengths greater than 0.15m may be necessary to properly secure the RECP's.

GENERAL NOTES:

1. Prepare soil before installing rolled erosion control products (RECPs), including any necessary application of lime, fertilizer, and seed.
2. Begin at the top of the channel by anchoring the RECPs in a 0.15m deep X 0.15m wide trench with approximately (0.3m) of RECPs extended beyond the up-slope portion of the trench. Anchor the RECPs with a row of staples/stakes approximately 0.3m apart in the bottom of the trench. Backfill and compact the trench after stapling. Apply seed to the compacted soil and fold the remaining 0.3m portion of RECPs back over the seed and compacted soil. Secure RECPs over compacted soil with a row of staples/stakes spaced approximately 0.3m apart across the width of the RECPs.
3. Roll center RECPs in direction of water flow in bottom of channel. RECPs will unroll with appropriate side against the soil surface. All RECPs must be securely fastened to soil surface by placing staples/stakes in appropriate locations as shown in the staple pattern guide.
4. Place consecutive RECPs end-over-end (Shingle style) with a 0.2m overlap. Use a double row of staples staggered 0.1m apart and 0.1m on center to secure RECPs.6. Adjacent RECPs must be overlapped approximately 0.15m.
5. Full length edge of RECPs at top of side slopes must be anchored with a row of staples/stakes approximately 0.3m apart in a 0.15m deep X 0.15m wide trench. Backfill and compact the trench after stapling.
6. In high flow channel applications a staple check slot is recommended at 9-12m intervals. Use a double row of staples staggered 0.1m apart and 0.1m on center over entire width of the channel.
7. The terminal end of the RECPs must be anchored with a row of staples/stakes approximately 0.3m apart in a 0.15m deep X 0.15 wide trench. Backfill and compact the trench after stapling.
8. Staple pattern for low flow channels applied in conjunction with the perimeter staples.

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UPDATED PRELIMINARY REMEDIATION DESIGN

TURF REINFORCEMENT MAT
DRAINAGE SWALES

SRK JOB NO.:	1CS056.003
FILE NAME:	1CS056.003- FIGURE 2_3 JUNE2016 CANMORE.dwg

GUNNAR MINE "OTHER SITE ASPECTS"

DATE:	APPROVED:	FIGURE:
JULY 2016	TPP/MWL	3

C:\MODSINC\CLIENTS\SRK\2016\1CS056.002 GUNNAR\DRAWINGS\JUNE 2016\1CS056.003- FIGURE 2_3 JUNE2016 CANMORE.dwg

Appendix I – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Opening Closures Report and Design Drawings

DESIGN REPORT

TO:	**Saskatchewan Research Council (SRC)**	PAGE:	**1 of 13**
PROJECT:	**Gunnar Mine Opening Closures**	DATE:	**June 30, 2016**
REPORT BY:	**Jonathan Lambert, P.Eng.**	PROJECT #:	**2321-01664-00 T2000**
DISTRIBUTION:	**Skye Ketilson (SRC), Christoher Ried (SRC)** **Trevor Podaima (SRK)**		
ATTACHMENTS:	**None**		

BACKGROUND

This report discusses the design methodology and decision making process taken while designing the closures for three current mine sites. Currently the designs have been submitted for a 60% completion review. A site survey, which is required to finish the design, has not yet been completed. The sites include:

1. Gunnar Mine Main Shaft
2. Gunnar Mine Back Raise
3. Gunnar Mine Ventilation Raise

This report will discuss the following aspects for each closure:

A. Design Criteria
B. Field Review
C. Geometry and Positioning
D. Material Selection
E. Structural Design
F. Anchorage Determination
G. Loading Scenarios
H. Site Specific Installation Considerations
I. Cost-Saving Initiatives

Additional documents which pertain to this project include:

- SRC Service Order #6 dated June 28, 2016
- McElhanney 60% design drawings (9): 1664-01, 1664-02, 1664-03, 1664-04, 1664-05, 1664-06, 1664-07, 1664-08, 1664-09

DESIGN METHODOLOGY

A. DESIGN CRITERIA

The general specifications for the design of the closures as indicated by the original SRC proposal are that the closures must:

- meet regulatory requirements,
- be of an economical design,
- have a sufficiently long lifetime to ensure permanent closure of these openings,
- be composed of a material that will resist deterioration in a range of existing and probable future surface conditions in the Athabasca region of northern Saskatchewan,
- have a load capacity chosen based on probable future land use in the area,
- prevent the collection of rain water on the cap and surrounding ground,
- be secured to competent bedrock or to a competent concrete mine shaft or raise collar,
- be vented (i.e., not completely sealed) to allow for flow of air and water,
- include an inscription on the cap, the wording of which to be provided by SRC,
- include fabrication and installation instructions for outside contractors,
- minimize the number of field cut walls in the design,
- minimize rock removal at site,
- size the closures to accommodate shipping of fabricated components by truck to site

B. FIELD REVIEW

The field review has not yet been complete. The goal of the initial site visit will be to obtain the data required in order to complete the design of the closures for each unique location. Information to be obtained includes the overall size of the opening, the location of sound bedrock, the surrounding site grading (for drainage), the risks posed by up-slope rock, locations of competent bedrock for anchorage, and to make a determination of the accessibility of the site (both current and anticipated future access). In order to obtain the geometry of the site, a reflector-less total station will be used. Survey data obtained will be referenced to coordinates obtained from a GPS unit.

In order to perform a visual inspection of the bedrock surface and best determine the anchorage locations and lid geometry, the existing concrete closures and overburden must be cleared away from the sites.

C. GEOMETRY AND POSITIONING

For site-specific geometries, see section H: Site Specific Installation Considerations.

<u>Plan</u>

A high density of survey points will be taken on the bedrock during the topographical survey and will be used to create a representative 3D model in AutoCAD Civil 3D. This model, combined with field notes taken during the field review, will allow the closures to be designed to fit the contours of the site while minimizing the overall plan dimensions of the lid, thus saving material and fabrication costs and allowing efficient transportation (The Ministry of Highways and Infrastructure Policy #W&DAM901 indicates that the maximum load width for shipping on Highway 102 and 905 North of La Ronge using only 1 pilot car is 4.0m).

Profile

The lids were designed to be raised from the ground rather than to be lying directly on the ground. The decision for doing so was based on:

1. By specifying the locations of the vertical posts welded to the mounting plates on the side of the closure, a well-defined load path was established between the gravity loads on the surface of the closure and the bedrock anchorage.
2. By raising the lid off the ground, the undulating bedrock surface could be accommodated without requiring additional bedrock removal and profiling.
3. By raising the lid off the ground, the lid would not be forced to “comply” with the existing bedrock profile, therefore eliminating the risk of the material exceeding the yield point during flexures induced while efforts are being made to reduce the gaps between the lid and the bedrock surface.
4. By raising the lid off the ground, the structures will be less likely to be driven on by light trucks and recreational vehicles.
5. By raising the lid off the ground, a potential inspection panel is created, thus allowing future inspections of the main structural components of the lid, if required.

The drawbacks to raising the lid off the ground include:

1. Additional material costs (the side wall plates)
2. Additional field installation time (trimming the side wall plates and anchoring them to the bedrock.

Efforts will be made to alleviate the aforementioned drawbacks by minimizing the height of the lids, and by specifying an allowable gap between the bedrock profile and the sidewalls. Furthermore, the 3D model will facilitate easier development of a bill of materials, which will identify the size of the side wall plates required, thus providing a control in the amount of potential waste material shipped to site.

D. MATERIAL SELECTION

Several materials were investigated in order to determine which material to use for the closures. The following table outlines the decision making process:

Criteria	Material Options				
	Stainless Steel	**Galvanized Steel**	**Weathering Steel**	**Aluminum**	**Concrete**
Raw Material Cost	Very High (Approximately $2-$3.50/pound)	Mid (Approximately $1.05/pound)	Mid	High (Approximately $2.50-$3.00/pound)	Low
Availability	Plate usually in stock in fabrication shops in Saskatoon. Hot rolled sections are available with a 1-2 week shipping time.	All structural steel shapes up to 6.5m long may be galvanized in Saskatoon.	Pre-order.	Common shapes are available in fabrication shops in Saskatoon.	Available in Saskatoon. Not available in large quantities in Uranium City (Must be hand-mixed).
Corrosion/Degradation (Adjusted for Northern Saskatchewan)	Very Low (Approximately 0.0025 µm/year)	Low (Approximately 0.8-2.0 µm/year)	Mid. (Approximately 1.3-3.1 µm/year) Not to be used in applications where water may accumulate (melting snow)	Mid (Approximately 0.025-0.050 µm/year)	Low in theory if properly selected concrete mix design is used and quality control is in place; however, in practice concrete closures have experienced premature deterioration. May be subject to freeze-thaw if porosity is too high and can have adverse reactions if alkalis and sulphates are present in soils.
Durability	High	Medium. Zinc coating may be damaged due to abrasion, handling, and vandalism.	High	Subject to fatigue especially in weld areas. Easily damaged due to low hardness.	High. See corrosion/degradation notes.
Field Installation and Ability for Modification (Constructability)	Easy. Cutting, Drilling, and Welding operations may be performed in the field with acceptable results.	Easy. Cutting, Drilling, and Welding operations may be performed in the field with acceptable results. Field modifications require touch up to zinc coating.	Easy. Cutting, Drilling, and Welding operations may be performed in the field with acceptable results.	Hard. While field drilling and cutting are easy, quality field welding is difficult to achieve.	Hard. It is difficult to accommodate geometrical changes or fasten additional brackets if required. Cast-in-place very difficult on remote sites.
Fabrication	Not difficult. No appreciable loss in strength due to welding. May require post-fabrication treatment (pickling).	Not difficult but requires post-fabrication galvanizing. Distortions during galvanizing can be problematic.	Not difficult. No appreciable loss in strength due to welding.	Subject to fatigue and loss of strength in HAZ in weld areas. Easily damaged due to low hardness.	Easy. See notes on field installation.
Shipping	May be fabricated off-site and shipped to site.	May be fabricated off-site and shipped to site.	May be fabricated off-site and shipped to site.	May be fabricated off-site and shipped to site.	May be pre-cast off-site and shipped to site.
Quality Control	Shop fabrication may be inspected.	Shop fabrication may be inspected.	Shop fabrication may be inspected.	Shop fabrication may be inspected.	Shop fabrication may be inspected for pre-cast panels. Quality control on site is very difficult.
Material Approved by Chief Mines Inspector	Yes	No	No	No	Yes

Table 1 - Summary of Materials Comparisons

Based on SRC's design requirements, the remote location, and the aforementioned material qualities, stainless steel was determined to be the material of choice. This material offers the best balance of structural strength, durability, ease of fabrication, field modifications, availability, and familiarity with fabricators and installation contractors. It has also been previously approved to be used for mine opening closures by the chief mines inspector. Furthermore, shop fabrication can also easily be monitored for quality control. The initial cost may be offset by the reduction in on-going maintenance costs, although no life cycle analyses have been performed. Two stainless steel grades were considered to be appropriate for the project; AISI 304 and AISI 316. It was determined that AISI grade 304 stainless steel offers the appropriate level of corrosion resistance in the Northern Saskatchewan environment which has been considered to exhibit low atmospheric corrosion (non-marine, no industrial pollution). The 304 grade offers cost saving over the 316 grade (approximately $1-2/pound difference), which is used for more corrosive environments (marine, processing plants, etc). Both grades offer suitable welding and fabrication properties. Pickling has been specified post-fabrication (both shop fabrication and field fabrication) in order foster the re-creation of the protective passive layer.

An acceptable second choice for the closures would be galvanized steel or a combination of a galvanized steel frame and stainless steel covers (including galvanic corrosion isolators). Significant cost savings may be realized by using galvanized steel over stainless steel and, while published values suggest only a 100 year life span, a higher life span may be possible in Northern Saskatchewan.

Had the locations been closer to a ready-mix concrete plant, high performance concrete with hot-dipped-galvanized or stainless steel rebar would have provided acceptable closures at lower cost. These materials would easily conform and anchor to the undulations of the bedrock profile.

Weathering steel was considered, however it does not perform well when continuously wet (as would be found during the snow-melt season) as the surface patina does not have the ability to form.

Aluminum structures, while offering satisfactory corrosion resistance in a non-marine environment, are inherently fragile, cannot easily be field modified/repairs, and require a higher degree of maintenance.

E. STRUCTURAL DESIGN

For specific fabrication details and specifications, please refer to the aforementioned fabrication and installation drawings.

A 3/16" minimum element thickness was maintained for the main structural elements (beams, joists, and posts) for durability and for weld-ability, regardless of the structural requirements. However, the side panels were chosen to utilize 1/8" plate rather than 3/16" plate to ease field cutting and installation and to save on material costs. These are considered secondary members and are subject to less loads (and thus risk) then the lids. The corrosion rates are negligible and minimum support spacing has been specified in the drawings to limit deflections and resist tampering/vandalism.

Hot rolled sections in readily available shapes were chosen in an effort to eliminate the fabrication costs associated with custom-fabricating structural shapes. Furthermore, the lid was designed to have a minimum of complex compound angle joints, while maintaining a low profile and providing drainage.

The upper assembly of the closure (top plate, main beams, joists, and perimeter channel) will be pre-fabricated off-site in a shop to which will have the necessary equipment to efficiently fabricate the closures, while also providing a higher degree of quality control. The overall structural arrangement provides redundancy (at reduced load rating) to mitigate any potential failure of structural connections.

Typical Members used in design include (All AISI 304 grade Stainless Steel):

- W8x10, W10x12, W12x16
- C6x8.2, C8x11.5, C9x15
- L 76x76x6.4
- T 76x76x6.4
- Plate: 6.4mm (1/4") and 3.2mm (1/8")

Installation instructions were provided as an approved method for the contractor to refer to while installing the closures. Engineering support will be available should the need to deviate from the proposed installation method arise.

<u>Beams and Joists</u>

The closure concept utilizes a series of main Wide Flange beams between 4.0m to 7.4m long which generally span in the short direction of the openings. Inverted L section joists approximately 1000mm span run between these beams and are designed to act compositely with the 6.4mm plate lid. Where the edge of the closure is perpendicular to the main beams, a channel has been installed. This channel provides robust edge stiffness as well as a location for the side walls to weld to. Where required, the downslope perimeter channel will be skewed to accommodate the installation angle of the lid, and to maintain the vertical alignment of the tee posts.

<u>Vertical Supports (Posts)</u>

Rolled Tee sections were specified as vertical post supports. The tees provide two flanges for the side plates to mount behind, and provide stiffness in three directions. The tees will be welded to the mounting plates on the structure to provide an increased stiffness over bolted connections. The structure also utilizes oversized baseplates and mounting plates which provide the contractor with some flexibility when laying out the posts and field-cutting the required post lengths and compound angles.

<u>Side Plates</u>

The lower sidewalls are secured at specific locations by an L section clip which is bolted to the bedrock and field welded to the side wall. The side wall anchor spacing was specified to provide an adequate level of stiffness while reducing field installation times and fabrication costs. In addition to preventing access to the hole for the sides, the side walls will be welded to the tee posts to provide localized lateral restraint to the posts, as well as overall lateral load resistance to the structure. A seal weld is provided between the side walls and the perimeter members of the lid to prevent water from draining along the inside surface of the side walls.

F. ANCHORAGE DETERMINATION

Anchor bolts are not subject to significant lateral loading or uplift. Therefore, anchor bolt diameters and embedment lengths were chosen which provide an acceptable level of structural integrity while requiring a lower installation effort. The bolt embedment length was also chosen to extend through the bedrock surface layer, which may be fractured. The drawings also specify that the contractor should remove any loose surface rock prior to installation of the anchor bolts.

Epoxy grouting of the anchor bolts will provide lateral load resistance, prevent general movement of the structure, and resist vandalism. However, the closures are not designed to rely upon withdrawal resistance of the anchor bolts, and as such should the epoxy grout fail the structure should remain in position.

G. LOADING SCENARIOS

Several loading scenarios were determined which attempted to predict the likely loads that the closures would be subject to given a long life span. These loads included vehicle loads (Light Duty Truck, ATV, Snowmobile, UTV), wildlife loads, climatic loads (snow drifts), soil overburden loads, and future industrial loads. The governing load case was a 4.8kPa uniformly distributed load. Load factors of 1.25 Dead and 1.5 Live were utilized for the Ultimate Limit States design.

H. SITE SPECIFIC INSTALLATION CONSIDERATIONS

The following sub-sections include details of the previous sub-sections but which are specific to the individual closure sites.

<u>Gunnar Main Mine Shaft</u>
The main shaft existing concrete cover was measured by SRC with approximate dimensions of 9.2mx2.3m. Bedrock is estimated to be 2-3m below grade. The existing concrete cover and overburden will have to be removed to bedrock prior to the site survey, and before installation of the closure. The current design extends beyond the previous closure dimensions to allow for an adequate distance from the edge of the shaft, so that anchorage is not close to fractured bedrock. Because of the large size of the opening, this closure was designed to be fabricated in two pieces in order to facilitate shipping regulations. The individual pieces will be welded together on site. Drainage is anticipated to occur towards the south and the lid is sloped 2 degrees in that direction. Ventilation will be provided by the gaps between the edge of the bedrock and the specified side wall closures.

<u>Gunnar Ventilation Raise</u>
The ventilation raise existing concrete cover was measured by SRC with approximate dimensions of 3.6mx6.1m. There is an existing concrete staircase adjacent to the raise. Bedrock depth has not been estimated by is expected to be relatively deep (perhaps 3m). The existing concrete cover, staircase, and overburden will have to be removed to bedrock prior to the site survey, and before installation of the closure. The current design extends beyond the previous closure dimensions to allow for an adequate distance from the edge of the shaft, so that anchorage is not close to fractured bedrock. Because of the large size of the opening, this closure was designed to be fabricated in two pieces in order to facilitate shipping regulations. The individual pieces will be welded together on site. Drainage is

anticipated to occur towards the east and the lid is sloped 2 degrees in that direction. Ventilation will be provided by the gaps between the edge of the bedrock and the specified side wall closures.

Gunnar Back Raise

The back raise existing concrete cover was measured by SRC with approximate dimensions of 5.6mx5.6m. Bedrock depth is estimated to be 0-0.5m below grade. The existing concrete cover and overburden will have to be removed to bedrock prior to the site survey, and before installation of the closure. The current design extends beyond the previous closure dimensions to allow for an adequate distance from the edge of the shaft, so that anchorage is not close to fractured bedrock. Because of the large size of the opening, this closure was designed to be fabricated in two pieces in order to facilitate shipping regulations. The individual pieces will be welded together on site. Drainage is anticipated to occur towards the north and the lid is sloped 2 degrees in that direction. Ventilation will be provided by the gaps between the edge of the bedrock and the specified side wall closures.

I. COST-SAVING INITIATIVES

The following table summarizes costs saving initiatives which were taken while designing the closures:

Initiative	Benefits	Drawbacks
Composite Design	Reduction in material costs	Marginal increase in required welds
Reduction in side wall height	Reduced material costs	None
Increase in side wall gap tolerance	Reduction in field fitting costs	Aesthetics
Reduction in compound angles	Reduced fabrication costs	None
Topographic Survey	Reduction in lid footprint	Survey Costs
Design 2-piece units (Pat Claim and Raise)	Second pilot car not required during shipping	Requires assembly on site
Use hot rolled stainless steel structural shapes	Reduced fabrication costs	Requires pre-ordering
Specified AISI304 grades stainless steel	Less expensive than 316 grade while maintaining adequate corrosion resistance.	None
Reduced side wall thickness	Reduced material costs	Requires intermediate supports to limit deflections.
Reduced anchor bolt embedment length	Reduced material costs and installation time	None

Table 2 - Cost Saving Initiatives

CONCLUSION

We are pleased to provide you with this design report. Please feel free to contact the undersigned if you have any questions with any aspects of this report.

Sincerely,

Jonathan Lambert, P.Eng.
Division Manager – Structural Engineering
McElhanney Consulting Services Ltd.

Drawings

GENERAL NOTES:

1. CHECK AND VERIFY ALL DIMENSIONS BEFORE COMMENCING ANY WORK. NOTIFY THE DESIGNER OF ANY ERRORS OR OMISSIONS. DO NOT CONSTRUCT FROM THESE DRAWINGS UNLESS MARKED "ISSUED FOR CONSTRUCTION".

2. DESIGN CODE: NBCC 2015, CAN/CSA S16-09.

DESIGN LOADS:

SPECIFIED VEHICLE LOAD: 11 kN
SPECIFIED UDL: SNOW: SS=2kPa, Sr=0.1kPa OVERBURDEN: 1.2 kPa
SPECIFIED INDUSTRIAL LOADING: 4.8 kPa

3. ALWAYS READ WRITTEN DIMENSIONS. DO NOT SCALE OFF THE DRAWINGS OR CAD FILES.

4. SUPPLY OF RECORD DRAWINGS IS OUTSIDE THE SCOPE OF SERVICES.

5. THE FABRICATOR IS RESPONSIBLE FOR ALL COSTS ASSOCIATED WITH THE CORRECTION OF DEFICIENCIES, AS DIRECTED BY THE ENGINEER.

6. REVIEW OF WORK, OR ANY PORTION OF WORK, BY THE ENGINEER SHALL NOT RELIEVE THE FABRICATOR OF THEIR RESPONSIBILITY AND OBLIGATION TO COMPLY WITH CONTRACT DRAWINGS AND SPECIFICATIONS.

7. DO NOT DRILL OR ATTACH TO STRUCTURAL FRAME WITHOUT AUTHORIZATION FROM THE ENGINEER, UNLESS NOTED ON DRAWINGS.

STRUCTURAL STEEL:

1. ALL STRUCTURAL STEEL WORK SHALL CONFORM TO CAN/CSA S16-09.

2. ALL STRUCTURAL STEEL MATERIAL SHALL CONFORM TO THE FOLLOWING MATERIAL GRADES:

i) ANCHOR BOLTS	ASTM F593 (AISI 304/316)
ii) NUTS	ASTM F594 (AISI 304/316)
iii) WASHERS	ASTM A240 (AISI 304/316)
iV) PLATES AND BARS	AISI 304
v) ROLLED AND HSS SHAPES	AISI 304

3. DRAIN HOLES ARE TO BE PROVIDED AT THE BASE OF ALL HSS TUBES.

4. ALL FABRICATED PARTS TO BE DEGREASED AND PICKLED WITH A BRUSH ON PASTE OR GEL PRIOR TO DELIVERY.

WELDING:

1. ALL WELDING SHALL CONFORM TO CSA W59 AND BE PERFORMED BY CWB CERTIFIED WELDERS UNDER CSA W47.1. FABRICATORS TO BE APPROVED BY CWB. FABRICATOR TO PROVIDE COORDINATING ENGINEER WITH PROPOSED WELDING PROCEDURE PRIOR TO FABRICATION. WELDS SHALL BE MADE WITH ELECTRODES AND FILLER MATERIAL RATED AS FOLLOWS:

MATERIAL GRADE	ELECTRODE
304/304L	ER308/ER308L
316/316L	ER316/ER316L

2. ADEQUATE SHIELDING GAS AND CORRECT HEAT SHALL BE USED TO AVOID CARBIDE PRECIPITATION. SHIELDING MUST CONTINUE POST WELD UNTIL THE HEAT AFFECTED ZONE HAS COOLED TO BELOW 430°C

3. FABRICATOR TO CONTROL WARPING OF COMPONENTS DURING WELDING BY ALTERNATING WELDS AND/OR ALLOWING COOLING PERIODS BETWEEN WELDS AND/OR CLAMPING OF MATERIALS.

4. MINIMUM WELD SIZE TO BE 3/16" FILLET, UNLESS NOTED OTHERWISE.

5. WELDING PROCEDURE TO ENSURE A CLEAN WORK ENVIRONMENT INCLUDING TOOLS AND GLOVES. GREASE, DUST, AND EXCESS AIR FLOW IN THE WELDING AREA IS NOT ACCEPTABLE. CONTAMINATED ELECTRODES MUST BE CLEANED PRIOR TO USE. HEAT TINT TO BE REMOVED PRIOR TO DELIVERY.

INSPECTIONS:

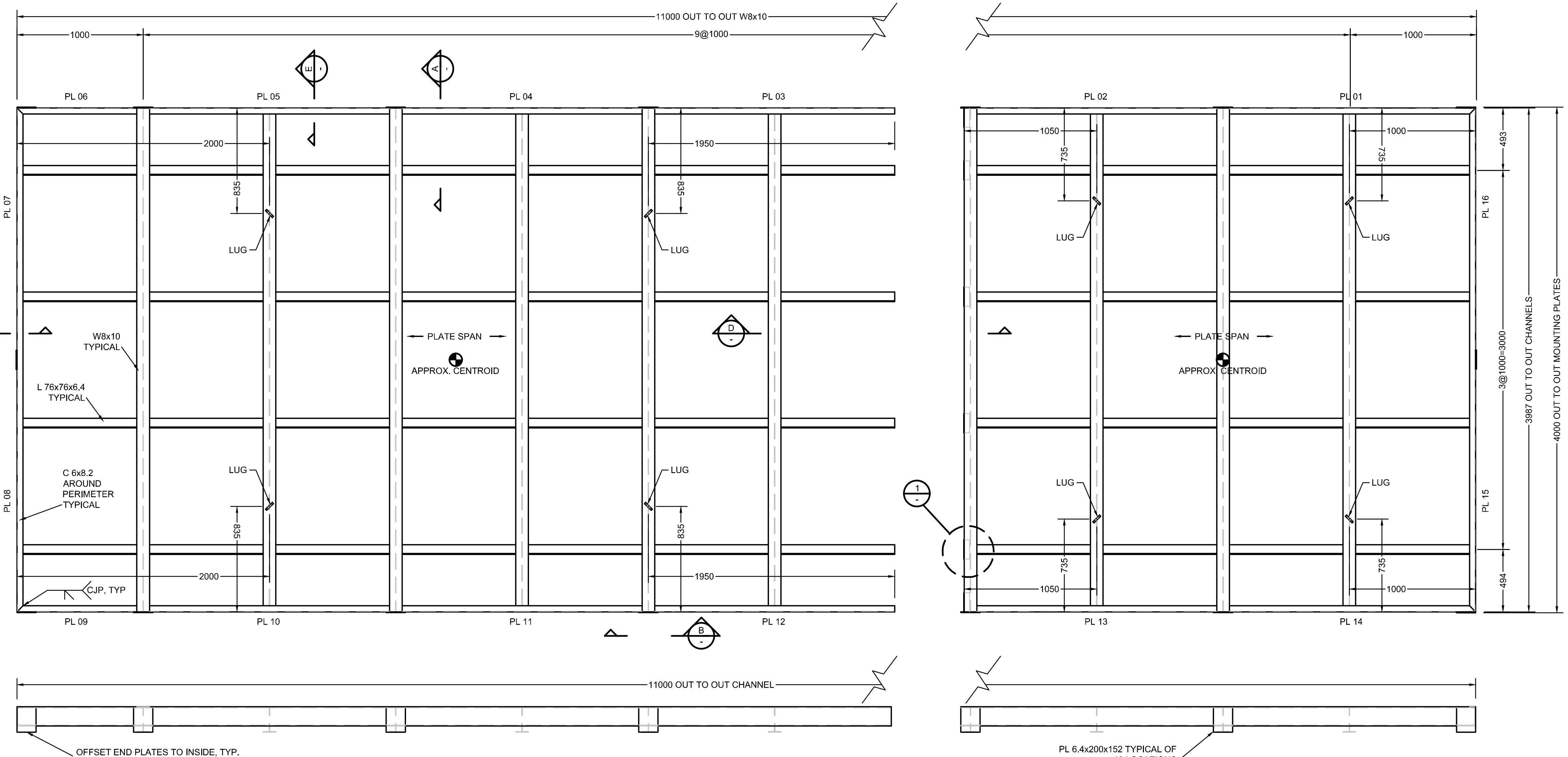
1. ONLY WORK SHOWN ON THE STRUCTURAL CONSTRUCTION DOCUMENTS BY MCELHANNEY CONSULTING WILL BE REVIEWED.

2. QUALITY CONTROL OF WORK IS THE FABRICATORS RESPONSIBILITY.

3. NOTIFY THE ENGINEER 7 DAYS IN ADVANCE FOR INSPECTION AND APPROVAL OF THE FABRICATED PARTS.

4. NUMBER OF REVIEWS AND ITEMS REVIEWED WILL BE AT THE DISCRETION OF THE ENGINEER TO DETERMINE GENERAL CONFORMANCE WITH THE DESIGN INTENT.

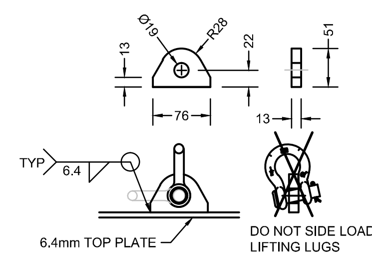
5. ADDITIONAL INSPECTIONS REQUIRED DUE TO DEFICIENT OR INCOMPLETE WORK WILL BE AT THE EXPENSE OF THE FABRICATOR.



PLAN AND PROFILE
SCALE: 1:20

6.4mm COVER PLATE NOT SHOWN FOR CLARITY. CUT PLATE 4.8mm LESS THAN OUTSIDE DIMENSIONS (BOTH WAYS) TO ALLOW FOR PERIMETER SEAL WELD. SEE SECTIONS A AND C.

COVER PLATE TO SPAN A MINIMUM OF 3 MEMBERS. BUTT SIDES AND JOIN WITH COMPLETE PENETRATION GROOVE WELDS.



LUG DETAIL
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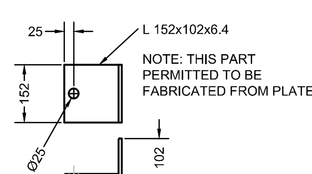

SIDEWALL CLIP
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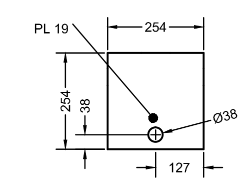
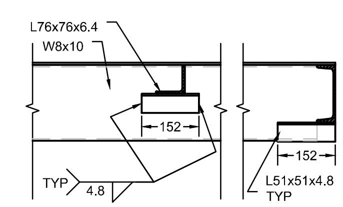


BASE PLATE DETAIL
SCALE: 1:10 16 REQUIRED



DETAIL 1
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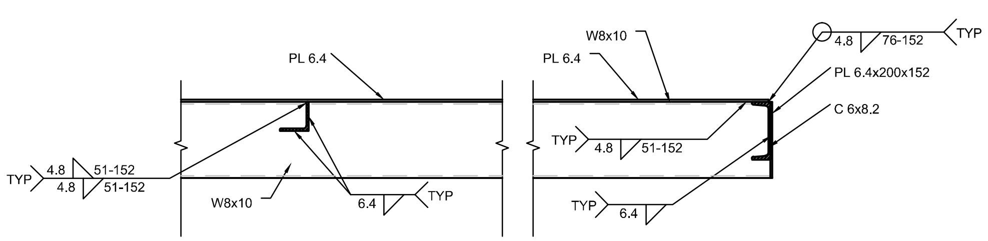
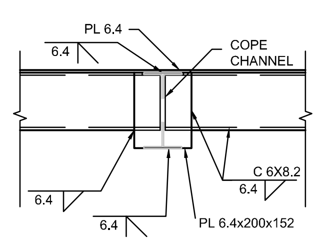
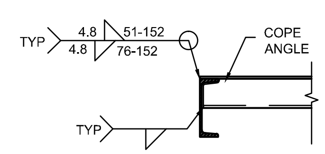


SECTION A
SCALE: 1:10



SECTION B
SCALE: 1:10



SECTION C
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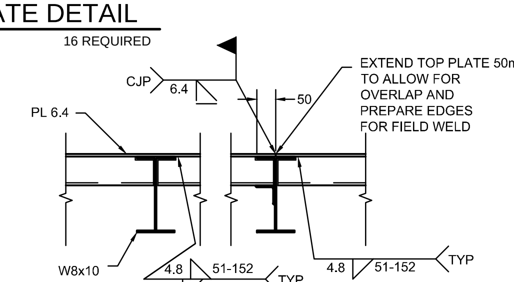

SECTION D
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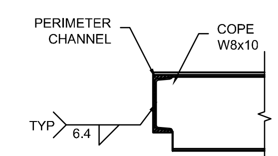


SECTION E
SCALE: 1:10

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
McElhanney Consulting Services Ltd.
Number 20663
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature

Rev	Date	Description	Drawn	Design	App'd
A	2016-06-28	ISSUED FOR 60% REVIEW	JKD	JRL	-

0 1:20 1
OR AS NOTED
ORIGINAL DWG SIZE: ANSI D (22" x 34")

McElhanney
McElhanney Consulting Services Ltd.
Suite 1
5008 Pohle Avenue
Terrace BC
Canada V8G 4S8
Tel 250 635 7163

Approved Sealed

SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR MAIN SHAFT
FABRICATION DETAILS
STRUCTURAL

Drawing No. 1664-01
Project Number 2321-01664-00
Rev. A

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

DATE: 2016-06-29 11:45 FILE: H:\2321-01600\01664-00 Structural Engineering of Stainless Steel Mine Closures\10.0 Drawings\10.2 AutoCad Files\01664-01 to 03 (Gunnar Main Shaft) Detailed Design.dwg

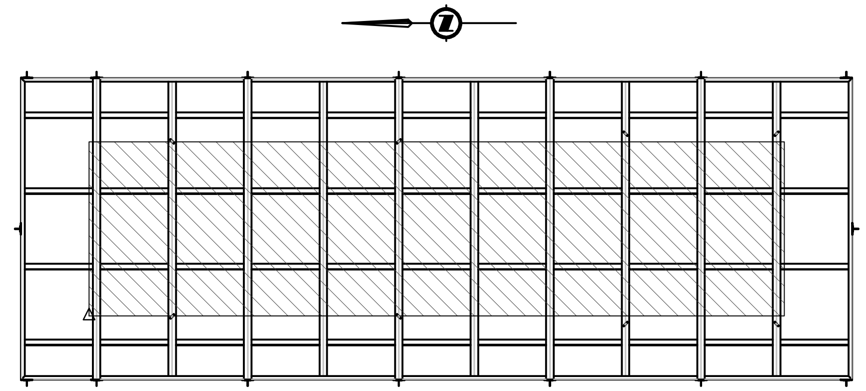
McElhanney ANSI D - 15-05-22

McElhanney ANSI D - 15-05-22

SURVEY NOTES:
1. SITE SURVEY NOT YET COMPLETE.

GENERAL NOTES:
FOR INSTALLATION NOTES REFER TO DRAWING 1664-03 "INSTALLATION DETAILS AND NOTES".
FOR CAP, BASEPLATE, AND CLIP DETAILS REFER TO DRAWING 1664-01 "FABRICATION DETAILS".

INSTALLATION SEQUENCE
1. USE SPRAY PAINT TO MARK THE AS-BUILT OUTLINE OF THE LID ON THE GROUND SURFACE, ADHERING TO ANY SPECIFIC LAYOUT DIMENSIONS SHOWN ON THE DRAWINGS.
2. HOIST LID INTO POSITION AND PROVIDE WOOD BLOCKING BELOW LID SUCH THAT THE LID IS STABLE IN BOTH DIRECTIONS AND THE SPECIFIED LID SLOPE HAS BEEN ACHIEVED.
3. USE A PLUMB BOB (FOR LOCATIONS WITH VERTICAL POSTS) OR A STRAIGHT EDGE (FOR LOCATIONS WITH HORIZONTAL SUPPORTS) TO LOCATE THE BASE PLATE LOCATIONS IN RELATION TO THE MOUNTING SURFACES ON THE LID. MARK THESE LOCATIONS ON THE GROUND SURFACE, SCALING ANY LOOSE ROCK PRESENT IN THE PROXIMITY OF THE ANCHOR POINT LOCATIONS.
4. REMOVE THE LID AND INSTALL THE BASE PLATES ONTO THE BEDROCK AND/OR CONCRETE. BLOCKING TO REMAIN IN POSITION IF POSSIBLE.
5. REPOSITION THE LID ONTO THE BLOCKING. PLACE THE POSTS OR HORIZONTAL SUPPORTS FLUSH TO THE MOUNTING SURFACE ON THE LID. KEEP THE POST FLUSH TO THE MOUNTING SURFACE AND TRANSLATE THE BASE PLATE SLOPE/SKEW ONTO THE POST. CUT THE BOTTOM OF THE POST TO SUIT.
6. WELD THE POSTS/HORIZONTAL SUPPORTS TO THE BASE PLATES AND THE MOUNTING SURFACE OF THE LID (SEE DETAILS).
7. INSTALL THE SIDE WALLS. (SEE DETAILS). TRIM THE POSTS FLUSH WITH THE TOP OF THE LID.
8. REMOVE ANY HEAT TINT IN LOCATIONS OF FIELD WELDS. SEE "FIELD WELDING" NOTES ON DRAWING 1664-03.



PLAN VIEW
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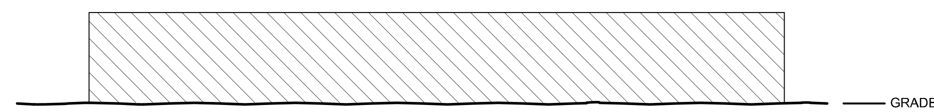
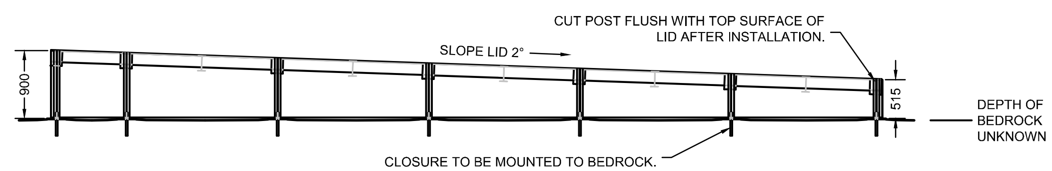




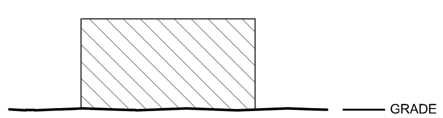
WEST PROFILE
SCALE: 1:50

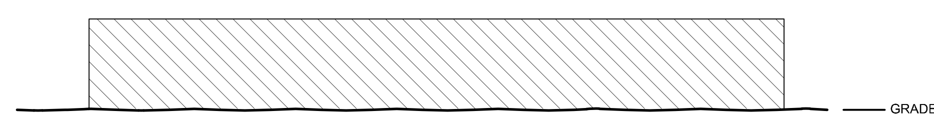
LEGEND
EXISTING

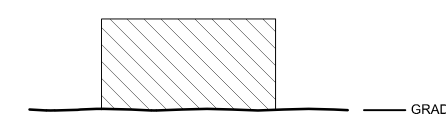
———	TOP OF BANK
– – – –	BOTTOM OF BANK
———	EDGE OF HOLE
(hatched)	SHAFT INTERIOR
△	SURVEY HUB

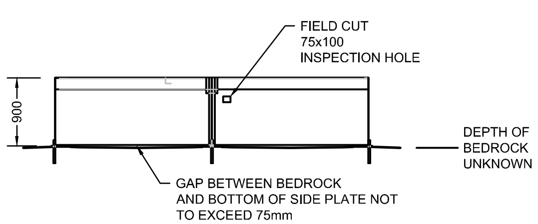
SURVEY CONTROL TABLE
NORTHWEST CORNER GPS POINT
Z12V 0620302
6584779

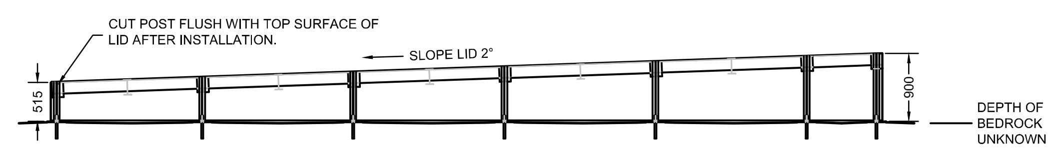
KEY PLAN
NOT TO SCALE
SITE PLAN COURTESY OF SRK CONSULTING 2016

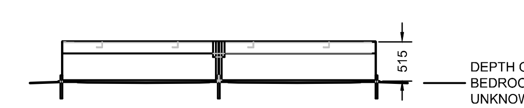












NORTH PROFILE
SCALE: 1:50

EAST PROFILE
SCALE: 1:50

SOUTH PROFILE
SCALE: 1:50

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
McElhanney Consulting Services Ltd.
Number 20663
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature

Rev	Date	Description	Drawn	Design	App'd
A	2016-06-28	ISSUED FOR 60% REVIEW	JKD	JRL	-

0 1:50 2
OR AS NOTED

ORIGINAL DWG SIZE: ANSI D (22" x 34")

McElhanney
McElhanney Consulting Services Ltd.
Suite 1
5008 Pohle Avenue
Terrace BC
Canada V8G 4S8
Tel 250 635 7163

Approved Sealed

SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR MAIN SHAFT
INSTALLATION PLAN AND PROFILES
STRUCTURAL

Drawing No.
1664-02

Project Number
2321-01664-00

Rev.
A

DATE: 2016-06-29, 11:45 FILE: H:\2321-01600\01664-00 Structural Engineering of Stainless Steel Mine Closures\10.0 Drawings\10.2 AutoCad Files\01664-01 to 03 (Gunnar Main Shaft) Detailed Design.dwg

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

GENERAL NOTES:

1. CHECK AND VERIFY ALL DIMENSIONS BEFORE COMMENCING ANY WORK. NOTIFY THE DESIGNER OF ANY ERRORS OR OMISSIONS. DO NOT CONSTRUCT FROM THESE DRAWINGS UNLESS MARKED "ISSUED FOR CONSTRUCTION".

2. DESIGN CODE: NBCC 2015, CAN/CSA S16-09.

DESIGN LOADS:

SPECIFIED VEHICLE LOAD: 11 kN
SPECIFIED UDL: SNOW: SS=2kPa, Sr=0.1kPa OVERBURDEN: 1.2 kPa
SPECIFIED INDUSTRIAL LOADING: 4.8 kPa

THE CONTRACTOR MUST ENSURE THAT CONSTRUCTION LOADS IMPOSED ON THE STRUCTURE DO NOT EXCEED THE SPECIFIED DESIGN LOADS NOTED ABOVE.

3. ALWAYS READ WRITTEN DIMENSIONS. DO NOT SCALE OFF THE DRAWINGS OR CAD FILES.

4. SUPPLY OF RECORD DRAWINGS IS OUTSIDE THE SCOPE OF SERVICES.

5. THE CONTRACTOR IS RESPONSIBLE FOR ALL COSTS ASSOCIATED WITH THE CORRECTION OF DEFICIENCIES, AS DIRECTED BY THE ENGINEER.

6. THE DESIGN AND INSPECTION OF FALSEWORK, SHORING AND RESHORING ARE THE RESPONSIBILITY OF THE CONTRACTOR, SHALL CONFORM TO WCB STANDARDS AND SHALL BE AS REQUIRED TO KEEP THE STRUCTURE PLUMB AND LEVEL DURING CONSTRUCTION.

7. THESE DRAWINGS SHOW REQUIREMENTS FOR COMPLETED STRUCTURE ONLY. THE CONTRACTOR IS RESPONSIBLE FOR ALL TEMPORARY BRACING AND HOISTING REQUIRED FOR CONSTRUCTION LOADINGS AND STABILITY UNTIL THE PROJECT IS COMPLETE.

8. REVIEW OF WORK, OR ANY PORTION OF WORK, BY THE ENGINEER SHALL NOT RELIEVE THE FABRICATOR OF THEIR RESPONSIBILITY AND OBLIGATION TO COMPLY WITH CONTRACT DRAWINGS AND SPECIFICATIONS.

9. DO NOT DRILL OR ATTACH TO STRUCTURAL FRAME WITHOUT AUTHORIZATION FROM THE ENGINEER, UNLESS NOTED ON DRAWINGS.

FIELD REVIEW:

1. ONLY WORK SHOWN ON THE STRUCTURAL CONSTRUCTION DOCUMENTS BY MCELHANNEY CONSULTING WILL BE REVIEWED.

2. QUALITY CONTROL OF WORK IS THE CONTRACTORS RESPONSIBILITY.

3. ENGINEER TO BE NOTIFIED OF CONSTRUCTION SCHEDULE IN ORDER TO SCHEDULE FIELD REVIEWS. MINIMUM 2 WEEKS NOTICE SHALL BE GIVEN PRIOR TO MANDATORY FIELD REVIEWS. IF ENGINEER IS NOT AFFORDED THE OPPORTUNITY TO REVIEW THE STRUCTURAL WORKS, FINAL CERTIFICATION OF THE PROJECT WILL NOT BE ISSUED.

4. NUMBER OF REVIEWS AND ITEMS REVIEWED WILL BE AT THE DISCRETION OF THE ENGINEER TO DETERMINE GENERAL CONFORMANCE WITH THE DESIGN INTENT. ADDITIONAL FIELD REVIEWS REQUIRED DUE TO DEFICIENT OR INCOMPLETE WORK WILL BE AT THE EXPENSE OF THE CONTRACTOR.

STRUCTURAL STEEL:

1. ALL STRUCTURAL STEEL WORK SHALL CONFORM TO CAN/CSA S16-09.

2. ALL STRUCTURAL STEEL MATERIAL SHALL CONFORM TO CSA G40.20/G40.21 WITH THE FOLLOWING MATERIAL GRADES:

i) THREADED ROD	ASTM F593 (AISI 304/316)
ii) NUTS	ASTM F594 (AISI 304/316)
iii) WASHERS	ASTM A240 (AISI 304/316)
iV) PLATES AND BARS	AISI 304
v) ROLLED AND HSS SHAPES	AISI 304

3. DRAIN HOLES ARE TO BE PROVIDED AT THE BASE OF ALL HSS TUBES.

4. VOIDS ON THE UNDERSIDE OF THE BEARING AND/OR BASE PLATES SHALL BE MINIMIZED BY LOCALIZED BUSH HAMMERING OF BEDROCK. BASE PLATES SHALL SUBSTANTIALLY CONTACT THE ROCK SURFACE BELOW.

EPOXY ANCHOR NOTES:

1. HILTI HIT ADHESIVE ANCHOR SYSTEM HY-150 ICE TO BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.

ASTM F593 (AISI 304/316) THREADED ANCHOR ROD
$\frac{3}{4}$"Ø IN $\frac{7}{8}$"Ø HOLE 6" MINIMUM DEPTH
1"Ø IN $1\frac{1}{8}$"Ø HOLE 10" MINIMUM DEPTH

FIELD WELDING:

1. ALL WELDING SHALL CONFORM TO CSA W59 AND BE PERFORMED BY CWB CERTIFIED WELDERS UNDER CSA W47.1. FABRICATORS TO BE APPROVED BY CWB. FABRICATOR TO PROVIDE COORDINATING ENGINEER WITH PROPOSED WELDING PROCEDURE PRIOR TO FABRICATION. WELDS SHALL BE MADE WITH ELECTRODES AND FILLER MATERIAL RATED AS FOLLOWS:

MATERIAL GRADE	ELECTRODE
304/304L	ER308/ER308L
316/316L	ER316/ER316L

2. ADEQUATE SHIELDING GAS AND CORRECT HEAT SHALL BE USED TO AVOID CARBIDE PRECIPITATION. SHIELDING MUST CONTINUE POST WELD UNTIL THE HEAT AFFECTED ZONE HAS COOLED TO BELOW 430°C

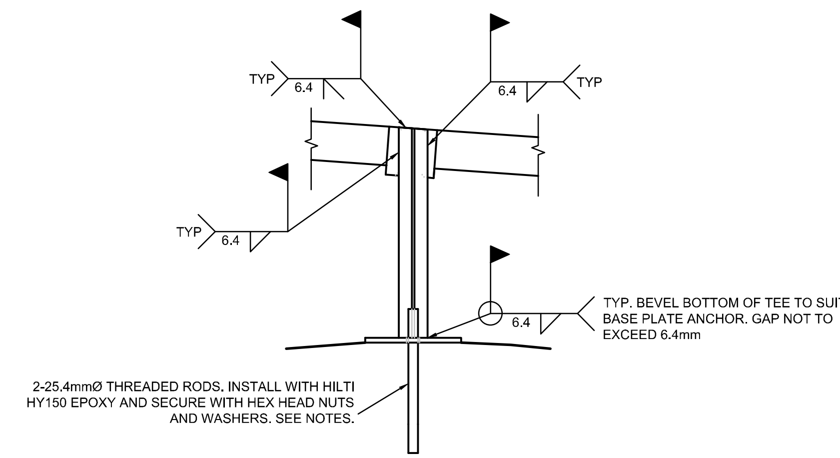
3. FABRICATOR TO CONTROL WARPING OF COMPONENTS DURING WELDING BY ALTERNATING WELDS AND/OR ALLOWING COOLING PERIODS BETWEEN WELDS AND/OR CLAMPING OF MATERIALS.

4. MINIMUM WELD SIZE TO BE $\frac{3}{16}$" FILLET, UNLESS NOTED OTHERWISE.

5. WELDING PROCEDURE TO ENSURE A CLEAN WORK ENVIRONMENT INCLUDING TOOLS AND GLOVES. GREASE, DUST, AND EXCESS AIR FLOW IN THE WELDING AREA IS NOT ACCEPTABLE. CONTAMINATED ELECTRODES MUST BE CLEANED PRIOR TO USE. HEAT TINT TO BE REMOVED BEFORE ITEMS ARE COVERED AND UPON COMPLETION OF THE INSTALLATION.

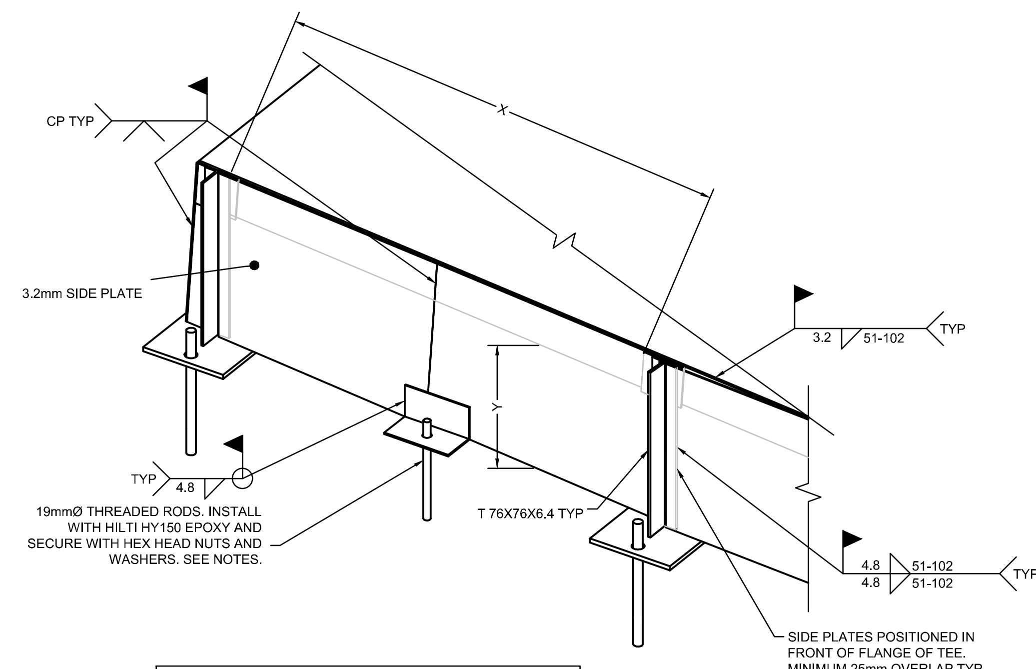
6. FIELD DEGREASING AND PICKLING USING A BRUSH ON PASTE OR GEL IS REQUIRED BEFORE ITEMS ARE COVERED AND UPON COMPLETION OF THE INSTALLATION.

NOTE: HOLES THROUGH BASE PLATE MAY BE ENLARGED TO SUIT INSTALLATION ANGLE OF ANCHOR BOLTS. PLATE WASHERS MAY BE REQUIRED TO ACCOMMODATE NUT PLACEMENT. NUT TO SIT SQUARE TO BASE PLATE UNLESS BEVELED WASHER IS INSTALLED.

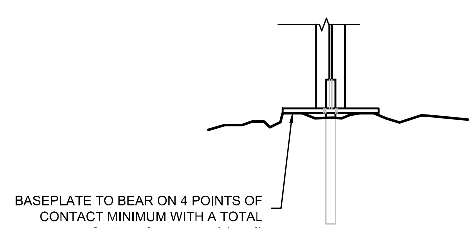


TYPICAL POST DETAIL

SCALE: 1:10



NOTE: SIDE CLIPS REQUIRED IF Y>380mm OR X >1.4m



BASE PLATE BEARING DETAIL

SCALE: 1:10

TYPICAL SIDE PLATE INSTALLATION DETAIL

NOT TO SCALE

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
McElhanney Consulting Services Ltd.
Number 20663
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature

Rev	Date	Description	Drawn	Design	App'd
A	2016-06-28	ISSUED FOR 60% REVIEW	JKD	JRL	-

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ORIGINAL DWG SIZE: ANSI D (22" x 34")

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Approved Sealed

SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR MAIN SHAFT
INSTALLATION DETAILS AND NOTES
STRUCTURAL

Drawing No.
1664-03

Project Number
2321-01664-00

Rev.
A

McElhanney ANSI D - 15-05-22
DATE: 2016-06-29, 11:45 FILE: H:\2321-01600\01664-00 Structural Engineering of Stainless Steel Mine Closures\10.0 Drawings\10.2 AutoCad Files\01664-01 to 03 (Gunnar Main Shaft) Detailed Design.dwg

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

GENERAL NOTES:

1. CHECK AND VERIFY ALL DIMENSIONS BEFORE COMMENCING ANY WORK. NOTIFY THE DESIGNER OF ANY ERRORS OR OMISSIONS. DO NOT CONSTRUCT FROM THESE DRAWINGS UNLESS MARKED "ISSUED FOR CONSTRUCTION".
2. DESIGN CODE: NBCC 2015, CAN/CSA S16-09.

DESIGN LOADS:

SPECIFIED VEHICLE LOAD: 11 kN
SPECIFIED UDL: SNOW: SS=2kPa, Sr=0.1kPa OVERBURDEN: 1.2 kPa
SPECIFIED INDUSTRIAL LOADING: 4.8 kPa

3. ALWAYS READ WRITTEN DIMENSIONS. DO NOT SCALE OFF THE DRAWINGS OR CAD FILES.
4. SUPPLY OF RECORD DRAWINGS IS OUTSIDE THE SCOPE OF SERVICES.
5. THE FABRICATOR IS RESPONSIBLE FOR ALL COSTS ASSOCIATED WITH THE CORRECTION OF DEFICIENCIES, AS DIRECTED BY THE ENGINEER.
6. REVIEW OF WORK, OR ANY PORTION OF WORK, BY THE ENGINEER SHALL NOT RELIEVE THE FABRICATOR OF THEIR RESPONSIBILITY AND OBLIGATION TO COMPLY WITH CONTRACT DRAWINGS AND SPECIFICATIONS.
7. DO NOT DRILL OR ATTACH TO STRUCTURAL FRAME WITHOUT AUTHORIZATION FROM THE ENGINEER, UNLESS NOTED ON DRAWINGS.

STRUCTURAL STEEL:

1. ALL STRUCTURAL STEEL WORK SHALL CONFORM TO CAN/CSA S16-09.
2. ALL STRUCTURAL STEEL MATERIAL SHALL CONFORM TO THE FOLLOWING MATERIAL GRADES:

i) ANCHOR BOLTS	ASTM F593 (AISI 304/316)
ii) NUTS	ASTM F594 (AISI 304/316)
iii) WASHERS	ASTM A240 (AISI 304/316)
iV) PLATES AND BARS	AISI 304
v) ROLLED AND HSS SHAPES	AISI 304

3. DRAIN HOLES ARE TO BE PROVIDED AT THE BASE OF ALL HSS TUBES.
4. ALL FABRICATED PARTS TO BE DEGREASED AND PICKLED WITH A BRUSH ON PASTE OR GEL PRIOR TO DELIVERY.

WELDING:

1. ALL WELDING SHALL CONFORM TO CSA W59 AND BE PERFORMED BY CWB CERTIFIED WELDERS UNDER CSA W47.1. FABRICATORS TO BE APPROVED BY CWB. FABRICATOR TO PROVIDE COORDINATING ENGINEER WITH PROPOSED WELDING PROCEDURE PRIOR TO FABRICATION. WELDS SHALL BE MADE WITH ELECTRODES AND FILLER MATERIAL RATED AS FOLLOWS:

MATERIAL GRADE	ELECTRODE
304/304L	ER308/ER308L
316/316L	ER316/ER316L

2. ADEQUATE SHIELDING GAS AND CORRECT HEAT SHALL BE USED TO AVOID CARBIDE PRECIPITATION. SHIELDING MUST CONTINUE POST WELD UNTIL THE HEAT AFFECTED ZONE HAS COOLED TO BELOW 430°C
3. FABRICATOR TO CONTROL WARPING OF COMPONENTS DURING WELDING BY ALTERNATING WELDS AND/OR ALLOWING COOLING PERIODS BETWEEN WELDS AND/OR CLAMPING OF MATERIALS.
4. MINIMUM WELD SIZE TO BE $\frac{3}{16}$" FILLET, UNLESS NOTED OTHERWISE.
5. WELDING PROCEDURE TO ENSURE A CLEAN WORK ENVIRONMENT INCLUDING TOOLS AND GLOVES. GREASE, DUST, AND EXCESS AIR FLOW IN THE WELDING AREA IS NOT ACCEPTABLE. CONTAMINATED ELECTRODES MUST BE CLEANED PRIOR TO USE. HEAT TINT TO BE REMOVED PRIOR TO DELIVERY.

INSPECTIONS:

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4. NUMBER OF REVIEWS AND ITEMS REVIEWED WILL BE AT THE DISCRETION OF THE ENGINEER TO DETERMINE GENERAL CONFORMANCE WITH THE DESIGN INTENT.
5. ADDITIONAL INSPECTIONS REQUIRED DUE TO DEFICIENT OR INCOMPLETE WORK WILL BE AT THE EXPENSE OF THE FABRICATOR.

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
McElhanney Consulting Services Ltd.
Number 20663
Permission to Consult held by:

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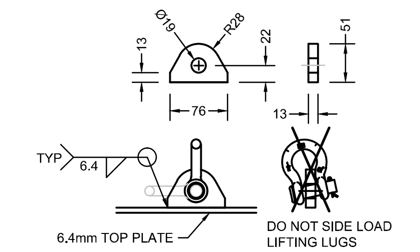
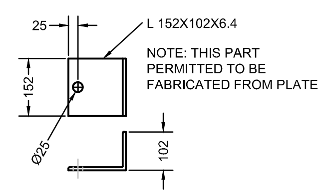


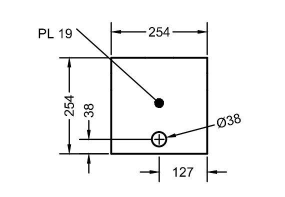
LUG DETAIL
SCALE: 1:5



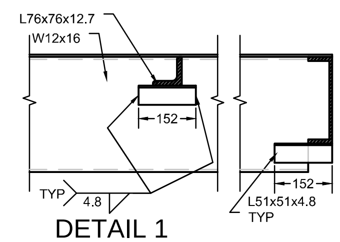
SIDEWALL CLIP
SCALE: 1:10

6.4mm COVER PLATE NOT SHOWN FOR CLARITY. CUT PLATE 4.8mm LESS THAN OUTSIDE DIMENSIONS (BOTH WAYS) TO ALLOW FOR PERIMETER SEAL WELD. SEE SECTIONS A AND C.

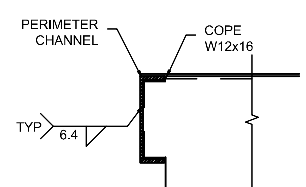
COVER PLATE TO SPAN A MINIMUM OF 3 MEMBERS. BUTT SIDES AND JOIN WITH COMPLETE PENETRATION GROOVE WELDS.



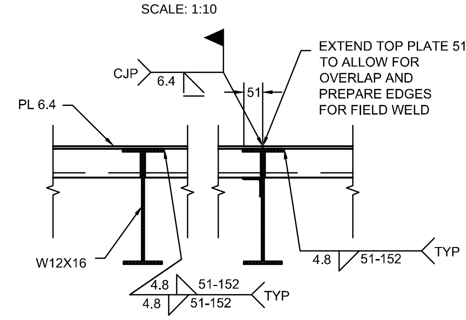
BASE PLATE DETAIL
SCALE: 1:10 16 REQUIRED



DETAIL 1
SCALE: 1:10



SECTION E
SCALE: 1:10



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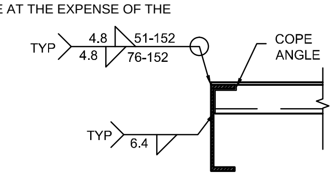
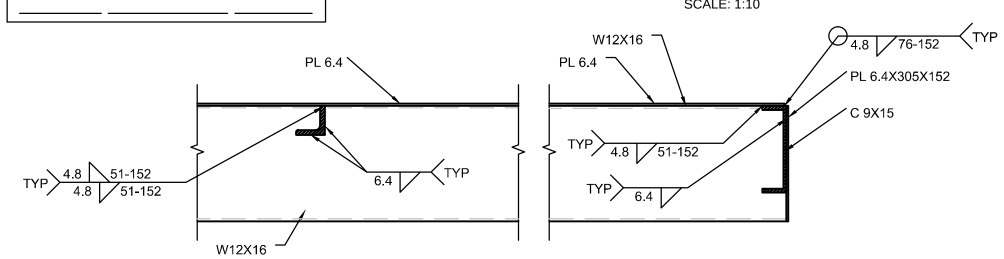
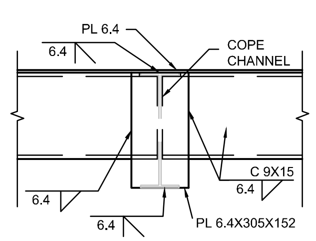


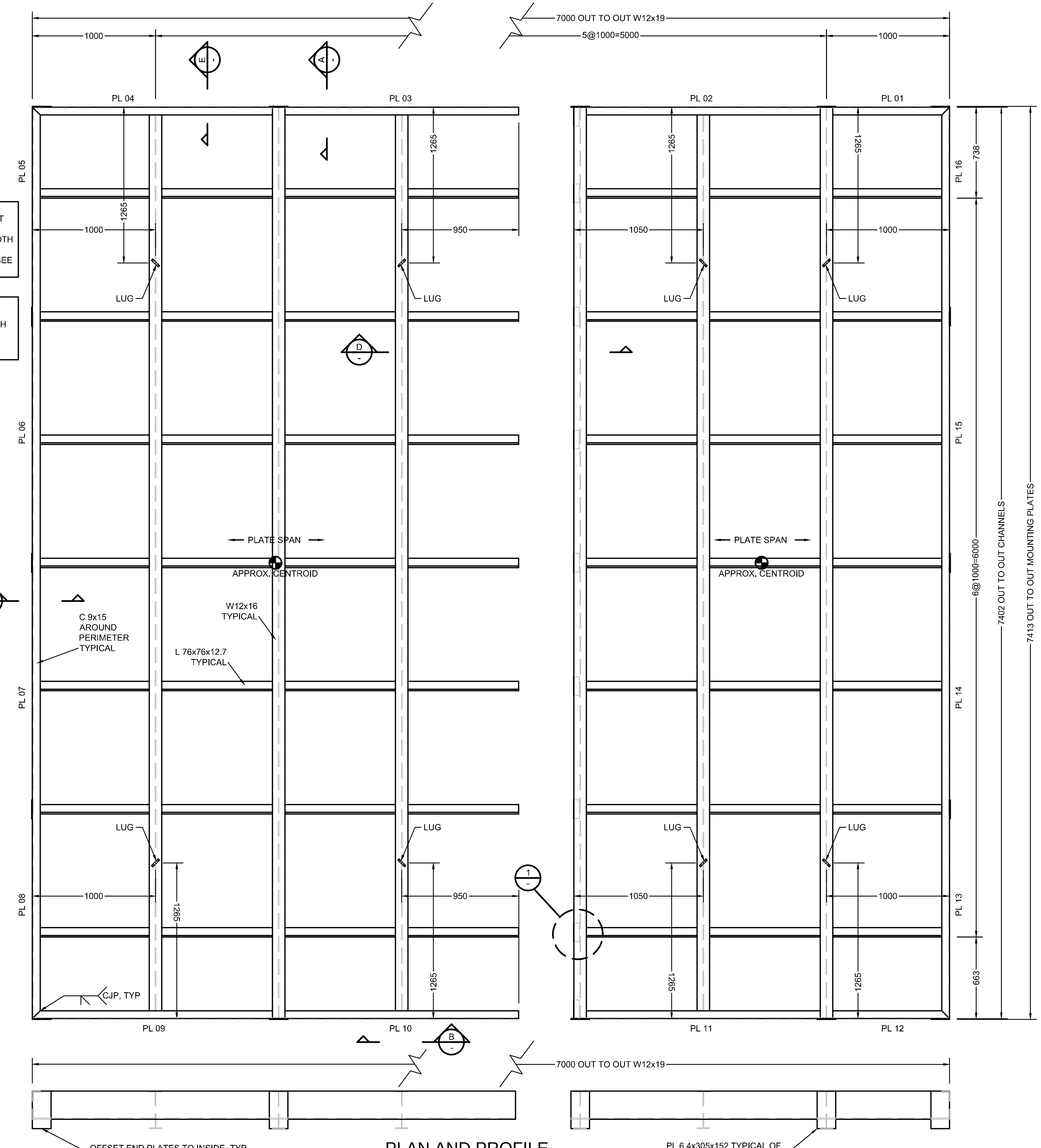
SECTION C
SCALE: 1:10



SECTION A
SCALE: 1:10



SECTION B
SCALE: 1:10



PLAN AND PROFILE
SCALE: 1:20

Rev	Date	Description	Drawn	Design	App'd
A	2016-06-28	ISSUED FOR 60% REVIEW	JKD	JRL	-

0 1:20 1
OR AS NOTED
ORIGINAL DWG SIZE: ANSI D (22" x 34")

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5008 Pohle Avenue
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Tel 250 635 7163

Approved Sealed

SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR BACK RAISE
FABRICATION DETAILS
STRUCTURAL

Drawing No.
1664-04
Project Number
2321-01664-00
Rev.
A

McElhanney ANSI D - 15-05-22

SURVEY NOTES:

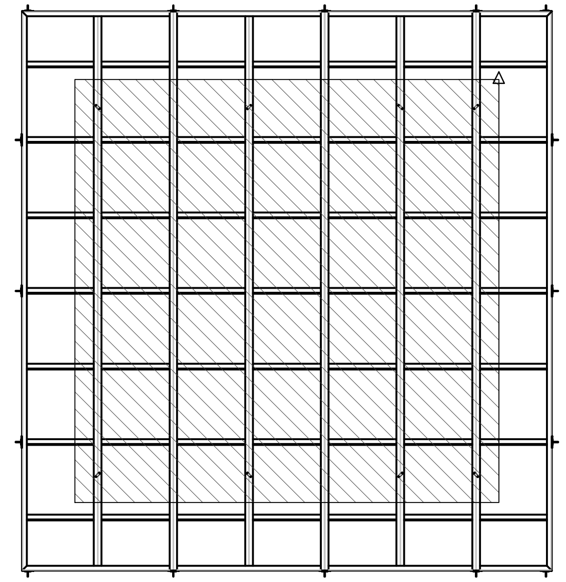
1. SITE SURVEY NOT YET COMPLETE.

GENERAL NOTES:

FOR INSTALLATION NOTES REFER TO DRAWING 1664-06 "INSTALLATION DETAILS AND NOTES".
FOR CAP, BASEPLATE, AND CLIP DETAILS REFER TO DRAWING 1664-04 "FABRICATION DETAILS".

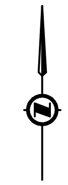
INSTALLATION SEQUENCE

1. USE SPRAY PAINT TO MARK THE AS-BUILT OUTLINE OF THE LID ON THE GROUND SURFACE, ADHERING TO ANY SPECIFIC LAYOUT DIMENSIONS SHOWN ON THE DRAWINGS.
2. HOIST LID INTO POSITION AND PROVIDE WOOD BLOCKING BELOW LID SUCH THAT THE LID IS STABLE IN BOTH DIRECTIONS AND THE SPECIFIED LID SLOPE HAS BEEN ACHIEVED.
3. USE A PLUMB BOB (FOR LOCATIONS WITH VERTICAL POSTS) OR A STRAIGHT EDGE (FOR LOCATIONS WITH HORIZONTAL SUPPORTS) TO LOCATE THE BASE PLATE LOCATIONS IN RELATION TO THE MOUNTING SURFACES ON THE LID. MARK THESE LOCATIONS ON THE GROUND SURFACE, SCALING ANY LOOSE ROCK PRESENT IN THE PROXIMITY OF THE ANCHOR POINT LOCATIONS.
4. REMOVE THE LID AND INSTALL THE BASE PLATES ONTO THE BEDROCK AND/OR CONCRETE. BLOCKING TO REMAIN IN POSITION IF POSSIBLE.
5. REPOSITION THE LID ONTO THE BLOCKING. PLACE THE POSTS OR HORIZONTAL SUPPORTS FLUSH TO THE MOUNTING SURFACE ON THE LID. KEEP THE POST FLUSH TO THE MOUNTING SURFACE AND TRANSLATE THE BASE PLATE SLOPE/SKEW ONTO THE POST. CUT THE BOTTOM OF THE POST TO SUIT.
6. WELD THE POSTS/HORIZONTAL SUPPORTS TO THE BASE PLATES AND THE MOUNTING SURFACE OF THE LID (SEE DETAILS).
7. INSTALL THE SIDE WALLS. (SEE DETAILS). TRIM THE POSTS FLUSH WITH THE TOP OF THE LID.
8. REMOVE ANY HEAT TINT IN LOCATIONS OF FIELD WELDS. SEE "FIELD WELDING" NOTES ON DRAWING 1664-06.



PLAN VIEW

SCALE: 1:50



LEGEND

EXISTING

TOP OF BANK

BOTTOM OF BANK

EDGE OF HOLE

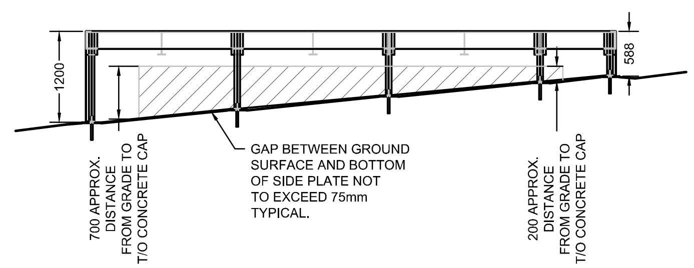
SHAFT INTERIOR

SURVEY HUB

SURVEY CONTROL TABLE
NORTHEAST CORNER GPS POINT
Z12V 0620476
6584776

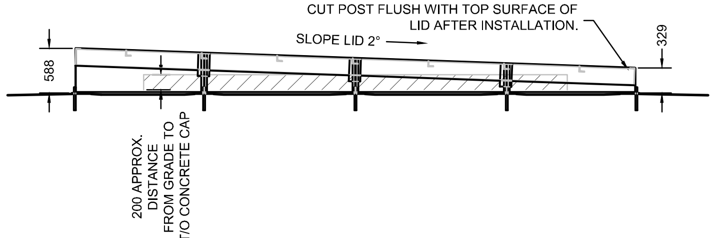
KEY PLAN

NOT TO SCALE
SITE PLAN COURTESY OF SRK CONSULTING 2016



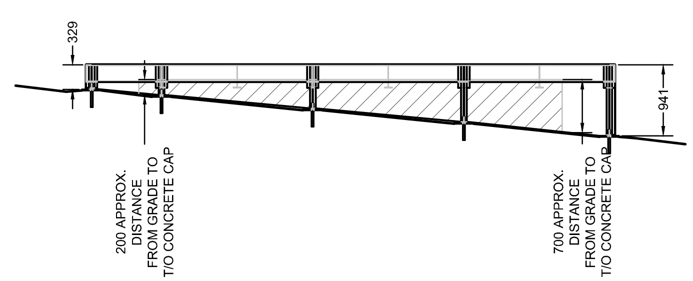
SOUTH PROFILE

SCALE: 1:50



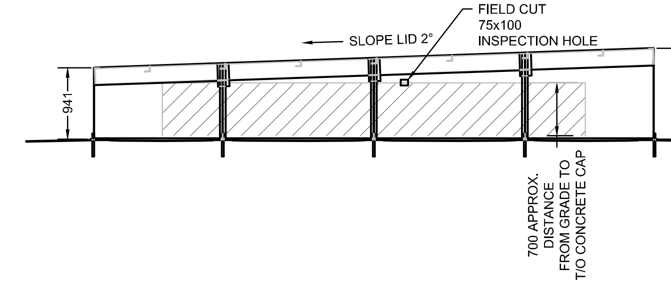
EAST PROFILE

SCALE: 1:50



NORTH PROFILE

SCALE: 1:50



WEST PROFILE

SCALE: 1:50

Association of Professional Engineers & Geoscientists of Saskatchewan
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McElhanney Consulting Services Ltd.
Number 20663
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature

Rev	Date	Description	Drawn	Design	App'd
A	2016-06-28	ISSUED FOR 60% REVIEW	JKD	JRL	-

0 1:50 2
OR AS NOTED

ORIGINAL DWG SIZE: ANSI D (22" x 34")

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SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR BACK RAISE
INSTALLATION PLAN AND PROFILES
STRUCTURAL

Drawing No.
1664-05

Project Number
2321-01664-00

Rev.
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DESTROY ALL PRINTS BEARING PREVIOUS REVISION

DATE: 2016-06-29, 11:45 FILE: H:\2321-01600's\01664-00 Structural Engineering of Stainless Steel Mine Closures\10.0 Drawings\10.2 AutoCad Files\01664-04 to 06 (Gunnar Back Raise) Detailed Design.dwg

GENERAL NOTES:

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2. DESIGN CODE: NBCC 2015, CAN/CSA S16-09.

DESIGN LOADS:

SPECIFIED VEHICLE LOAD: 11 kN
SPECIFIED UDL: SNOW: SS=2kPa, Sr=0.1kPa OVERBURDEN: 1.2 kPa
SPECIFIED INDUSTRIAL LOADING: 4.8 kPa

THE CONTRACTOR MUST ENSURE THAT CONSTRUCTION LOADS IMPOSED ON THE STRUCTURE DO NOT EXCEED THE SPECIFIED DESIGN LOADS NOTED ABOVE.

3. ALWAYS READ WRITTEN DIMENSIONS. DO NOT SCALE OFF THE DRAWINGS OR CAD FILES.

4. SUPPLY OF RECORD DRAWINGS IS OUTSIDE THE SCOPE OF SERVICES.

5. THE CONTRACTOR IS RESPONSIBLE FOR ALL COSTS ASSOCIATED WITH THE CORRECTION OF DEFICIENCIES, AS DIRECTED BY THE ENGINEER.

6. THE DESIGN AND INSPECTION OF FALSEWORK, SHORING AND RESHORING ARE THE RESPONSIBILITY OF THE CONTRACTOR, SHALL CONFORM TO WCB STANDARDS AND SHALL BE AS REQUIRED TO KEEP THE STRUCTURE PLUMB AND LEVEL DURING CONSTRUCTION.

7. THESE DRAWINGS SHOW REQUIREMENTS FOR COMPLETED STRUCTURE ONLY. THE CONTRACTOR IS RESPONSIBLE FOR ALL TEMPORARY BRACING AND HOISTING REQUIRED FOR CONSTRUCTION LOADINGS AND STABILITY UNTIL THE PROJECT IS COMPLETE.

8. REVIEW OF WORK, OR ANY PORTION OF WORK, BY THE ENGINEER SHALL NOT RELIEVE THE FABRICATOR OF THEIR RESPONSIBILITY AND OBLIGATION TO COMPLY WITH CONTRACT DRAWINGS AND SPECIFICATIONS.

9. DO NOT DRILL OR ATTACH TO STRUCTURAL FRAME WITHOUT AUTHORIZATION FROM THE ENGINEER, UNLESS NOTED ON DRAWINGS.

FIELD REVIEW:

1. ONLY WORK SHOWN ON THE STRUCTURAL CONSTRUCTION DOCUMENTS BY MCELHANNEY CONSULTING WILL BE REVIEWED.

2. QUALITY CONTROL OF WORK IS THE CONTRACTORS RESPONSIBILITY.

3. ENGINEER TO BE NOTIFIED OF CONSTRUCTION SCHEDULE IN ORDER TO SCHEDULE FIELD REVIEWS. MINIMUM 2 WEEKS NOTICE SHALL BE GIVEN PRIOR TO MANDATORY FIELD REVIEWS. IF ENGINEER IS NOT AFFORDED THE OPPORTUNITY TO REVIEW THE STRUCTURAL WORKS, FINAL CERTIFICATION OF THE PROJECT WILL NOT BE ISSUED.

4. NUMBER OF REVIEWS AND ITEMS REVIEWED WILL BE AT THE DISCRETION OF THE ENGINEER TO DETERMINE GENERAL CONFORMANCE WITH THE DESIGN INTENT. ADDITIONAL FIELD REVIEWS REQUIRED DUE TO DEFICIENT OR INCOMPLETE WORK WILL BE AT THE EXPENSE OF THE CONTRACTOR.

STRUCTURAL STEEL:

1. ALL STRUCTURAL STEEL WORK SHALL CONFORM TO CAN/CSA S16-09.

2. ALL STRUCTURAL STEEL MATERIAL SHALL CONFORM TO CSA G40.20/G40.21 WITH THE FOLLOWING MATERIAL GRADES:

i) THREADED ROD	ASTM F593 (AISI 304/316)
ii) NUTS	ASTM F594 (AISI 304/316)
iii) WASHERS	ASTM A240 (AISI 304/316)
iV) PLATES AND BARS	AISI 304
v) ROLLED AND HSS SHAPES	AISI 304

3. DRAIN HOLES ARE TO BE PROVIDED AT THE BASE OF ALL HSS TUBES.

4. VOIDS ON THE UNDERSIDE OF THE BEARING AND/OR BASE PLATES SHALL BE MINIMIZED BY LOCALIZED BUSH HAMMERING OF BEDROCK. BASE PLATES SHALL SUBSTANTIALLY CONTACT THE ROCK SURFACE BELOW.

EPOXY ANCHOR NOTES:

1. HILTI HIT ADHESIVE ANCHOR SYSTEM HY-150 ICE TO BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.

ASTM F593 (AISI 304/316) THREADED ANCHOR ROD
$\frac{5}{8}$"Ø IN $\frac{3}{4}$"Ø HOLE 6" MINIMUM DEPTH
1"Ø IN 1$\frac{1}{8}$"Ø HOLE 10" MINIMUM DEPTH

FIELD WELDING:

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316/316L	ER316/ER316L

2. ADEQUATE SHIELDING GAS AND CORRECT HEAT SHALL BE USED TO AVOID CARBIDE PRECIPITATION. SHIELDING MUST CONTINUE POST WELD UNTIL THE HEAT AFFECTED ZONE HAS COOLED TO BELOW 430°C

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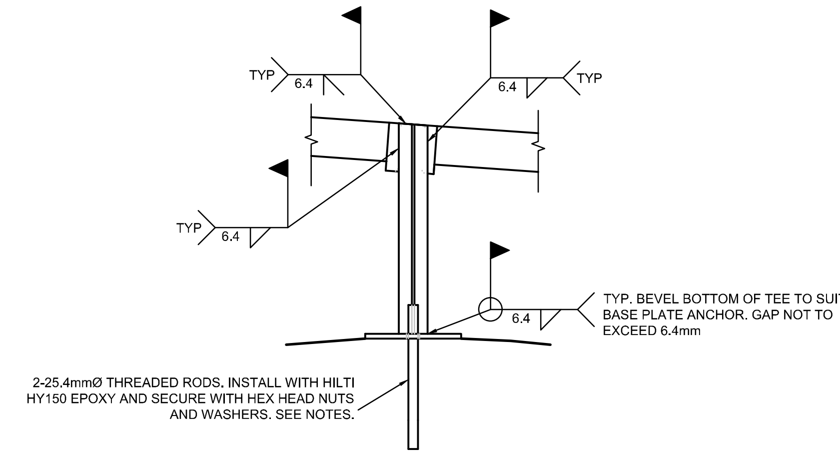
4. MINIMUM WELD SIZE TO BE $\frac{3}{16}$" FILLET, UNLESS NOTED OTHERWISE.

5. WELDING PROCEDURE TO ENSURE A CLEAN WORK ENVIRONMENT INCLUDING TOOLS AND GLOVES. GREASE, DUST, AND EXCESS AIR FLOW IN THE WELDING AREA IS NOT ACCEPTABLE. CONTAMINATED ELECTRODES MUST BE CLEANED PRIOR TO USE. HEAT TINT TO BE REMOVED BEFORE ITEMS ARE COVERED AND UPON COMPLETION OF THE INSTALLATION.

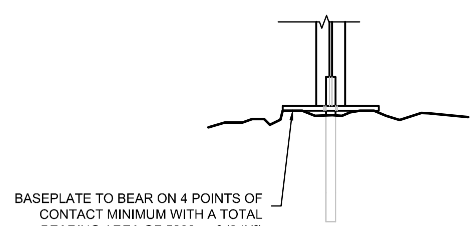
6. FIELD DEGREASING AND PICKLING USING A BRUSH ON PASTE OR GEL IS REQUIRED BEFORE ITEMS ARE COVERED AND UPON COMPLETION OF THE INSTALLATION.

NOTE: HOLES THROUGH BASE PLATE MAY BE ENLARGED TO SUIT INSTALLATION ANGLE OF ANCHOR BOLTS. PLATE WASHERS MAY BE REQUIRED TO ACCOMMODATE NUT PLACEMENT. NUT TO SIT SQUARE TO BASE PLATE UNLESS BEVELED WASHER IS INSTALLED.



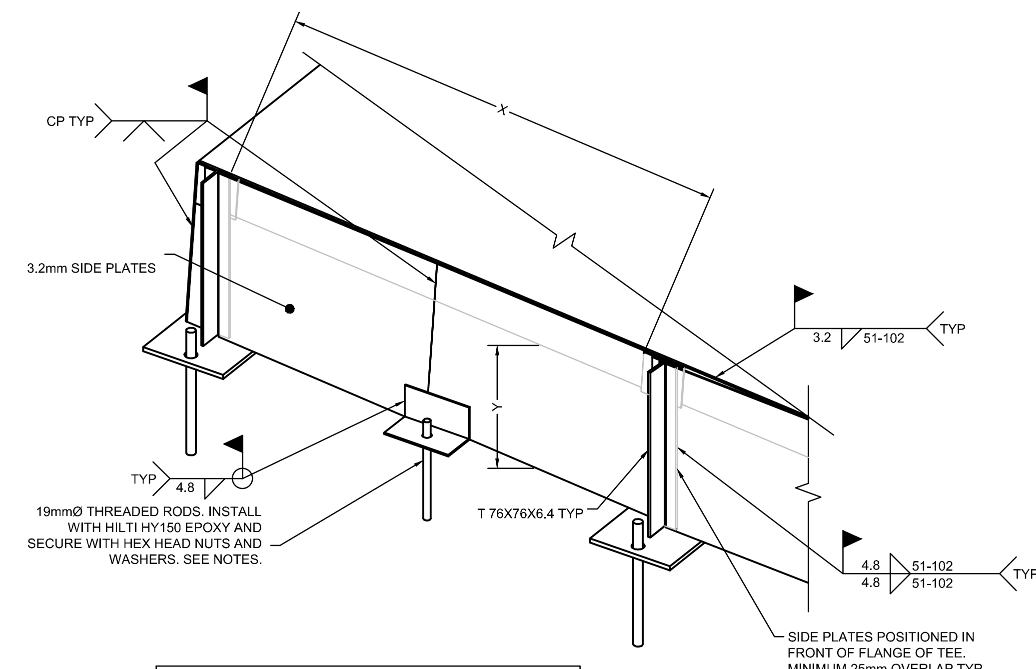
TYPICAL POST DETAIL

SCALE: 1:10



BASE PLATE BEARING DETAIL

SCALE: 1:10



NOTE: SIDE CLIPS REQUIRED IF Y>380mm OR X >1.4m

TYPICAL SIDE PLATE INSTALLATION DETAIL

NOT TO SCALE

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Approved Sealed

SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR BACK RAISE
INSTALLATION DETAILS AND NOTES
STRUCTURAL

Drawing No. 1664-06
Project Number 2321-01664-00
Rev. A

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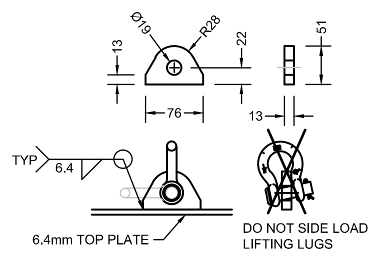
3. NOTIFY THE ENGINEER 7 DAYS IN ADVANCE FOR INSPECTION AND APPROVAL OF THE FABRICATED PARTS.
4. NUMBER OF REVIEWS AND ITEMS REVIEWED WILL BE AT THE DISCRETION OF THE ENGINEER TO DETERMINE GENERAL CONFORMANCE WITH THE DESIGN INTENT.
5. ADDITIONAL INSPECTIONS REQUIRED DUE TO DEFICIENT OR INCOMPLETE WORK WILL BE AT THE EXPENSE OF THE FABRICATOR.



LUG DETAIL
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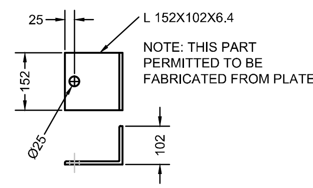
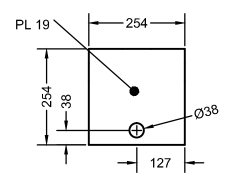
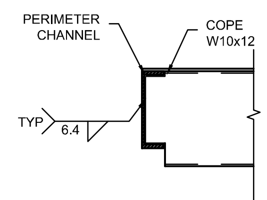


SIDEWALL CLIP
SCALE: 1:10



BASE PLATE DETAIL
SCALE: 1:10 14 REQUIRED



SECTION E
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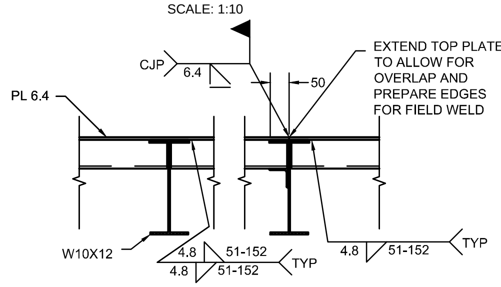

SECTION D
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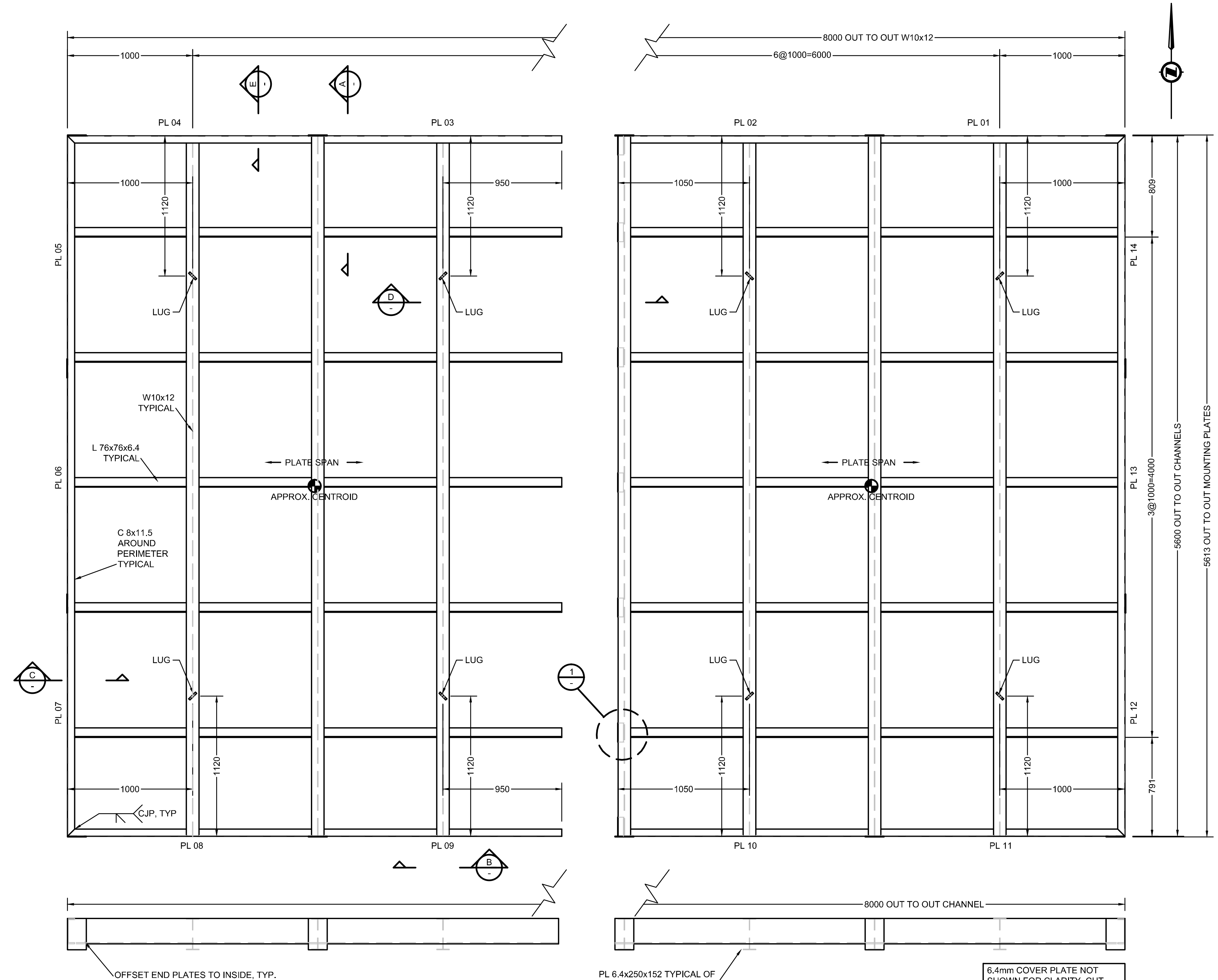
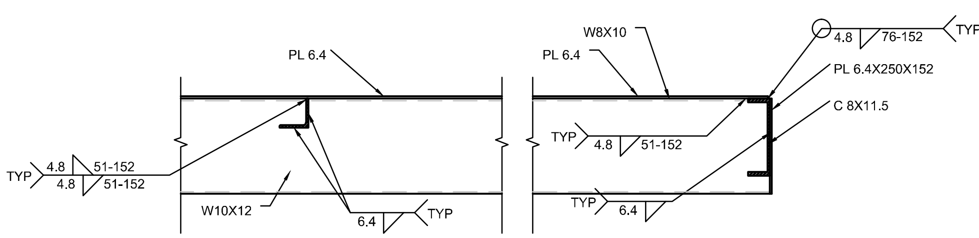


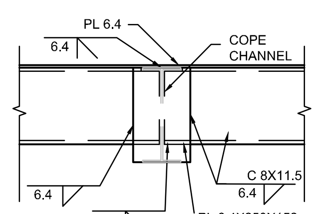
PLAN AND PROFILE
SCALE: 1:20

6.4mm COVER PLATE NOT SHOWN FOR CLARITY. CUT PLATE 4.8mm LESS THAN OUTSIDE DIMENSIONS (BOTH WAYS) TO ALLOW FOR PERIMETER SEAL WELD. SEE SECTIONS A AND C.

COVER PLATE TO SPAN A MINIMUM OF 3 MEMBERS. BUTT SIDES AND JOIN WITH COMPLETE PENETRATION GROOVE WELDS.



SECTION A
SCALE: 1:10



SECTION B
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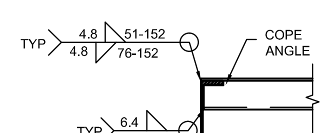

SECTION C
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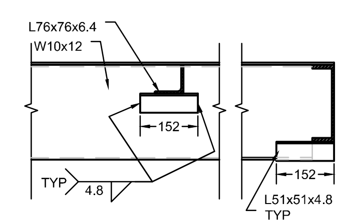

DETAIL 1
SCALE: 1:10

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Discipline	Sk. Reg. No.	Signature

Rev	Date	Description	Drawn	Design	App'd
A	2016-06-28	ISSUED FOR 60% REVIEW	JKD	JRL	-

0 1:20 1
OR AS NOTED
ORIGINAL DWG SIZE: ANSI D (22" x 34")

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Tel 250 635 7163

Approved Sealed

SASKATCHEWAN RESEARCH COUNCIL
SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR VENTILATION RAISE
FABRICATION DETAILS
STRUCTURAL

Drawing No. 1664-07
Project Number 2321-01664-00
Rev. A

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

SURVEY NOTES:

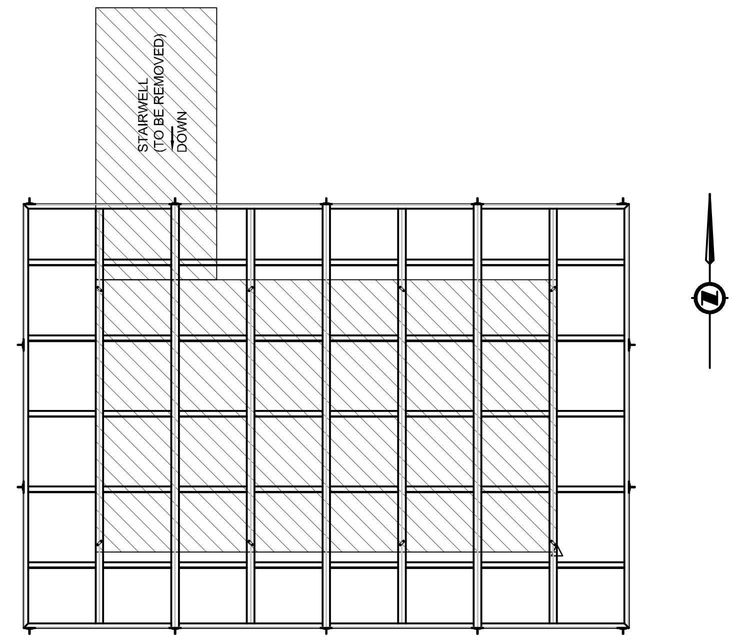
1. SITE SURVEY NOT YET COMPLETE.

GENERAL NOTES:

FOR INSTALLATION NOTES REFER TO DRAWING 1664-09 "INSTALLATION DETAILS AND NOTES".
FOR CAP, BASEPLATE, AND CLIP DETAILS REFER TO DRAWING 1664-07 "FABRICATION DETAILS".

INSTALLATION SEQUENCE

1. USE SPRAY PAINT TO MARK THE AS-BUILT OUTLINE OF THE LID ON THE GROUND SURFACE, ADHERING TO ANY SPECIFIC LAYOUT DIMENSIONS SHOWN ON THE DRAWINGS.
2. HOIST LID INTO POSITION AND PROVIDE WOOD BLOCKING BELOW LID SUCH THAT THE LID IS STABLE IN BOTH DIRECTIONS AND THE SPECIFIED LID SLOPE HAS BEEN ACHIEVED.
3. USE A PLUMB BOB (FOR LOCATIONS WITH VERTICAL POSTS) OR A STRAIGHT EDGE (FOR LOCATIONS WITH HORIZONTAL SUPPORTS) TO LOCATE THE BASE PLATE LOCATIONS IN RELATION TO THE MOUNTING SURFACES ON THE LID. MARK THESE LOCATIONS ON THE GROUND SURFACE, SCALING ANY LOOSE ROCK PRESENT IN THE PROXIMITY OF THE ANCHOR POINT LOCATIONS.
4. REMOVE THE LID AND INSTALL THE BASE PLATES ONTO THE BEDROCK AND/OR CONCRETE. BLOCKING TO REMAIN IN POSITION IF POSSIBLE.
5. REPOSITION THE LID ONTO THE BLOCKING. PLACE THE POSTS OR HORIZONTAL SUPPORTS FLUSH TO THE MOUNTING SURFACE ON THE LID. KEEP THE POST FLUSH TO THE MOUNTING SURFACE AND TRANSLATE THE BASE PLATE SLOPE/SKEW ONTO THE POST. CUT THE BOTTOM OF THE POST TO SUIT.
6. WELD THE POSTS/HORIZONTAL SUPPORTS TO THE BASE PLATES AND THE MOUNTING SURFACE OF THE LID (SEE DETAILS).
7. INSTALL THE SIDE WALLS. (SEE DETAILS). TRIM THE POSTS FLUSH WITH THE TOP OF THE LID.
8. REMOVE ANY HEAT TINT IN LOCATIONS OF FIELD WELDS. SEE "FIELD WELDING" NOTES ON DRAWING 1664-09.



PLAN VIEW
SCALE: 1:50

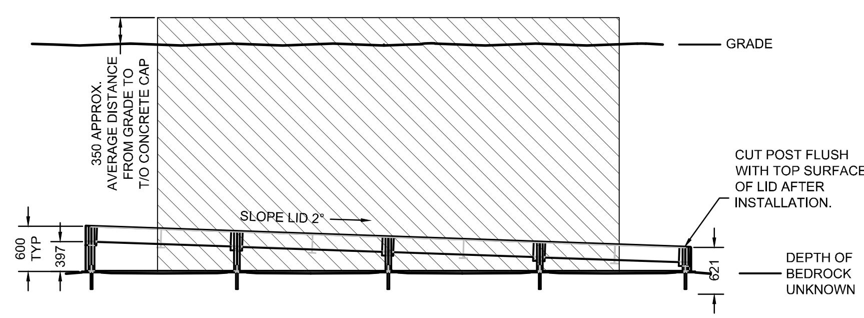
LEGEND

EXISTING

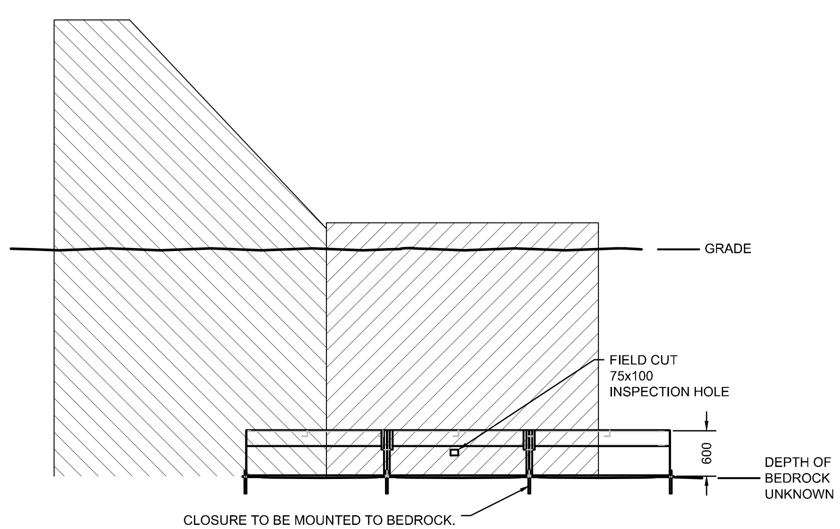
———	TOP OF BANK
— — —	BOTTOM OF BANK
———	EDGE OF HOLE
▨	SHAFT INTERIOR
△	SURVEY HUB

SURVEY CONTROL TABLE
SOUTHEAST CORNER GPS POINT
Z12V 0620271
6585028

KEY PLAN
NOT TO SCALE
SITE PLAN COURTESY OF SRK CONSULTING 2016



SOUTH PROFILE
SCALE: 1:50



WEST PROFILE
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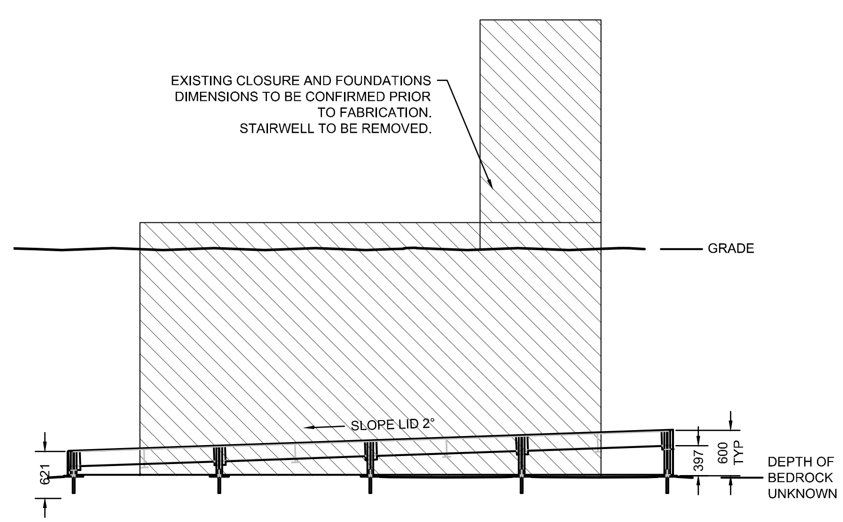

NORTH PROFILE
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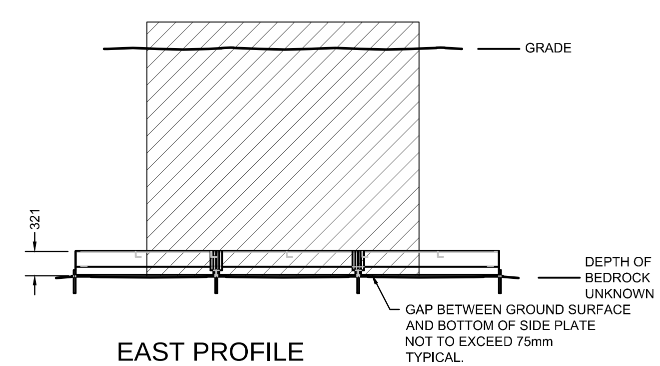

EAST PROFILE
SCALE: 1:50

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0 1:50 2
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ORIGINAL DWG SIZE: ANSI D (22" x 34")

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SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR VENTILATION RAISE
INSTALLATION PLAN AND PROFILES
STRUCTURAL

Drawing No. 1664-08

Project Number 2321-01664-00

Rev. A

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

McElhanney ANSI D - 15-05-22

DATE: 2016-06-29, 11:45 FILE: H:\2321-01600\01664-00 Structural Engineering of Stainless Steel Mine Closures\10.0 Drawings\10.2 AutoCad Files\01664-07 to 09 (Gunnar Vent Raise) Detailed Design.dwg

McElhanney ANSI D - 15-05-22

GENERAL NOTES:

1. CHECK AND VERIFY ALL DIMENSIONS BEFORE COMMENCING ANY WORK. NOTIFY THE DESIGNER OF ANY ERRORS OR OMISSIONS. DO NOT CONSTRUCT FROM THESE DRAWINGS UNLESS MARKED "ISSUED FOR CONSTRUCTION".

2. DESIGN CODE: NBCC 2015, CAN/CSA S16-09.

DESIGN LOADS:

SPECIFIED VEHICLE LOAD: 11 kN
SPECIFIED UDL: SNOW: SS=2kPa, Sr=0.1kPa OVERBURDEN: 1.2 kPa
SPECIFIED INDUSTRIAL LOADING: 4.8 kPa

THE CONTRACTOR MUST ENSURE THAT CONSTRUCTION LOADS IMPOSED ON THE STRUCTURE DO NOT EXCEED THE SPECIFIED DESIGN LOADS NOTED ABOVE.

3. ALWAYS READ WRITTEN DIMENSIONS. DO NOT SCALE OFF THE DRAWINGS OR CAD FILES.

4. SUPPLY OF RECORD DRAWINGS IS OUTSIDE THE SCOPE OF SERVICES.

5. THE CONTRACTOR IS RESPONSIBLE FOR ALL COSTS ASSOCIATED WITH THE CORRECTION OF DEFICIENCIES, AS DIRECTED BY THE ENGINEER.

6. THE DESIGN AND INSPECTION OF FALSEWORK, SHORING AND RESHORING ARE THE RESPONSIBILITY OF THE CONTRACTOR, SHALL CONFORM TO WCB STANDARDS AND SHALL BE AS REQUIRED TO KEEP THE STRUCTURE PLUMB AND LEVEL DURING CONSTRUCTION.

7. THESE DRAWINGS SHOW REQUIREMENTS FOR COMPLETED STRUCTURE ONLY. THE CONTRACTOR IS RESPONSIBLE FOR ALL TEMPORARY BRACING AND HOISTING REQUIRED FOR CONSTRUCTION LOADINGS AND STABILITY UNTIL THE PROJECT IS COMPLETE.

8. REVIEW OF WORK, OR ANY PORTION OF WORK, BY THE ENGINEER SHALL NOT RELIEVE THE FABRICATOR OF THEIR RESPONSIBILITY AND OBLIGATION TO COMPLY WITH CONTRACT DRAWINGS AND SPECIFICATIONS.

9. DO NOT DRILL OR ATTACH TO STRUCTURAL FRAME WITHOUT AUTHORIZATION FROM THE ENGINEER, UNLESS NOTED ON DRAWINGS.

FIELD REVIEW:

1. ONLY WORK SHOWN ON THE STRUCTURAL CONSTRUCTION DOCUMENTS BY MCELHANNEY CONSULTING WILL BE REVIEWED.

2. QUALITY CONTROL OF WORK IS THE CONTRACTORS RESPONSIBILITY.

3. ENGINEER TO BE NOTIFIED OF CONSTRUCTION SCHEDULE IN ORDER TO SCHEDULE FIELD REVIEWS. MINIMUM 2 WEEKS NOTICE SHALL BE GIVEN PRIOR TO MANDATORY FIELD REVIEWS. IF ENGINEER IS NOT AFFORDED THE OPPORTUNITY TO REVIEW THE STRUCTURAL WORKS, FINAL CERTIFICATION OF THE PROJECT WILL NOT BE ISSUED.

4. NUMBER OF REVIEWS AND ITEMS REVIEWED WILL BE AT THE DISCRETION OF THE ENGINEER TO DETERMINE GENERAL CONFORMANCE WITH THE DESIGN INTENT. ADDITIONAL FIELD REVIEWS REQUIRED DUE TO DEFICIENT OR INCOMPLETE WORK WILL BE AT THE EXPENSE OF THE CONTRACTOR.

STRUCTURAL STEEL:

1. ALL STRUCTURAL STEEL WORK SHALL CONFORM TO CAN/CSA S16-09.

2. ALL STRUCTURAL STEEL MATERIAL SHALL CONFORM TO CSA G40.20/G40.21 WITH THE FOLLOWING MATERIAL GRADES:

i) THREADED ROD	ASTM F593 (AISI 304/316)
ii) NUTS	ASTM F594 (AISI 304/316)
iii) WASHERS	ASTM A240 (AISI 304/316)
iV) PLATES AND BARS	AISI 304
v) ROLLED AND HSS SHAPES	AISI 304

3. DRAIN HOLES ARE TO BE PROVIDED AT THE BASE OF ALL HSS TUBES.

4. VOIDS ON THE UNDERSIDE OF THE BEARING AND/OR BASE PLATES SHALL BE MINIMIZED BY LOCALIZED BUSH HAMMERING OF BEDROCK. BASE PLATES SHALL SUBSTANTIALLY CONTACT THE ROCK SURFACE BELOW.

EPOXY ANCHOR NOTES:

1. HILTI HIT ADHESIVE ANCHOR SYSTEM HY-150 ICE TO BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.

ASTM F593 (AISI 304/316) THREADED ANCHOR ROD
¾"Ø IN ⅞"Ø HOLE 6" MINIMUM DEPTH
1"Ø IN 1⅛"Ø HOLE 10" MINIMUM DEPTH

FIELD WELDING:

1. ALL WELDING SHALL CONFORM TO CSA W59 AND BE PERFORMED BY CWB CERTIFIED WELDERS UNDER CSA W47.1. FABRICATORS TO BE APPROVED BY CWB. FABRICATOR TO PROVIDE COORDINATING ENGINEER WITH PROPOSED WELDING PROCEDURE PRIOR TO FABRICATION. WELDS SHALL BE MADE WITH ELECTRODES AND FILLER MATERIAL RATED AS FOLLOWS:

MATERIAL GRADE	ELECTRODE
304/304L	ER308/ER308L
316/316L	ER316/ER316L

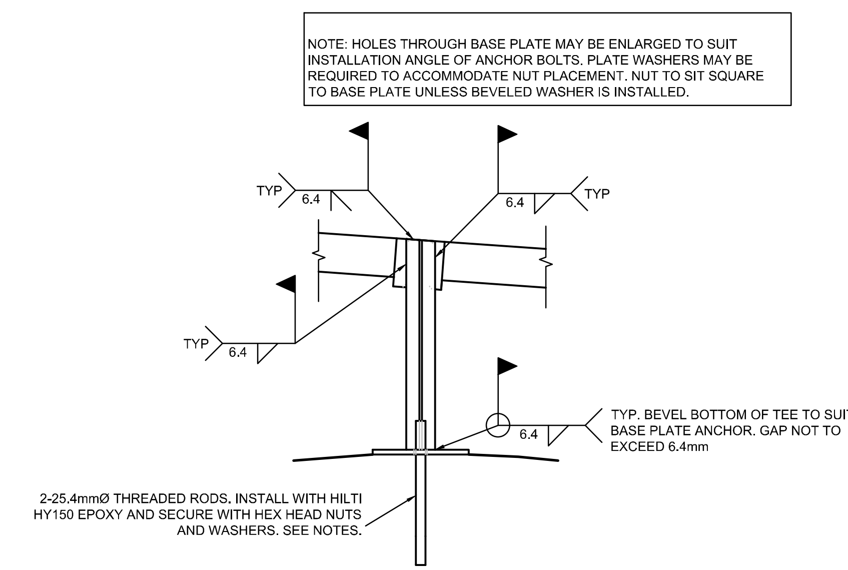
2. ADEQUATE SHIELDING GAS AND CORRECT HEAT SHALL BE USED TO AVOID CARBIDE PRECIPITATION. SHIELDING MUST CONTINUE POST WELD UNTIL THE HEAT AFFECTED ZONE HAS COOLED TO BELOW 430°C

3. FABRICATOR TO CONTROL WARPING OF COMPONENTS DURING WELDING BY ALTERNATING WELDS AND/OR ALLOWING COOLING PERIODS BETWEEN WELDS AND/OR CLAMPING OF MATERIALS.

4. MINIMUM WELD SIZE TO BE $\frac{3}{16}$" FILLET, UNLESS NOTED OTHERWISE.

5. WELDING PROCEDURE TO ENSURE A CLEAN WORK ENVIRONMENT INCLUDING TOOLS AND GLOVES. GREASE, DUST, AND EXCESS AIR FLOW IN THE WELDING AREA IS NOT ACCEPTABLE. CONTAMINATED ELECTRODES MUST BE CLEANED PRIOR TO USE. HEAT TINT TO BE REMOVED BEFORE ITEMS ARE COVERED AND UPON COMPLETION OF THE INSTALLATION.

6. FIELD DEGREASING AND PICKLING USING A BRUSH ON PASTE OR GEL IS REQUIRED BEFORE ITEMS ARE COVERED AND UPON COMPLETION OF THE INSTALLATION.



TYPICAL POST DETAIL
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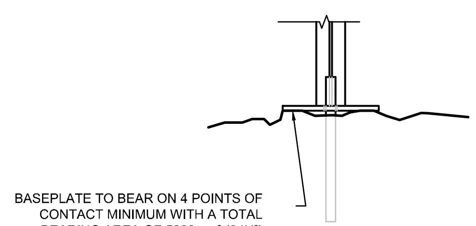

BASE PLATE BEARING DETAIL
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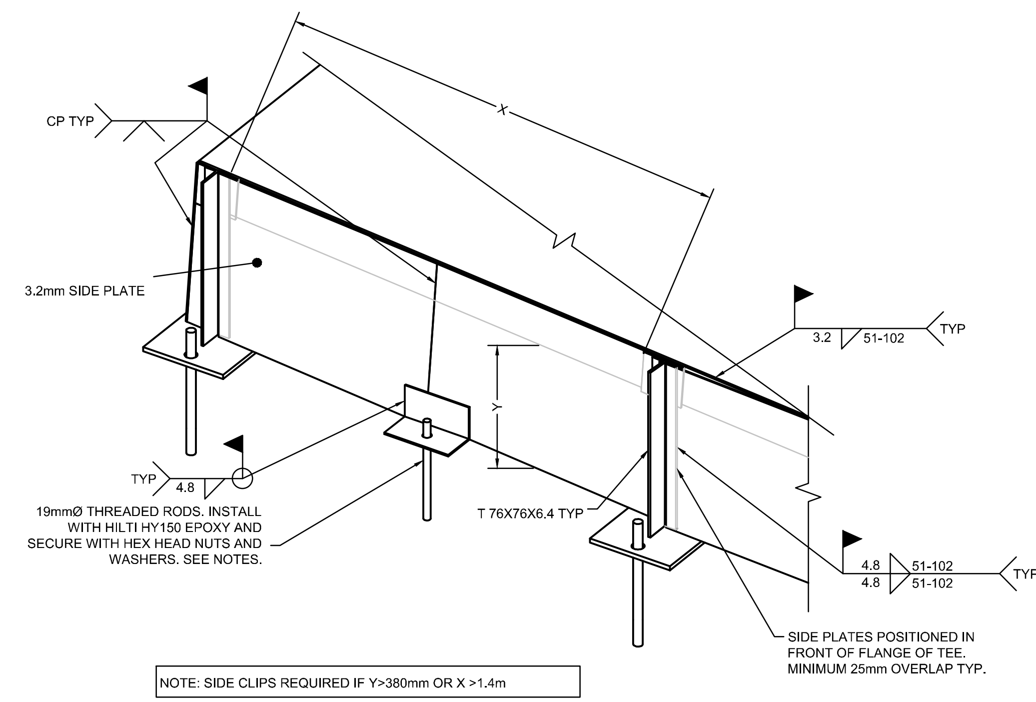

TYPICAL SIDE PLATE INSTALLATION DETAILS
NOT TO SCALE

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0 1:10 0.5
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SASKATOON, SK

MINE OPENING CLOSURES
GUNNAR VENTILATION RAISE
INSTALLATION DETAILS AND NOTES
STRUCTURAL

Drawing No. 1664-09
Project Number 2321-01664-00
Rev. A

DATE: 2016-06-29 11:45 FILE: H:\2321-01600\01664-00 Structural Engineering of Stainless Steel Mine Closures\10.0 Drawings\10.2 AutoCad Files\01664-07 to 09 (Gunnar Vent Raise) Detailed Design.dwg

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

Appendix J – Gunnar Mine “Other Site Aspects” Updated Preliminary Remediation Design – Revegetation Plan

TECHNICAL REPORT

PROJECT CLEANS
CLEANUP OF ABANDONED NORTHERN SITES PROJECT
REVEGETATION PLAN
GUNNAR MINE "OTHER SITE ASPECTS" REMEDIATION PROJECT

GUNNAR MINE SITES REMEDIATION

Prepared by:

Saskatchewan Research Council
Environment Division

SRC Publication No. 12194-440-45A16

July 2016

Saskatchewan Research Council
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Table of Contents

List of Acronyms

AAFC - Agriculture and Agrifood Canada
AAM - An Assessment of Abandoned Mines in Northern Saskatchewan
AANDC - Aboriginal Affairs and Northern Development Canada, a federal line department (formerly INAC)
ACM - Asbestos-Containing Material
ALARA - As Low As Reasonably Achievable
ATV - all terrain vehicle
CALA - Canadian Association for Laboratory Accreditation
CCME - Canadian Council of Minister of the Environment
CFIA - Canadian Food Inspection Agency
CIDA - Canadian International Development Agency
CEQG - Canadian Environmental Quality Guidelines
CLEANS - Cleanup of Abandoned Northern Sites
CMD - Commission Members Document
CNSC - Canadian Nuclear Safety Commission
COPC - contaminants of particular concern
DRDC - Defense Research and Development Canada, part of the Department of National Defense (DND)
DFAIT - Department of Foreign Affairs and International Trade
DND - Department of National Defense, a federal line department
DRR - discount rate ratio
EA - environmental assessment
EC - Environment and Climate Change Canada
EFAP - employee family assistance program
EIS - environmental impact statement
ELC - Ecological Landscape Classification
EPB - Environmental Protection Branch (a former branch of MOE that led to their naming convention)
FRV - future value ratio
ICCMF - Institutional Control Monitoring and Maintenance Fund
ICP - Institutional Control Program
ICMMF - Institutional Control Monitoring and Maintenance Fund
ICUEF - Institutional Control Unforeseen Events Fund
IDRC - International Development Research Centre, a federal Crown Corporation
IFT - issued for tender
INAC - Indian and Northern Affairs
ISO - International Standards Organization
IT - information technologies
KHS - (KHS) Environmental Management Group Ltd.
LCH - Licence Condition Handbook
LDIS - Land Disposition Information System
LIMS - Laboratory Information Management System
MECON - Saskatchewan Ministry of the Economy
MN-S - Métis Nation of Saskatchewan
MOE - Saskatchewan Ministry of Environment
MOU - memorandum of understanding
NEW - Nuclear Energy Worker

NIST - National Institute of Standards and Technology
NORM - Naturally Occurring Radioactive Materials
NRCan - Natural Resources Canada
NSCA - Nuclear Safety and Control Act
NSERC - Natural Sciences and Engineering Research Council of Canada
OH&S - Occupational Health and Safety
PCB - polychlorinated biphenyl
PPE - personal protective equipment
PRC - Project Review Committee that was established at the beginning of Project CLEANS
PUF - polyurethane foam
QA/QC - Quality assurance and quality control
QMAN - Quality Assurance/Quality Control Manual
RA - regulatory agencies
RD&D - research, development, and demonstration
RFP - request for proposal
RPP - Radiological Protection Plan
SER - Saskatchewan Ministry of Energy and Resources
SMAD - Saskatchewan Mineral Assessment Database
SMDI - Saskatchewan Mineral Deposit Index
SRC - Saskatchewan Research Council
SREDA - Saskatoon Regional Economic Development Authority
SSRO - site-specific remedial objective
SSWQO - Saskatchewan Surface Water Quality Objectives
STEP - Saskatchewan Trade and Export Partnership
SU - survey unit
U of R - University of Regina
U of S - University of Saskatchewan
UCC - Uranium City Contracting Ltd.
UN - United Nations
UTM - Universal Transverse Mercator conformal projection

1.0 BACKGROUND

The Gunnar Uranium Mine and Mill Site (the Site) is located on the north shore of Lake Athabasca in northern Saskatchewan. The site was originally the location of uranium mining operations started in 1955 and ceased in 1963. In 2008 the remediation of the Gunnar Mine and Mill Site (the Project) was initiated to reduce the risk to the environment, health, and safety that is presented by the Site over the long-term. Saskatchewan Research Council (SRC), on contract with the Ministry of the Economy, is responsible for the Project implementation. SRC is a CNSC licence holder for the site remediation until 2025 and currently is engaged in site monitoring and planning remediation activities for all the Site aspects.

Those with interests in the Project, i.e., the local community, aboriginal people in the region, and provincial and federal agencies, expect not only a reduction of site contamination, but also in long-term sustainability of the remediated site, which can be achieved only by forming natural wildlife habitats in the disturbed areas. Therefore, a key aspect of the site remediation is to assist ecosystem recovery on all sites affected by remediation activities.

The Site is located in Taiga Shield Ecozone, which is a pattern of coniferous and deciduous forests with inclusions of exposed bedrock and various wetland habitats. Local ecosystems accommodate wildlife, stabilize the hydrological regime, provide hunting and recreation opportunities, and is the basis for traditional activities of aboriginal people. The Project Environmental Impact Statement (EIS) identifies that, despite positive endpoints, remediation activities may have some negative impacts on local ecosystems, as follows:

- Alteration or loss of wildlife habitat due to borrow pit construction and vegetation removal
- Soil erosion and degradation
- The introduction and spread of invasive weeds and non-native species of concern
- The loss of rare, threatened, or endangered plant species, including their critical habitats.

To prevent or mitigate these undesirable impacts, SRC is committed to undertake a number of mitigation measures including the following:

- Re-contouring tailings cover and borrow pits to maintain drainage patterns and mitigate erosion
- Reclaiming tailing cover, borrow pits, and other disturbed areas by using a native seed mix to mimic native vegetation communities
- Storing and replacing woody debris and topsoil to enhance native revegetation
- Establishing weed control to prevent introduction and spread of invasive and noxious weed materials
- Long-term monitoring and maintenance in case of introduction of invasive or noxious weeds to the area.

The above commitments are aimed at establishing a sustainable vegetation cover on the areas to be affected by the Project, which is the first stage in overall ecosystem recovery. The altimate vegetation recovery can take a long time under the local climate due to low annual temperatures, limited precipitation, short growing season, and harsh and long winters. Recovery process can be also slowed down by specific site conditions, in particular shallow topsoil that is poor in nutrients and organic matter. This revegetation plan (the Plan) is developed to address the above issues through analysis of the main environmental aspects of the potentially affected areas and in-advance planning of the corresponding revegetation activities.

2.0 PURPOSE

This Plan outlines basic activities to be undertaken by SRC and its contractors for revegetation of areas affected by the Project, in particular the tailings cover system and natural areas disturbed due to excavation of borrow material. It also provides overview of key roles and responsibilities for site revegetation, identifies site conditions and key factors affecting ecosystem recovery, and provides justification of the revegetation strategy to be utilized at each site. The Plan is a part of the design stage of the Project and can be modified to incorporate any updates in the design and ensure using the most efficient revegetation techniques by the time of its implementation.

It should be noted that currently SRC is implementing revegetation at Lorado Mill Site that is located at the same region and has similar site conditions. Most of revegetation techniques proposed in the Plan are being applied at Lorado Mill Site. Lorado Project includes monitoring of vegetation recovery in 2016 to 2018. The monitoring results will be used to adjust the revegetation approach proposed in this document, as applicable.

3.0 ROLES AND RESPONSIBILITIES

3.1 Managers

The Vice-President, Environment is responsible for ensuring that the activities of the Environmental Remediation Unit are in keeping with SRC's core values and goals with respect to protecting the environment. The Vice-President, Environment is also responsible for ensuring that resources are available to carry out this plan.

The Environmental Remediation Business Unit Manager is accountable for the creation and implementation of this plan.

3.2 Supervisors

The Gunnar Mine "Other Site Aspects" Project Manager, and designates such as SRC field supervisors, will be familiar with the revegetation plan and responsible for ensuring its implementation. The project manager or designates will ensure that all project aspects that may affect revegetation success are considered during the Project planning.

SRC Site Representative is responsible for monitoring of revegetation activities and revegetation success during the remediation stage of the Project, and providing timely awareness and advice in case of any concerns.

SRC Revegetation Specialist is responsible for development and update of this plan, facilitation of seed supply for revegetation activities, overseeing contractor activities when required, and assessment of overall revegetation success.

3.3 Employees

All employees involved in site revegetation need to be aware of the Plan and be familiar with the sections applicable to their work.

3.4 Contractors and Consultants

Contractors and Consultants will be required to implement revegetation within the framework of their contractual obligations and in line with the Plan requirements as follows:

- Consultant (SRK Consulting) will ensure that the Plan is incorporated in the project detailed design
- Revegetation Contractor (to be specified) will be responsible for revegetation work and associated quality control as a part of the site reclamation activities
- Telfer Seed Supplier (and/or other seed suppliers to be identified as needed) is responsible for timely delivery of seed mix and ensuring that its quality is in line with SRC requirements.

4.0 GUIDING DOCUMENTATION

The Plan was developed in line with the following regulatory documents and guidelines:

Governing regulations:

- Guidelines for Decommissioning, Clean-up and Reclamation of Northern Mine Sites (EPB-381)
- Mineral Exploration Guidelines for Saskatchewan (2012)
- Native Species Recommended for Site Restoration within the Mid-Boreal Upland, Mid-Boreal Lowland and Boreal Transition Ecoregions of Saskatchewan (2004)
- Reclamation Guidelines for Sand and Gravel Operators (2012)
- Saskatchewan Guidelines For Use of Native Plants in Roadside Revegetation (2008)
- The Environmental Management and Protection Act (2002)
- The Weed Control Act (2010)
- Visual Slash Loading Guide (2000).

Project documentation:

- Environmental Impact Statement, Gunnar Site Remediation Project (SRC, 2015)
- Gunnar Mine “Other Site Aspects” Preliminary Remediation Design (SRK Consulting, 2016)
- CNSC Waste Nuclear Substance Licence No. WNSL-W5-3151.00/2024.

SRC and the University of Saskatchewan have carried out a number of studies to identify native plant species and optimal revegetation techniques for reclamation of abandoned uranium mines in northern Saskatchewan. The following studies have been taken into consideration during the Plan development:

- Harms, 1982. A plant taxonomic survey of the Uranium City region, Lake Athabasca north shore, emphasizing the naturally colonizing plants on uranium mine and mill wastes and other human disturbed sites. W.P Fraser Herbarium Report No. 82-1.
- Redmann, R.E., and F.T. Frankling, 1982. Revegetation of abandoned uranium mill tailings near Uranium City, Saskatchewan – Plant Selection. University of Saskatchewan.
- Petelina E., 2012. Gunnar Revegetation Research, Progress Report. SRC Publication No. 12194-320-4PQ12.
- Petelina E., 2013. Gunnar Revegetation Research, Field Trials, Stage II. SRC Publication No. 12194-460-10B12.
- Petelina E., 2014. Restoration of Native Plant Cover after Uranium Mining: a Case Study from Northern Saskatchewan, Canada. (Master's report). University of Saskatchewan.

SRC also carried out two workshops with local aboriginal communities to get the local input on which native plant species should be used for the Site revegetation. The workshop outcome is summarized in the following documents:

- SRC, 2016. Revegetation Elder Workshop Community Meeting Record January 19, 2016.
- SRC, 2016. Revegetation Elder Workshop Community Meeting Record February 2, 2016.

To ensure the best management practices, other Canadian guidelines for restoration of boreal ecosystems were also considered during the Plan development as follows:

- Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region (Alberta 2009)
- Native Plant Revegetation Guidelines For Alberta (Alberta, 2001)
- Revegetation Using Native Plant Materials, Guidelines for Industrial Development Sites (Alberta 2003)
- Sites Reclaimed Using Natural Recovery Methods, Guidance on Site Assessment (Alberta, 2003)
- Yukon Revegetation Manual (2012).

5.0 REVEGETATION OBJECTIVES AND CONSTRAINS

The Plan was developed to meet the following short- and long-term Project objectives:

- to ensure erosion control on sensitive areas, e.g., slopes or sites exposed to wind
- to assist vegetation recovery toward to self-sustaining state
- to minimize presence of invasive species and noxious weeds to the lowest practicable level on the project sites
- to increase aesthetic value of remediated sites
- to identify cost-effective solutions which will help to meet the above objectives by utilizing optimal amount of resources.

The above objectives can only be achieved if revegetation design takes into account the key project features, as follows:

- Regional conditions (harsh and long winter, short growing season, lack of precipitation) that may impede plant community development
- Specific site conditions, e.g., poor growing media or bedrock exposure
- Presence of the exotic species and noxious and nuisance weeds in the surrounding ecosystems
- Limited availability of native boreal species seeds at Canadian market, which may vary depending on each harvest year
- Remote location and limited accessibility of the site, which results in logistics constraints and high shipping costs.

The Plan outlines how the above features and potential related issues are to be addressed for each revegetation unit (sites affected by the Project).

6.0 REVEGETATION UNITS AND STRATEGY

In total, four following revegetation units were outlined at the design stage:

- Waste Rock Deposition Area
- Process Area
- Townsite Area
- Temporary Infrastructure (access roads, maintenance areas, etc.).

Revegetation for each unit is to be performed taking into account specific conditions and level of disturbance in each area due to remediation activities. A summary of key features and recommended revegetation techniques for each revegetation unit is provided below.

Prior to the cover construction start-up, SRC revegetation specialist will visit the Site to:

- Identify ecosites associated with the revegetation units (as per “Field Guide to the Ecosites of Saskatchewan's Provincial Forests” (McLaughlan et al., 2010))
- Study site soil conditions (including soil sampling for nutrient/organic content analysis)
- Advise if any updates of the Plan are required.

6.1 Waste Rock Deposition Area

This area includes east Waste Rock Pile (17 hectare [ha]) and South Waste Rock Pile (9 ha). According to the engineering design, the piles are to be re-shaped and covered with 0.5 metre (m) engineered cover to shield gamma radiation and serve as a growth media for vegetation cover. The borrow material proposed as a source of the cover, has satisfactory physico-mechanical properties, but poor of organic carbon and nutrients.

The top surface of the waste rock piles with cover will be shaped to 1% gradient to prevent surface ponding and the pile slopes will vary from 3.0H:1.0V to 5.0H:1.0V. All existing vegetation is to be eliminated before the cover installation. Vegetation recovery is required to ensure integrity of the engineered cover (protection from water and wind erosion), provide dust suppression, and improve wildlife habitat and aesthetic value of the land. As the area is vast and growing substrate is poor, unassisted vegetation recovery is likely to run slow, which can delay achievement of the project goals. To speed up the revegetation process, implementation of revegetation techniques is planned, as follows.

The engineered cover will be seeded with native grasses and forbs. Prior to seeding, soil scarification (decompaction) will be done to the maximum depth of 10 centimetres (cm) below the finished cover surface to create microrelief favorable for seed germination. The proposed seed mix and seeding rates are provided in section "Propagation Materials". Seeds will be broadcasted over the cover surface in fall before the first snow. Shallow harrowing to the maximum depth of 10 cm, followed by soil compaction should be done upon completion the seeding to ensure close contact of the seeds with soil. Agrochemical properties of the cover will be improved with application of mineral fertilizer. The rate and application schedule depend on a fertilizer type (see section "Soil Amendments" for more details).

The engineering design requires that the vegetation cover on steep slopes shall develop to at least 40% within the first year after remediation to ensure adequate erosion control. SRC revegetation trials showed that this target is achievable by application of organic amendments, such as peat. Therefore, application of organic amendments is to be considered to improve the cover properties on the slopes. Hydroseeding or bioengineering techniques will be considered as potential erosion measures for steepest slopes. In addition, advanced erosion control of drainage features will be provided through application of cocomats and riprap.

6.2 Process Area

This area includes Acid Plant (7 ha) and Mill (15 ha) sub-areas. This area comprises processing buildings and structure footprints. According to the design, most of the area (approximately 60%) will be covered with 0.5 m of clean borrow material to shield radiation and serve as a growth media for vegetation cover. The engineering design also includes installation of a landfill in this area. The landfill will be about 3 ha and up to 6 m in height with 4.0H:1.0V slopes. Revegetation in this area will be implemented the same way as in the waste rock area.

Areas not designed for the cover shall be cleaned from contaminated materials and garbage, leveled, and left for natural recovery. As soil compaction can prevent vegetation encroachment into disturbed areas, the area surface is to be decompacted or scarified. Previously stripped vegetation (if any) shall be spread across the area. If there is no enough stockpiled vegetation on the site, natural recovery may be supplemented with grass/legume seeding or planting tree cuttings.

6.3 Townsite Area

This area includes mine residential area footprints with building remnants and historical garbage and debris. The total area is about 70 ha and comprises a pattern of historical mine footprint with natural ecosystems. Natural revegetation of the areas disturbed during the past mining activities has occurred on majority of the area. The newly established vegetation cover is composed by regrowth of young trees and bushes and early successional herb species.

Remediation at this site will be limited to clean-up of historical waste and placing engineered cover over small areas with elevated gamma levels. Revegetation of the engineered cover in the area will be done the same way as on the waste rock piles. Areas not designed for the cover shall be cleaned from contaminated materials and garbage, leveled, and left for natural recovery. During the clean-up, on-site woody vegetation will be cleared and stockpiled at the adjacent areas. Upon completion of the clean-up, the stockpiled tree debris shall be distributed over the cover surface to create conditions for natural ecosystem recovery. It is assumed that the disturbed area will be small and abundant surrounding natural revegetation occur within a short time period. To ensure faster re-vegetation and better erosion control, in some spots natural recovery may be supplemented by grass/legume seeding and fertilizer application.

6.4 Project Temporary Infrastructure

Remediation of the Gunnar Mine Other Aspects require set up of temporary infrastructure such as temporary access roads, temporary storage sites for materials, equipment maintenance areas, parking areas, and a construction camp. The infrastructure will be set up in a way to minimize project footprint. Upon the project completion all project facilities and materials are to be removed from the site. The disturbed areas are to be cleaned from any garbage and leveled. Then that the surface of the disturbed sites will be decompacted or scarified and covered by previously stripped vegetation (if any) to create conditions for natural vegetation recovery. If there is not enough stockpiled vegetation on the site, natural recovery can be supplemented by grass/legume seeding.

7.0 PROPAGATION MATERIALS

The following two types of plant propagation material are to be used for revegetation of sites affected by the Project:

- Stripped vegetation and topsoil
- Native legume/grass seed mixture.

As described in the previous section, vegetation and topsoil are to be salvaged wherever is possible. The stockpiled vegetation and topsoil serve as a storage pool for various propagules, including plant seeds and branch/root cuttings and soil microbiota as well as a source of organic matter and nutrients. Therefore, use of these materials for revegetation will promote site recovery towards pre-disturbed ecosystem condition. Salvaged vegetation and topsoil will be spread over disturbed areas upon completion of the remediation activities.

When salvaged vegetation and topsoil are not available or erosion control require rapid vegetation establishment, native legume/grass seed mixture is to be applied.

The following seed mixture is proposed:

Plant species	**PLS dry weight, %**
Rocky Mountain Fescue (*Festuca saximontana*)	20
American Vetch (*Vicia Americana*)	20
Slender Wheat Grass (*Elymus trachycaulus*)	15
Rough Hair Grass (*Agrostis scabra*)	10
White Bluegrass (*Poa glauca*)	10
Fowl bluegrass (*Poa palustris*)	10
Tufted Hairgrass *(Deschampsia caespitosa*)	7
Canada Milkvetch (*Astragalus canadensis*)	5
Marsh Reed Grass (*Calamagrostis canadensis)*	2
Common Yarrow *(Achillea millefolium*)	1

The above seed mixture composition was suggested on the basis of revegetation studies carried out by SRC and University of Saskatchewan at the Uranium City area and input from local elders and also takes into consideration the availability of native boreal herb seeds in the Canadian market. As native seed availability can significantly vary depending on a harvest year, the recommended seed mixture composition may be adjusted before the seed procurement.

The seeding rates were developed on the basis of the SRC trials and also are in line with recommendations of Yukon Revegetation Manual.

The following factors were taken into account:

- Poor quality of the growing substrate
- Availability of salvaged vegetation and topsoil
- Risk of erosion
- Soil treatment before and after seeding
- Seeding methods
- Intent to encourage establishment of woody species on the site.

The proposed seeding rates vary from to 4,000 pure live seeds/m^2 (about 16 kilograms [kg] of bulk seed mixture per ha) on steep slopes with poor soil to 1,000 pure live seeds/m^2 (about 2 kg of bulk seed mixture per ha) on flat areas with good topsoil quality. Seeding rates for bulk seed mixture can vary on annual basis depending on seed mixture composition and quality.

8.0 SOIL AMENDMENTS

Most boreal species have evolved on soils with poor properties, i.e., having limited content of organic matter and nutrients; therefore, soil amendments are required only for those sites with extremely poor or no organic matter and nutrients in the soil. In general, low organic matter and nutrients can be compensated by placement of stripped vegetation and topsoil over the disturbed area.

If the amount of salvaged vegetation and topsoil is limited, application of organic amendments and/or mineral fertilizer is recommended.

Since shipment of organic amendments to the Site can be cost-prohibitive, they should be only applied in the areas where fast vegetation recovery is critical in term of erosion control (e.g., steep slopes). Revegetation trials at Gunnar showed that peat application at rate higher than 160 t/ha combined with fertilizer application at rate of 45 N kg/ha, 84 P2O5 kg /ha, 112 K2O kg/ha, and 20 S kg/ha resulted in 40% vegetation cover within a year after seeding, which is in line with engineering design requirements for steep slopes. For the rest of the site, soil conditioning will be mostly performed through application of mineral fertilizer. Revegetation trails at Gunnar showed that using mineral fertilizer boosts establishment of both seeded plants and natural volunteers, so revegetation goals can be achieved within three growing seasons after seeding. Mineral fertilizer is to be applied either right after seeding (in fall) or as early as possible in the next field season, the recommended rate is 50 N kg/ha, 70 P2O5 kg /ha, 60 K2O kg/ha, and 20 S kg/ha. The rate and application schedule can be modified depending on a fertilizer type.

9.0 INVASIVE EXOTIC SPECIES MANAGEMENT

In Saskatchewan exotic species management is regulated by the Saskatchewan Weed Control Act intended to protect agriculture and natural lands from adverse impact of invasive species which already occur in the province or can invade in it (Brenzil, 2010; Saskatchewan Organic Directorate, 2010). Saskatchewan legislation encompasses only those species posing significant risk to local ecosystems. These species are divided into three categories as follows: prohibited weeds (species rarely occurring in the province), noxious weeds (species partially expanding in Saskatchewan), and nuisance weeds (species widely spreading through the entire province). There are 71 species restricted by the Act, some of these species were introduced into the region and observed across the Site prior the Project start up as follows:

- Noxious weeds
  - Annual hawksbeard (*Crepis tectorum*).
- Nuisance weeds
  - Common dandelion (*Taraxacum officinale*)
  - Foxtail barley (*Hordeum jubatum*).

In addition to the regulated weeds, the following exotic species were observed on the site:

- Clover (*Trifolium spp.*)
- Lamb's quarters (*Chenopodium album*)
- Pineappleweed (*Matricaria discoidea*)
- Plantain (*Plantago major*)
- Red fescue (*Festuca rubr*)
- Sheep fescue *(Festuca ovina*)
- Sweet clover (*Melilotus officinalis*).

Due to presence of the above species in local ecosystems, it is impossible to eliminate exotic invasive species presence on the Site after remediation, but SRC and its contractors will take all efforts to prevent further distribution of occurring invasive exotic species and introduction of new species. The following preventive measures will be undertaken:

- All equipment and vehicles used on the Project must be cleaned of dirt and vegetative material to control the introduction of weeds within the reclaimed area
- The Gunnar Mine and Mill Site and its vicinity are regularly monitored to identify presence of exotic and invasive species and need in corresponding mitigation measures, e.g., restricted access to infested area
- Revegetation strategy developed for each disturbed area aims to encourage establishment of native plant communities with dense cover which will limit further spread of weeds and exotic species already presenting in the region
- Seeds of only native plant species from Canadian populations are to be used for the revegetation
- A Seed Analysis Certificate is to be provided with each seed lot purchased from commercial seed suppliers to verify that seeds are clear from weeds controlled by the Act.

Implementation of the above measures will minimize presence of exotic species and nuisance and noxious weeds to the lowest practicable level on the Site. Upon remediation completion long term monitoring of vegetation cover on the affected areas will be used to detect any infestation by invasive exotic species and identify need in maintenance as described below.

10.0 REVEGETATION TIMELINE

10.1 Natural Recovery

As topsoil properties deteriorate with storage, the placement of stripped vegetation and topsoil must follow other remediation activities, e.g., cover placement, as soon as possible.

10.2 Seeding

As seed viability depends on storage timing and condition, no seed storage is planned on the Site. Seeds are to be supplied by request just before the seeding. The request is to be initiated by PNM through submitting a list of sites to be revegetated not later than three weeks before the seeding start up. Proceeding from the PNM data, SRC revegetation specialist will arrange seed supply to the Site.

Seed application is to be performed in fall, on completion of other remediation activities. Timing of seed application will depend on the project schedule and weather conditions. The weather conditions are to be addressed as follows:

- Seeding shall be performed under early frost conditions, i.e., when mean day temperature drops below 5 degree Celcius (°C), to ensure that seeds stay dormant until spring
- If there is a snow cover on the ground, seeding must stop until the snow melts down to prevent seed loss due to run-off.

Under the above conditions the window of opportunity at Gunnar is presumably second or third week of October.

Soil treatment timing shall be synchronized with seeding as follows:

- Soil decompaction (if required), is to be completed just before the seeding
- Soil compaction (raking) shall follow immediately after seeding.

Fertilizer application depends on type of fertilizer. In principle, spring fertilizing is recommended to prevent nutrient loss due to run-off and volatilization, but slow release fertilizer may be applied in fall just before the seeding.

11.0 ADAPTIVE MANAGEMENT

Overall Project success as well as sustainability of local communities and ecosystems depend on recovery of sites affected by the Project, yet vegetation recovery takes a long time and can be affected by a number of factors which do not depend on the Project team, e.g., severe weather events or pest outbreaks. Therefore, adaptive management of the revegetated areas is to be integrated into the long-term post-remediation plans to ensure achievement of all the Project endpoints.

Adaptive management practices include monitoring of vegetation, documentation of site recovery trends, and maintenance/repair activities (if necessary). These practices will help to identify key conditions affecting site recovery and establishment of target ecosystems, as well as potential threats to the ecosystem integrity and ways to prevent or mitigate undesirable processes and trends.

Final ecosystem recovery to the pre-disturbed state may sometimes take decades, which cannot be accounted for under the Project lifespan. Therefore, application of adaptive management is recommended until the monitoring records demonstrate that newly established vegetation cover has become self-sustaining and compatible with surrounding ecosystems (presumably three to five years). The following sections provide a description of adaptive management practices and ways of their integration in the Project to ensure revegetation success.

11.1 Monitoring

Post-remediation monitoring of vegetation recovery will start up in the first field season following the seeding. It includes vegetation surveys for all revegetation units by qualified specialists. This kind of monitoring pursues the following goals:

- To determine if implemented erosion protection is sufficient for soil stabilization and vegetation development
- To estimate vegetation recovery rates and need for maintenance
- To assess plant community composition, infestation by invasive exotic species and need for weed control measures
- To determine if the established vegetation cover is self-sustaining and capable to provide erosion control and aesthetic functions
- To determine if soil properties are sufficient to support sustainable vegetation growth

- To ensure that vegetation established on the tailing cover does not uptake radionuclides or other contaminants of concern from underlying layers.

The following parameters are to be monitored to meet the above goals:

- Vegetation cover condition (visual assessment and photographing)
- Vegetation cover (area, %)
- Bare ground (area, %)
- Plant community composition (including species richness)
- Dry biomass (only for herb species on tailings)
- Site infestation by undesirable plants (visual assessment):
    - Prohibited, noxious, and nuisance weeds (as per Saskatchewan Weed Control Act)
    - Exotic species
- Litter and organic matter accumulation (visual assessment and photographing)
- Soil cover condition including degree of soil erosion (visual assessment and photographing)
- COPC in soil and plant tissues (sampling followed by chemical analysis).

The first monitoring survey shall to be performed the first growing seasons after the seeding and will include recognisance survey and set up of long-term monitoring transects on each revegetation unit. Transects will consist of 1 x 1 m plots on the engineering cover and 10 x 10 m on the other revegetation units. Number of transects and monitoring plots is to be identified upon completion of site revegetation and will depend on local topography, revegetation techniques applied, and condition and composition of vegetation cover observed during visual assessment. Planned vegetation surveys will also include mapping of the areas that may require additional maintenance and/or repair.

Monitoring reports will include an overview of soil and vegetation cover condition, trends in plant community development, and (if necessary) recommendations on additional revegetation activities, weed control, and erosion control to be done.

11.2 Maintenance

Maintenance of revegetated areas includes, but is not limited to additional seeding, weed control, fertilizing, soil treatment, or implementation of erosion control measures, which create favorable conditions for vegetation growth. The revegetation strategy developed for each revegetation unit allows to avoid regularly scheduled maintenance, but occasional maintenance may be required in case of unforeseen circumstances, e.g., severe weather events.

Any issues with the soil and vegetation cover identified by the monitoring will be a subject to corrective action(s). In each case, an appropriate maintenance and repair plan and schedule will be prepared and subsequently executed by appropriately qualified professionals and/or contractors. The need for vegetation maintenance is expected to decrease over time, as vegetation features in the affected areas will become compatible with successional pattern typical for the region.

11.3 Reporting

Revegetation progress and final results will be documented by SRC and its contractors on a regular basis. Revegetation progress and related issues are to be reported by the remediation contractor and consultants as follows:

- Revegetation contractor reports will include data on revegetation progress and quality of the work done
- SRC site representative reports will indicate any concerns regarding impact of remediation activities on environment including vegetation recovery.

Monitoring reports on vegetation recovery will be issued annually. Each monitoring report will include an overview of soil and vegetation cover condition, trends in the plant community development, and (if necessary) recommendations on additional revegetation activities/maintenance, such as weed or erosion control.

Any issues with revegetation performance and success identified in the above reports will be investigated by SRC specialist, and the corresponding corrective actions will be developed as needed. SRC will provide a summary of revegetation progress and vegetation recovery to external parties as a part of compliance reporting including:

- Quarterly reports to Canadian Nuclear Safety Commission (CNSC)
- Annual reports to the CNSC, Saskatchewan Environmental Assessment Branch, Saskatchewan Ministry of Environment, and the site holder, Saskatchewan Ministry of the Economy.

12.0 SUPPORTING DOCUMENTS

Not applicable.

13.0 RELATED PLANS

Not applicable.

14.0 CLOSURE

This report, *Cleanup of Abandoned Northern Sites Project 2015, Annual Report, Remediation of the Satellite Mine Sites*, has been prepared by the Saskatchewan Research Council, Saskatoon, Saskatchewan for the Saskatchewan Ministry of the Economy.

Any use that a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such parties. SRC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust this report meets your current requirements. Please do not hesitate to contact us with questions or comments.

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