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Memo

To:	Jeff Eng, PEng	**Client:**	Sabina Gold & Silver Corp.
From:	Maritz Rykaart, PhD, PEng	**Project No:**	1CS020.008
cc:		**Date:**	November 6, 2015
Subject:	Back River Property: Waste Rock Storage Area Management Approach and Associated Design Criteria – Final		

1 Introduction

SRK Consulting (Canada) Inc. was retained by Sabina Gold & Silver Corp. to develop a waste rock storage area (WRSA) management approach and associated design criteria for the Back River Project (the Project). WRSA designs were completed by JDS Energy and Mining Inc. Geochemical characterization in support of the WRSA management strategy was developed by SRK (SRK 2015a).

The Back River Property (the Property) will include four waste rock storage areas (WRSAs) at the Goose Property (Llama, Umwelt, Echo, and Goose Main).

This memo summarizes the overall WRSA management approach and design criteria adopted for the Project. Results of key engineering analysis, including the stability and thermal assessment, are included as Attachments A and B.

2 Waste Rock Storage Area Management Approach

Geochemical characterization has confirmed that all of the Property's waste rock will leach metals under neutral conditions. With respect to acid rock drainage (ARD), the majority of the waste rock in-situ is non-potentially acid generating (NPAG); however, due to operational recovery estimates and conservative waste segregation practices, the majority of the waste rock will be grouped as potentially acid generating rock (PAG). That being said, testing shows that this PAG material will take decades to oxidize and produce ARD. The geochemistry also confirms that blending of the PAG and NPAG material, to take advantage of the buffering offered by the NPAG and thereby neutralize the PAG, would not be viable (SRK 2015a).

The waste rock management strategy for the Project is to ensure that in the long term, all PAG material is fully encapsulated so as to minimize the potential for discharge of water to the receiving environment that might exceed standards. Water and load balance modelling (SRK 2015b) has confirmed that the waste load associated with neutral metal leaching from exposed NPAG waste rock would be low enough to ensure environmental compliance.

Strategies for ensuring PAG rock encapsulation include waste freeze back, low permeability covers, and subaqueous disposal. Sub-aqueous disposal can include disposal in an engineered structure, in a natural waterbody (i.e. lake) or in a mined-out open pit (or underground development). Construction of a permanent, water retaining, engineered structure was considered, but it was not the preferred long-term approach in light of other alternatives. Deposition in a large natural water body was also ruled out as the lakes around the Property are either generally shallow, offering limited confinement, or are larger lakes that provide good aquatic habitat and would require the lake to delist in accordance with Schedule II of the Metal Mining Effluent Regulations (MMER).

The underground mining methods employed on the Property require a portion of material as mine backfill. As such, this backfill material will be composed of, as much as practical, PAG waste rock, either sourced locally from underground development or will be hauled underground for this purpose. Even maximizing the volume that is stored underground, there still remains a portion of PAG material on the surface.

Consideration was given to storing PAG rock in mined-out open pits. At the Goose Property, the mine scheduling and the need to use the open pits for tailings management and water management makes this a less desirable option; however, there is substantial additional capacity in the Goose Main or Llama open pit at closure to relocate PAG waste rock as a contingency measure.

For the remaining PAG waste rock on the surface, consideration was given to low permeability covers to reduce oxygen and/or water ingress. Generally, the use of low permeability covers would be the most cost effective; however, since there are no suitable natural materials to construct such covers, this would not be a cost effective option. Therefore, the only viable low permeability cover would be geosynthetic liners. The initial capital cost and long-term replacement costs of these liners make them an undesirable option.

The final encapsulation approach is promoting freeze back of the waste rock and placement of a NPAG thermal cover to ensure long-term frozen conditions.

The improved understanding of geochemical behaviour of the PAG waste rock, specifically the long lag time to the onset of oxidation conditions, confirmed that freeze back of PAG waste rock was the most suitable waste rock management strategy for any PAG waste rock stored on the surface. From this additional geochemical understanding and appropriate thermal analysis, practical design criteria were developed for implementation.

3 Co-Disposal and Co-Mixing

Co-disposal of PAG waste rock with tailings in the mined out-open pits would be another viable waste rock management approach for the Project; however, as mentioned, project scheduling and the requirements for use of the mined-out open pits for tailings and water management makes this an undesirable option.

Co-mixing is a waste rock management strategy whereby NPAG tailings and PAG rock are physically mixed to generate a potentially physically and geochemically more stable product. The concept holds promise; however, there is not yet precedent for full-scale application in hard rock mining. Until there is sufficient proof of concept, this option was considered too uncertain to become the design basis.

4 Thermal Analysis

Thermal modelling was carried out to confirm the viability of freeze back given the climatic conditions. Freeze back was considered to be validated if the temperature throughout the WRSA remains below 0°C. Freezing point depression was not considered since mined rock is not expected to have saline properties and blast residues are predicted to have a negligible effect on freezing point.

Modelling was completed in a two-dimensional domain by solving for conductive heat movement in the soil, using commercial software (Attachment A). The conceptual geometry of the model consists of a critical section with sufficient width that it can be compared to a continuous layer problem. The conceptual model conservatively excludes convective cooling; however, allowance for super cooling through convective action has been assessed. Such super cooling has been observed at other Arctic sites. The modelling includes climate change.

The thermal modelling confirms that the WRSAs will freeze back after placement and remain frozen. The time to freeze back is estimated to be less than five years. The active layer in the WRSAs will initially decrease over the first 20 years as the system reaches environmental equilibrium, after which it will gradually increase as the effects of climate change become more prevalent. The modelling shows considerable uncertainty; however, the most realistic scenarios suggest that the active layer will on average remain within the 5 m NPAG cover up to the year 2100, which is as far as climate change predictions should be extrapolated (IPCC 2014)

5 Stability Analysis

The short and long term stability of the proposed WRSAs for the Property was assessed. The recommended minimum design values for Factors of Safety (FoS) for WRSAs, as published by the British Columbia Guidelines for Mined Rock and Overburden Piles (BCMDC 1991), was adopted. To help inform the stability analysis, a Dump Stability Rating (DSR) for the WRSAs was also completed in accordance with these guidelines and are presented in Attachment B.

The slope stability analysis was carried out using commercial limit equilibrium software using the critical (i.e. maximum ultimate slope height) for each of the WRSAs. Two different analysis methods were applied in each case. For the stability analyses, the overburden material and the

WRSAs were conservatively assumed to be unfrozen. The stability of the WRSAs was also analyzed with consideration of haul truck wheel loads applied near the crest. The complete stability analysis results are summarized in Attachment B and confirm that for all cases, the required minimum FoS are exceeded.

6 Waste Rock Storage Area Design Criteria

Considering the WRSA management strategy and the results of the thermal and stability analysis, the following WRSA design criteria were adopted for the Project:

- The WRSAs should be constructed in benches using the bottom-up technique.
- The lift thickness is not critical for freeze back or stability and can therefore be determined based on constructability requirements of the mine haul truck fleet. Based on the proposed 64t haul trucks, lift heights of around 5 to 8 meters can reasonably be expected.
- The final overall slope of the WRSAs should be 3H:1V or less. The one exception is Echo WRSA, which is very small is size, and will have a final overall slope of 2.4H:1V. Individual bench slopes can be at angle of repose with bench setbacks designed to allow for an overall slope at the desired grade. The slope is not a function of stability but rather a reasonable long-term slope considering overall landscape design. Final landscape design should also consider where practical a configuration that would promote shedding snow to minimize the insulating effects of snow.
- The WRSA must be designed to allow for complete encapsulation with on average 5 m of NPAG waste rock.. As an outside limit, such covers must be placed within 10 years of completion of each WRSA. This is planned to be achieved largely through progressive reclamation.
- In general, overburden will not be useable for either construction or structural reclamation material (frozen chunks in winter and supersaturated silt in summer). However, some sand and gravel overburden is expected at the Property and would be geotechnically suitable as a portion of the 5 m NPAG cover. This will need to be reviewed and assessed during Operations. The overburden that is not deemed geotechnically suitable as cover material should be placed in interior cells within the WRSA. These cells should not be within 20 m of the outer edge of the WRSA.

A discussion of the foundation requirements and considerations are provided below. With regard to possible engineering restrictions of the location of the WRSAs, the following should be noted:

- WRSAs can be placed in close proximity of the pits; however, an offset distance of 100 m is recommended.
- An offset distance of 50 m from any watercourse or river bank full supply level is recommended.
- WRSAs, or portions thereof, should not be placed in ponds or lakes that have been identified as containing fish so as not to trigger the requirements for a MMER Schedule II application.

- The overall WRSA height should be limited to less than 80 m.
- Consideration must be given to the location and height of any WRSA in the vicinity of the Goose airstrip, specifically for any WRSAs planned within the approach and departure flight paths.
- Ensure that there is sufficient room downstream of any WRSA to construct an appropriately sized water management structure.
- There is no requirement for a liner, or NPAG base layer, prior to placing PAG rock within the WRSAs.

7 Foundation Conditions

Geotechnical field investigations have confirmed that the proposed locations of the Llama, Umwelt, and Echo WRSAs are underlain by less than 2 m of overburden. Waste rock from Goose Main will be placed on the TSF (called the TSF WRSA), which is underlain by overburden of variable thickness ranging from 2 m to 11 m (SRK 2015c).

The permafrost soils will provide suitable foundation conditions for WRSAs provided the foundations remain frozen. To ensure the foundation remains frozen, it is recommended that the first lift of all new WRSAs be constructed during the winter season. In the event the first lift of waste rock will have to be constructed during the summer months, the WRSA will be subject to differential settlement during the first summer, due to consolidation settlement of the active layer. However, since there is less than 2 m of overburden under the WRSAs such settlement does not pose any material risk or concern.

In all cases, whether WRSA construction is started in the summer or winter, once freeze back has been achieved and the active layer is demonstrated to remain within the base of the waste rock stockpile, there will likely be few further restrictions on what the maximum lift thickness would be for construction of the WRSA. Overall maximum height (i.e. total vertical thickness) of the WRSA should be limited to 80 m unless appropriate analysis to confirm otherwise is carried out. For both of these conditions (summer and winter construction), the overall WRSA slopes can be based solely on the waste rock properties and no special buttressing considerations are required.

Provided the WRSA foundation remains frozen, the only deformation the stockpile will experience is creep deformation as a result of the thin overburden. Creep deformation is a long-term process; however, given the thin overburden present, this is not expected to be a concern. In areas where the WRSA foundation is on exposed bedrock, no significant issues are expected; therefore, placement on exposed bedrock is preferred and can proceed during any season provided adequate clearing of snow and ice has been completed.

8 WRSA Construction Sequencing

Table 1 summarizes the waste rock production schedule for the Project. All waste rock gets produced during the two year pre-production period (during the Construction phase) and the first six years of Operation. Umwelt WRSA gets constructed first over a period of four years (although the fourth year has very limited waste rock placed). The Llama WRSA takes three years to construct and overlaps with Umwelt WRSA construction by one year. The TSF WRSA takes five years to construct (with the fifth year placement being negligible), overlapping Llama WRSA construction for two years. Echo WRSA placement occurs in parallel with TSF WRSA construction, but is completed in two years.

As far as practical, WRSA construction will be done to minimize re-handling by placing NPAG concurrently as an outer shell around the PAG. However, based on material sequencing, there may be periods when NPAG rock will have to be separately stockpiled and re-handled such as to ensure that the whole PAG surface area can be covered with an NPAG cover of at least 5 m.

Table 1. Waste Rock Production Schedule

WRSA	Material Type	Waste Rock by Mining Year (ktonnes)								
		-2	-1	1	2	3	4	5	6	Totals
Umwelt	Overburden	1,289	-	-	-	-	-	-	-	1,289
	NPAG	1,292	3,458	831	21	-	-	-	-	5,602
	PAG	2,796	8,110	2,126	20	-	-	-	-	13,052
	Total	**5,377**	**11,568**	**2,957**	**41**	**-**	**-**	**-**	**-**	**19,943**
Llama	Overburden	-	-	1,037	-	-	-	-	-	1,037
	NPAG	-	-	2,019	2,175	228	-	-	-	4,422
	PAG	-	-	4,532	5,519	496	-	-	-	10,547
	Total	**-**	**-**	**7,588**	**7,694**	**724**	**-**	**-**	**-**	**16,006**
Goose Main	Overburden	-	-	-	2,362	392	-	-	-	2,754
	NPAG	-	-	-	685	6,683	5,575	1,309	3	14,255
	PAG	-	-	-	466	4,232	3,933	1,461	8	10,100
	Total	**-**	**-**	**-**	**3,513**	**11,307**	**9,508**	**2,770**	**11**	**27,109**
Echo	Overburden	-	-	-	-	-	250	-	-	250
	NPAG	-	-	-	-	-	286	103	-	389
	PAG	-	-	-	-	-	412	172	-	584
	Total	**-**	**-**	**-**	**-**	**-**	**948**	**275**	**-**	**1,223**

9 References

Intergovernmental Panel on Climate Change (IPCC). 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

SRK Consulting (Canada) Inc. (2015a). Geochemical Characterization in Support of the Final Environmental Impact Statement (FEIS) for the Back River Project, Nunavut. Report prepared for Sabina Gold & Silver Corp. Project No. 1CS020.008, November 2015.

SRK Consulting (Canada) Inc. (2015b). Back River Project Water and Load Balance Report. Report prepared for Sabina Gold & Silver Corp. Project No. 1CS020.008, October 2015.

SRK Consulting (Canada) Inc. (2015c). Back River Property Geotechnical Design Parameters. Report prepared for Sabina Gold & Silver Corp. Project No. 1CS020.008, November 2015.

Attachment A:
Waste Rock Storage Area Thermal Modelling

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Memo

To:	Project File	**Client:**	Sabina Gold & Silver Corp.
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Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	November 13, 2015
Subject:	Back River Property: Waste Rock Storage Areas Thermal Modelling - Final		

1 Introduction

SRK Consulting (Canada) Inc. was retained by Sabina Gold & Silver Corp. to complete numerical modelling to predict short-term freeze back rates and the long-term active layer thickness of the waste rock storage areas (WRSAs). The modelling includes consideration of climate change at the Back River Property (the Property), Nunavut, Canada.

The WRSA design adopted for the Property consists of bottom-up construction using haul truck end dumping in layers. After a layer has been completed the “bubble-dumps” will be dozed level and the process repeated. The overall WRSA slope angle will range from 2.4H:1V to 3H:1V, but this slope will be attained through a series of 6 to 8 m benches, each at angle of repose with setback distances. Some of the planned WRSAs will be produced in as short a time as two to three years.

Both potentially acid generating (PAG) and non-potentially acid generating (NPAG) waste rock will be produced. Freeze back of the PAG waste rock is the planned management strategy to ensure geochemical stability. Once freeze back has been obtained, the long-term success of the management strategy relies on preservation of freezing conditions, which will be ensured through application of a NPAG waste rock cover that will be sufficiently thick such that the active layer does not penetrate into the underlying PAG waste rock.

Freeze back of the WRSAs is considered to be validated if the temperature throughout the PAG waste rock remains below 0°C. Freezing point depression was not considered since the mined rock is not expected to have saline properties and blast residue is predicted to have a negligible effect on the freezing point. For the model, the in-situ overburden (sand and gravel) was assumed to have some pore water salinity (23 ppt) as confirmed by SRK (SRK 2015b), which increases the model conservatism.

This memo summarizes the approach, assumptions, and results of the thermal modelling as well as provides some benchmarking data that helps to place the results in context.

2 Thermal Behaviour of Waste Rock Piles

Heat transfer in waste rock piles takes place from both thermal conduction and convection. Thermal conduction is the process by which heat is transferred directly from one solid particle of waste rock to another. Natural convection of heat is the process by which differences in fluid density (air or liquid), caused by concentration or temperature gradients, results in the mass transport of heat. Forced convection (advection) is fluid movement from an external force, such as wind or pressure gradients which move heat.

In northern Canada, natural air-convection has been shown to increase winter heat loss from coarse-grained run-of-mine (ROM) waste rock. Cold dense air can develop gravity driven air movement through the waste rock during the winter. The reverse in thermal gradient between the air and waste rock occurs in the thawing season which limits convection. The low thermal conductivity of air acts as an insulator and heat transfer is mainly in the form of conduction. Waste rock temperatures measured at northern mine sites in Canada have shown temperatures to be 4 to 6°C colder than the natural permafrost due to air-convection (EBA 2006; BGC 2007). In addition, numerical modelling of waste rock piles has demonstrated that temperatures are colder than from conduction alone and become “supercooled” (Arenson et al. 2007a, 2007b; Klassen et al. 2007). Modelling these effects is not without oversimplification of the heterogeneity of waste rock which can limit air flow. Wind movement across the waste rock can also result in the advection of heat and further cooling of the waste rock surface.

The thermal regime of WRSAs can also be influenced by sulfide oxidation which releases heat during an exothermic reaction. The reaction is a function of sulfide content, temperature, pH, microbial activity, surface area of the material, the rate of wreathing of the rock, and the availability of oxygen and water. Internal heat generation can also produce convection cells that move heat within the waste rock and supply oxygen to the system. Harries and Ritchie (1985) indicate that $7x10^{-7}$ moles of pyrite generate 1J of heat (0.012 kJ / kg of FeS_2). Once freeze back takes place, the oxidation process and heat generation is greatly limited due to the lack of liquid water.

The sulfidic PAG waste rock at the Back River Project (the Project) has very slow oxidation rates, with acidic drainage predicted to be observed only in the decadal scale assuming no limitation to oxygen and moisture (SRK 2015a). In reality, the Property has limited moisture available, and more importantly the waste rock is expected to freeze back very rapidly. Under these conditions, onset of oxidation processes that would generate sufficient heat to counter the freezing process is not expected. Sufficient oxidation are therefore not expected to develop in the majority (>95%) of the waste rock during the freeze back period.

3 Modelling Methods

3.1 Model Setup

Modelling was completed in a two-dimensional domain by solving for conductive heat transfer in the ground, using SoilVision's SVHeat (SoilVision 2011) software package version 6 in combination with FlexPDE solver to complete the calculations (FlexPDE 2014). The model is solely based on conductive heat transfer which is a more conservative approach to estimating thermal evolution of the WRSA. Air-convection would be expected to result in more rapid heat loss from the waste rock and slower rates of warming in response to climate change. This conservative approach without air-convection influences was adopted for thermal modelling of the WRSA at the High Lake project in Nunavut (BGC 2007).

The conceptual geometry of the model consists of a critical section; this critical section was selected to be through the TSF WRSA. It is not the single thickest section, but it has sufficient width that it can be compared to a continuous layer problem. Other sections had thicker profiles on moderate side-hill arrangements, but were discounted since two sub-parallel climate boundaries, as well as convective cooling, would enhance freeze back rates and therefore be less conservative. The complete model geometry is presented in Figure 1.

3.2 Model Inputs

3.2.1 Material Properties

Two material units were considered in the model: ROM waste rock material and natural overburden soil (sand with gravel). Peat or organic layers were not considered in the model for areas outside of the WRSA since these layers are negligible at the site, and are therefore not expected to have a material impact on the modelling outcome. Table 1 presents a summary of the thermal properties of the materials used in the model.

Table 1: Material Thermal Properties

Material	Thermal conductivity (kJ m^{-1} day^{-1} $°C^{-1}$)		Volumetric Heat Capacity (kJ m^{-3} $°C^{-1}$)	
	Unfrozen	Frozen	Unfrozen	Frozen
ROM Material, 17% Saturation	85	90	1,534	1,427
ROM Material, 30% Saturation	104	117	1,697	1,509
ROM Material, 60% Saturation	128	162	2,074	1,697
Overburden Sand with Gravel (23 ppt pore water salinity)	150	185	2,178	1,801

Note: ROM material porosity based on 0.3 m^3 m^{-3}

A ROM saturation value of 17%, 30%, and 60% was used for different model scenarios to test the sensitivity of initial saturation to the timing of freeze back and the long-term thermal condition of the WRSAs. The thermal properties were estimated for the ROM material based on the change in saturations in accordance to Cote and Konrad (2005). The properties for overburden sand with gravel and pore water salinity of 23 parts per thousand (ppt) were taken from previous work completed by SRK for the granular pad design (SRK 2015b).

3.2.2 Climate Boundary

Rescan (2014a) presents the available baseline meteorological data collected from the Property. Mean annual air temperature (MAAT) for the period of record was calculated to be -10.6°C at the Goose Meteorological Station. Regional air temperatures were also reviewed and analyzed to establish MAAT for a recent 10-year period. Local air temperature data was then correlated with two regional meteorological stations operated by Environment Canada: Lupin A Station (ID: 23026HN), and Lupin LC Station (ID: 230N002). These two sites are located approximately 220 km to the west of the Goose Station.

A ground response curve was developed from 10-year MAAT (2003 to 2012), representing the ground temperature at, and immediately below, ground surface (SRK 2015b). The parameters developed from the 10-year period are provided in Table 2. The boundary condition was applied to the model as a sinusoidal function of temperature and time based on Equation 1 and the parameters shown in Table 2.

$$T = \max(nf * \left[MAAT + (C_A * t) + Amp * Sin\left(\frac{2\pi+(t+230)}{365}\right)\right], \mathrm{nt}\left[MAAT + (C_A * t) + Amp * Sin\left(\frac{2\pi+(t+230)}{365}\right)\right] \qquad \text{Eq.1}$$

Where:

- T *is the ground temperature measured in °C*
- nf *is the surface freezing n-factor*
- nt *is the surface thawing n-factor*
- $MAAT$ *is the mean annual air temperature measured in °C*
- Amp *is the air temperature amplitude measured in °C*
- C_A *is the air climate change factor in °C* d^{-1}
- t *is time measured in days*

Climate change is considered in Equation 1 using the air climate change factor. This factor allows for a daily increase in air temperature based on the results of SRK (2015c). The air climate change factor applied to Equations 1 was 0.00016°C d^{-1}. This rate is equivalent to an increase in air temperature of +5.30°C by the year 2100 (85 years). Climate change model predictions are currently accepted as being plausible to the year 2100 (IPCC 2014) and therefore the maximum timeframe for which thermal modelling was completed.

Table 2: Current Climate Boundary Parameters

Model Parameter	Value
Mean annual air temperature *(MAAT)*	-10.6°C
Air temperature amplitude *(Amp)*	21.5°C
Air climate change factor (C_A)	0.00016°C d^{-1}
ROM Surface, Thawing n-factor *(nt)*	1.0, 1.3, 1.5, 2.0
ROM Surface, Freezing n-factor *(nf)*	0.7, 0.5, 0.4
Natural Overburden, Thawing n-factor *(nt)*	0.85
Natural Overburden, Freezing n-factor *(nf)*	0.65

Note: N-factors are dimensionless values

3.2.3 N-Factors

Seasonal n-factors are applied as multipliers to air temperature to estimate the ground surface temperature. An n-factor of 1.0 represents equal air and surface temperature and no thermal offset exists. A value greater or less than 1.0 represents a departure between the air and ground surface temperature.

The thawing and freezing n-factors for exposed ROM surfaces and Natural Overburden are shown in Table 2. The ROM n-factors were based on published values and engineering judgment. A ROM freezing n-factor (*nf*) of 0.7 and thawing n-factor (*nt*) of 1.3 are considered reasonable base case conditions for the Property. Sensitivity of the model results to a decrease in ROM freezing n-factors was also accessed using values of 0.5 and 0.4. The ROM surface value of 1.0, 1.5, and 2.0 were also used in the model for sensitivity analysis. N-factors for natural overburden represent values that have been calibrated to ground temperatures measured at the Property (SRK 2015d).

The freezing n-factor with consideration for climate change was estimated using the expected change in air temperature and snow thickness using a separate 1D SVHeat model. Snow thermal properties were calculated using late winter snow density (Sturm et al. 1997) as:

$$\lambda s = 10^{(2.65\rho - 1.652)} \qquad \text{Eq. 2}$$

The volumetric heat capacity of snow was calculated as:

$$HCs = SHs * \rho \qquad \text{Eq. 3}$$

Where:

- λs *is the thermal conductivity of the snow* (*W m^{-1} °C^{-1}*
- ρ *is the density of the snow* λs *is the thermal conductivity of the snow (g cm^{-3})*
- HCs *is the volumetric heat capacity of snow (J m^{-3} °C^{-1})*
- SHs *is the specific heat capacity of snow (J kg^{-1} °C^{-1})*

Average end of winter snow density (0.35 g cm^{-3}) and snow thickness (0.59 m) were taken from measurements collect at the Property (Rescan 2012). The 1D model did not consider seasonal change in snow properties, thickness, or advection of heat. The snow thermal conductivity and volumetric heat capacity were calculated to be 16 kJ m^{-1} day^{-1} °C^{-1} and 731.5 kJ m^{-3} °C^{-1}, respectively.

The long-term climate change freezing n-factor was estimated to be 0.5 using the measured snow density and an estimated decrease in snow depth. The decrease in snow depth is based on air temperature and precipitation predicted by climate change models for the Property (SRK 2015c).

3.2.4 Initial Conditions

The initial conditions in the model were defined by each material (Figure 1). The WRSA (ROM material) was set to an initial temperature of +3°C. This is conservative as the ROM will initially be removed from the pits and underground at a temperature of roughly -4°C to -7°C, which is the approximate range of permafrost temperature at the Property. The WRSA will be constructed over 2 to 3 years resulting in burial of cold material placed in the winter and summer. The overall heat retained by the WRSA at closure will be less than +3°C and therefore conservative conditions are used for the initial conditions. This assumption assume no additional heat generation from the oxidation of sulfides within the waste rock. Note that some WRSAs will be built over a longer time frame than 2 to 3 years, and as such, the model represents the most conservative scenario.

The initial conditions for natural overburden were set to a constant temperature of -6.5°C which is consistent with ground temperatures measured at the Property (Rescan 2014b). The model assumes continuous permafrost beneath the WRSA.

The sides of the model not exposed to the atmosphere are represented as a zero flux boundary (Figure 1). The lower boundary of each model was set to a constant thermal flux of 2.59 kJ m^{-2} day^{-1} $°C^{-1}$, equivalent to the geothermal gradient observed at the Property (Rescan 2014b).

3.2.5 Model Scenarios

Table 3 outlines the model scenarios used to predict thermal performance of the WRSA. For each model run, the climate boundary applied to the surface of the model accounted for an increase in air temperature of +4.93°C over the next 85 years. This reflected in varying ground surface temperatures through the use of freezing and thawing n-factors.

Model parameters for natural overburden were based on values calibrated to measurements made at the Property (Table 2). These parameters were not adjusted over time since they are not a major influence on the thermal condition of the waste rock material.

Model Scenario 1, 2, and 3 consider the influence of the degree of saturation of ROM material at a saturation of 17%, 30%, and 60%, respectively (Table 3). Heat movement from the infiltration of water is numerically represented in the model; and the effects of surface water infiltration are addressed in Section 4.1.2.

Table 3: Model Scenarios and Key Parameters

Model Description	N-factors		Saturation (%)
	freezing	thawing	
Scenario 1 – Moisture Sensitivity Model	0.7	1.0	17%
Scenario 2 – Moisture Sensitivity Model	0.7	1.0	30%
Scenario 3 – Moisture Sensitivity Model/Freezing N-factor Model	0.7	1.0	60%
Scenario 4 – Freezing N-factor Sensitivity Model	0.5	1.0	30%

Model Description	N-factors		Saturation (%)
	freezing	thawing	
Scenario 5 – Freezing N-factor Sensitivity Model	0.4	1.0	30%
Scenario 6 – Thaw N-factor Sensitivity Model (BASE CASE)	0.7	1.3	30%
Scenario 7 – Thaw N-factor Sensitivity Model	0.7	1.5	30%
Scenario 8 – Freezing and Thaw N-factor Sensitivity Model	0.5	1.5	30%
Scenario 9 – Thaw N-factor Sensitivity Model	0.7	2.0	30%
Scenario 10 – Operational Freeze Back Model	0.7	1.0	30%
Scenario 11 – Cover with Overburden Model	0.7	1.0	30%
Scenario 12 – NPAG Cover over Frozen Tailings Model	0.7	1.3	30%

Notes: MAGST – modelled mean annual ground surface temperature based on n-factors and boundary condition.

Model Scenarios 1, 2, and 4 assess the sensitivity of the moisture content of the waste rock, with a 30% saturation value deemed as the most realistic. Model scenarios 2, 4, and 5 assess sensitivity of the results to a freezing n-factor value of 0.7, 0.5, and 0.4, respectively (Table 3). Model Scenario 6 is considered to be a reasonable base case (freezing n-factor of 0.7 and a thawing n-factor of 1.3) for the Property. Model Scenarios 2, 6, 7, and 9 test the sensitivity of the thawing factor. Model Scenario 8 considers warmer winter conditions from increased insulation of the ROM where great snow accumulation occurs, such as the base of the slopes on the WRSA benches. Model Scenario 9 considers higher solar radiation contributing to greater input of heat along southerly facing slopes. Model Scenario 10 considers progressive freeze back of the waste rock as it is placed. Model Scenario 11 evaluates a closure cover consisting of 5 m of NPAG overlain by 1 m of overburden sand. Scenario 12 presents the case where a 5 m NPAG cover is placed over the frozen TSF tailings surface.

4 Results

4.1 Waste Rock Freeze Back

4.1.1 Model Estimates

Thermal modelling was completed to estimate the duration of freeze back of waste rock. Figure 2 shows the estimated time for freeze back as defined by the 0°C isotherm, and Table 4 summarizes the results. The duration of freeze back ranged from 3.5 years to 4.9 years with no consideration for freezing during material placement. For the base case (Scenario 6), freeze back is estimated to be 3.8 years. The freeze back is estimated to be 2.3 years under conditions where progressive freezing takes place during winter placement.

Model Scenarios 1 through 3 examine the sensitivity of freeze back relative to the degree of saturation of the ROM material from 17% to 60%, respectively (Figure 2). The change in saturation for the ROM material with 30% porosity is equivalent to a change in volumetric water content from 0.05 $m^3\ m^{-3}$ to 0.18 $m^3\ m^{-3}$. More rapid freeze back is achieved in waste rock with the lowest moisture content. The difference in the timing of freeze back due to the change in saturation prescribed in the model is about 1 year.

The timing of freeze back was also evaluated using a freezing n-factor from 0.7 to 0.4 for a ROM saturation of 30% (Model Scenarios 2, 4, and 5). A decrease in the freezing n-factor from 0.7 to 0.4 causes an increase in mean annual ground surface temperature from -6.8°C to -2.9°C (Table 4). The duration of freeze back is estimated to range from 3.5 years to 4.9 years, representing a difference of 1.1 years in the timing of freeze back. The average modelled temperature measured 20 m below the surface of the ROM is also shown in Table 4.

Table 4: Sensitivity of WRSA Freeze Back to Changes in ROM Material Saturation and N-factors

Model Description	Saturation (%)	N-factors		MAGST (°C)[3]	Duration of Freeze Back (yrs)	Average Temperature, Year 20 (°C)[4]
		freezing	thawing			
Scenario 1	17%	0.7	1.0	-6.8	4.3[1]	-5.1
Scenario 2	30%	0.7	1.0	-6.8	3.7[1]	-5.5
Scenario 3	60%	0.7	1.0	-6.8	3.5[1]	-5.8
Scenario 4	30%	0.5	1.0	-4.1	4.3[1]	-3.9
Scenario 5	30%	0.4	1.0	-2.9	4.9[1]	-2.9
Scenario 6	30%	0.7	1.3	-6.1	3.8[1]	-4.7
Scenario 7	30%	0.7	1.5	-5.6	3.9[1]	-4.8
Scenario 8	30%	0.5	1.5	-3.0	4.6[1]	-3.0
Scenario 9	30%	0.7	2.0	-4.4	4.1[1]	-4.0
Scenario 10	30%	0.7	1.0	-6.8	2.3[2]	-
Scenario 11	30%	0.7	1.0	-6.8	3.6[1]	-5.2

Note:

1. Duration of freeze back following placement of NPAG cover at closure
2. Progressive freeze back during placement of material
3. MAGST- Mean annual ground surface temperature calculated for year 1 of the model using Equation 1
4. Average temperature for model at year 20 is measured at a position 20 m below ROM material surface
5. Hyphen (-) indicates parameter is not available

4.1.2 Lift Thickness

Three additional models were run to estimate the maximum amount of summer waste rock that could be frozen back over one winter. The model simulations included two summer lifts with a thickness of 6, 8, or 10 m (total material thickness of 12, 18, or 20 m, respectively) which was placed over a frozen winter lift of 8 m.

Figures 3 through 5 show the modelled ground temperature at the end of the winter period. The model estimates a total of 12 m of waste rock (two - 6 m thick lifts) can freeze back over one winter (Figure 3). Incomplete winter freeze back was achieved for the summer placement of 16 and 20 m of waste rock material (Figures 4 and 5). These findings assume no heat generation within the material which could limit freeze back. Alternatively, natural air-convection contributing to waste rock cooling would be expected to freeze a greater amount of material.

4.1.3 Surface Water Infiltration

Heat transported by the infiltration of surface water through the waste rock would be expected to have some influence on the timing of freeze back due to the mass transport of energy into the system. Water may also contribute to oxidation of sulfides which could result in an exothermal reaction. These processes are not directly accounted for in the SVHeat model. However, if it is conservatively assumed 75% of the total annual precipitation (412 mm) infiltrates the waste rock at an initial water temperature of +4°C and leave at 0°C, the total heat loss from the water and gained by the pile would be about 4.5 MJ m^{-2} yr^{-1}. For perspective, the estimate net annual surface heat loss from the waste rock is 52 MJ m^{-2} yr^{-1} without added cooling from natural air-convection. Heat contributed to the waste rock pile by infiltration of surface water with a 4°C change in temperature would be less than 8.7% of the annual heat loss, and is considered to have negligible effects on the timing of freeze back. This finding excludes the potential influence of heat generation of oxidation.

4.1.4 Exothermic Reactions

Heat generation from the oxidation of sulfidic waste was simulated using a constant heat source. Figure 6 shows the WRSA model with heat generation from 10% of the PAG waste rock. A constant heat source is used in the model which assumes no decrease in the oxidation process over time due to temperature, moisture, or oxygen, among other factors. Figure 7 shows WRSA temperature at the end of Year 1. Figure 8 shows that freeze encapsulation is achieved around the heat generating zone. However by the end of year 85, the encapsulating zone warms in response to increasing air temperature (Figure 9). It is not currently anticipated that waste rock at the Property will generate heat on the time scale of freeze back (i.e. less than 5 years) (SRK 2015a); exothermic reactions were examined in the model for the sake of completeness.

4.2 Waste Rock Active Layer

4.2.1 Modelled Results

Figure 10 shows the estimated active layer thickness for Model Scenarios 1 through 12, with Scenario 6 being the assumed base case for the Property. Active layer thickness is estimate to decrease from model year 6 to 20 as the ROM material nears equilibrium conditions with the applied surface boundary temperature. Following model year 20, the active layer thickness is observed in the model to deepen in response to the increase in air temperature related to climate change; i.e. increasing air temperature controls long-term active layer thickness within the model.

Active layer thickness at 6 years is estimated to range from 3.0 m to 6.2 m for the different model scenarios (Figure 10). At twenty years, the range in active layer thickness is estimated to range from 2.8 m to 5.3 m. The greatest active layer is associated with the combined effects of low freezing and high thawing n-factors, as shown with model Scenario 7 (MAGST -3.0°C) and Scenario 8 (MAGST -4.4°C). These conditions would be analogous to isolated areas of the WRSA with snow drifting and south facing aspects which receive a greater amount of incoming solar radiation. The ground surface temperature for these two scenarios is at least 2.3°C warmer than the average ground surface temperature measured at the Property. Snow would however be expected to be less across most of the windswept WRSA.

The active layer thickness for the base case (Scenario 6) at year 20 is 3.6 m. It reaches a thickness of 5 m by year 66. The average active layer thickness is also 3.6 m for year 20 when considering model scenarios with 30% ROM saturation, a freezing n-factor of 0.7, and a thawing n-factor of 1.0, 1.3, and 1.5, respectively (Model Scenarios 2, 6, 7). After 85 years, the active layer thickness for all model scenarios is estimated to range from 4.4 m to 9.86 m. The average active layer thickness for Model Scenarios 2, 6, and 7 at year 85 is 5.7 m (range from 4.6 m to 6.7 m).

The sensitivity of active layer thickness to the thermal conductivity of waste rock was evaluated using a minimum and average thermal conductivity values reported in the literature (Figure 11). The active layer is estimated to increases by 0.5 m using the average thermal conductivity reported for waste rock. The active layer thickness is estimated to vary by 0.25 m with differences in ROM saturation (Model Scenarios 1, 2, and 3).

4.2.2 Supercooling from Natural Air-Convection

The influence of enhanced cooling from natural air-convection was evaluated by decreasing the mean annual waste rock temperature from the SVHeat thermal conduction model. The temperature was decreased by 2.5°C and 5°C which is within range of “supercooling” observed in in natural coarse block material in alpine environments (Harris and Pederson 1998) and within waste rock piles in Canada (EBA 2006).

Figures 12 through 15 show the decrease in active layer thickness as a function of supercooling. The colder waste rock temperature acts to prolong seasonal thaw due to additional energy required to warm the ground above the thawing point. For the base case, the active layer thickness is decreased by 1.1 m by supercooling the waste rock by 5°C. The additional cooling also extends the duration of time that the active layer is less than 5 m thick, from approximately 66 years to 85 years (Figure 13).

4.2.3 Waste Rock Active Layer in Northern Canada

Table 5 summarizes active layer thickness for waste rock in northern Canada. The influence of site conditions on waste rock active layer must be considered when directly comparing values from other sites to those estimated for the Project WRSAs. Some of the considerations include local climate conditions, waste rock type, placement history, facility design and stage, and reactivity of the material. In this memo, the information provide in Table 5 is to provide context for the WRSA model results.

Table 5: Waste Rock Active Layer Thickness for Sites in Northern Canada

Mine	Latitude	MAAT (°C)	Facility	Measurement	Active Layer Thickness (m)
Snap Lake, NWT	63°36’	-7.7	Test Pile	Observed	~2.0[1]
Diavik, NWT	64°30’	-9.1	Test Pile	Observed	5 m
				Modelled	4.2 to 6 m[3]
Ekati, NWT	64°43’	-10.2	Test Piles	Observed	1.5 - 4 m[1]
			Panda/ Koala/ Beartooth	Observed	2 - 3 m
			Fox uncovered WRSA	Observed	1.5 - 4 m
			Misery	Observed	2.5 - 14 m[1,2]
			Pigeon WRSA	Modelled	2.4 - 5 m
Meadowbank, NU	65°01’	-11.1	Portage Rock	Modelled	1.5 m[4]
High Lake, NU	67°22’	-11.8	-	Modelled	~5.0[1]
Mary River Project, NU	71°20’	-13.3	Porous Waste Rock	Modelled (convective)	50 – 100m
			Non-porous Waste Rock	Modelled (conduction)	3m

Note:

1. Value report by BGC Engineering (BGC 2007).
2. Deep active layer thought to be associated with proximity to side slopes and accumulation of snow.
3. After 100 years with 5.6°C/100-year climate warming, the active layers will be 6 m, 5 m and 4.2 m at 10 %, 20 % and 30 % volumetric moisture content, respectively.
4. 4 m NPAG cover proposed.

4.3 Long-Term Thermal Condition of WRSA

The thermal condition of the ROM material for Scenarios 3, 6, 7, and 8 is shown in Figures 16 through 19. These results are based on thermal conduction and do not account for convective cooling or possible heat generation from the oxidation of sulfides. The ROM material is estimated to remain frozen (below 0°C) to Year 85 with exception to the seasonal active layer. Estimated active layer thaw depth for each scenario is shown in Figure 10. The ROM material is observed to warm from Year 20 to Year 85 in response to increasing air temperature defined by the Equation 1.

5 Conclusion

A conductive heat transfer model was used to estimate the thermal behaviour of WRSA on the Property. The thermal model analyses indicate that the WRSAs will freeze back during material placement and immediately following closure. This finding assumes no generation of heat from the oxidation of sulfides, which is reasonable for the Property. Freeze back at the Property is estimated to be less than five (5) years with no allowance for convective cooling in the winter. The time for freeze back to occur is less than 2.5 years with allowance for winter freezing during operation of the WRSAs (i.e. with convective cooling). Over the course of one winter, a maximum of 12 m of summer material is expected to freeze back.

Natural air-convection would be expected to contribute to colder waste rock temperatures which act to reduce the active layer thickness and prolong the onset of climate warming effects. Active layer thickness for the majority of the WRSAs would be expected to be less than 5 m for contemporary conditions and increase in response to the predicted increase in air temperature for the Property. The active layer thickness may be locally greater than base case conditions (Model Scenario 6) due to variability in surface conditions, such as increased solar radiation received along south-facing slopes.

6 References

Arenson, L.U., Pham, H.-N., Klassen, R. and Sego, D.C. 2007a. Heat convection in coarse waste rock piles and tailings covers. In Proceedings of the 60th Canadian Geotechnical Conference, October 21-24, 2007, Ottawa, ON, Canada.

Arenson, L.U., Chen, J.F., Pham, H.-N., and Sego, D.C. 2007b. Laboratory investigations on air convection in porous media. In Proceedings of the 60th Canadian Geotechnical Conference, October 21-24, 2007, Ottawa, ON, Canada.

BGC 2007. Super-cooling Effects and Long-Term Modelling of Waste Rock Piles High Lake Project, NU. Submitted to Zinifex/Lorax. Project No. 0385-003-22.

Cote J., and Konrad, J-M. 2005. A Generalized Thermal Conductivity Model for Soils and Construction Materials. Canadian Geotechnical Journal. 42: 443-458.

EBA. 2006. Thermal Evaluation of Waste Rock Piles Ekati Diamond Mine, NT. Report: 0101-94-11580033.004.

Flex PDE Solutions Inc. 2014. FlexPDE 6. Version 6.36 7/29/2014. http://www.pdesolutions.com /download/flexpde636.pdf, Accessed Dec. 17, 2014.

Harris, S.A., and Pedersen, D.E., 1998. Thermal regime beneath coarse blocky materials. Permafrost and Periglacial Processes. 9: 107-120.

Intergovernmental Panel on Climate Change (IPCC). 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Klassen, R., Arenson, L.U., Sego, D.C., and Biggar, K.W. 2007. Heat convection modeling in waste rock piles. In Proceedings of the 5th Biennial Workshop on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates (ARCSACC), May 6-8, 2007, Edmonton, AB, Canada.

Rescan. 2012. Back River Project: 2012 Hydrology Baseline Report. Report submitted to Sabina Gold & Silver Corp. November 2012.

Rescan 2014a. Back River Project 2006 to 2013 Meteorology Baseline Report. Report submitted to Sabina Gold & Silver Corp. January 2014.

Rescan 2014b. Back River Project Cumulative Permafrost Baseline Data Report (2007 to May 2014). Report submitted to Sabina Gold & Silver Corp. June 2014.

SRK Consulting (Canada) Inc. 2015a. Geochemical Characterization in Support of the Final Environmental Impact Statement (FEIS) for the Back River Project, Nunavut. Report submitted to Sabina Gold & Silver Corp. Project No. 1CS020.008. November 2015.

SRK Consulting (Canada) Inc. 2015b. Thermal Modelling to Support Run-of-Quarry Pad Design. Memorandum submitted to Sabina Gold & Silver Corp. Project No. 1CS020.008, October 14, 2015.

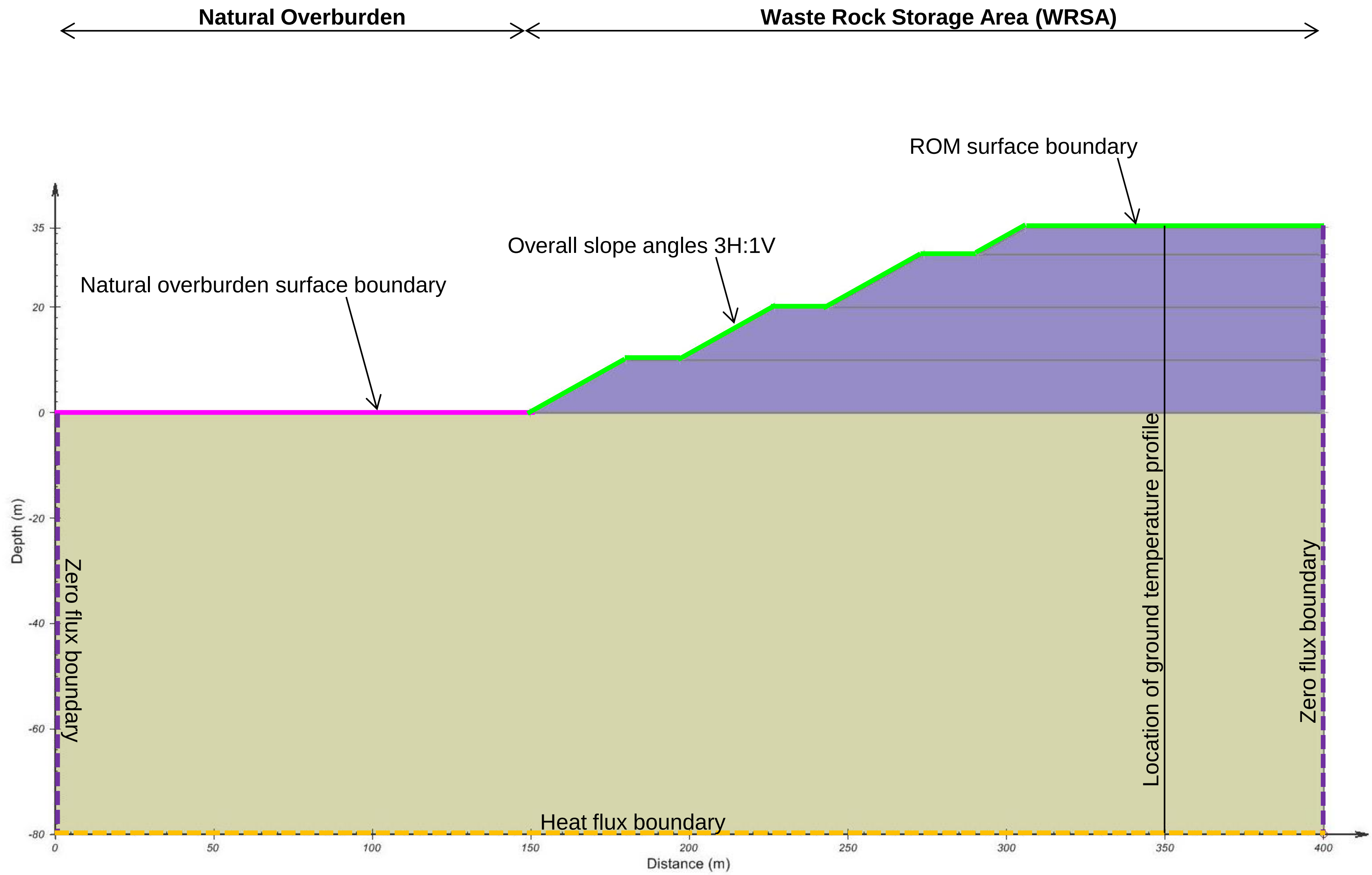
SRK Consulting (Canada) Inc. 2015c. Standardized Procedure for Climate Change Integration into Engineering Design. Memorandum submitted to Sabina Gold & Silver Corp. Project No. 1CS020.008, September 4, 2015.

SRK Consulting Inc. 2015d. Back River Project: Saline Water Pond Containment Dam Thermal Modeling. Memorandum submitted to Sabina Gold & Silver Corp. Project No. 1CS020.008, September 29, 2015.

SoilVision Systems Ltd. 2011. SVHeat 1D/2D/3D Geothermal Modelling Software Examples Manual. Soil Vision Systems Ltd. Saskatoon, Saskatchewan, Canada. http://www soilvision .com/downloads/software/svoffice2009/SVHeat_Examples_Manual.pdf, Accessed on Dec. 17, 2014.

Sturm, M., Holmgren, J., Konig, M., and Morris, K. 1997. The thermal conductivity of seasonal snow. Journal of Glaciology. 43: 42–59.

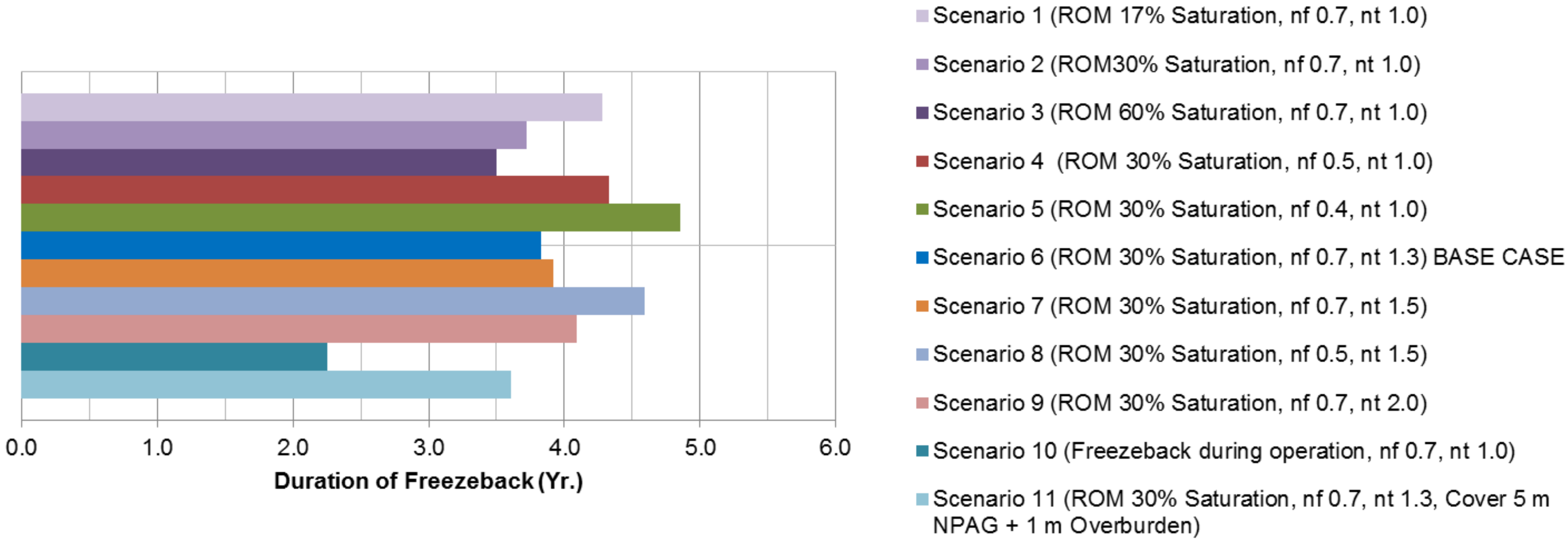
Figures



Materials

- Sitewide Sand Gravel
- ROM Material

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model **Thermal Model Geometry**
Job No: 1CS020.008 Filename: WRSA_Model_Geometry.pptx	BACK RIVER PROJECT	Date: 9/23/2015 Approved: cws Figure: 1



Note:
1. Duration of freezeback following placement of cover at closure
2. ROM – Run of Mine material with varying degree of saturation
3. nf – freezing n-factor
4. nt – thawing n-factor

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
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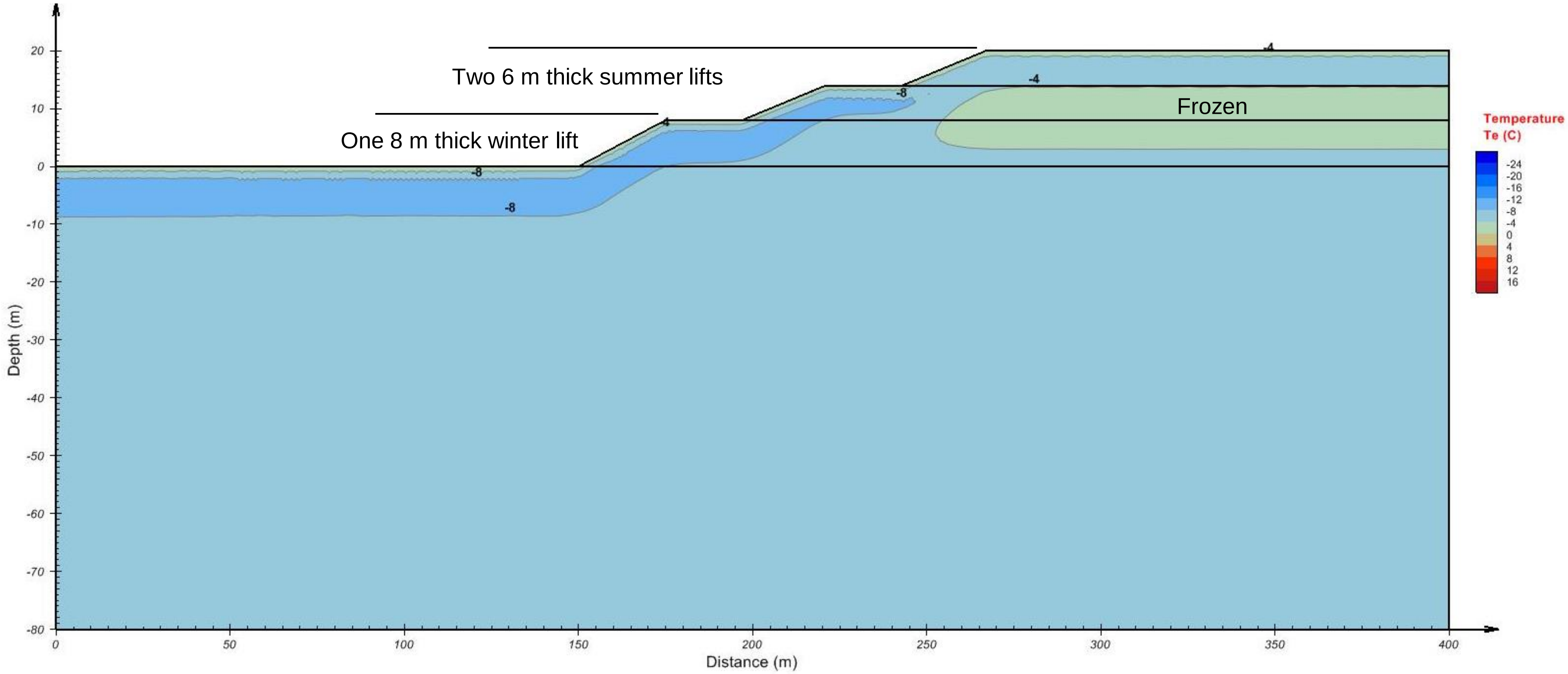
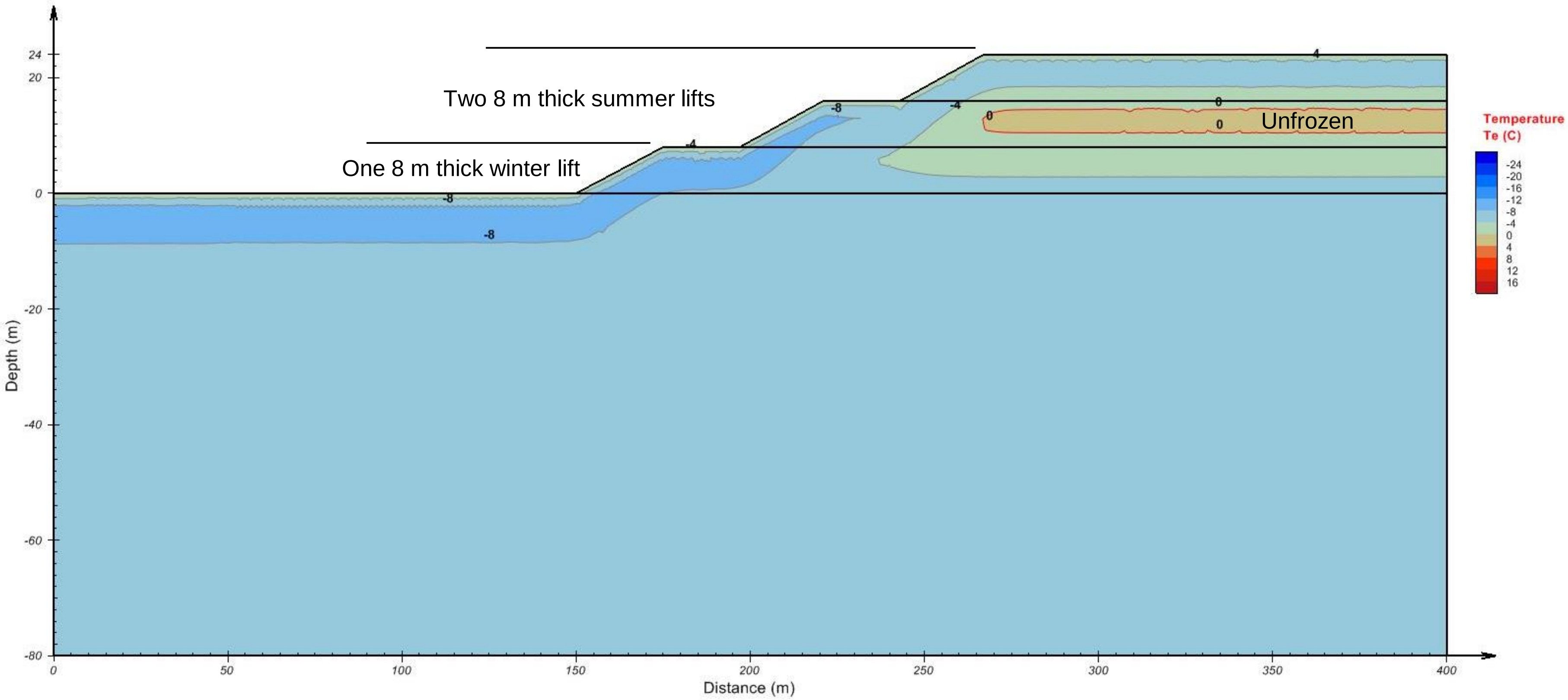
Job No: 1CS020.008 Filename: WRSA_FreezeBack_Estimates.pptx	BACK RIVER PROJECT	Date: 9/23/2015 / Approved: cws / Figure: 2



Note:

1. Thermal model extends from freeze-up to onset of thaw (1 winter)
2. Initial conditions include 12 m of ROM with initial temperature +3°C at start of freeze-up
3. ROM material degree of saturation 30%
4. ROM freezing n-factor of 0.7 and thawing n-factor 1.0
5. 0°C isotherm shown with solid red line

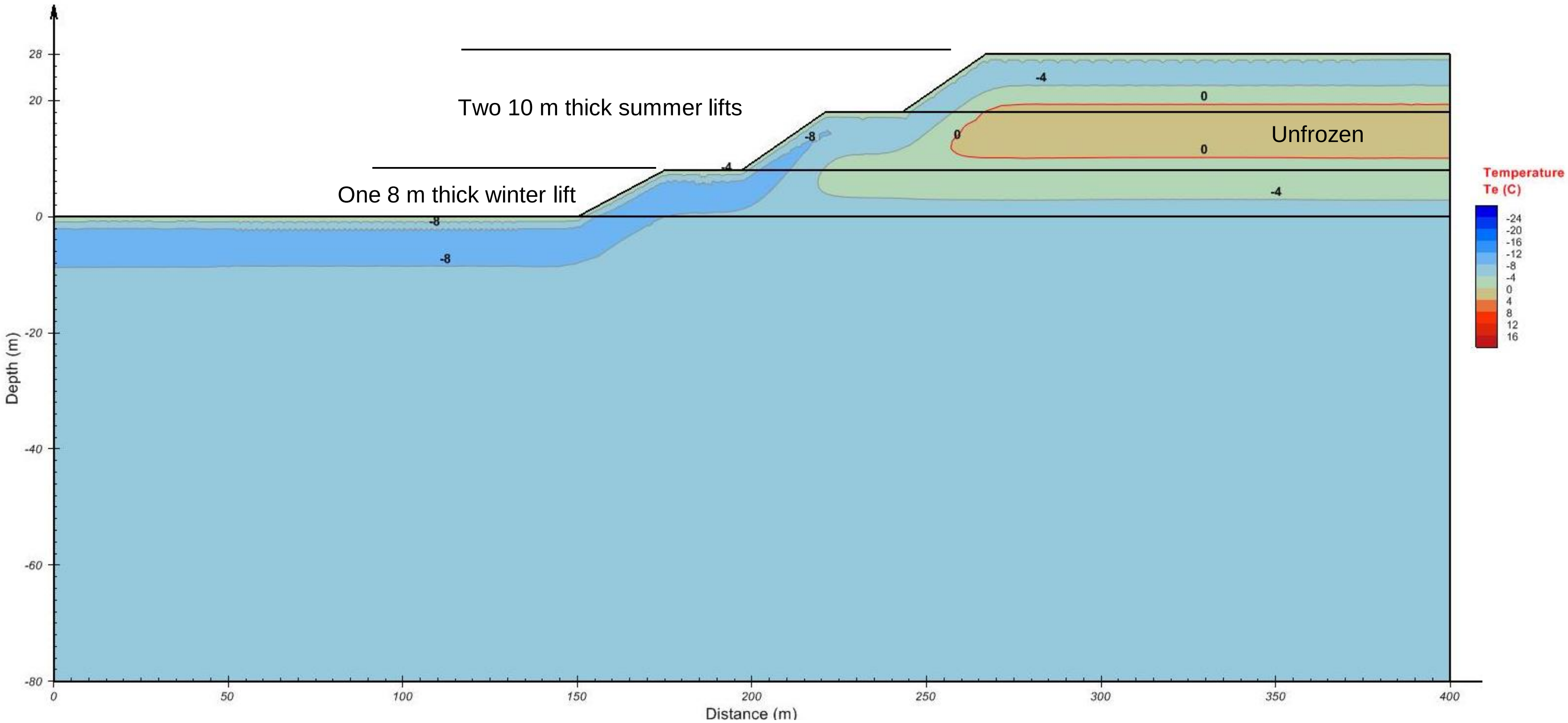
srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		WRSA Temperature – Freezeback 12 m Waste Rock
Job No: 1CS020.008 Filename: WRSA_Model12mLiftFreezeback.pptx	BACK RIVER PROJECT	Date: 11/1/2015 · Approved: cws · Figure: 3



Note:

1. Thermal model extends from freeze-up to onset of thaw (1 winter)
2. Initial conditions include 16 m of ROM with initial temperature +3°C at start of freeze-up
3. ROM material degree of saturation 30%
4. ROM freezing n-factor of 0.7 and thawing n-factor 1.0
5. 0°C isotherm shown with solid red line

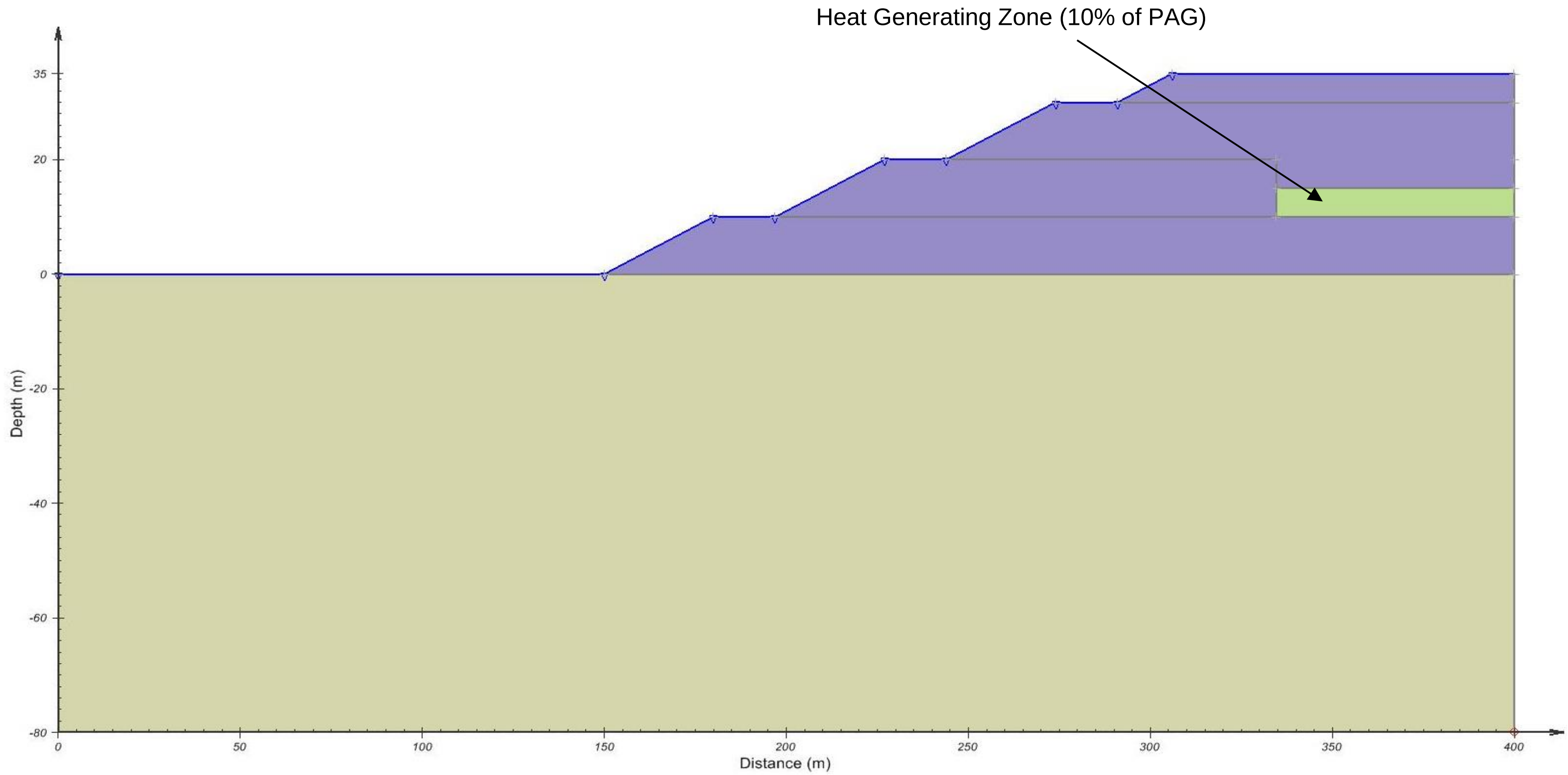
srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		WRSA Temperature – Freezeback 16 m Waste Rock
Job No: 1CS020.008 Filename: WRSA_Model16mLiftFreezeback.pptx	BACK RIVER PROJECT	Date: 11/1/2015 · Approved: cws · Figure: 4



Note:

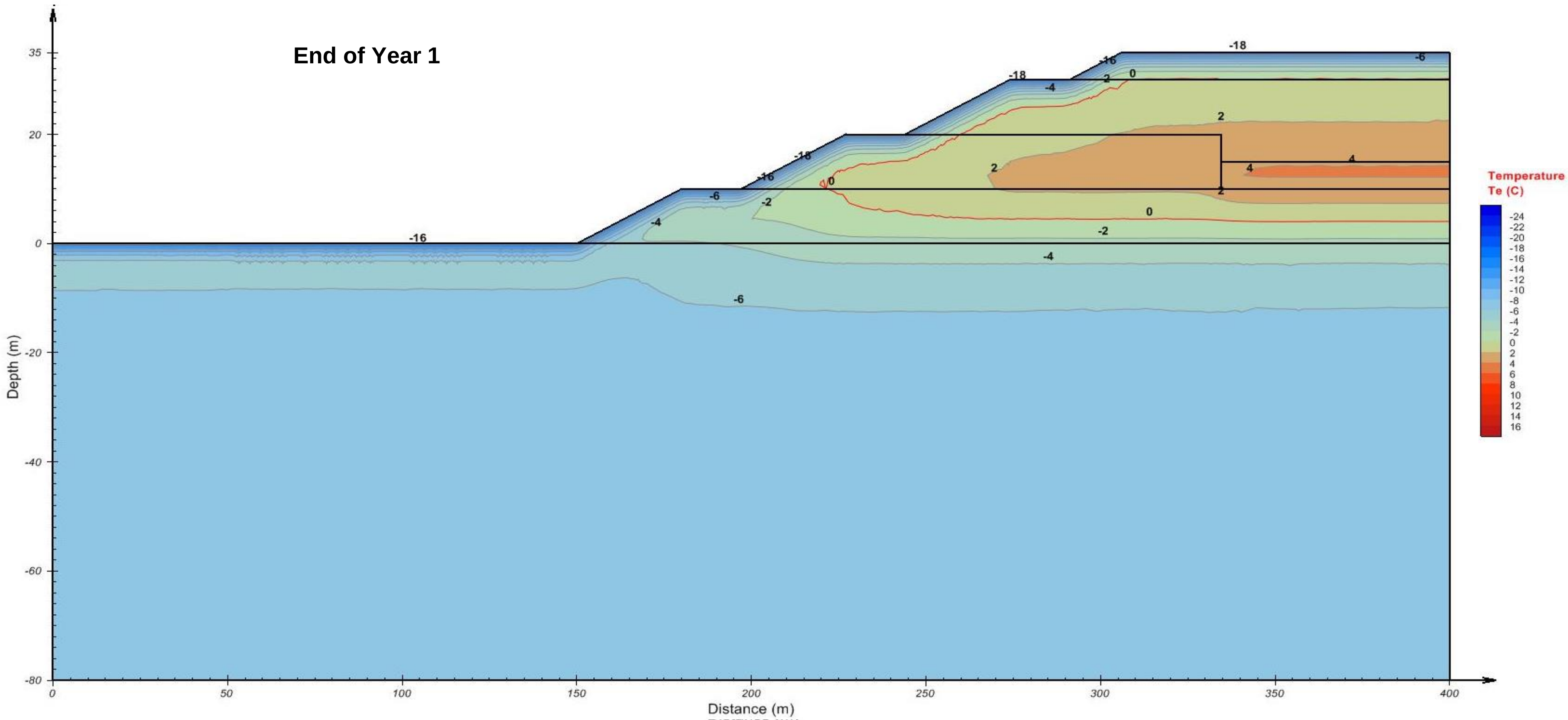
1. Thermal model extends from freeze-up to onset of thaw (1 winter)
2. Initial conditions include 20 m of ROM with initial temperature +3°C at start of freeze-up
3. ROM material degree of saturation 30%
4. ROM freezing n-factor of 0.7 and thawing n-factor 1.0
5. 0°C isotherm shown with solid red line

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		WRSA Temperature – Freezeback 20 m of Waste Rock
Job No: 1CS020.008 Filename: WRSA_Model20mLiftFreezeback.pptx	BACK RIVER PROJECT	Date: 11/1/2015 | Approved: cws | Figure: 5



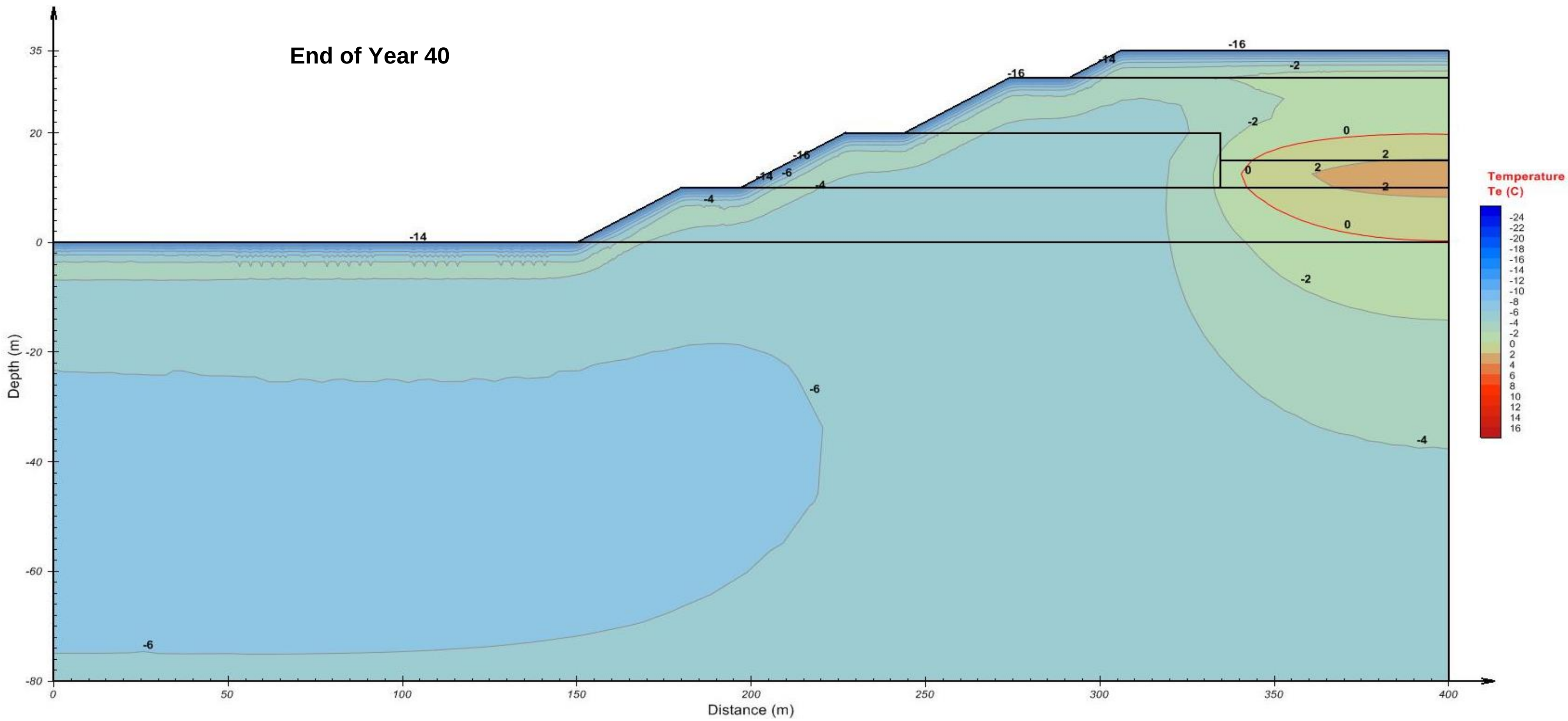
Note:
1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.0
3. 10% of PAG Waste Rock assumed to be generating heat (constant rate over time)

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model **Heat Generation Model Space**		
Job No: 1CS020.008 Filename: WRSA_HeatGeneration10%.pptx	BACK RIVER PROJECT	Date: 11/6/2015	Approved: cws	Figure: 6



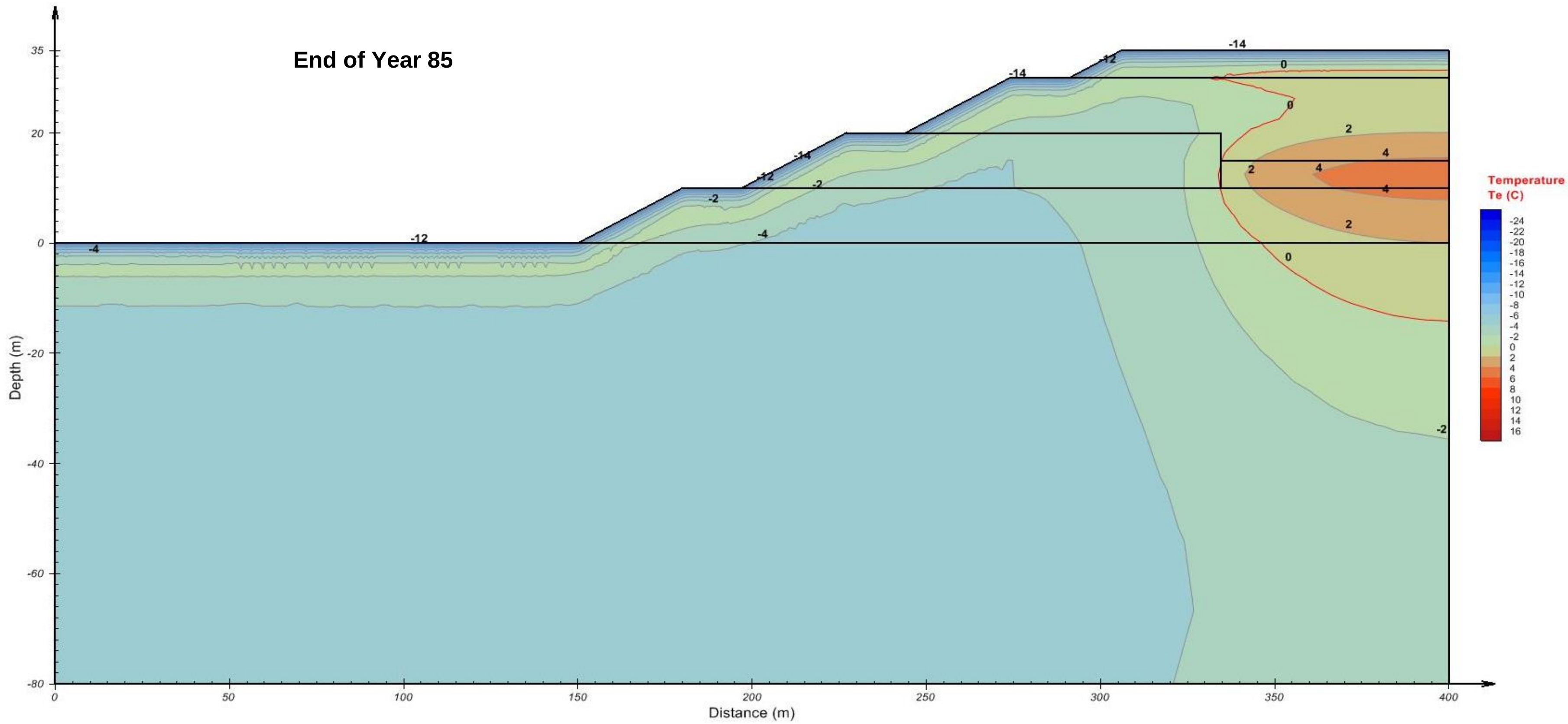
Note:
1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.3
3. 0°C isotherm shown with solid red line
4. 10% of PAG Waste Rock assumed to be generating heat (constant rate over time)

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		Heat Generation (10% PAG) – End of Year 1
Job No: 1CS020.008 Filename: WRSA_HeatGeneration10%_Year1.pptx	BACK RIVER PROJECT	Date: 11/6/2015 · Approved: cws · Figure: 7



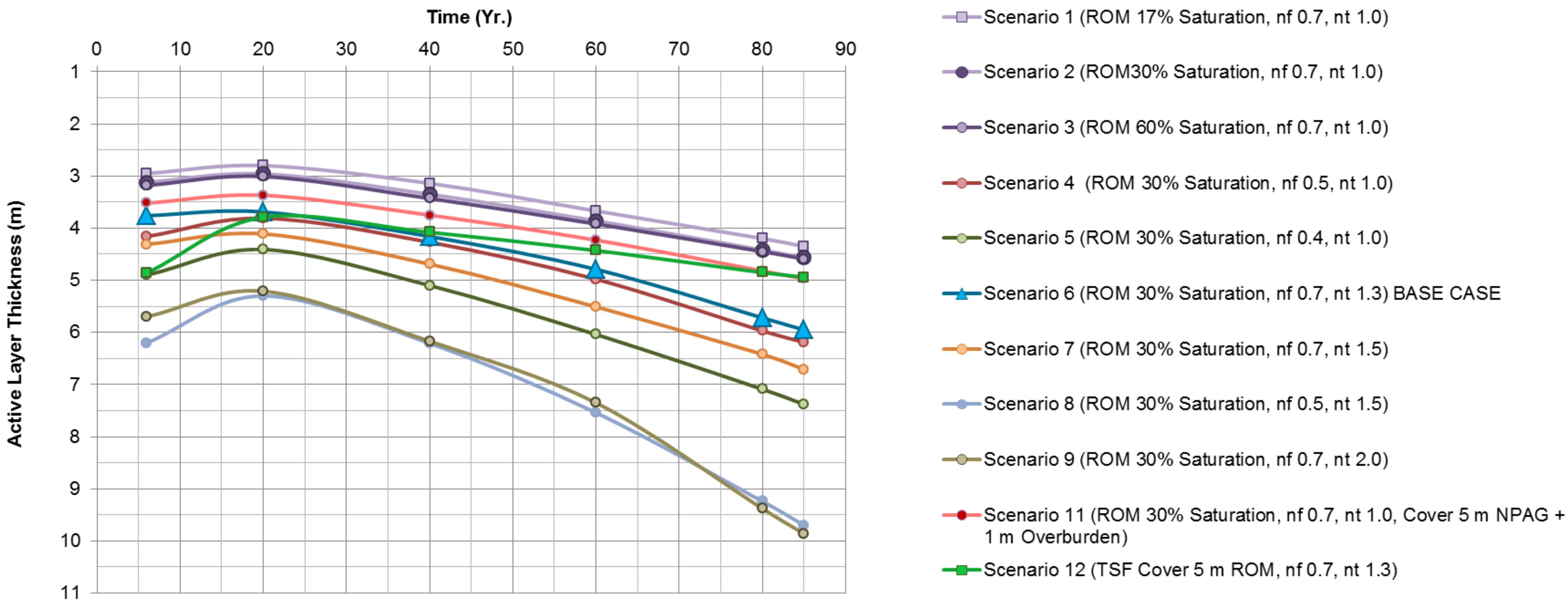
Note:
1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.3
3. 0°C isotherm shown with solid red line
4. 10% of PAG Waste Rock assumed to be generating heat (constant rate over time)

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model		
		Heat Generation (10% PAG) – End of Year 40		
Job No: 1CS020.008 Filename: WRSA_HeatGeneration10%_Year40.pptx	BACK RIVER PROJECT	Date: 11/6/2015	Approved: CWS	Figure: 8



Note:
1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.3
3. 0°C isotherm shown with solid red line
4. 10% of PAG Waste Rock assumed to be generating heat (constant rate over time)

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		Heat Generation (10% PAG) – End of Year 85
Job No: 1CS020.008 Filename: WRSA_HeatGeneration10%_Year40.pptx	BACK RIVER PROJECT	Date: 11/6/2015 · Approved: cws · Figure: 9



Note:

1. Active layer depth following freezeback of WRSA
2. ROM – Run of Mine material with varying degree of saturation
3. nf – freezing n-factor
4. nt – thawing n-factor

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
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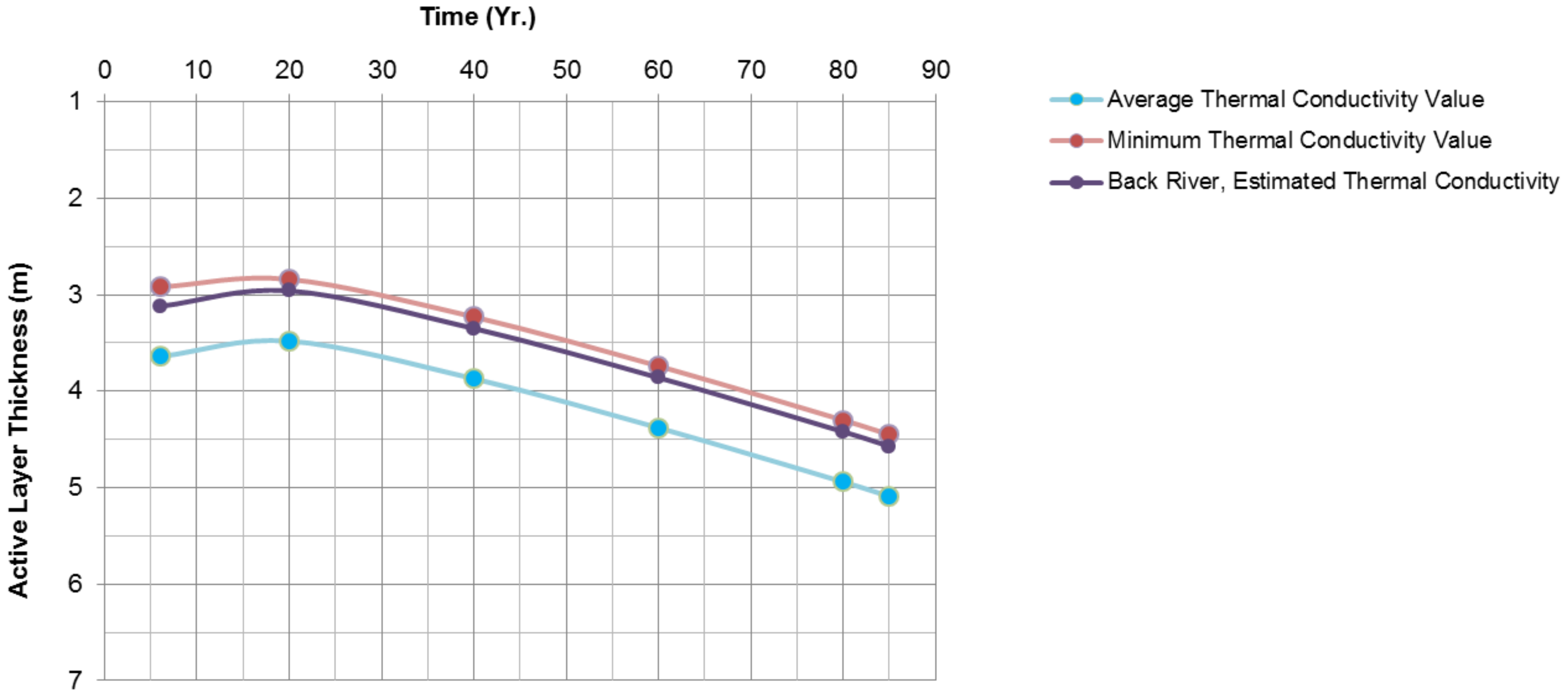
Job No: 1CS020.008 Filename: WRSA_ActiveLayer_Estimates.pptx	BACK RIVER PROJECT	Date: 11/1/2015 · Approved: cws · Figure: 10



Note:
1. Active layer depth following freezeback of WRSA
2. ROM – Run of Mine material with 30% of saturation
3. Modeling based on a seasonal freezing factor of 0.7 and thawing factor of 1.0
4. Average thermal conductivity of 132 kJ m^{-1} day^{-1} °C^{-1} based on review of published values for waste rock
5. Minimum thermal conductivity of 105 kJ m^{-1} day^{-1} °C^{-1} based on review of published values for waste rock

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Waste Rock Storage Area Thermal Model

Active Layer – Sensitivity to Thermal Conductivity

Job No: 1CS020.008

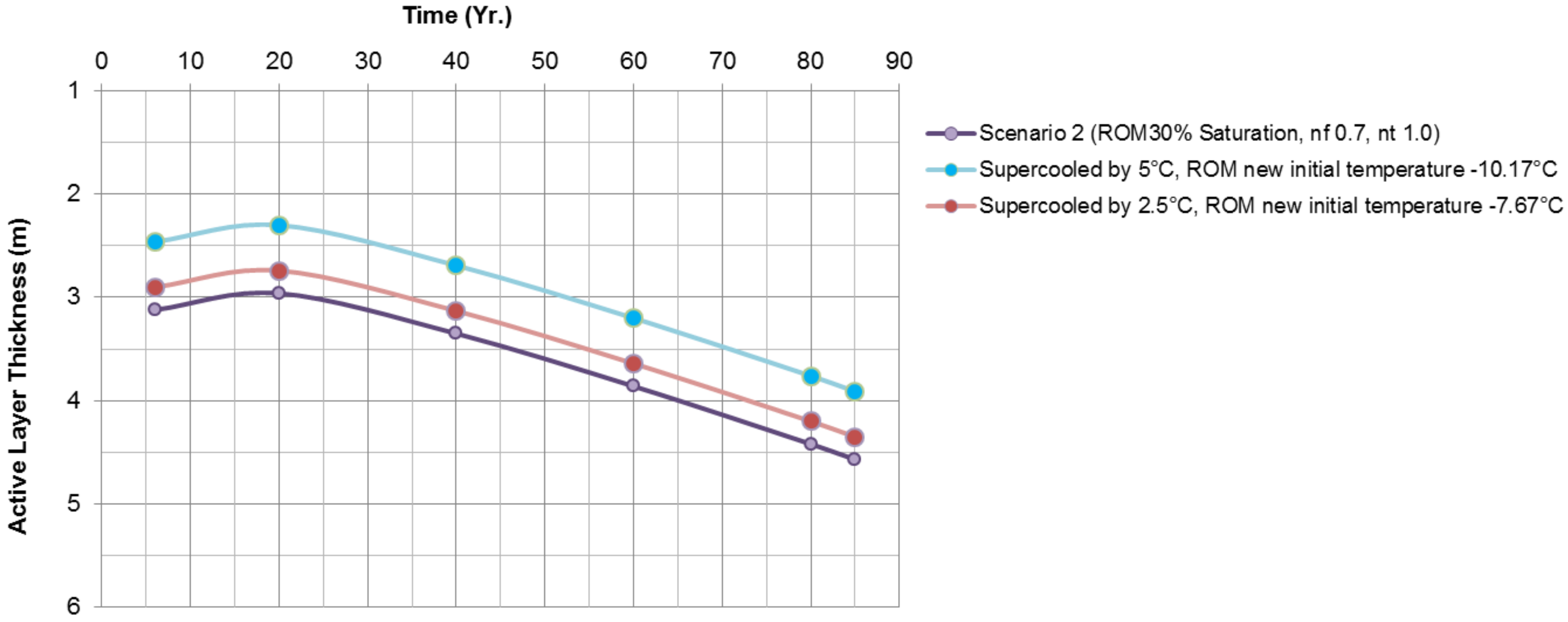
Filename: WRSA_ActiveLayer_SensitivityThermalK.pptx

BACK RIVER PROJECT

Date: 11/1/2015

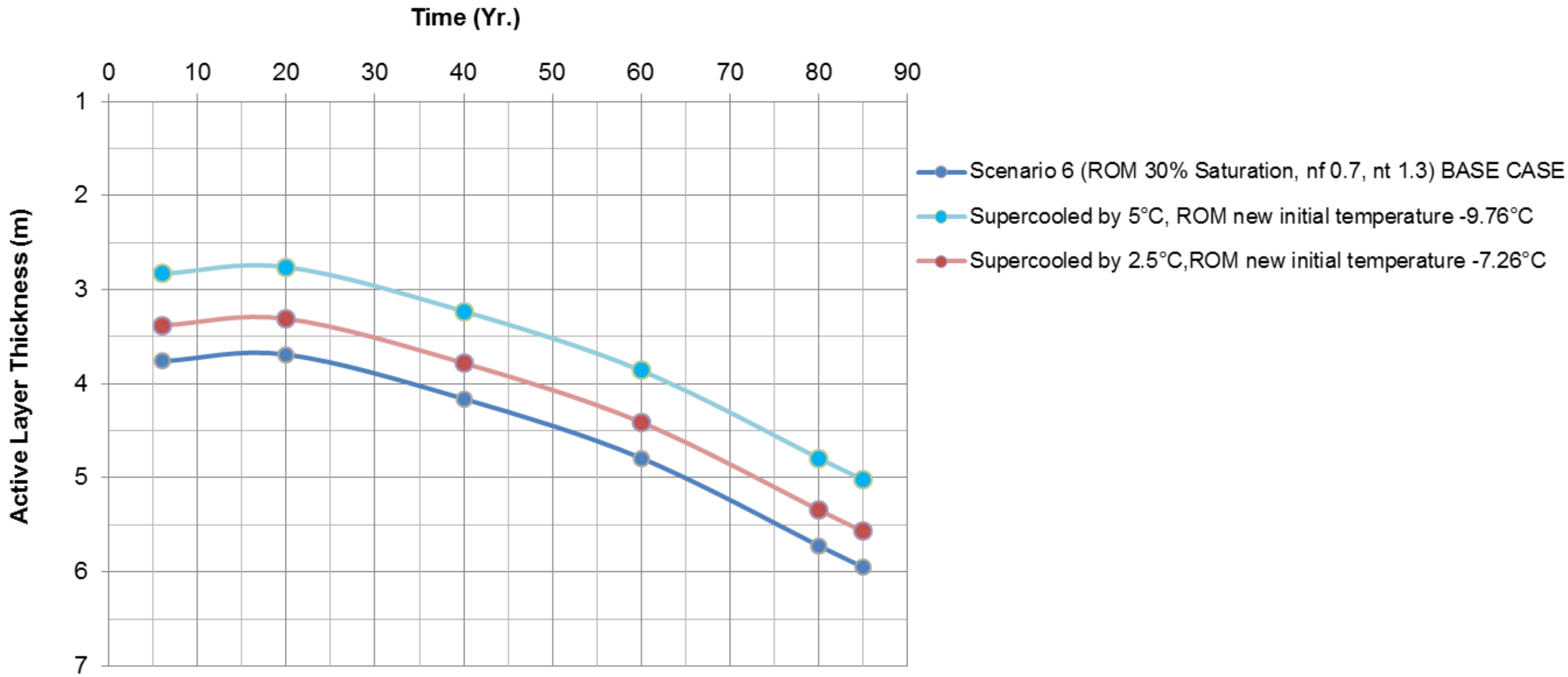
Approved: cws

Figure: 11



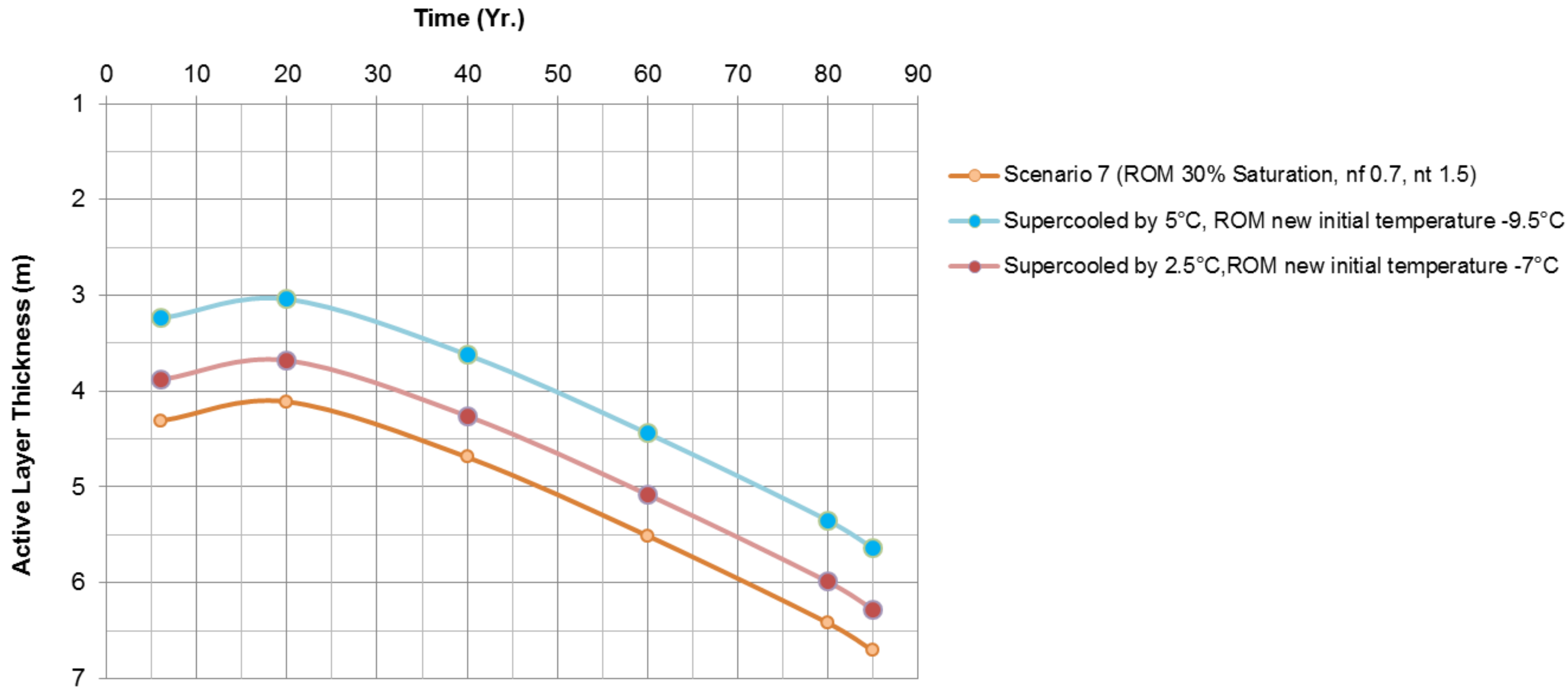
Note:
1. Active layer depth following freezeback of WRSA
2. ROM – Run of Mine material with 30% of saturation
3. nf – freezing n-factor
4. nt – thawing n-factor
5. Supercooled refers to addition cooling expected from natural air-convection

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model **Active Layer – Scenario 2 Supercooled**
Job No: 1CS020.008 Filename: WRSA_ActiveLayer_Estimates.pptx	BACK RIVER PROJECT	Date: 11/1/2015 · Approved: cws · Figure: **12**



Note:
1. Active layer depth following freezeback of WRSA
2. ROM – Run of Mine material with 30% of saturation
3. nf – freezing n-factor
4. nt – thawing n-factor
5. Supercooled refers to addition cooling expected from natural air-convection

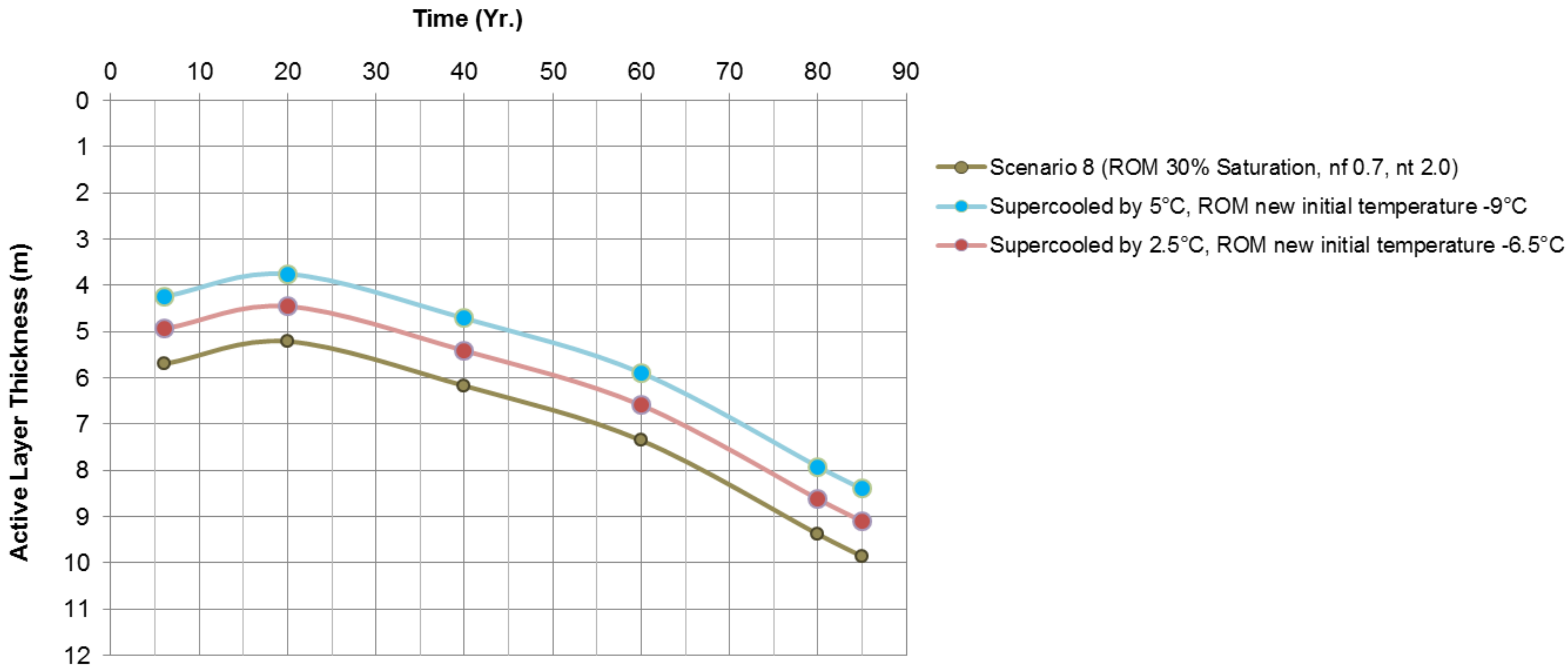
srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model **Active Layer – Scenario 6 Supercooled**
Job No: 1CS020.008 Filename: WRSA_ActiveLayer_Estimates.pptx	BACK RIVER PROJECT	Date: 11/1/2015 · Approved: cws · Figure: **13**



Note:

1. Active layer depth following freezeback of WRSA
2. ROM – Run of Mine material with 30% of saturation
3. nf – freezing n-factor
4. nt – thawing n-factor
5. Supercooled refers to addition cooling expected from natural air-convection

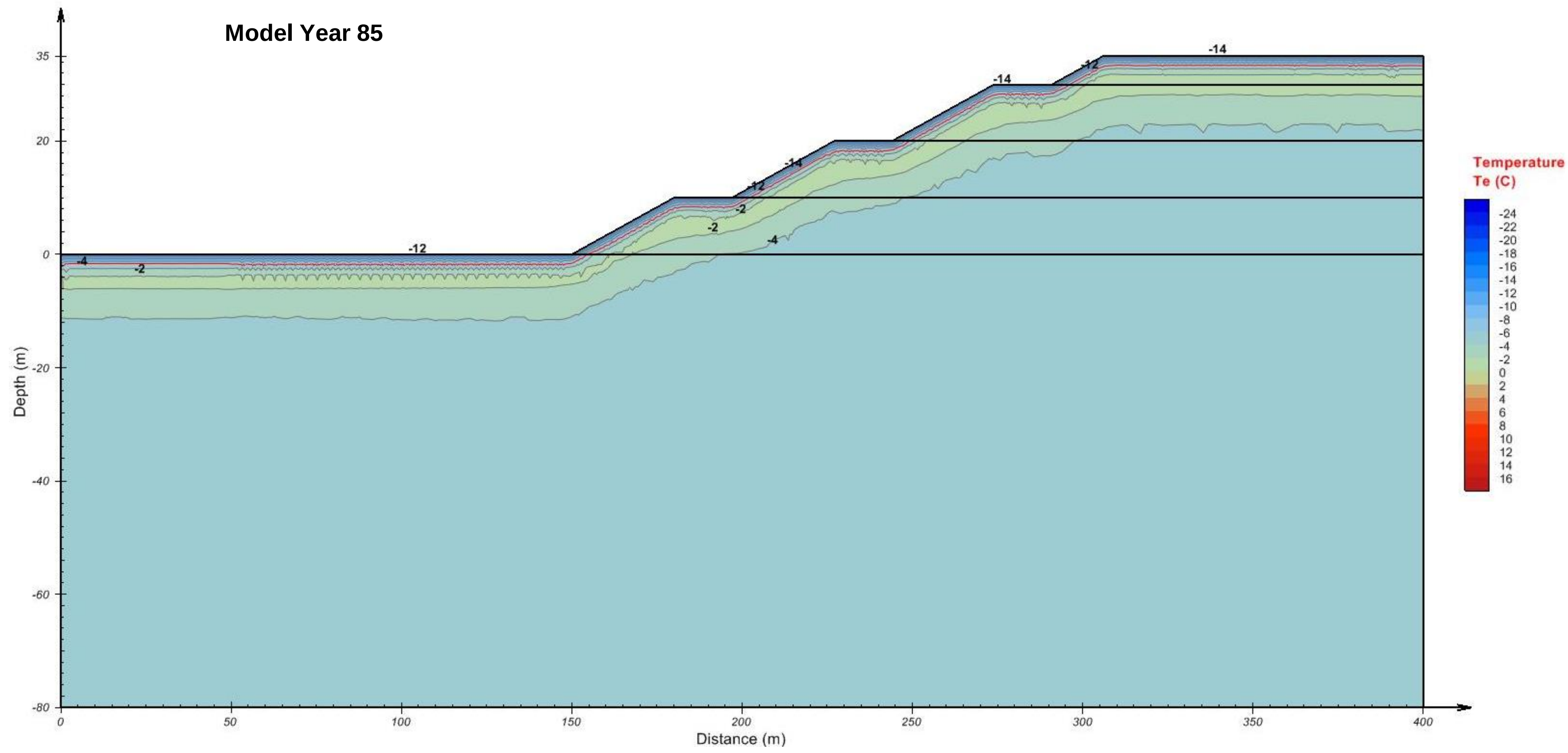
srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		Active Layer – Scenario 7 Supercooled
Job No: 1CS020.008 Filename: WRSA_ActiveLayer_Estimates.pptx	BACK RIVER PROJECT	Date: 11/1/2015 | Approved: cws | Figure: **14**



Note:

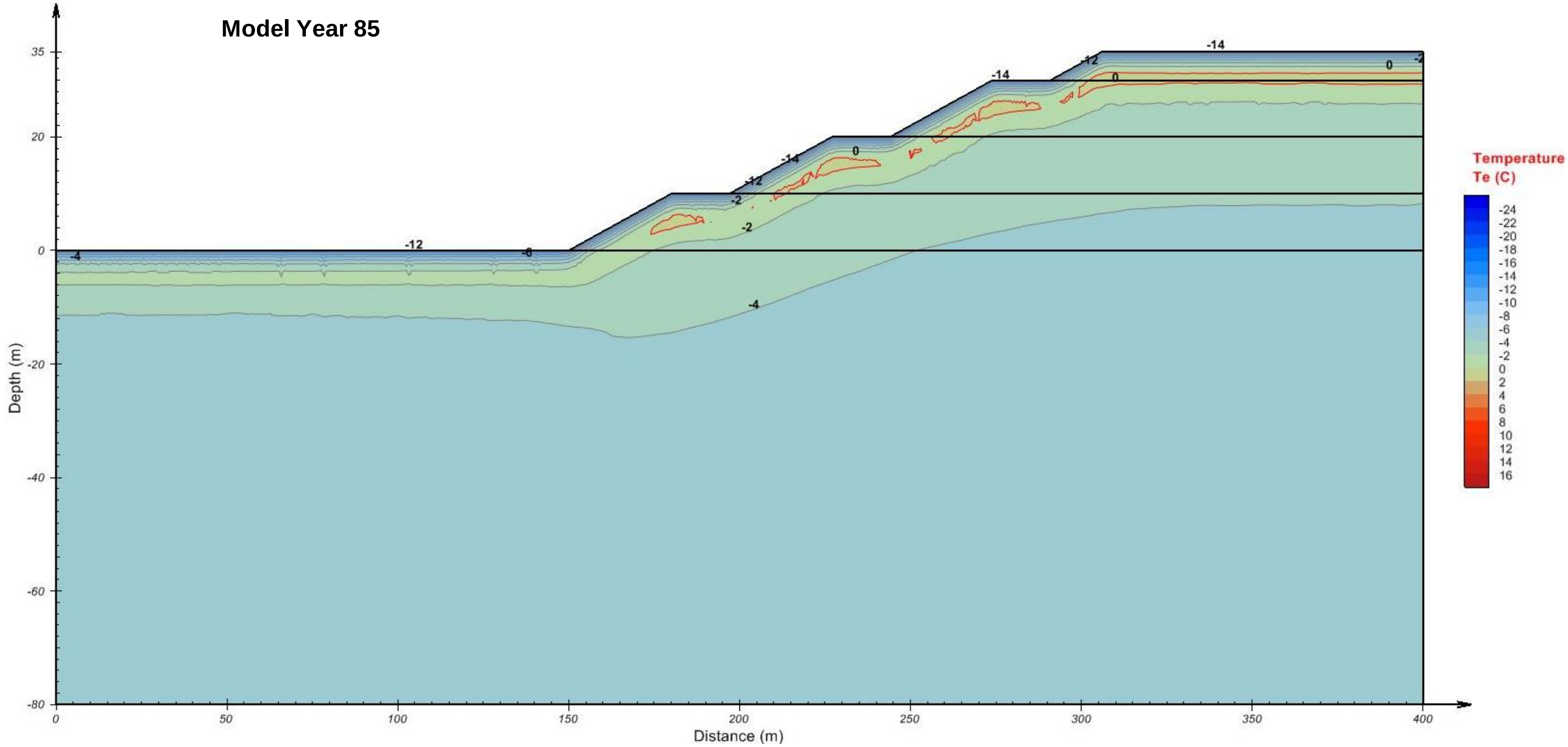
1. Active layer depth following freezeback of WRSA
2. ROM – Run of Mine material with 30% of saturation
3. nf – freezing n-factor
4. nt – thawing n-factor
5. Supercooled refers to addition cooling expected from natural air-convection

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		Active Layer – Scenario 8 Supercooled
Job No: 1CS020.008 Filename: WRSA_ActiveLayer_Estimates.pptx	BACK RIVER PROJECT	Date: 11/1/2015 · Approved: cws · Figure: **15**



Note:
1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.0
3. Red solid line indicates 0°C isotherm, maximum active layer not shown

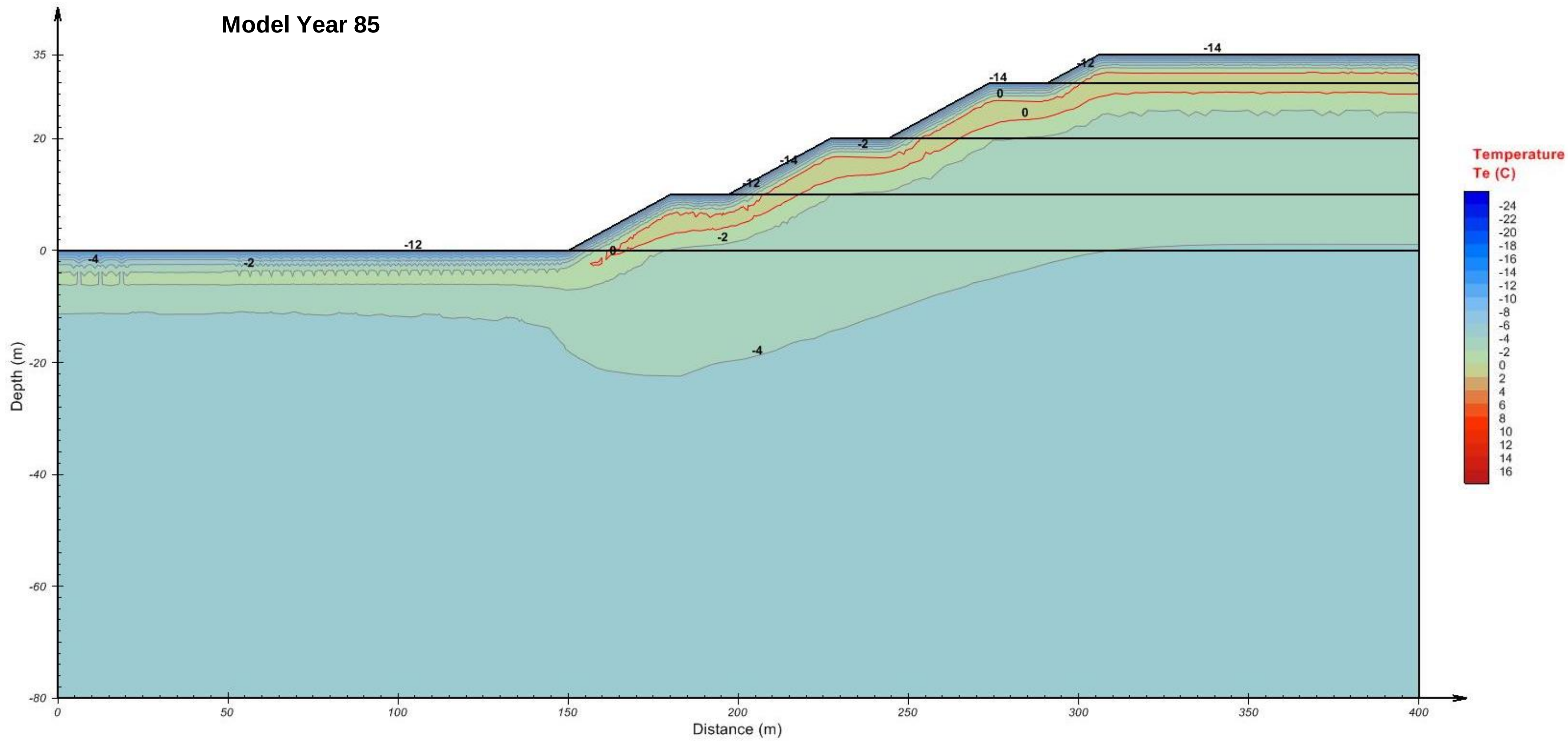
srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model **WRSA Temperature – 85 Years (Model Scenario 3)**
Job No: 1CS020.008 Filename: WRSA_ModelYr85_Sat30_Nf0.7Nt1.0.pptx	BACK RIVER PROJECT	Date: 11/4/2015 · Approved: cws · Figure: **16**



Note:

1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.3
3. Red solid line indicates 0°C isotherm, maximum active layer not shown

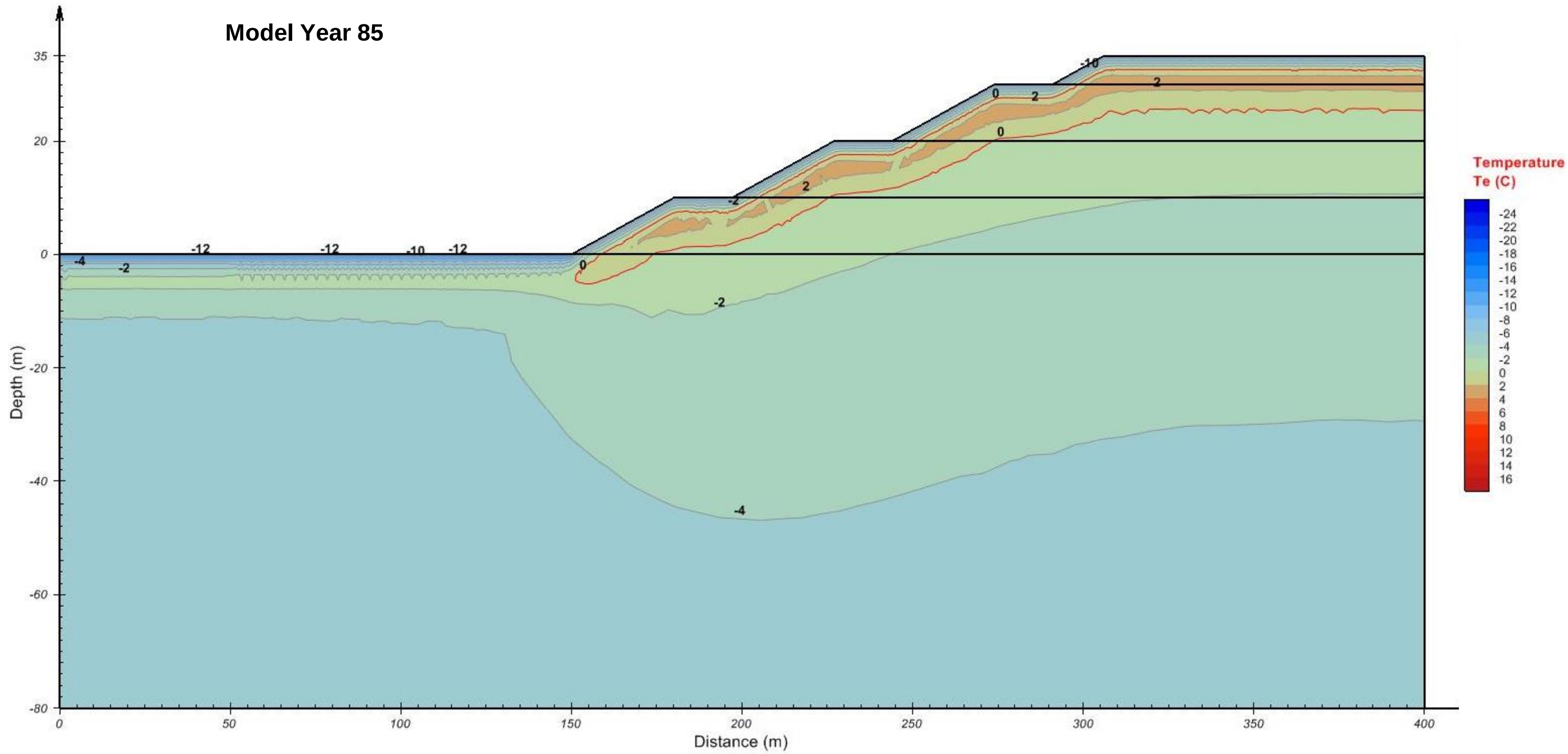
srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		WRSA Temperature – 85 Years (Model Scenario 6)
Job No: 1CS020.008 Filename: WRSA_ModelYr85_Sat30_Nf0.7Nt1.3.pptx	BACK RIVER PROJECT	Date: 11/4/2015 · Approved: cws · Figure: **17**



Note:

1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.7 and thawing n-factor 1.5
3. Red solid line indicates 0°C isotherm, maximum active layer not shown

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		WRSA Temperature – 85 Years (Model Scenario 7)
Job No: 1CS020.008 Filename: WRSA_ModelYr85_Sat30_Nf0.7Nt1.5.pptx	BACK RIVER PROJECT	Date: 11/4/2015 Approved: cws Figure: **18**



Note:
1. ROM material degree of saturation 30%
2. ROM freezing n-factor of 0.5 and thawing n-factor 1.5
3. Red solid line indicates 0°C isotherm, maximum active layer not shown

srk consulting	Sabina GOLD & SILVER CORP	Waste Rock Storage Area Thermal Model
		WRSA Temperature – 85 Years (Model Scenario 8)
Job No: 1CS020.008 Filename: WRSA_ModelYr85_Sat30_Nf0.5Nt1.5.pptx	BACK RIVER PROJECT	Date: 11/4/2015 · Approved: cws · Figure: **19**

Attachment B
Waste Rock Storage Area Stability Analysis

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Memo

To:	Project File	**Client:**	Sabina Gold & Silver Corp.
From:	Sam Amiralaei, EIT	**Project No:**	1CS020.008
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	November 6, 2015
Subject:	Back River Project: Waste Rock Storage Area Stability Analysis – Final		

1 Introduction

1.1 General

SRK Consulting (Canada) Inc. is providing engineering services for Sabina Gold & Silver Corp's. Back River Property (the Property). The Back River Project (the Project) consists of a series of open pit and underground mines at the Goose Property. The Property is located approximately 520 km northeast of Yellowknife and 130 km southwest of Bathurst Inlet in the western Kitikmeot Region of Nunavut, Canada.

1.2 Objective

SRK has analyzed the short and long term stability of the four proposed waste rock storage areas (WRSAs) located at the Goose Property (Llama, Umwelt, Echo, and Goose Main).

The British Columbia Guidelines for Mined Rock and Overburden Piles (BCMDC 1991) suggests the waste rock piles should meet minimum design values for Factors of Safety (FoS) as presented in Table 1. These guidelines are used as there are no equivalent Nunavut or Federal guidelines. The ranges in FoS, for Cases A and B, reflect the different levels of confidence in understanding site conditions, material parameters, and consequences of instability. The main objective for conducting the stability analyses for the WRSAs was to confirm the waste rock piles design meets these FoS guidelines.

Table 1: British Columbia British Columbia Guidelines for Mined Rock and Overburden Piles (BCMDC 1991) Factor of Safety Guidelines

Stability Condition	Suggested Minimum Design Values for Factor of Safety	
	Case A	Case B
Stability of Waste Rock Pile Surface		
Short-term (during construction) - (Stability Condition 1)	1.0	1.0
Long-term (reclamation – abandonment) – (Stability Condition 2)	1.2	1.1
Overall Waste Rock Pile Stability		
Short-term (static) – (Stability Condition 3)	1.3 - 1.5	1.1 - 1.3
Long-term (static) – (Stability Condition 4)	1.5	1.3
Pseudo-Static (earthquake)[2]	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)		

Notes:
1. A range of suggested minimum design values are given to reflect different levels of confidence in understanding site conditions, material parameters, consequences of instability, and other factors.
2. Where pseudo-static analyses, based on peak ground accelerations which have a 10% probability of exceedance in 50 years, yield F.O.S. < 1.0, dynamic analysis of stress-strain response, and comparison of results with stress-strain characteristics of dump materials is recommended.

2 Slope Stability Assessment

2.1 Material Properties

Geotechnical characterization at the WRSA locations shows bedrock near surface with a thin layer of sandy overburden. The upper few meters of bedrock is frost shattered, with competent bedrock beneath (SRK 2015). Typical overburden and waste rock properties for the Property are presented in Table 2.

Table 2: Typical Overburden Material Properties Summarized from SRK (2015)

Parameter		Overburden (Silty Sand)	Waste Rock
Moist Unit Weight (kN/m^3)		19 (average)	20
Degree of Saturation (%)		67 (average)	30
Porosity, n		0.36 (average)	0.3
Volumetric Water Content		0.28 (average)	0.09
Frozen	Apparent Cohesion, c' (kPa)	24	0
	Friction Angle, ϕ (^{o})	33	38
Unfrozen	Apparent Cohesion, c' (kPa)	49	5
	Friction Angle, ϕ (^{o})	32	38

Source: J:\01_SITES\Back River\1CS020.006_FS_Study\Task 2100_Overburden_Geotechnical\Task 2130_GeotechDesignParameters\Text\GeotechDesignParameters_DRAFT_Report_1CS020-006-2410_EH_LW_EMR_RevB

2.2 Regional Seismicity

The Goose Property is located in a low seismicity zone. Seismic parameters were calculated using the National Building Code of Canada's website (NRCC 2014a) which provides ground accelerations and probability of occurrence. At both of the properties, the peak ground acceleration (PGA), at a set spectral acceleration, are the same and are summarized in Table 3. The seismic hazard is described by spectral acceleration (Sa) values at periods of 0.2, 0.5, 1.0 and 2.0 seconds. The PGA value of 0.036, corresponding to the 1:2,500 year event, was used in the stability analysis.

Table 3: Back River Property Seismic Hazard Values

Spectral Acceleration	Ground Motion (g)
$Sa_{(0.2)}$	0.095
$Sa_{(0.5)}$	0.057
$Sa_{(1.0)}$	0.026
$Sa_{(2.0)}$	0.008
PGA	0.036

2.3 Model Setup

A slope stability model for each of the four WRSAs was set up in SLOPE/W, a limit equilibrium slope stability analysis software tool developed by GEO-SLOPE International Ltd (Geoslope 2007). The software is commonly used to compute the FoS of earth and rock slopes.

Table 4 summarizes the material properties used in the analyses. For the stability analyses, the overburden material and the WRSAs were conservatively assumed to be unfrozen. This is conservative since in the long term, freeze back will occur in both the waste rock pile and its foundation.

A critical cross-section through each WRSA, based on the ultimate WRSA height and slope, was selected to create the model used to run the analyses (Figure 1). The cross-sectional views of the critical sections are shown in Figure 2.

Table 4: Summary of Material Properties used in the Analysis

Material	Unit Weight (kN/m^3)	Friction Angle (°)	Cohesion (kN)
Overburden (Silty Sand)	18	33	0
Waste Rock	20	38	0

2.4 Methodology

The stability of the WRSAs was analyzed with consideration of haul truck wheel loads applied near the crest. The loaded Caterpillar 785D was assumed to be the heaviest vehicle driving on the WRSAs. The wheel loading calculation for the 785D haul truck is included as Attachment 1. For analysis purposes, the wheel loading was applied at a minimum of 7 m to the crest of the WRSA. Following completion of this analysis, the mining fleet was reduced to Caterpillar 775G trucks. These trucks are smaller and therefore the analysis remains valid, although extremely conservative.

The slope stability of the WRSAs was evaluated under four stability conditions, listed in Table 1. The following five stability analyses were evaluated:

- Short-term (during construction) (Stability Conditions 1 and 3): Stability Condition 1 considers the stability of the WRSA surface with the truck loading applied near the crest of the WRSA. Stability Condition 2 considers the overall stability of the WRSA with the truck loading also applied near the crest of the WRSA.
- Long-term (reclamation/abandonment/static) (Stability Conditions 2 and 4): These stability cases consider the stability of the WRSA surface and the overall stability without the haul truck wheel loads applied.
- Long-term (pseudo-static) (Stability Conditions 5): For pseudo-static analysis, a horizontal seismic load coefficient of 0.036 (equal to the PGA) was applied to the model and the overall stability of the WRSA was analyzed.

The slope stability analyses were carried out using the Spencer Limit Equilibrium Method (Spencer's Method) and the results checked using the Morgenstern-Price Limit Equilibrium Method (Morgenstern-Price Method). These limit equilibrium methods satisfy all limit equilibrium conditions. Each differs in its assumptions. Spencer's method makes the least amount of static assumptions while Morgenstern-Price method assumes the side forces follow a prescribed function, side forces can vary from slice to slice (ASCE 2002) and is considered to be more conservative.

To provide confidence in the results, the models were analyzed using three modes of searching for the failure surface:

- grid and radius;
- specified entry and exit locations; and
- fully specified failure surface.

Each analysis mode allowed the slip surface with the lowest FoS to be identified for static and pseudo-static drained (i.e. no excess pore pressure) loading conditions.

3 Results

The summary of the FoS calculated for each stability condition is presented in Table 5; a complete list of results for all stability analyses is provided in Attachment 2. Since limited foundation characterization data is available, the FoS were compared to the Case A recommendations of Table 1. As shown in Table 5, the FoS for all of the WRSAs exceed Case A minimum requirements, which is the more conservative case between Case A and B.

Table 5: Summary of Stability Analysis Results

Name of Facility	Stability Condition	Search Function	Suggested Minimum Design Values for FoS		Calculated FoS
			Case A	Case B	
Llama WRSA	Condition 1	Fully Specified	1.0	1.0	1.3
	Condition 2	Grid and Radius	1.2	1.1	1.5
	Condition 3	Enter and Exit	1.3-1.5	1.1-1.3	2.2
	Condition 4	Grid and Radius	1.5	1.3	2.2
	Condition 5	Grid and Radius	1.1-1.3	1.0	2.0
Umwelt WRSA	Condition 1	Grid and Radius	1.0	1.0	1.2
	Condition 2	Grid and Radius	1.2	1.1	1.6
	Condition 3	Enter and Exit	1.3-1.5	1.1-1.3	2.3
	Condition 4	Enter and Exit	1.5	1.3	2.5
	Condition 5	Enter and Exit	1.1-1.3	1.0	2.2
Echo WRSA	Condition 1	Enter and Exit	1.0	1.0	1.3
	Condition 2	Enter and Exit	1.2	1.1	1.4
	Condition 3	Fully Specified	1.3-1.5	1.1-1.3	1.6
	Condition 4	Enter and Exit	1.5	1.3	2.4
	Condition 5	Enter and Exit	1.1-1.3	1.0	2.1
TSF WRSA	Condition 1	Enter and Exit	1.0	1.0	1.3
	Condition 2	Enter and Exit	1.2	1.1	1.3
	Condition 3	Fully Specified	1.3-1.5	1.1-1.3	1.7
	Condition 4	Fully Specified	1.5	1.3	2.1
	Condition 5	Fully Specified	1.1-1.3	1.0	1.9

4 Waste Rock Pile Stability Rating

A Dump Stability Rating (DSR) for each of the WRSAs was also completed in accordance with the guidelines set by the British Columbia Mine Waste Rock Pile Research Committee (1991). For frozen foundation conditions, the stability rating for all of the WRSAs are 300 (Class 2 Stability). The details of the DSR are summarized in Attachment 3.

5 Discussion

The results of the slope stability analysis which were evaluated are summarized as follows. These results assume the haul truck wheel loads are applied at 7 m away from the crest of the waste rock piles. It is assumed the haul tucks will unload the waste rock at least 7 m from the crest and a dozer will push the material to the crest.

<u>Short-term (during construction) (Stability Conditions 1 and 3)</u>: The minimum required FoS of 1.0 was met and exceeded for all analyses conducted for the Stability Condition 1. The results of these slope stability analyses indicate the FoS range from 1.2 to 1.3. The FoS for Stability Condition 3 ranges from 1.6 to 2.3, which exceeds the minimum 1.3 to 1.5 FoS recommendations.

Long-term (reclamation/abandonment/static) (Stability Conditions 2 and 4): The stability analyses conducted for Stability Condition 2 had FoS ranging from 1.3 to 1.6, which exceeds the recommended FoS of 1.2. The overall long-term stability of the waste rock piles was analyzed and the FoS resulted from the analyses ranged from 2.1 to 2.5, which again exceeded the recommended 1.5 FoS.

Long-term (pseudo-static) (Stability Conditions 5): The FoS computed for the pseudo-static analysis, simulating the waste rock piles stability during an earthquake event, indicates that the piles are safe in the event with a return period of 1:2,500 years. The FoS for Stability Condition 5 ranged from 1.9 to 2.2, which exceeded the 1.3 recommended values.

6 References

National Research Council of Canada. 2014a. 2010 National Building Code of Canada Seismic hazard calculator. Available at: http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2010-eng.php (Accessed August 4, 2014).Rescan Environmental Services Ltd., 2013b. Back River Project: 2013 Geochemistry Baseline Report. Prepared for Sabina Gold and Silver Corp. Project No. 0194096-0006, March, 2014.

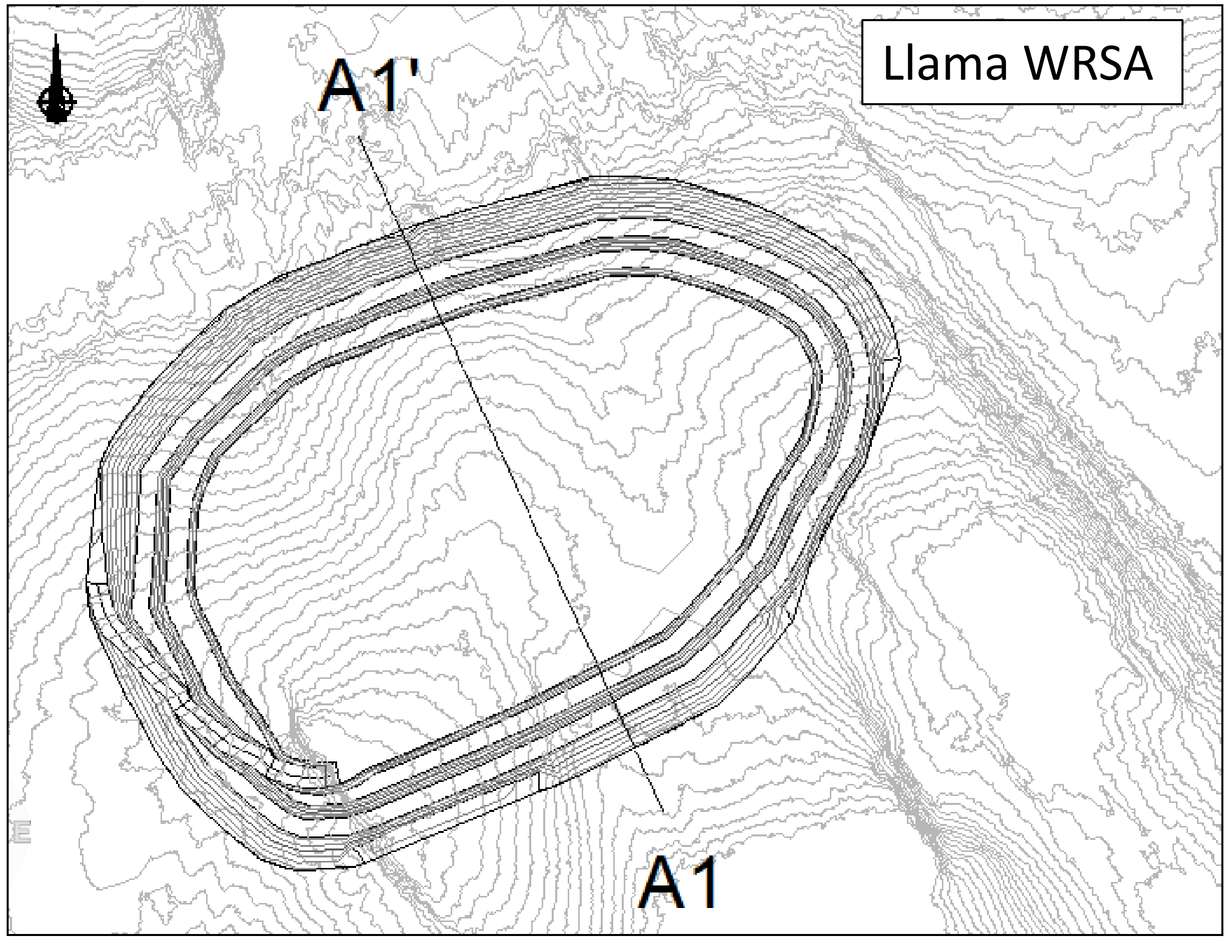
SRK Consulting (Canada) Inc. (2015). Back River Property Geotechnical Design Parameters. Report prepared for Sabina Gold & Silver Corp. Project No. 1CS020.008, November 2015.

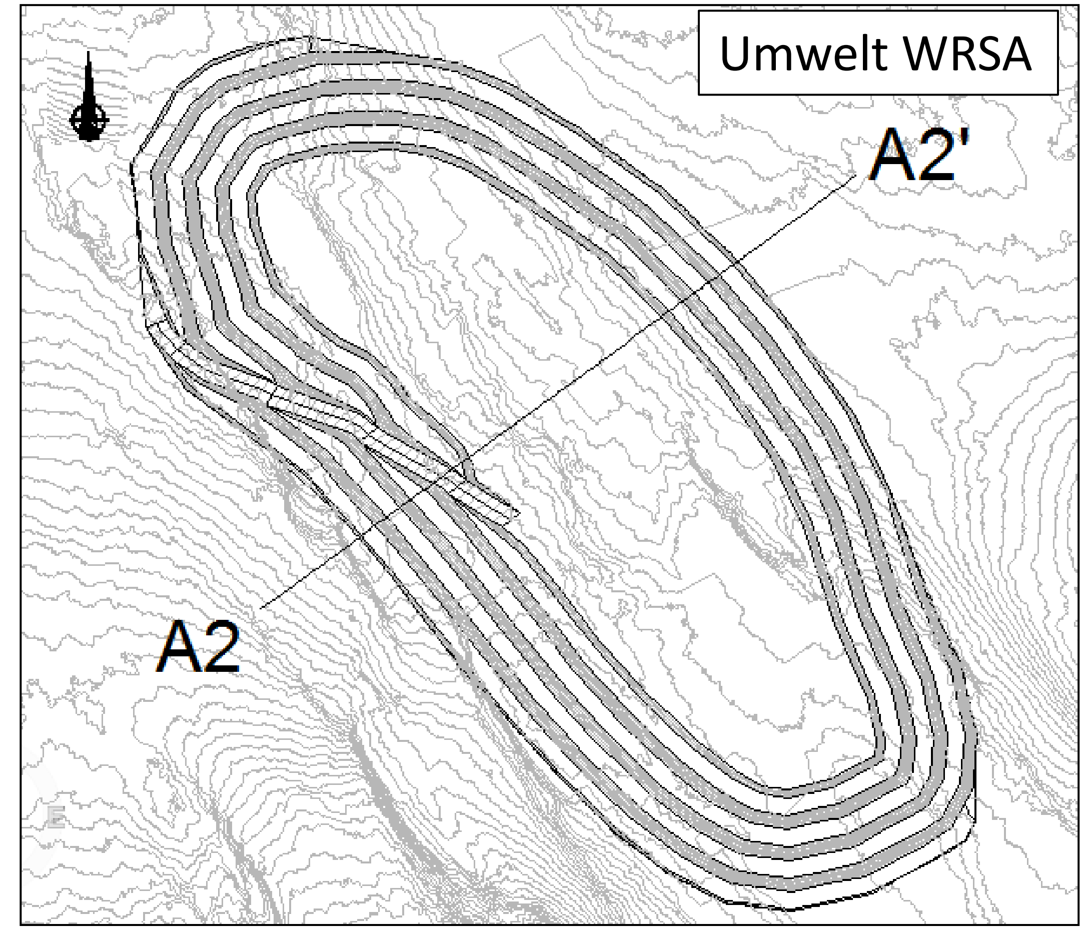
GEO-SLOPE International, Ltd.2007. GeoStudio. 2007 (Version 7.17, Build 4921). Calgary, Alberta.

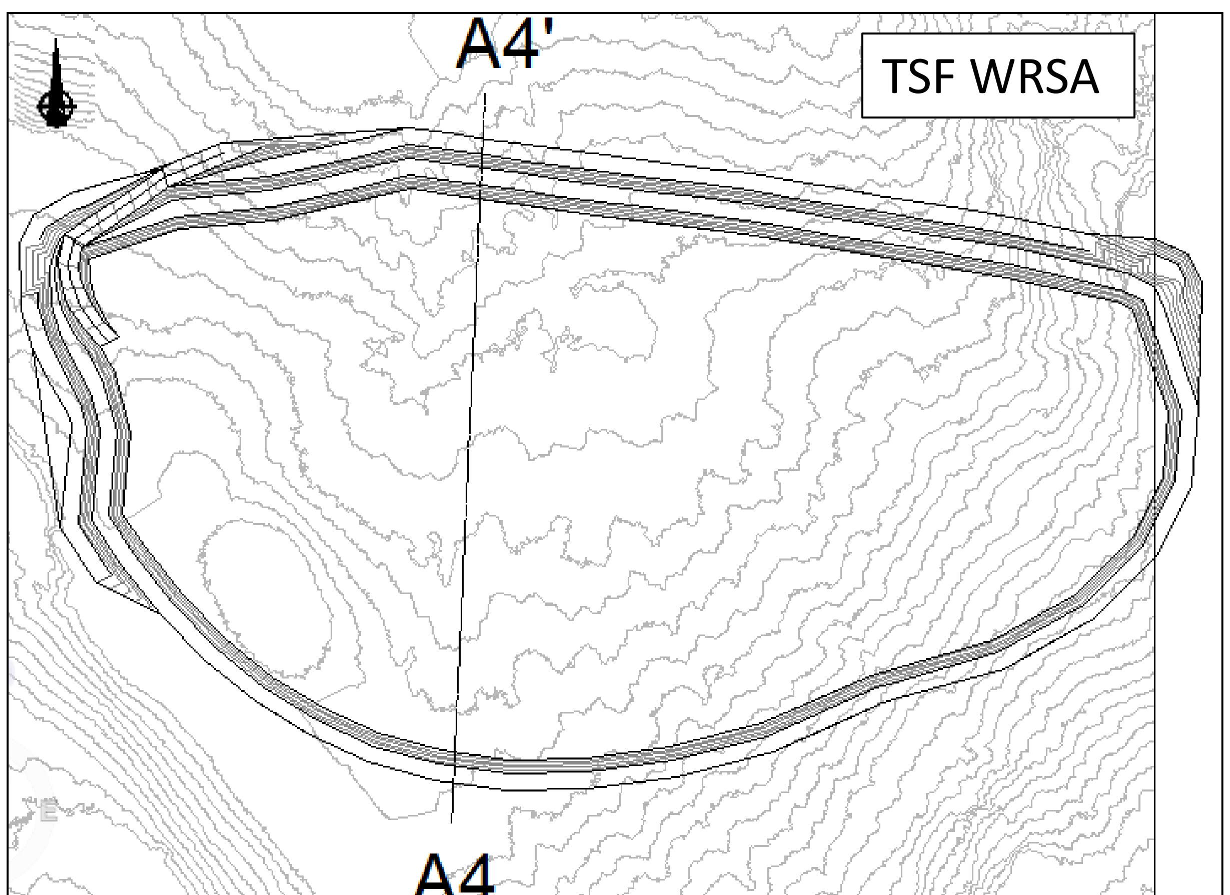
American Society of Civil Engineers, Committee of the ASCE Los Angeles Section Geotechnical Group, 2002. Recommended Procedures for Implementation of DMG Special Publication 117 – Guidelines for Analyzing and Mitigating Landslide Hazards in California.

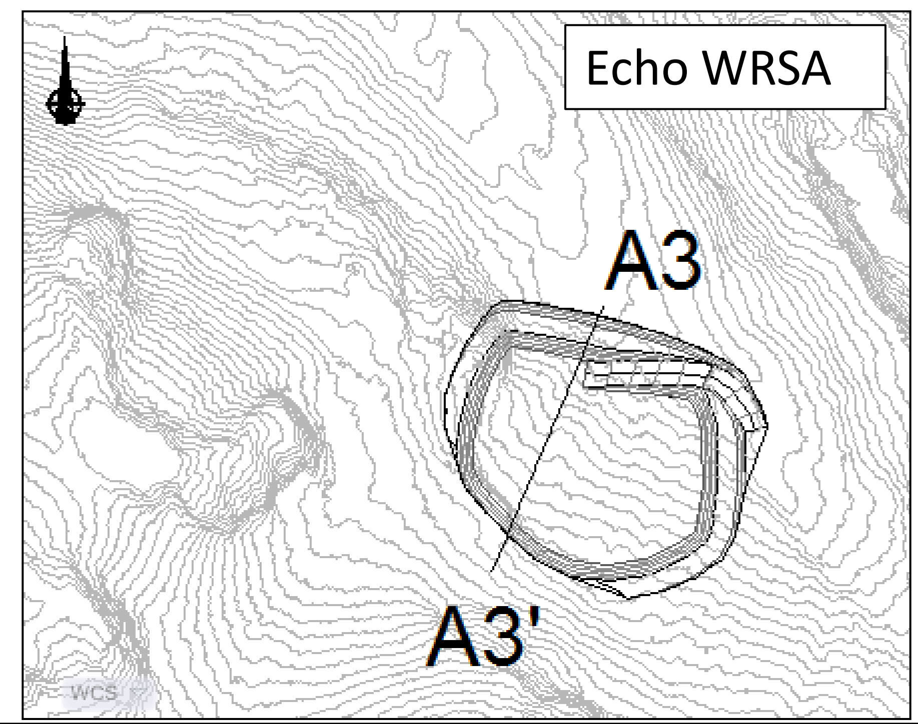
British Columbia Mine Waste Rock Pile Research Committee. 1991. British Columbia Mined Rock and Overburden Piles Investigation and Design Manual, Interim Guidelines. May. ISBN 0- 7718-9118-0.

Figures









srk consulting	Sabina	Back River Project
		Overview of Goose Waste Rock Storage Areas
Job No: 1CS020.006 Filename: Backriver_FS_WasteRockStorageStabilityAnalysis_SA.pptx	**Sabina Gold & Silver Group**	Date: Nov 2015 · Approved: SA · Figure: 1

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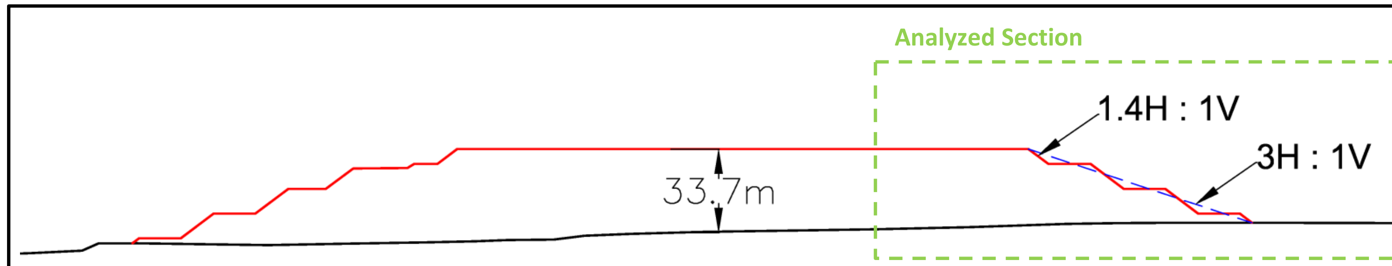
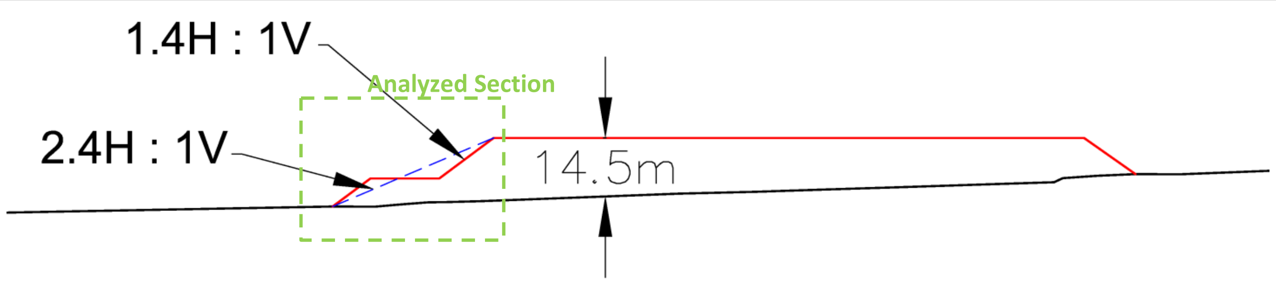
Profile A1-A1'

Llama WRSA Cross-Section



Profile A2-A2'

Umwelt WRSA Cross-Section



Profile A3-3'

Echo WRSA Cross-Section

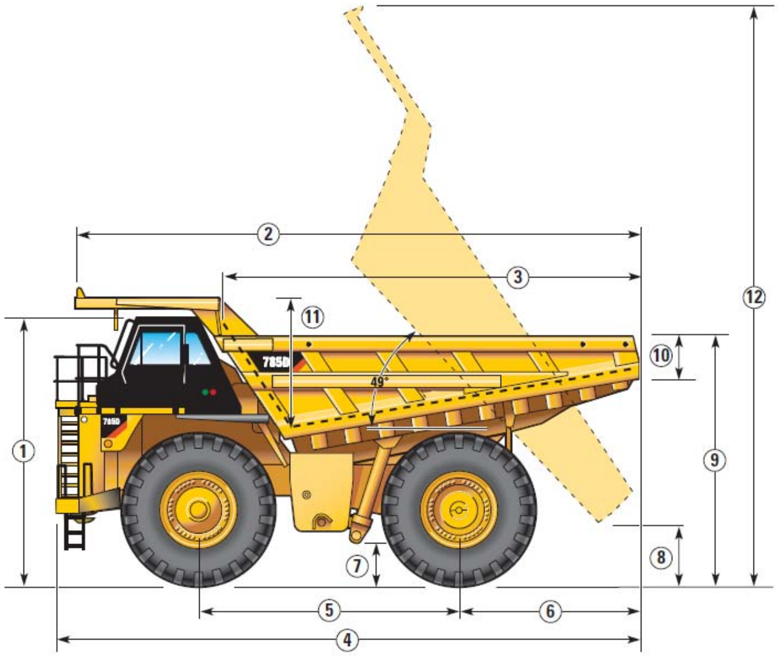
Profile A4-4'

TSF WRSA Cross-Section

srk consulting	Sabina GOLD & SILVER CORP.	Back River Project
		Goose Waste Rock Storage Areas Cross-Sections
Job No: 1CS020.006 Filename: Backriver_FS_WasteRockStorageStabilityAnalysis_SA.pptx	**Sabina Gold & Silver Group**	Date: Nov 2015 | Approved: SA | Figure: **2**

\\VAN-SVR0\Projects\01_SITES\Back River\1CS020.006_FS_Study\080_Deliverables\TSF Design Report\030_Appendices\Waste Rock Pile Stability Analysis\Memo\Figure\BackRiver_FS_WasteRockStorageStabilityAnalysis_SA_Figure 1_Rev01

Attachment 1: Caterpillar 785D Haul Truck Wheel Loads



1	Height to Top of ROPS	5122 mm	16 ft 10 in
2	Overall Body Length	11 550 mm	37 ft 9 in
3	Inside Body Length	7652 mm	25 ft 2 in
4	Overall Length	11 548 mm	37 ft 10 in
5	Wheelbase	5180 mm	17 ft 0 in
6	Rear Axle to Tail	3410 mm	11 ft 3 in
7	Ground Clearance	987 mm	3 ft 3 in
8	Dump Clearance	1200 mm	3 ft 11 in
9	Loading Height – Empty	4968 mm	16 ft 4 in
10	Rear Sidewall Height	906 mm	3 ft 0 in
11	Inside Body Depth – Max.	2132 mm	7 ft 0 in

777G
785D
789D
793D
793F
795F AC
797F

The popular Cat® 785 has b
emissions without comprom
payloads have been maintai
HD engine is Tier 2 emission
maintaining fuel efficiency. D
high production mining and c
the 785D keeps material mo
lower cost per ton.

View Interior 360°
View Exterior 3

Rated Payload	136 tonnes / 150 tons
Engine Model	Cat® 3512C HD
Gross Power - SAEJ1995	1 082 kW / 1,450 hp
Net Power - SAEJ1349	1 005 kW / 1,348 hp
Gross Machine Weight	249 476 kg / 550,000 lb

785D Product Brochure

Weight Distributions – Approximate

Front Axle – Empty*	45-46%
Rear Axle – Empty*	54-55%
Front Axle – Loaded (Target)	33%
Rear Axle – Loaded (Target)	67%

*Depends on body configuration.

Operating Specifications

Top Speed – Loaded	54.8 km/h	34 mph
Steer Angle	36 Degrees	
Turning Diameter – Front	29.8 m	97.7 ft
Machine Clearance Turning Diameter	33.2 m	108.9 ft
Target Payload (Dual Slope)*	133 tonnes	146 tons
Minimum Target Payload	131 tonnes	144 tons
Maximum Target Payload	143 tonnes	157 tons

• Refer to the Cat Mining Truck 10-10-20 payload policy for maximum gross machine weight limitations.

* Includes standard liners.

Caterpillar's 10/10/20 Policy

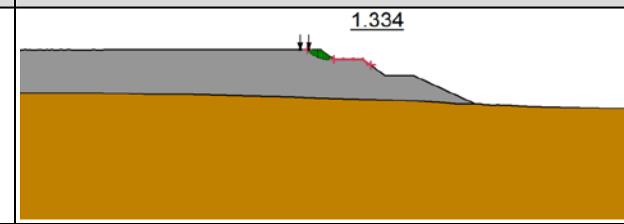
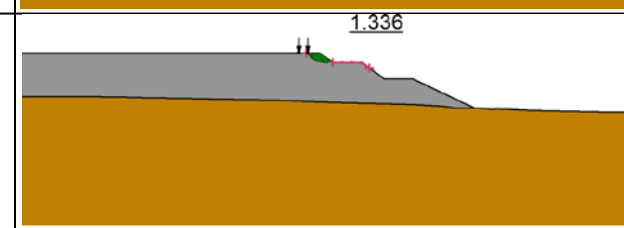
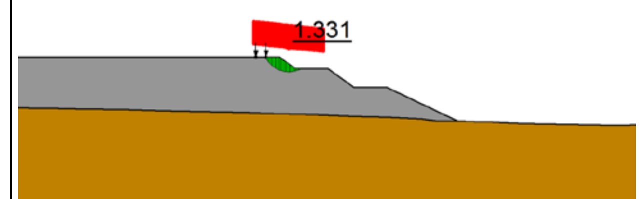
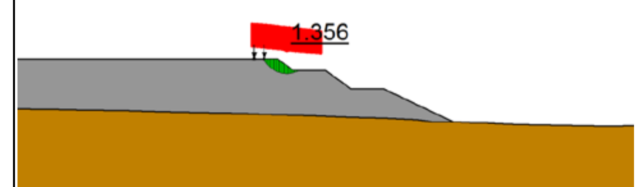
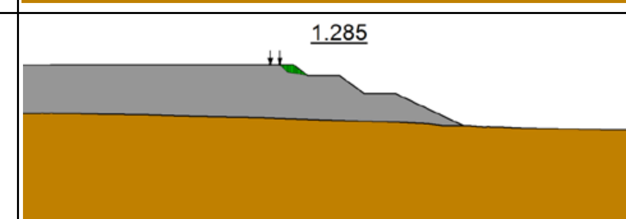
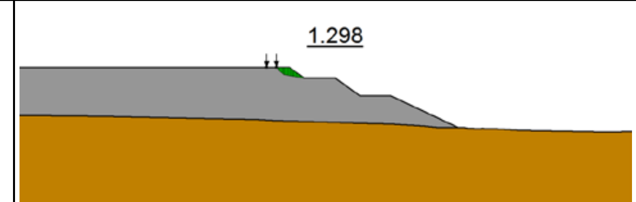
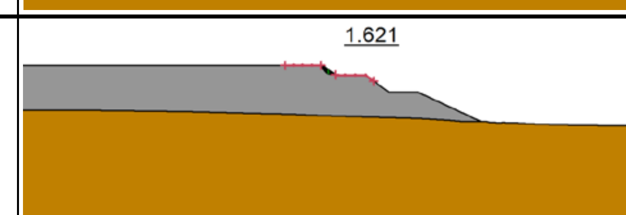
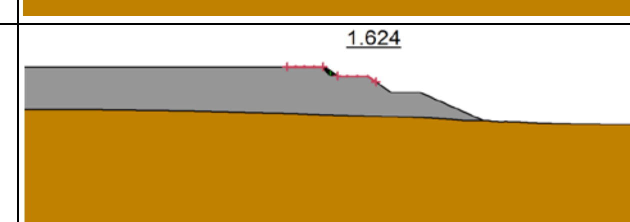
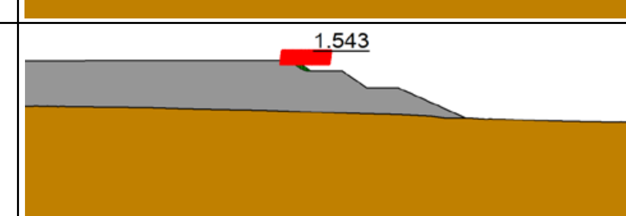
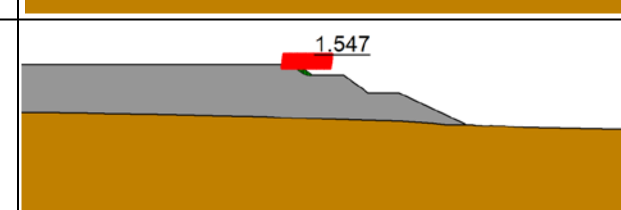
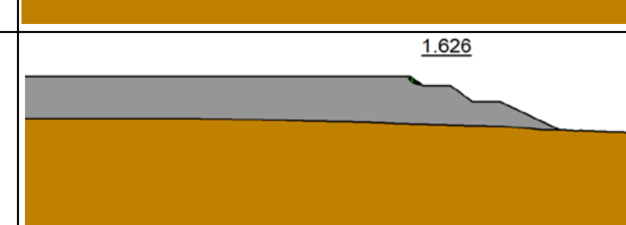
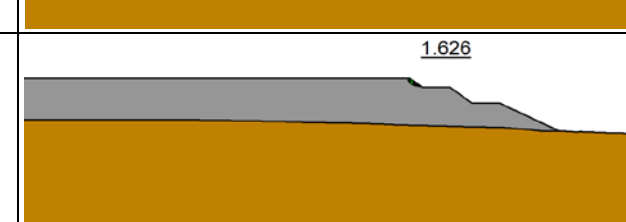
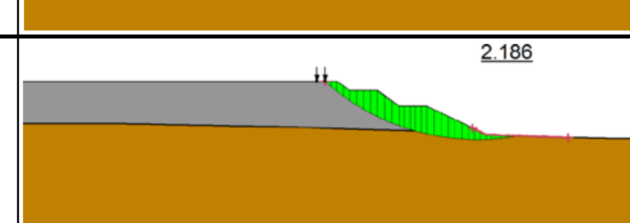
Caterpillar's 10/10/20 Payload Guidelines are in place to help you maximize component life and the availability of your truck. Your Cat dealer can further explain the 10/10/20 policy. For optimum body life, Caterpillar recommends that 110% payloads occur no more than 10% of the time and that the average of all loads equal the nominal payload. Payloads in excess of 120% of nominal exceed the truck's design parameters.

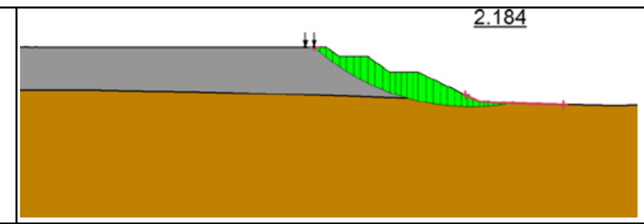
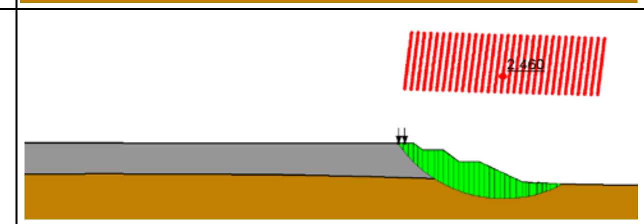
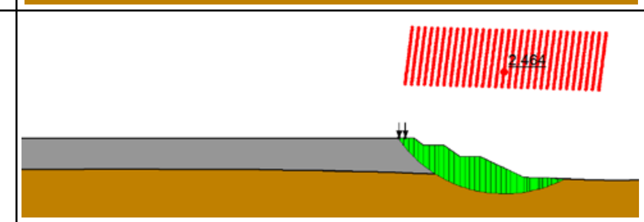
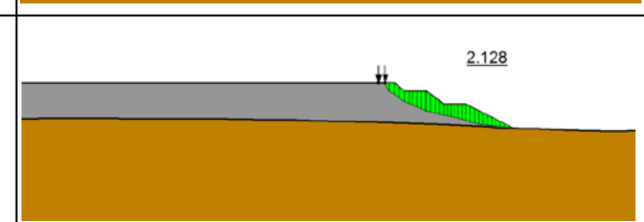
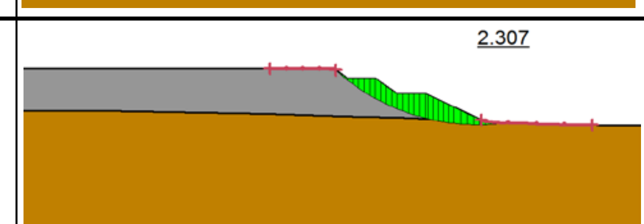
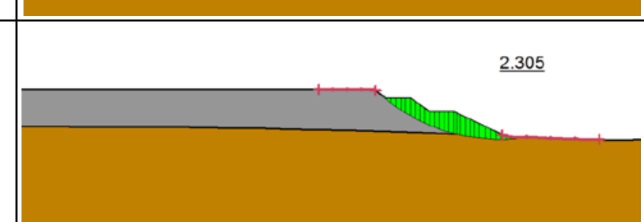
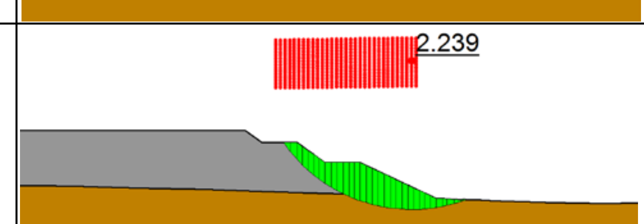
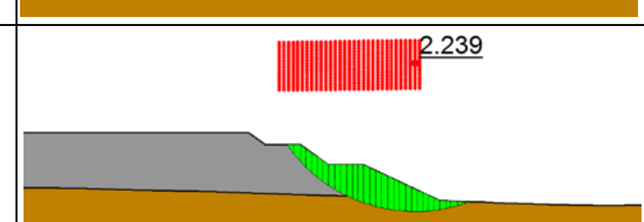
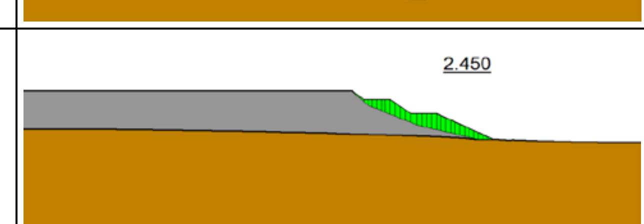
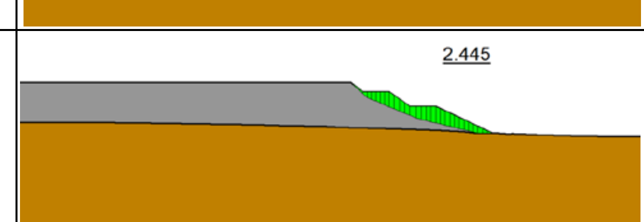
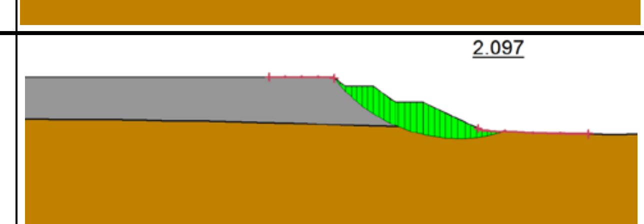
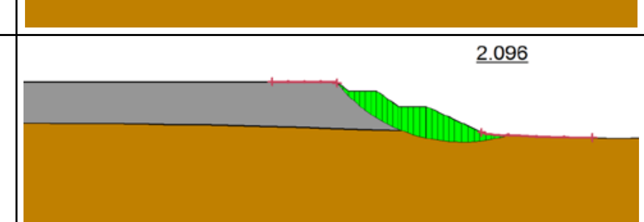
Load Calculations:

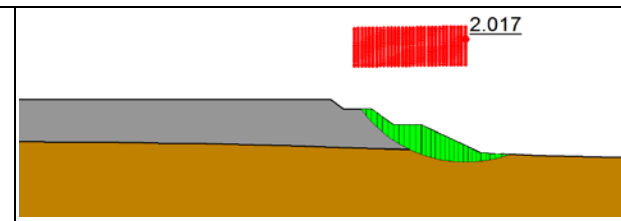
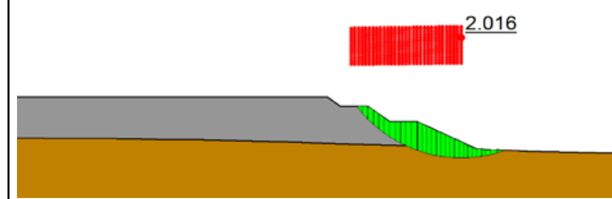
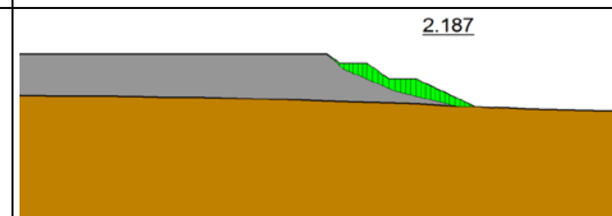
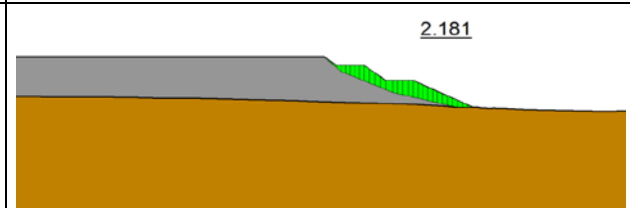
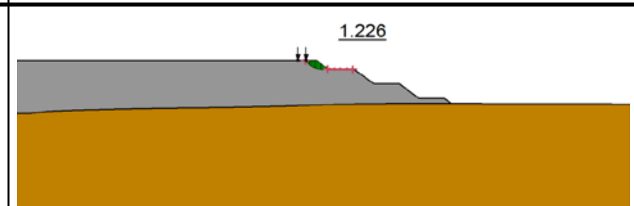
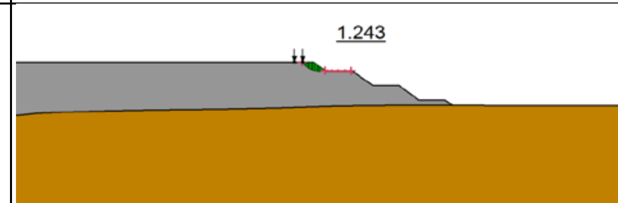
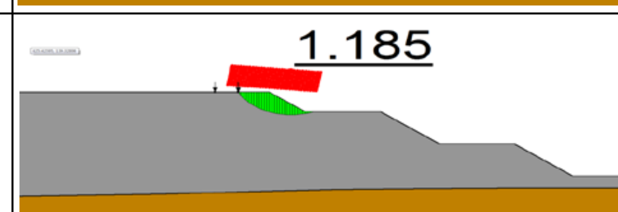
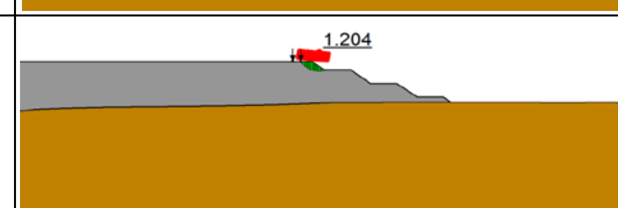
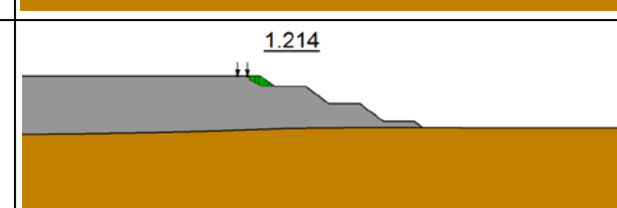
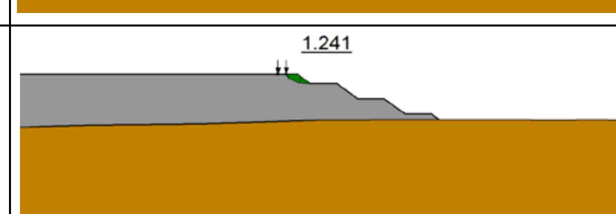
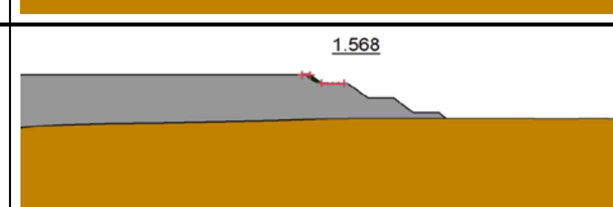
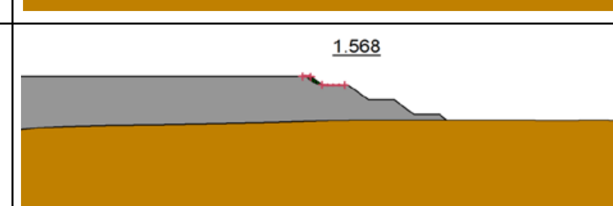
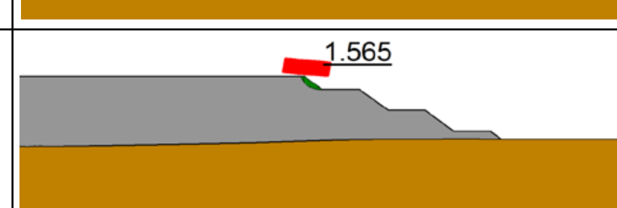
Maximum Gross machine weight = 250,000 ton
Total force = 250,000 x 9.81 = 2,450 kN

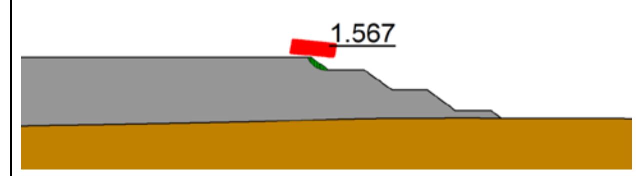
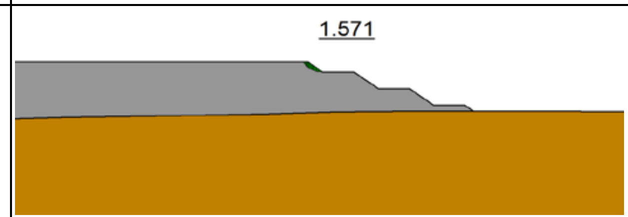
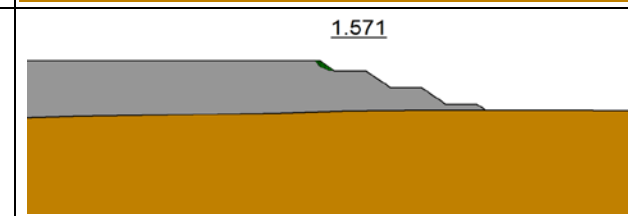
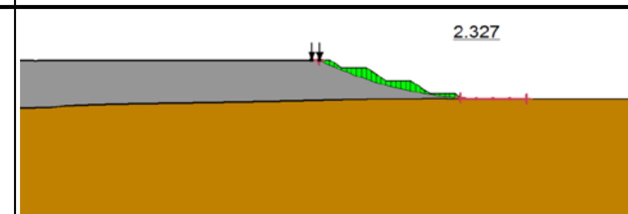
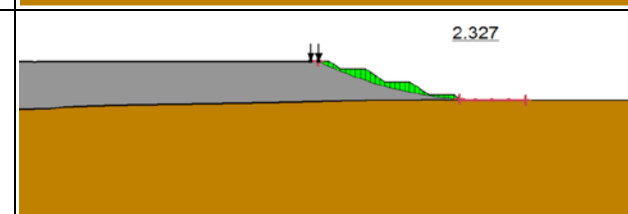
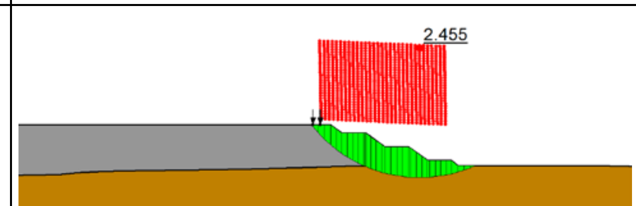
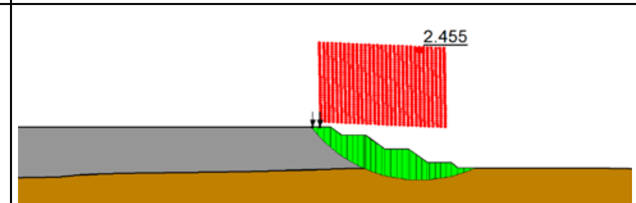
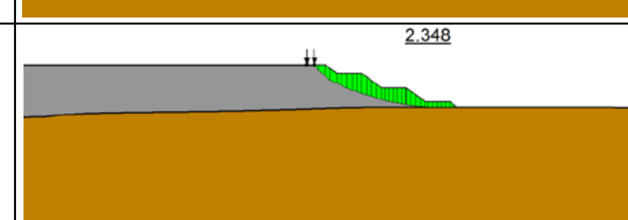
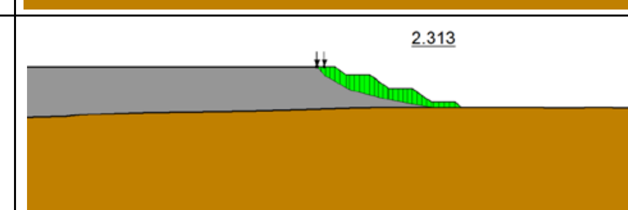
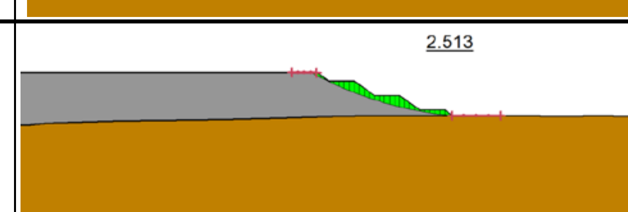
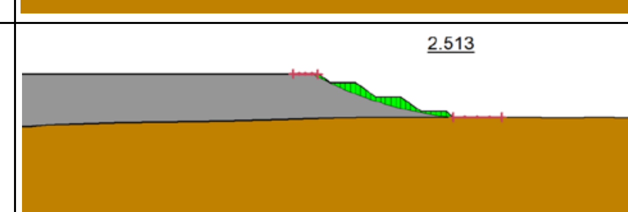
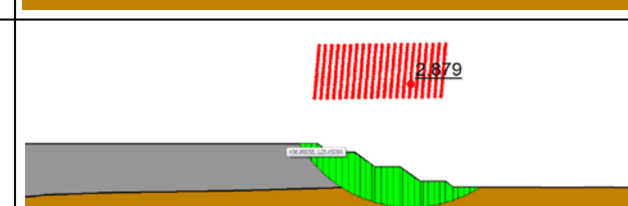
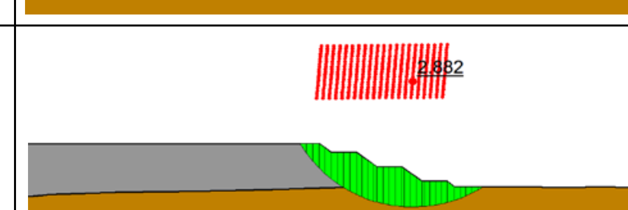
Front axle= (1,850 x 0.33) = 808.5 kN
Rear axle= (1,850 x 0.67) = 1641.5 kN

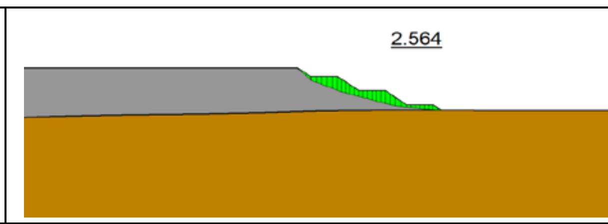
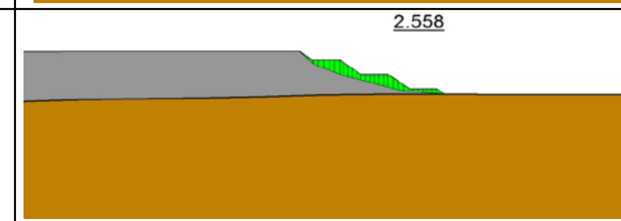
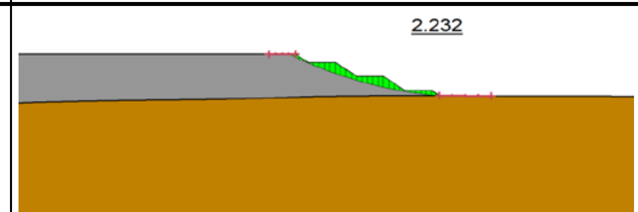
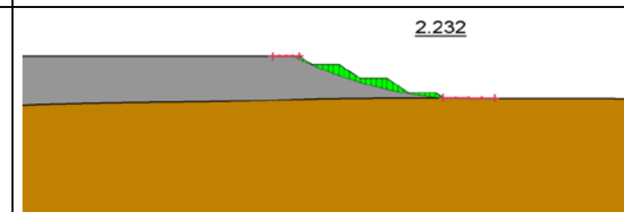
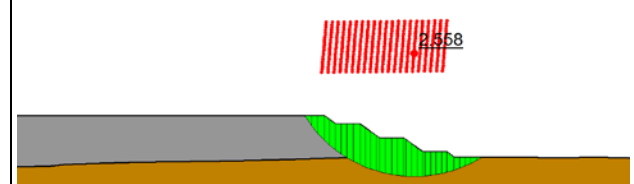
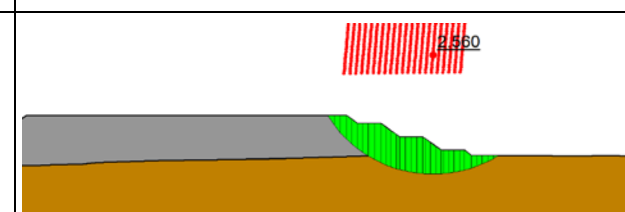
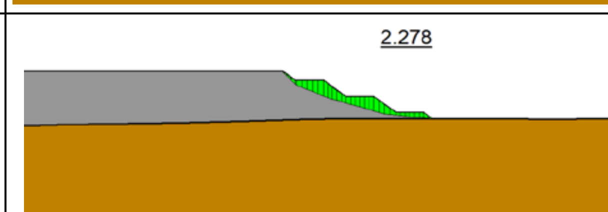
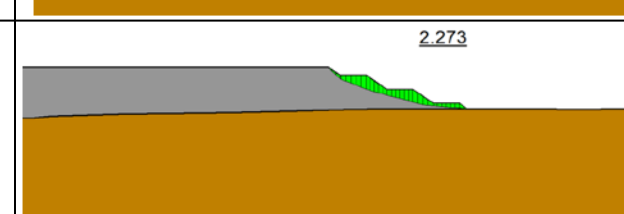
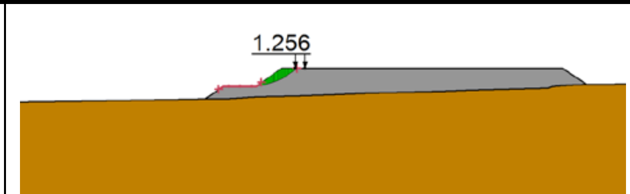
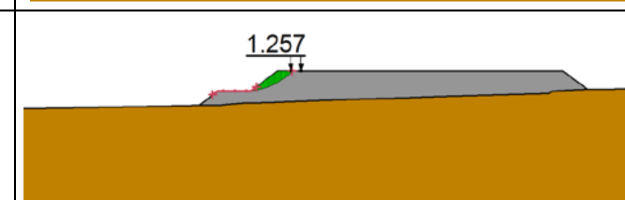
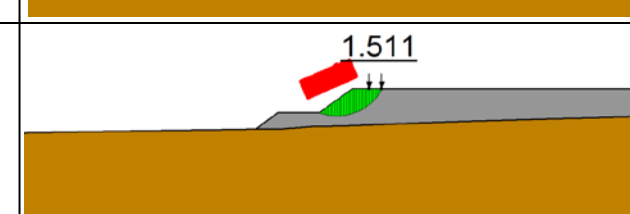
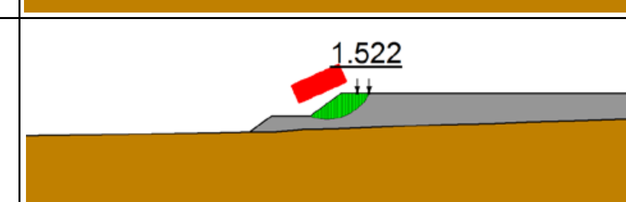
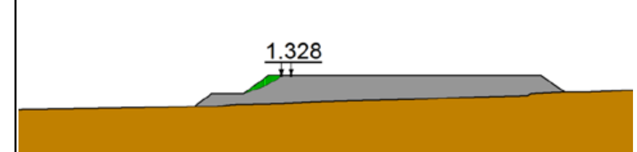
Attachment 2: Summary of Slope Stability Analyses

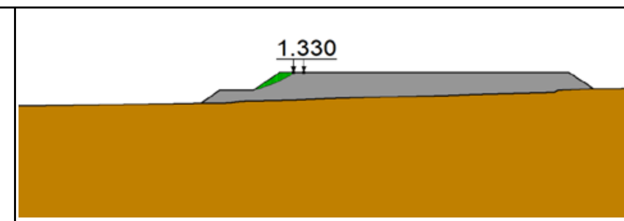
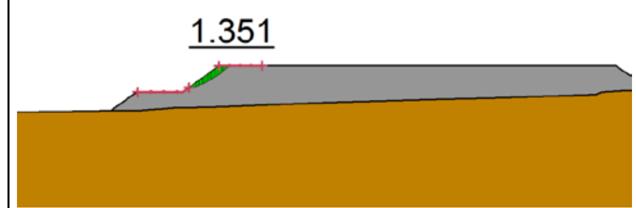
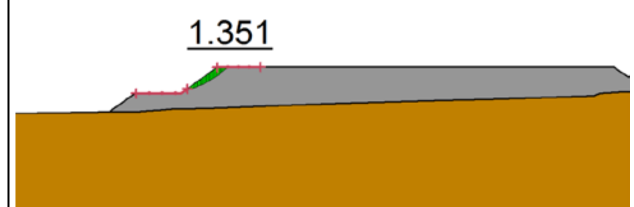
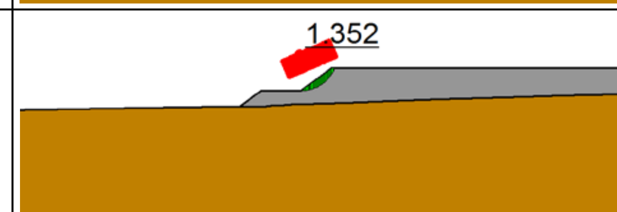
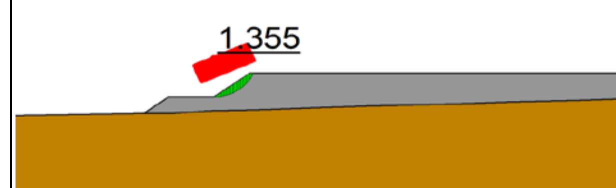
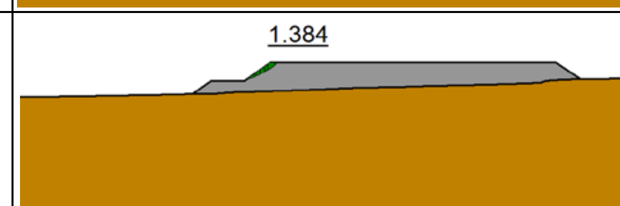
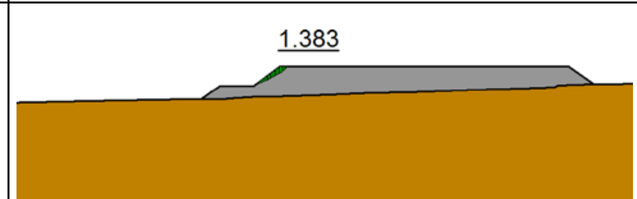
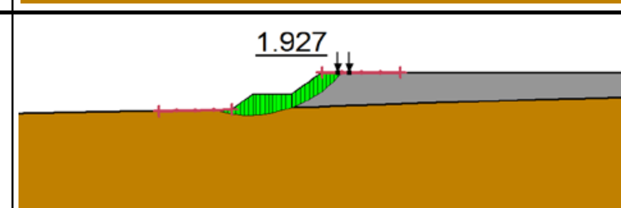
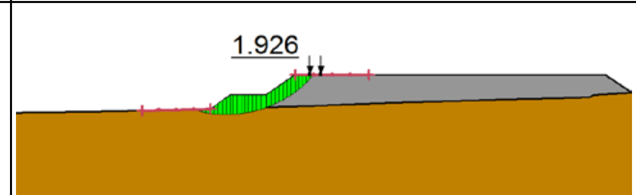
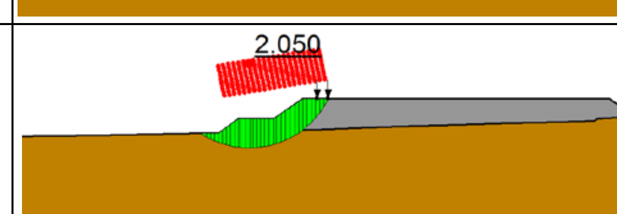
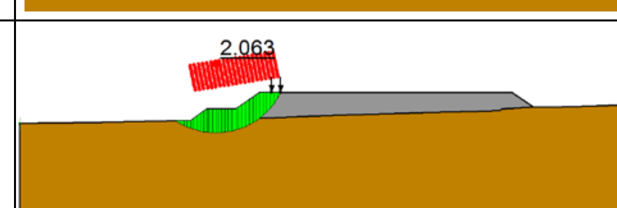
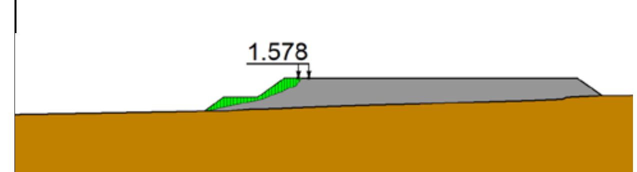
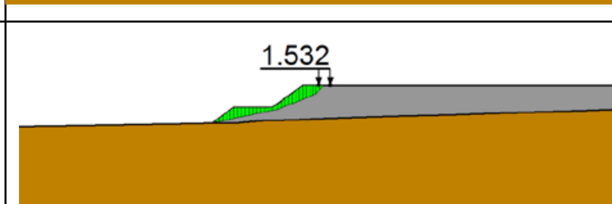
Run #	Location	Stability Condition	Limit Equilibrium Method	Minimum FoS	Search Function	Other Notes	Critical Slip Surface
1	Goose - Llama WRSA	Condition 1	Spencer	1.334	Enter and Exit	-	
2	Goose - Llama WRSA	Condition 1	Morgenstern-Price	1.336	Enter and Exit	-	
93	Goose - Llama WRSA	Condition 1	Spencer	1.331	Grid and Radius	-	
94	Goose - Llama WRSA	Condition 1	Morgenstern-Price	1.356	Grid and Radius	-	
95	Goose - Llama WRSA	Condition 1	Spencer	1.285	Fully Specified	-	
96	Goose - Llama WRSA	Condition 1	Morgenstern-Price	1.298	Fully Specified	-	
97	Goose - Llama WRSA	Condition 2	Spencer	1.621	Enter and Exit	3m	
98	Goose - Llama WRSA	Condition 2	Morgenstern-Price	1.624	Enter and Exit	3m	
99	Goose - Llama WRSA	Condition 2	Spencer	1.543	Grid and Radius	3m	
100	Goose - Llama WRSA	Condition 2	Morgenstern-Price	1.547	Grid and Radius	3m	
101	Goose - Llama WRSA	Condition 2	Spencer	1.626	Fully Specified	3m	
102	Goose - Llama WRSA	Condition 2	Morgenstern-Price	1.626	Fully Specified	3m	
103	Goose - Llama WRSA	Condition 3	Spencer	2.186	Enter and Exit	-	

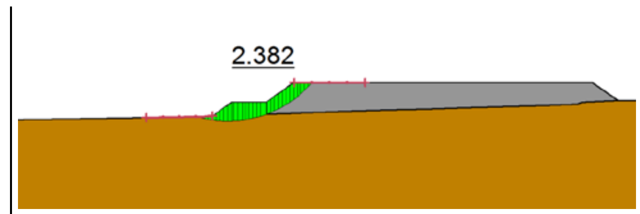
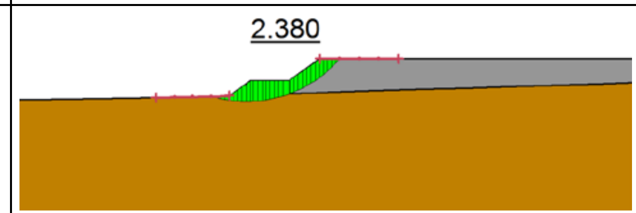
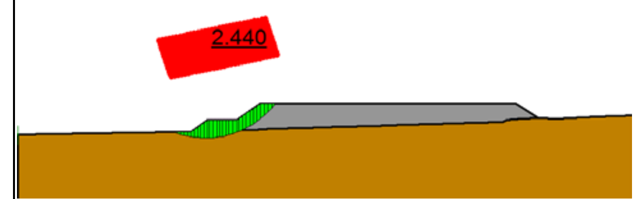
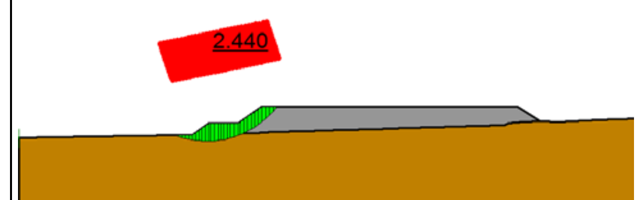
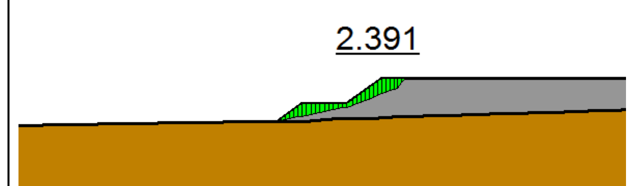
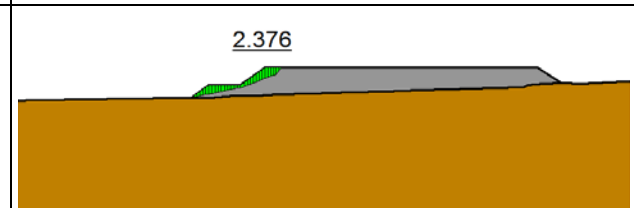
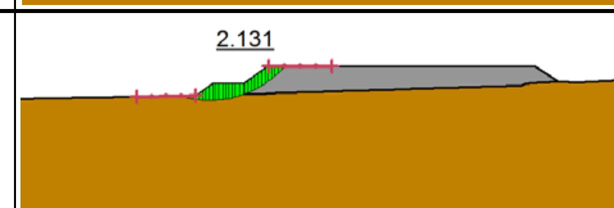
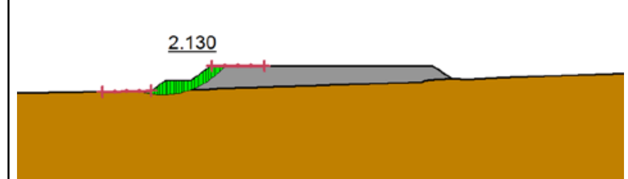
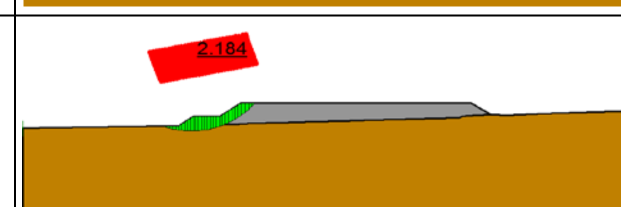
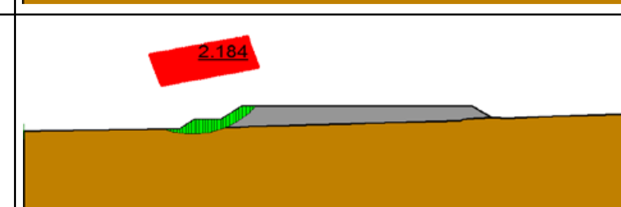
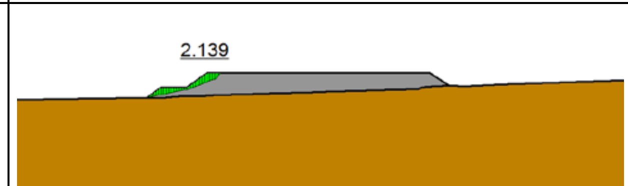
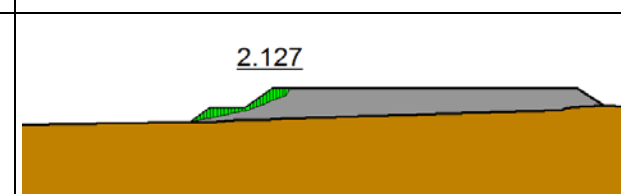
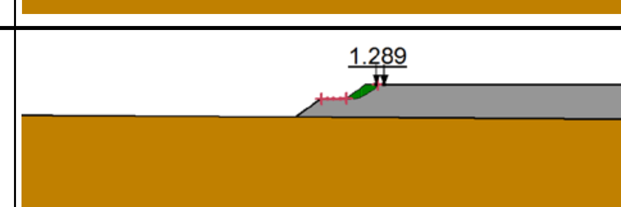
104	Goose - Llama WRSA	Condition 3	Morgenstern-Price	2.184	Enter and Exit	-	
105	Goose - Llama WRSA	Condition 3	Spencer	2.46	Grid and Radius	-	
106	Goose - Llama WRSA	Condition 3	Morgenstern-Price	2.464	Grid and Radius	-	
107	Goose - Llama WRSA	Condition 3	Spencer	2.196	Fully Specified	-	
108	Goose - Llama WRSA	Condition 3	Morgenstern-Price	2.128	Fully Specified	-	
109	Goose - Llama WRSA	Condition 4	Spencer	2.307	Enter and Exit	-	
110	Goose - Llama WRSA	Condition 4	Morgenstern-Price	2.305	Enter and Exit	-	
111	Goose - Llama WRSA	Condition 4	Spencer	2.239	Grid and Radius	-	
112	Goose - Llama WRSA	Condition 4	Morgenstern-Price	2.239	Grid and Radius	-	
113	Goose - Llama WRSA	Condition 4	Spencer	2.45	Fully Specified	-	
114	Goose - Llama WRSA	Condition 4	Morgenstern-Price	2.445	Fully Specified	-	
115	Goose - Llama WRSA	Condition 5	Spencer	2.097	Enter and Exit	-	
116	Goose - Llama WRSA	Condition 5	Morgenstern-Price	2.096	Enter and Exit	-	

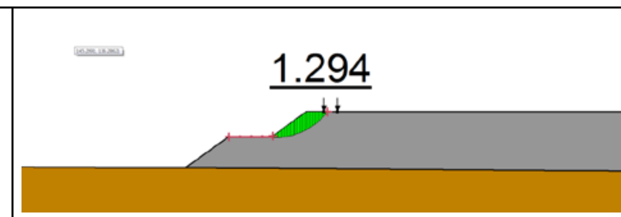
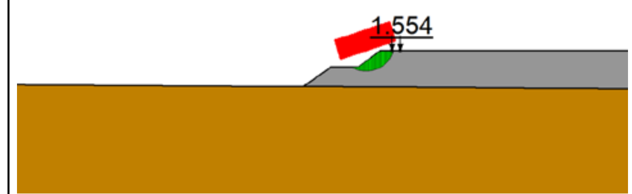
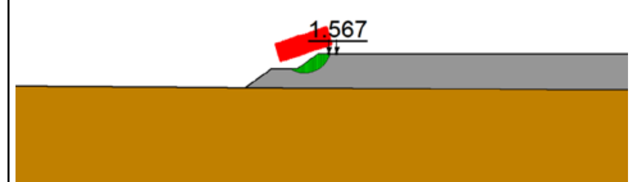
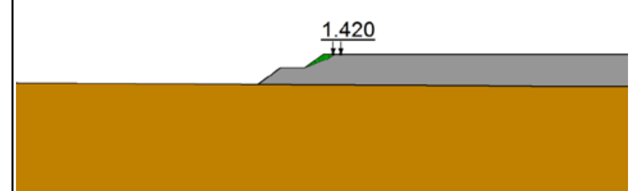
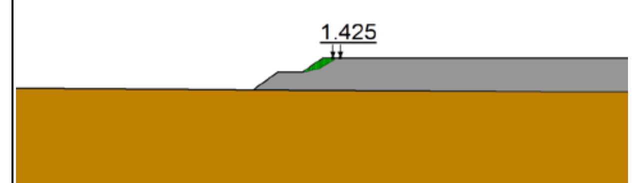
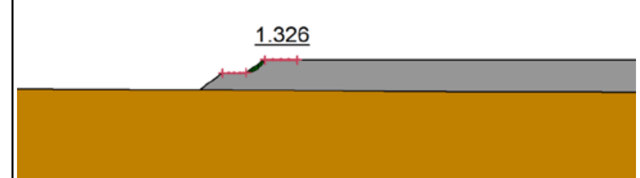
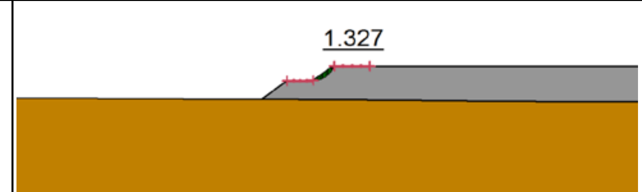
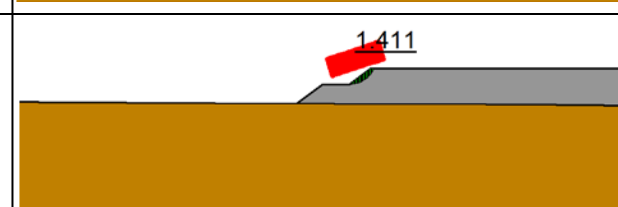
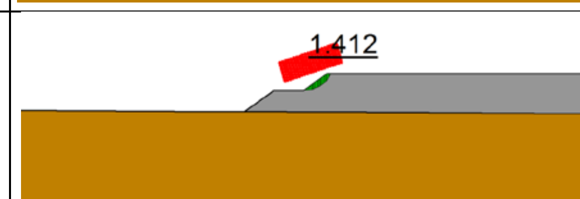
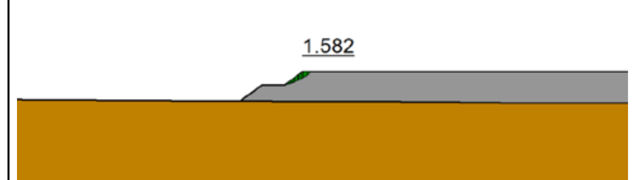
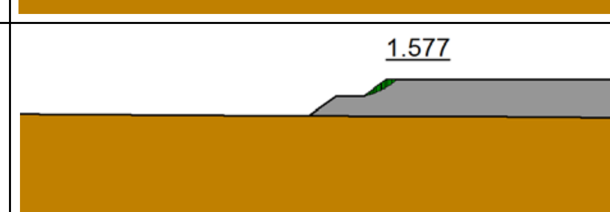
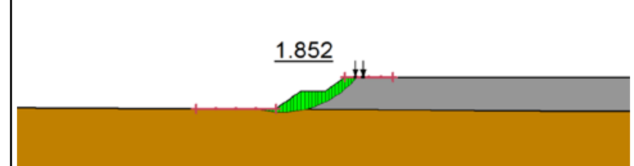
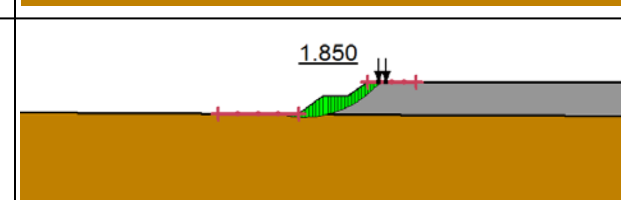
117	Goose - Llama WRSA	Condition 5	Spencer	2.017	Grid and Radius	-	
118	Goose - Llama WRSA	Condition 5	Morgenstern-Price	2.016	Grid and Radius	-	
119	Goose - Llama WRSA	Condition 5	Spencer	2.187	Fully Specified	-	
120	Goose - Llama Dump	Condition 5	Morgenstern-Price	2.181	Fully Specified	-	
121	Goose - Umwelt WRSA	Condition 1	Spencer	1.226	Enter and Exit	-	
122	Goose - Umwelt WRSA	Condition 1	Morgenstern-Price	1.243	Enter and Exit	-	
123	Goose - Umwelt WRSA	Condition 1	Spencer	1.185	Grid and Radius	-	
124	Goose - Umwelt WRSA	Condition 1	Morgenstern-Price	1.204	Grid and Radius	-	
125	Goose - Umwelt WRSA	Condition 1	Spencer	1.214	Fully Specified	-	
126	Goose - Umwelt WRSA	Condition 1	Morgenstern-Price	1.241	Fully Specified	-	
127	Goose - Umwelt WRSA	Condition 2	Spencer	1.568	Enter and Exit	3m	
128	Goose - Umwelt WRSA	Condition 2	Morgenstern-Price	1.568	Enter and Exit	3m	
129	Goose - Umwelt WRSA	Condition 2	Spencer	1.565	Grid and Radius	3m	

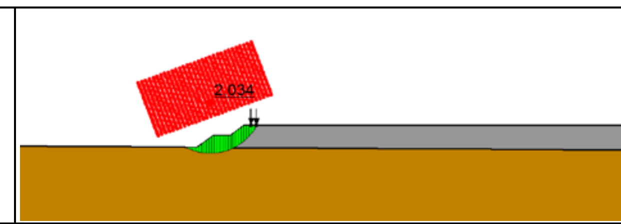
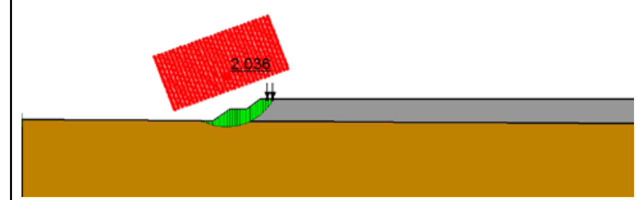
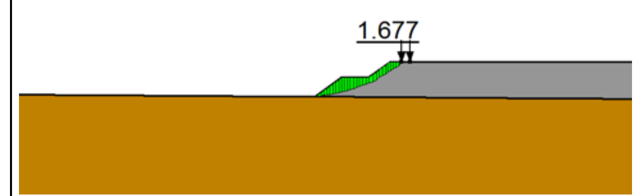
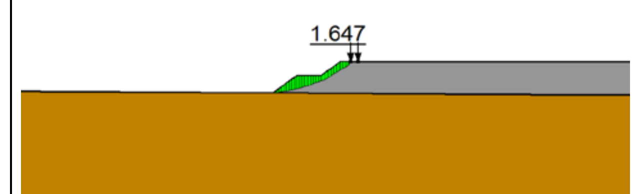
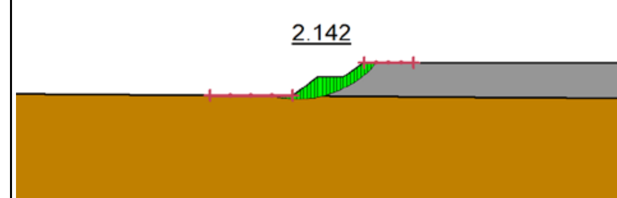
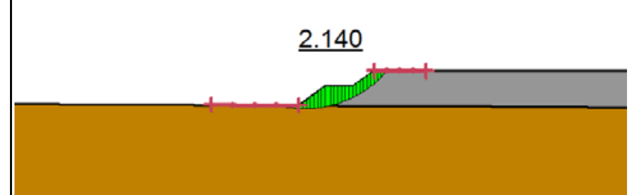
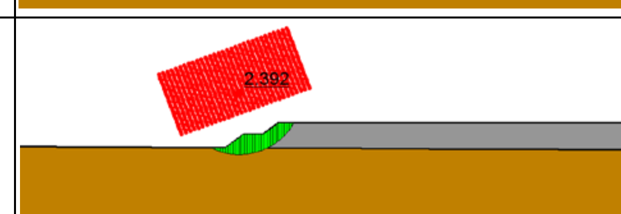
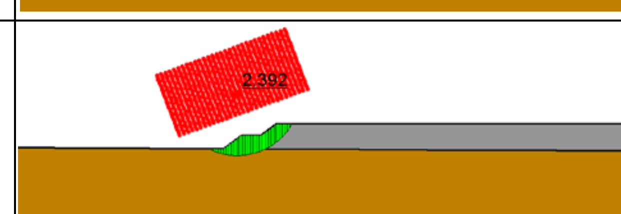
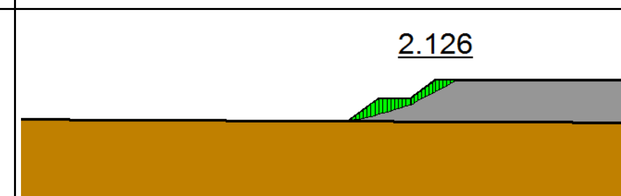
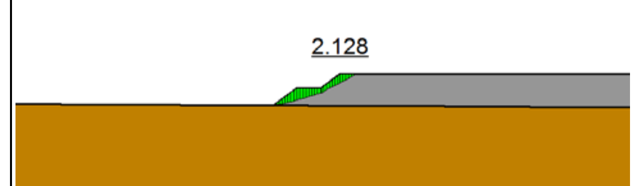
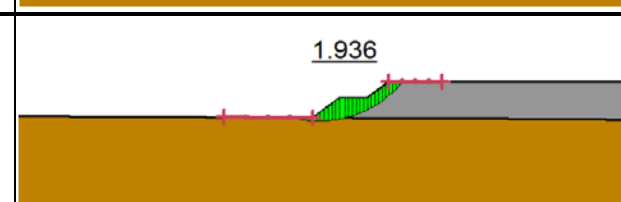
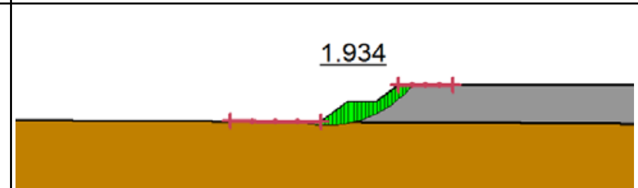
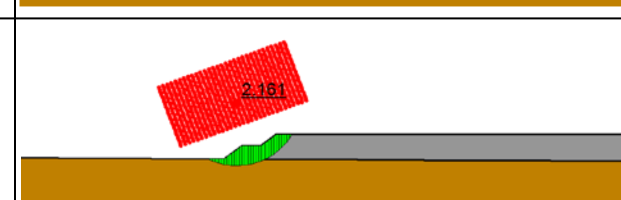
130	Goose - Umwelt WRSA	Condition 2	Morgenstern-Price	1.567	Grid and Radius	3m	
131	Goose - Umwelt WRSA	Condition 2	Spencer	1.571	Fully Specified	3m	
132	Goose - Umwelt WRSA	Condition 2	Morgenstern-Price	1.571	Fully Specified	3m	
133	Goose - Umwelt WRSA	Condition 3	Spencer	2.327	Enter and Exit	-	
134	Goose - Umwelt WRSA	Condition 3	Morgenstern-Price	2.327	Enter and Exit	-	
135	Goose - Umwelt WRSA	Condition 3	Spencer	2.455	Grid and Radius	-	
136	Goose - Umwelt WRSA	Condition 3	Morgenstern-Price	2.455	Grid and Radius	-	
137	Goose - Umwelt WRSA	Condition 3	Spencer	2.348	Fully Specified	-	
138	Goose - Umwelt WRSA	Condition 3	Morgenstern-Price	2.313	Fully Specified	-	
139	Goose - Umwelt WRSA	Condition 4	Spencer	2.513	Enter and Exit	-	
140	Goose - Umwelt WRSA	Condition 4	Morgenstern-Price	2.513	Enter and Exit	-	
141	Goose - Umwelt WRSA	Condition 4	Spencer	2.879	Grid and Radius	-	
142	Goose - Umwelt WRSA	Condition 4	Morgenstern-Price	2.882	Grid and Radius	-	

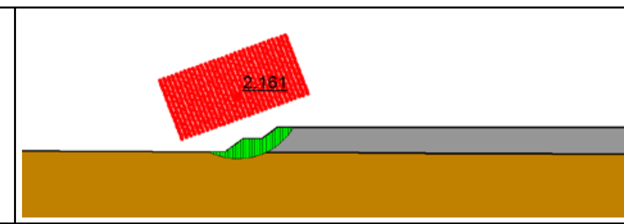
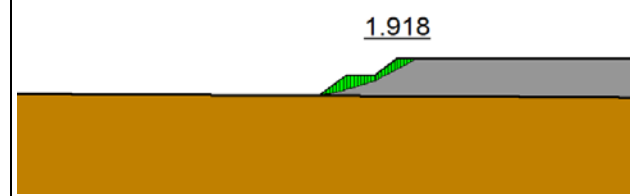
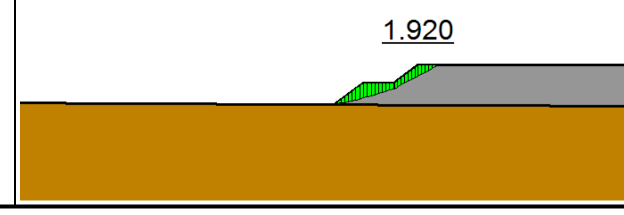
143	Goose - Umwelt WRSA	Condition 4	Spencer	2.564	Fully Specified	-	
144	Goose - Umwelt WRSA	Condition 4	Morgenstern-Price	2.558	Fully Specified	-	
145	Goose - Umwelt WRSA	Condition 5	Spencer	2.232	Enter and Exit	-	
146	Goose - Umwelt WRSA	Condition 5	Morgenstern-Price	2.232	Enter and Exit	-	
147	Goose - Umwelt WRSA	Condition 5	Spencer	2.558	Grid and Radius	-	
148	Goose - Umwelt WRSA	Condition 5	Morgenstern-Price	2.56	Grid and Radius	-	
149	Goose - Umwelt WRSA	Condition 5	Spencer	2.278	Fully Specified	-	
150	Goose - Umwelt WRSA	Condition 5	Morgenstern-Price	2.273	Fully Specified	-	
151	Goose - Echo WRSA	Condition 1	Spencer	1.256	Enter and Exit	-	
152	Goose - Echo WRSA	Condition 1	Morgenstern-Price	1.257	Enter and Exit	-	
153	Goose - Echo WRSA	Condition 1	Spencer	1.511	Grid and Radius	-	
154	Goose - Echo WRSA	Condition 1	Morgenstern-Price	1.522	Grid and Radius	-	
155	Goose - Echo WRSA	Condition 1	Spencer	1.328	Fully Specified	-	

156	Goose - Echo WRSA	Condition 1	Morgenstern-Price	1.33	Fully Specified	-	
157	Goose - Echo WRSA	Condition 2	Spencer	1.351	Enter and Exit	3m	
158	Goose - Echo WRSA	Condition 2	Morgenstern-Price	1.351	Enter and Exit	3m	
159	Goose - Echo WRSA	Condition 2	Spencer	1.352	Grid and Radius	3m	
160	Goose - Echo WRSA	Condition 2	Morgenstern-Price	1.355	Grid and Radius	3m	
161	Goose - Echo WRSA	Condition 2	Spencer	1.384	Fully Specified	3m	
162	Goose - Echo WRSA	Condition 2	Morgenstern-Price	1.383	Fully Specified	3m	
163	Goose - Echo WRSA	Condition 3	Spencer	1.927	Enter and Exit	-	
164	Goose - Echo WRSA	Condition 3	Morgenstern-Price	1.926	Enter and Exit	-	
165	Goose - Echo WRSA	Condition 3	Spencer	2.05	Grid and Radius	-	
166	Goose - Echo WRSA	Condition 3	Morgenstern-Price	2.063	Grid and Radius	-	
167	Goose - Echo WRSA	Condition 3	Spencer	1.578	Fully Specified	-	
168	Goose - Echo WRSA	Condition 3	Morgenstern-Price	1.532	Fully Specified	-	

169	Goose - Echo WRSA	Condition 4	Spencer	2.382	Enter and Exit	-	
170	Goose - Echo WRSA	Condition 4	Morgenstern-Price	2.38	Enter and Exit	-	
171	Goose - Echo WRSA	Condition 4	Spencer	2.44	Grid and Radius	-	
172	Goose - Echo WRSA	Condition 4	Morgenstern-Price	2.44	Grid and Radius	-	
173	Goose - Echo WRSA	Condition 4	Spencer	2.391	Fully Specified	-	
174	Goose - Echo WRSA	Condition 4	Morgenstern-Price	2.376	Fully Specified	-	
175	Goose - Echo WRSA	Condition 5	Spencer	2.131	Enter and Exit	-	
176	Goose - Echo WRSA	Condition 5	Morgenstern-Price	2.131	Enter and Exit	-	
177	Goose - Echo WRSA	Condition 5	Spencer	2.184	Grid and Radius	-	
178	Goose - Echo WRSA	Condition 5	Morgenstern-Price	2.184	Grid and Radius	-	
179	Goose - Echo WRSA	Condition 5	Spencer	2.139	Fully Specified	-	
180	Goose - Echo WRSA	Condition 5	Morgenstern-Price	2.127	Fully Specified	-	
181	Goose - Goose Main WRSA	Condition 1	Spencer	1.289	Enter and Exit	-	

182	Goose - Goose Main WRSA	Condition 1	Morgenstern-Price	1.294	Enter and Exit	-	
183	Goose - Goose Main WRSA	Condition 1	Spencer	1.554	Grid and Radius	--	
184	Goose - Goose Main WRSA	Condition 1	Morgenstern-Price	1.567	Grid and Radius	-	
185	Goose - Goose Main WRSA	Condition 1	Spencer	1.42	Fully Specified	-	
186	Goose - Goose Main WRSA	Condition 1	Morgenstern-Price	1.425	Fully Specified	-	
187	Goose - Goose Main WRSA	Condition 2	Spencer	1.326	Enter and Exit	3m	
188	Goose - Goose Main WRSA	Condition 2	Morgenstern-Price	1.327	Enter and Exit	3m	
189	Goose - Goose Main WRSA	Condition 2	Spencer	1.411	Grid and Radius	3m	
190	Goose - Goose Main WRSA	Condition 2	Morgenstern-Price	1.412	Grid and Radius	3m	
191	Goose - Goose Main WRSA	Condition 2	Spencer	1.582	Fully Specified	3m	
192	Goose - Goose Main WRSA	Condition 2	Morgenstern-Price	1.577	Fully Specified	3m	
193	Goose - Goose Main WRSA	Condition 3	Spencer	1.852	Enter and Exit	-	
194	Goose - Goose Main WRSA	Condition 3	Morgenstern-Price	1.85	Enter and Exit	-	

195	Goose - Goose Main WRSA	Condition 3	Spencer	2.034	Grid and Radius	-	
196	Goose - Goose Main WRSA	Condition 3	Morgenstern-Price	2.036	Grid and Radius	-	
197	Goose - Goose Main WRSA	Condition 3	Spencer	1.677	Fully Specified	-	
198	Goose - Goose Main WRSA	Condition 3	Morgenstern-Price	1.647	Fully Specified	-	
199	Goose - Goose Main WRSA	Condition 4	Spencer	2.142	Enter and Exit	-	
200	Goose - Goose Main WRSA	Condition 4	Morgenstern-Price	2.14	Enter and Exit	-	
201	Goose - Goose Main WRSA	Condition 4	Spencer	2.392	Grid and Radius	-	
202	Goose - Goose Main WRSA	Condition 4	Morgenstern-Price	2.392	Grid and Radius	-	
203	Goose - Goose Main WRSA	Condition 4	Spencer	2.126	Fully Specified	-	
204	Goose - Goose Main WRSA	Condition 4	Morgenstern-Price	2.128	Fully Specified	-	
205	Goose - Goose Main WRSA	Condition 5	Spencer	1.936	Enter and Exit	-	
206	Goose - Goose Main WRSA	Condition 5	Morgenstern-Price	1.934	Enter and Exit	-	
207	Goose - Goose Main WRSA	Condition 5	Spencer	2.161	Grid and Radius	-	

208	Goose - Goose Main WRSA	Condition 5	Morgenstern-Price	2.161	Grid and Radius	-	
209	Goose - Goose Main WRSA	Condition 5	Spencer	1.918	Fully Specified	-	
210	Goose - Goose Main WRSA	Condition 5	Morgenstern-Price	1.92	Fully Specified	-	

Attachment 3: BC Mine Waste Rock Pile Research Committee – Dump Stability Rating

Instructions
1 - Select condition and description that best represents the specific case (grey cell)
2 - The sum of the rating points will automatically be added (should be checked on first run)
3 - Subsequent runs can be recorded by copying each column and pasting to the right, in empty space.

Structure Name: Llama, Umwelt, Echo, and Goose Main WRSFs (Goose)

Key Factor Affecting Stability	Conditions	Description	Rating Points
WRSF height	<50m		0
WRSF Volume	Small	< 1 million BCM's	0
WRSF slope	Moderate	26 - 35 deg	50
Foundation Slope	Flat	<10%	0
Degree of confinement	Moderately Confined	-Natural benches or terraces on slope -Even slopes, limited natural topographical diversity -Heaped, sidehill or broad valley or cross-valley fills	50
Foundation Type	Intermediate	- Intermediate between competent and weak -Soils gain strength with consolation -Adverse pore pressures dissipate if loading rate controlled	100
WRSF Material Quality	High	- Strong, durable - Less than about 10% fines	0
Method of Construction	Favorable	- Thin lifts (<25m thick), wide platforms -Dumping along contours -Ascending construction -Wrap-arounds or terraces	0
Piezometric and Climatic Conditions	Intermediate	- Moderate piezometric pressures, some seeps in foundation - Limited development of phreatic surface in dump possible - Moderate precipitation - High infiltration into dump - Discontinuous snow or ice lenses or layers in dump	100
Dumping rate	Slow	- <25 BCM's per lineal metre of crest per day - Crest advancementrate < 0.1m per day	0
Seismicity	Low	Seismic Risk Zone 0 and 1	0
		Dump Stability Rating (DSR)	

WRSF Stability Class	Failure Hazard	Recommended Level of Effort for Investigation, Design and Construction	Dump Stability Rating (DSR)
2	**Low**	- Thorough site investigation - Test pits, sampling may be required - Limited lab index testing - Stability may or may not influence design - Basic stability analysis required - Limited restrictions on construction - Routine visual and instrument monitoring	**300**

Comments:

Structure Name: Llama, Umwelt, Echo, and Goose WRSF (Goose)

Key Factor Affecting Stability	Conditions	Description	Rating Points
WRSF height	<50m		0
WRSF Volume	Small	< 1 million BCM's	0
WRSF slope	Moderate	26 - 35 deg	50
Foundation Slope	Flat	<10%	0
Degree of confinement	Moderately Confi	-Natural benches or terraces on slope -Even slopes, limited natural topographical diversity -Heaped, sidehill or broad valley or cross-valley fills	50
Foundation Type	Weak	- Limited bearing capacity, soft soils - Subject to adverse pore pressure generation upon loading -Adverse groundwater conditions, springs or seeps - Strength sensitive to shear strain, potentially liquifiable	200
WRSF Material Quality	High	- Strong, durable - Less than about 10% fines	0
Method of Construction	Favorable	- Thin lifts (<25m thick), wide platforms -Dumping along contours -Ascending construction -Wrap-arounds or terraces	0
Piezometric and Climatic Conditions	Unfavorable	- High piezometric pressures, springs in foundation - high precipitation Significant potential for development of phreatic surface or perched watertables in dump - Continuous layers or lenses of snow or ice in dump or foundation	200
Dumping rate	Slow	- <25 BCM's per lineal metre of crest per day - Crest advancementrate < 0.1m per day	0
Seismicity	Low	Seismic Risk Zone 0 and 1	0
		Dump Stability Rating (DSR)	

WRSF Stability Class	Failure Hazard	Recommended Level of Effort for Investigation, Design and Construction	Dump Stability Rating (DSR)
2	**Low**	- Thorough site investigation - Test pits, sampling may be required - Limited lab index testing - Stability may or may not influence design - Basic stability analysis required - Limited restrictions on construction - Routine visual and instrument monitoring	**500**

Comments:

Based on the BC Mine Waste Rock Pile Research Committee; Mined Rock and Overburden Piles Investigation and Design Manual, Interm Guidelines, May 1991.