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Memorandum

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From:	Ben Freidman, Senior Engineer
Cc:	Camilo Cordova, Geotechnical Engineer (Okane) Martine Goldner – Project Manager – MRO Mine Closure (Evolution Mining)
Our ref:	1178-224-002
Date:	7 January 2025
Re:	**MRO NWRD – Berm Geotechnical Stability Assessment**

Introduction

Mount Rawdon Operations (MRO) is scheduled for closure in July 2025, with mining operations concluding in September 2024 and processing activities ceasing in April 2025. MRO has identified early work activities that can commence prior to the full closure of the site. Among these activities, reshaping and placing cover material on the top tier of the Northern Waste Rock Dump (NWRD) is being considered as part of the early works program.

The scope of Okane Project No. 1178-224 is to support the detailed cover system design for the NWRD. The primary objective is to identify and address any potential failure modes early in the design process.

This memorandum comprises Task 2 (Berm Geotechnical Stability Assessment) under Okane Project No. 1178-224. A series of memoranda will be prepared under Okane Project No. 1178-224 to address the key design and landform stability gaps identified in the concept review study (Okane Project No. 1178-222). These memoranda will be progressively integrated into the detailed cover system design report.

Task 1 – Cover System Modelling

Task 2 – Berm Geotechnical Stability Assessment

Task 3 – Landform Evolution Modelling

Task 4 – Drainage Assessment

Objective and Scope

The primary objective is to assess the geotechnical stability of the NWRD post-closure. This involves conducting comprehensive assessments to confirm that the berm's geotechnical stability is adequate for the proposed cover system and the overall closure landform. Compliance with regulatory requirements and the mitigation of environmental risks are key considerations. As per (DES, 2021), the landform design objective is targeted to achieve long-term stability.

The scope of work for the berm geotechnical stability assessment includes the following tasks:

- Identify potential failure mechanisms.
- Perform a deterministic stability analysis using GeoStudio SLOPE/W software to evaluate the slope configuration for closure and ensure compliance with design acceptance criteria.
- Provide recommendations for closure design and maintenance practices to enhance the long-term stability of the NWRD berms.

Background Review

Early rehabilitation works, such as reshaping and covering the top tier of the NWRD, are currently under consideration. A recent options assessment study, supported by the Mine Material Management Plan (MMMP) conducted by RGS in 2022, identified a preferred conceptual closure design for the NWRD. The current commitment by MRO involves placing an initial 3.0 m layer of non-acid forming (NAF) material on the potentially-acid forming (PAF) surface before constructing a soil cover on the top tier of the NWRD.

Based on the assessment, Okane has identified a preferred cover system design, which will be the selected design for the final landform. This design integrates the findings from the MMMP and aligns with the overall objective of ensuring long-term stability and environmental protection. The chosen design will be implemented to optimise the management of water ingress and minimise erosion, providing a robust solution for the closure of the NWRD.

The NWRD has a final approved footprint of 103 hectares and contains PAF material encapsulated by NAF, coupled with low permeability clay layers on the benches to limit water ingress into the NAF embankments. The current design intent of the final landform aims to shed rainfall and channel runoff along the benches through stormwater infrastructure and drop structures to the existing interception dams. During operations, water is collected within these dams and pumped back through the processing circuit. Upon decommissioning of the processing plant and rehabilitation of the NWRD,

rainfall captured within the interception dams will either be pumped to the pit or undergo passive treatment via constructed wetlands currently being trialled on site.

The NWRD was designed and built to produce neutral pH drainage by encapsulating PAF waste rock within an outer core of neutralising rock. This design ensures that any acidic runoff formed within the centre of the dump is neutralised as it passes through the outer ring of neutralising rocks. The NWRD was constructed in four lifts, each up to 25 m in height. The inner PAF core was (and continues to be) covered by external NAF batters at the angle of repose using competent rock comprising gravel (~20 mm diameter) up to boulders (1.0 m diameter), with a nominal particle size distribution (PSD) of D80 > 250 mm (RGS, 2022).

To provide long-term geotechnical stability and minimise erosion, the NWRD features NAF rock armour. This minimises the movement of mineralised sediment from the NWRD into the receiving environment and avoids the need for soil cover systems on external batters, which can be prone to long-term slope failure at such gradients. The NAF external batters were constructed with a 30 m horizontal and 25 m vertical cover over the internal waste rock. Each batter was designed with a berm layer comprised of compacted, low-permeability clay/silt/sand, graded at 5% towards the centre of the facility to collect interflow (RGS, 2022).

It's important to note that, as described in the following sections, the site visit confirmed that the berms are graded from 0-2% towards the facility centre, with a longitudinal grade of 0-2% and a bund ranging from 1.0-1.5 m in height along the outer edge of the berms.

Design Objectives

The primary design objectives for the NWRD closure design reported by (RGS, 2022) include:

- Ensuring long-term stability using NAF rock armour and compacted low permeability layers.
- Implementing contour drains and drop structures to minimise water ingress and manage surface runoff effectively.
- Preventing erosion and the release of mineralised sediment into the environment, thereby maintaining neutral pH drainage.

The present work develops from the previous NWRD geotechnical stability assessment performed under the Progressive Rehabilitation and Closure Plan (PRCP) framework by (Cartledge, 2024) that utilised parameters from previous studies due to the lack of site-specific laboratory data. Key strength parameters, such as cohesion and friction angle were adjusted based on (Leps, 1970). Additionally, empirical data from (Williams, 1984) and research by (Hawley and Cunning, 2017) were used to assess shear strength functions. They performed two-dimensional and three-dimensional modelling to analyse stability and deformation under post-closure conditions. The material properties were assigned, incorporating a subsoil clayey-sand layer and regolith as defined in the final void study by

(SLR, 2020). The Morgenstern-Price Limit Equilibrium method was adopted for its capability to resolve horizontal and vertical force and moment equilibrium.

The stability analysis by (Cartledge, 2024) identified two primary failure modes: localised (bench-scale) and global (overall slope). Under static loading, the minimum factor of safety (FoS) varied with material parameters, with some areas on the north side showing marginal safety. Deformation analysis results revealed vertical and E-W displacements that aligned closely with InSAR monitoring data, suggesting no significant long-term stability concerns. The Waste Dump Stability Rating (WSR) (Hawley and Cunning, 2017) classified the NWRD within the moderate hazard category, guiding site preparation, monitoring, and mitigation measures.

Cartledge (2024) made several recommendations to ensure the long-term stability of the NWRD, including:

- Enhancing stability through buttressing in areas with marginal FoS.
- Implementing effective surface water management strategies.
- Conducting site-specific investigations to validate input parameters.
- Establishing continuous monitoring with well-defined Trigger Action Response Plans (TARPs) to address any anomalies promptly.

NWRD site visit

Okane performed a site visit in October 2024 which included a walkover of the NWRD's top tier plateau, ramps, and berms to refine the detailed cover system design, with a focus on engineering, drainage, and constructability. Observations identified water retention capacity in berms due to low points and bunds, which may lead to instability and vertical seepage in the current backslope gradient configuration. Inspection also showed that coarse batter materials have remained stable with minimal fines mobilisation. Mine operations staff from Evolution Mining confirmed that the batters were constructed by end tipping from upper levels which confirmed a top-down method of construction.

In terms of geotechnical stability, no significant signs of instability were identified, aside from a localised failure on the northeast berm, likely triggered by erosion during a severe storm. The use of large volumes of coarse material in the batters provides general stability and reduces the risk of phreatic surface development within the batters. Material segregation could potentially generate preferential flow paths within the batter that can lead to geotechnical instability of the slope (Figure 1).

If instability from fine material segregation (as shown in Figure 1) in the batters occurs, it's expected to result in minimal material displacement, deemed as a low likelihood low consequence physical failure to downstream infrastructure, natural water streams and population. Recommendations

included regrading to limit water retention on berms, which would lower erosion and stability risks during high-flow events.

a) **b)**

Figure 1: Site visit: a) varying PSD within the angle of repose batters; b) localised gully formation in the berms.

Phreatic Condition

The phreatic condition was assessed based on a long-term scenario at the base of the NWRD, as reported by (SLR, 2020) and shown in Figure 2.

Recent site observations suggest that water ponding occurs in some berm areas and at certain areas at the toe of the NWRD. This ponding on the berms is generated by the compacted topsoil implemented in the design to limit net percolation through the batters. It has been recognised that a potential geotechnical failure mechanism could arise from water ponding on the berms as a combination of the compacted topsoil layer and water retention within the batters due to layers of fine particles segregated by the construction method of the external batters. To address the influence of water retention properties in the berms, a shallow phreatic surface has been included in the berms.

In summary, the modelled case is described as follows:

- Long term phreatic – phreatic surface at the base of the NWRD and in berms.

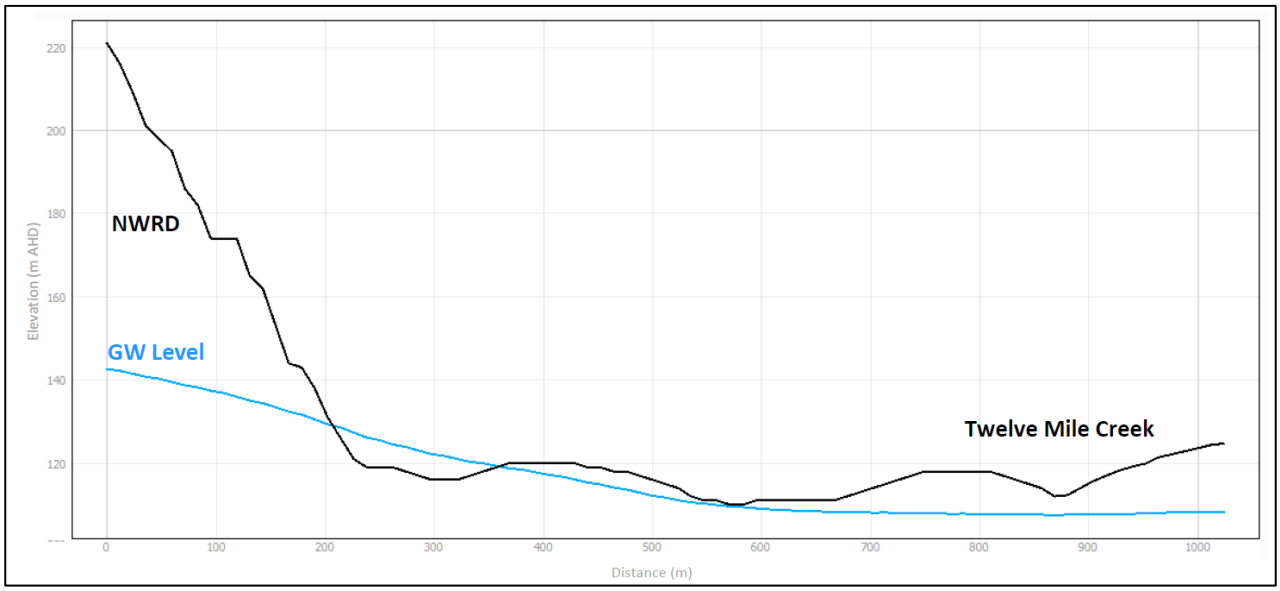


Figure 2: Phreatic surface post mining condition (SLR, 2020).

Site Seismicity

A probabilistic seismic hazard analysis (PSHA) was conducted at MRO in 2020 (Cartledge, 2024). In this analysis, two design events were considered: the operational basis earthquake (OBE) with a peak ground acceleration of 0.09g, and the site evaluation earthquake (SEE) with a peak ground acceleration of 0.25g, both having a magnitude of 7.5. For post-closure analysis, the OBE event was used to assess the stability of the final WRD landform.

Geotechnical Model

GeoStudio 2021 (Slope/W) was used to assess the geotechnical stability of the NWRD batter. The software uses a limit equilibrium analysis and calculates factors of safety for the assessed slip surfaces.

The Morgenstern-Price calculation method was adopted in combination with the entry-exit method for defining slip circle boundary conditions.

Modelling Section and Loading Conditions

Several cross sections were assessed to determine the most critical section for analysis in the stability model. The northeastern batter was ultimately selected for the geotechnical stability analysis because it exhibits the highest differential elevation and shows signs of geotechnical instability in the berms, such as the identified local slip failure (Figure 3).

MRO reported that the most accurate as-built configuration of the NWRD batter is shown in Figure 4. The following specific loading conditions were assessed in the study:

- Drained condition of materials - This scenario represents the NWRD landform in the long term with the suggested phreatic surface at the base of the facility based on (SLR, 2020).

- Undrained condition of contractive materials - This scenario assumes that the berms are saturated because it is believed that, due to the lack of a drainage system, the berms method of construction, and the low permeability of the compacted soil, they will tend to retain water during heavy rainfall.

The modelling section representing the extreme rainfall scenario is shown in Figure 5.

Figure 3: NWRD plan view - analysed section.

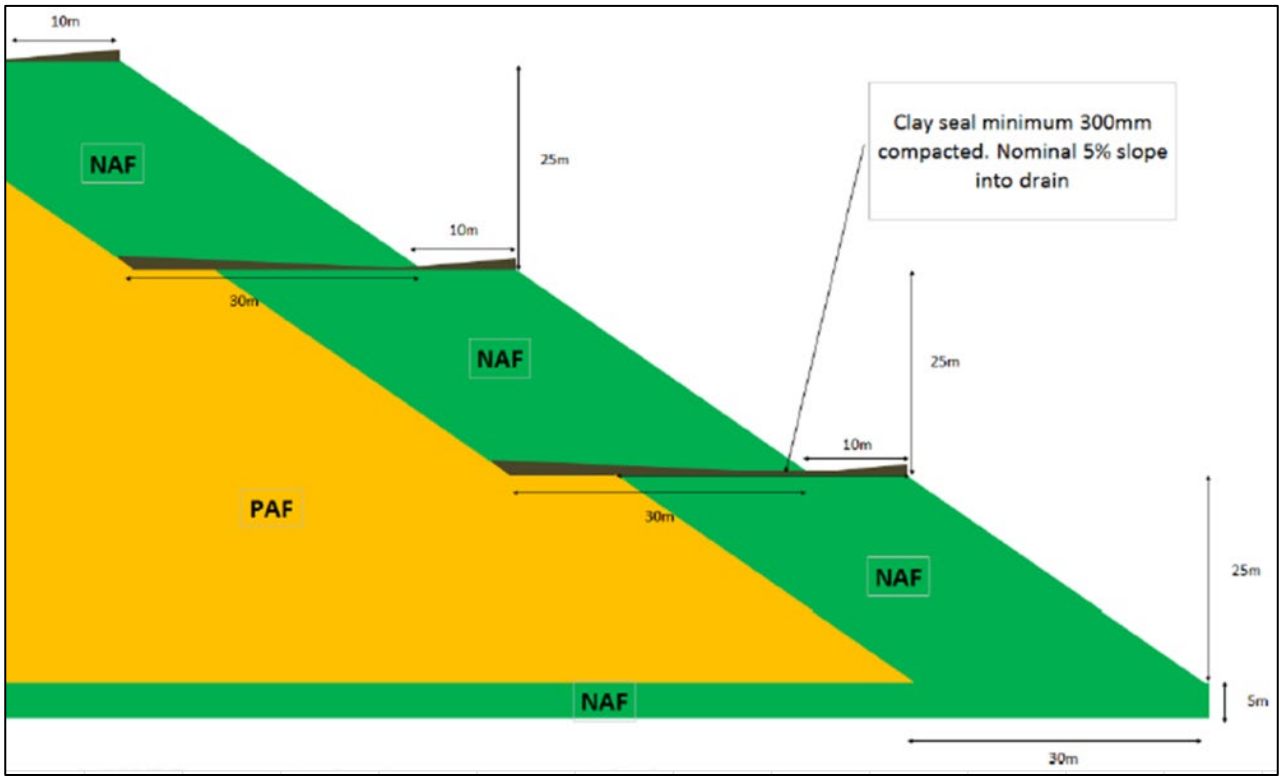


Figure 4: Schematic cross section of the conceptual NWRD design.

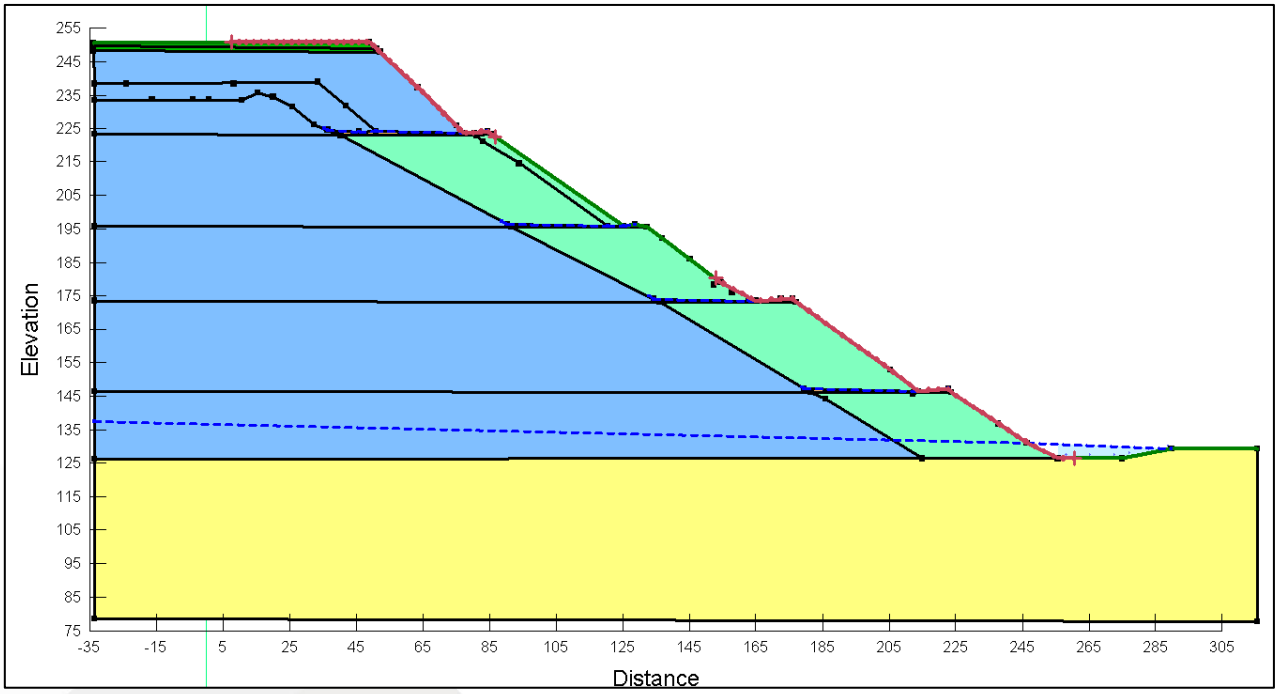


Figure 5: Modelling section representing long term condition.

Material Parameters

The following section assesses the waste rock material parameters used in the NWRD geotechnical stability assessment. A summary of the shear strength parameters is presented in Table 1. These parameters are derived from frictional shear strength parameters for coarse-grained materials from (Hawley and Cunning, 2017). Foundation parameters are based on (Cartledge, 2024). Additional geotechnical supporting information about waste rock characterisation for geotechnical stability analysis is included in Appendix A.

Table 1: Material Geotechnical Parameters.

Material	Unit Weight (kN/m³)	C' (kPa)	Friction Angle ϕ (degrees)	Undrained Shear Strength (Su kPa)	Source
Cover material	22	10	35		Okane
Compacted soil	18	2	30	0.35	Okane
Waste Rock Average Leps	22		Appendix A		(Leps, 1970)
Waste Rock Lower Quartile Leps	22		Appendix A		(Leps, 1970)
Foundation	26	200	37		(Cartledge, 2024)

Acceptance Criteria

A required minimum FoS of 1.5 was adopted for slip circle assessment, based on a consequence risk assessment performed by (Cartledge, 2024). The methodology for the risk-based assessment of the consequence category is described in detail by (Hawley and Cunning, 2017) and shown in Table 2. Cartledge reported that "the MRO NWRD is located away from critical infrastructure, has unrestricted access, and features overall slopes less than 30° and less than 250 m high, classifying its consequence level as moderate". However, the material input parameters in this assessment were collected from previous studies and are deemed to be of low confidence due to inherent uncertainties. Therefore, the minimum FoS for static and pseudo-static analyses were set at 1.5 and 1.15, respectively.

Table 2: Suggested stability acceptance criteria (Hawley and Cunning, 2017).

Consequence[1,3]	Confidence[2,3]	Static analysis		Pseudo-static analysis	Maximum allowable strain[5]
		Minimum FoS	Maximum PoF[4]	Minimum FoS	
Low	Low	1.3–1.4	10–15%	1.05–1.1	≤1%
	Moderate	1.2–1.3	15–25%	1.0–1.05	≤1.5%
	High	1.1–1.2	25–40%	1.0	≤2%
Moderate	Low	1.4–1.5	2.5–5%	1.1–1.15	≤0.75%
	Moderate	1.3–1.4	5–10%	1.05–1.1	≤1%
	High	1.2–1.3	10–15%	1.0–1.05	≤1.5%
High	Low	≥1.5	≤1%	1.15	≤0.5%
	Moderate	1.4–1.5	1–2.5%	1.1–1.15	≤0.75%
	High	1.3–1.4	2.5–5%	1.05–1.1	≤1%

Notes:
1. Consequence
Low – waste dumps and stockpiles with overall fill slopes less than 25° and less than 100 m high and repose angle slopes less than 50 m high. No critical infrastructure or unrestricted access within potential runout shadow. Limited potential for environmental impact. Long-term (more than 5 years) exposure for sites subject to very low to low (less than 350 mm) annual precipitation; medium-term (1–5 years) exposure for sites subject to moderate (350–1000 mm) annual precipitation; short-term (less than 1 year) exposure for sites subject to high (1000–2000 mm) annual precipitation; dry season construction/operation only for sites subject to very high (more than 2000 mm) annual precipitation or intensive rainy season(s).
Moderate – waste dumps with overall fill slopes less than 30° and less than 250 m high or repose angle slopes less than 100 m high. No critical infrastructure or unrestricted access, or robust containment/mitigative measures to protect critical infrastructure and access within potential runout shadow. Potential for moderate environmental impact, but manageable. Long-term (more than 5 years) exposure for sites subject to moderate (350–1000 mm) annual precipitation; medium-term (1–5 years) exposure for sites subject to high (1000–2000 mm) annual precipitation; short-term (less than 1 year) exposure for sites subject to very high (more than 2000 mm) annual precipitation or intensive rainy season(s).
High – waste dumps with overall fill slopes more than 30° and more than 250 m high, or with repose angle slopes more than 200 m high. Critical infrastructure or unrestricted access within potential runout shadow with limited runout mitigation/containment measures. Potential for high environmental impact that would be difficult to manage. Long-term exposure (more than 5 years) for sites subject to high (1000–2000 mm) annual precipitation; medium-term (1–5 years) exposure for sites subject to very high (more than 2000 m) annual precipitation or intensive rainy season(s).
2. Confidence
Low – limited confidence in foundation conditions, waste material properties, piezometric pressures, analysis technique or potential instability mechanism(s). Poorly defined or optimistic input parameters; high data variability. For proposed structures, investigations at the conceptual level with limited supporting data. For existing structures, poorly documented or unknown construction and operational history; lack of monitoring records; unknown or poor historical performance.
Moderate – moderate confidence in foundation conditions, waste material properties, piezometric pressures, analysis technique or potential failure mechanism(s). Input parameters adequately defined; moderate data variability. For proposed structures, investigations at the pre-feasibility study level with adequate supporting data. For existing structures, reasonably complete construction documentation and monitoring records; fair historical performance.
High – high confidence in foundation conditions, waste material properties, piezometric pressures, analysis technique and instability mechanism(s). Well-defined, conservative input parameters; low data variability. For proposed structures, investigations at the feasibility study level with comprehensive supporting data. For existing structures, well-documented construction and monitoring records and good historical performance.
3. In cases where the guidance for consequence or confidence conflicts or is unclear, selection of the appropriate level should be based on judgement, and the rationale fo the selection should be documented.
4. For the purposes of these criteria, PoF is assumed to be related to FoS and consequence as illustrated in Fig. 8.1.
5. A simplified and conservative estimate of the potential displacement or deformation that may occur during a seismic event may be obtained using a variety of methods (e.g. Newmark 1965; Swaisgood 2003). For the purposes of these acceptance criteria, displacement or deformation estimates derived using these methods can be converted to an 'equivalent' strain by dividing the estimated cumulative displacement or deformation by the length of the critical failure path and expressing the result as a percentage. If the length of the critical failure path is unknown or not easily obtainable, the overall slope length or height of the embankment can be used as a conservative estimate for the length of the critical failure path. If numerical techniques are used, then convergence of the numerical model is necessary before the cumulative displacement can be calculated. A non-convergent numerical model would not meet the acceptance criteria.

Stability Assessment Results

The resulting FoS of the stability assessment are presented in Table 3. The detailed results and reference figure sections of the assessment are presented in Appendix B.

Table 3: Stability Assessment Results.

Section	Loading Condition	Slip surface extent	FoS	Target FoS
A	Long term - Drained	Global	1.53	1.5
	Long term - Drained	Local	1.5	1.5
	Pseudo Static - Undrained	Global	1.25	1.15

The modeling results indicate that the minimum required FoS are achieved under all proposed loading conditions. The facility remains globally and locally stable for the long-term drained scenario.

It is worth noting that local slip surfaces related to extreme rainfall events are shallow in nature, similar to the observed localised failure in the northeastern berm of the NWRD. This suggests that the material properties used are adequate for the batters. Furthermore, it should be noted that this assessment shows that local instability of the berms is predominantly driven by their ability to pond and retain water.

Sensitivity Analysis

Sensitivity and back analyses were conducted to assess the impact of variability in the slope gradient of the low permeability layer at the berms on the FoS. Specifically, the factors evaluated in the sensitivity analysis were:

- Changing the geometry of the section varying the low permeability layer gradient from 0%, 2%, 5% and inversed -2% grade.

Berm Grade Analysis

A sensitivity analysis was performed for the internal berm gradient of the compacted low permeability layer considered in the design of the berms to assess if the gradient has any influence on the batter FoS.

The assessment was set to compare the worst-case scenario, which is the extreme rainfall event undrained materials and using the Leps lower quartile material parameter function, varying the grade of the inner slope of the compacted low permeability layer from flat (0%), 2%, 5% and inverse -2% grade. Results are shown in Figure 6.

The analysis indicates that the inner slope gradient does not significantly affect the FoS for either global or local slip surfaces. This is consistent with the slip surface mechanism, where block-type slip surfaces are less likely due to the relatively small thickness of the compacted low permeability layer compared to the height of each batter for global failures. For local slip failures, shallow slip surfaces dominate, driven primarily by the frictional forces of the waste rock and low confinement.

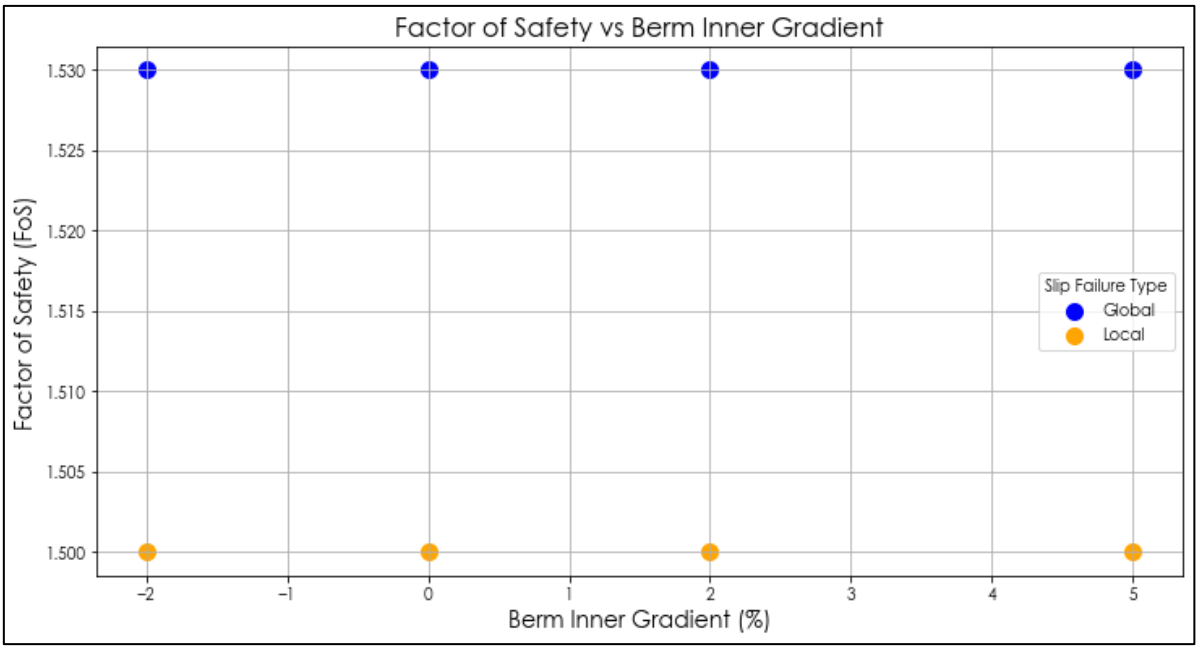


Figure 6: Berm inner gradient analysis.

Conclusions

The following engineering comments are made with respect to the analyses and results documented in this memorandum.

- The stability analysis indicates that the NWRD achieves the minimum required FoS under all studied conditions.
- Two primary failure modes were identified: localised (bench-scale) and global (overall slope). Local slip surfaces are particularly susceptible to extreme rainfall events, driven by the berms' ability to pond and retain water.
- Based on the sensitivity analysis, the berm grade does not affect global or local stability within the studied range of -2% to 5%.
- The lower quartile of the Leps curves for waste rock material properties was found to be suitable for modeling the geotechnical stability of the NWRD batters, given the construction method and the facility's low-risk classification. Evidence of the top-down construction method for the NAF rock batters, based on variability in PSD, was observed during the site visit.
- The assessment recognised that the capacity of the berms to retain water presents the most important risk to local stability. Water ponding on the berms due to compacted, low permeability topsoil and potential preferential flow paths within the batters are critical factors. Effective surface water management strategies are essential to mitigate these risks.

It is important to note that the risk of the facility in geotechnical terms is a function of the temporal probability of a threat (likelihood), and the utility value of the element at risk or influence of the failure (consequence). In closure timeframes, the probability of a berm failure triggered by a high intensity storm event is expressed as follows:

$$Probability\ of\ exceedance = 1 - e^{-(^{design\ life}/_{return\ period})}$$

The exceedance probability of an event triggering berm failure under its current condition, which has water retention properties and potential to induce piping in the berms is nearly one when the design life of the structure is large enough, such as in closure. With that said, even if the probability of exceedance of the berm local failure is one, the consequence of the berm failure is deemed to be low.

Recommendations

- Implement effective surface water management strategies and stormwater management infrastructure, to minimise water ponding, water ingress to the NWRD berms and manage surface runoff. A resilient design that considers potential surface deformations due to local berm material losses or consolidation should be implemented.

- Establish a robust monitoring program with well-defined TARPs to promptly address any anomalies or signs of instability, such as gully formation or presence of tension cracks. Inspections should address potential sediment movement, and other signs of water ponding.

References

Cartledge. (2024). *Mt Rawdon Mine Progressive Rehabilitation and Closure Plan (PRCP) Geotechnical Assessments - NWRD.*

DES. (2021). *Department of Environment and Science Guideline – Progressive Rehabilitation and Closure Plans.*

Hawley and Cunning. (2017). *Guidelines for Mine Waste Dump and Stockpile Design.* CSIRO, pg. 31-54.

Leps, T. (1970). *Review of shearing strength of rockfill.* Journal of the Soil Mechanics and Foundations Division. Proceedings of the American Society of Civil Engineers, 96(SM4), pg. 1159-1170.

RGS. (2022). *Mine Material Management Plan - Landform, cover system and final void design and assessment.*

SLR. (2020). *Mount Rawdon Operation – Final Void Study Report.*

Williams, D. W. (1984). *Laboratory and field strength of mine waste rock.* Proceeding of Fourth Australia – New Zealand Conference on Geomechanics, Perth, 14–18.

Appendix A

Supporting Geotechnical information

Waste Rock Characterisation

Leps curves were used by (Cartledge, 2024) to assess material strength parameters of waste rock. Leps in 1970 (Leps, 1970) conducted influential research on the shear strength of rockfill materials through large diameter triaxial testing on 15 different types of rockfill, representing a variety of grain size distributions, particle strengths, and densities. His work established a key understanding that the shear strength curve for rockfill is non-linear, especially at low confining stresses, which is a crucial consideration when selecting shear strength parameters for stability analyses of waste dumps and stockpiles (Figure A1). Leps identified that the strength envelopes of rockfill materials depend on factors such as density, gradation, particle shape, and intact strength. High-density, well-graded materials with angular, high-strength particles exhibited higher shear strength envelopes compared to lower-density, uniformly or gap-graded materials with rounded, lower-strength particles.

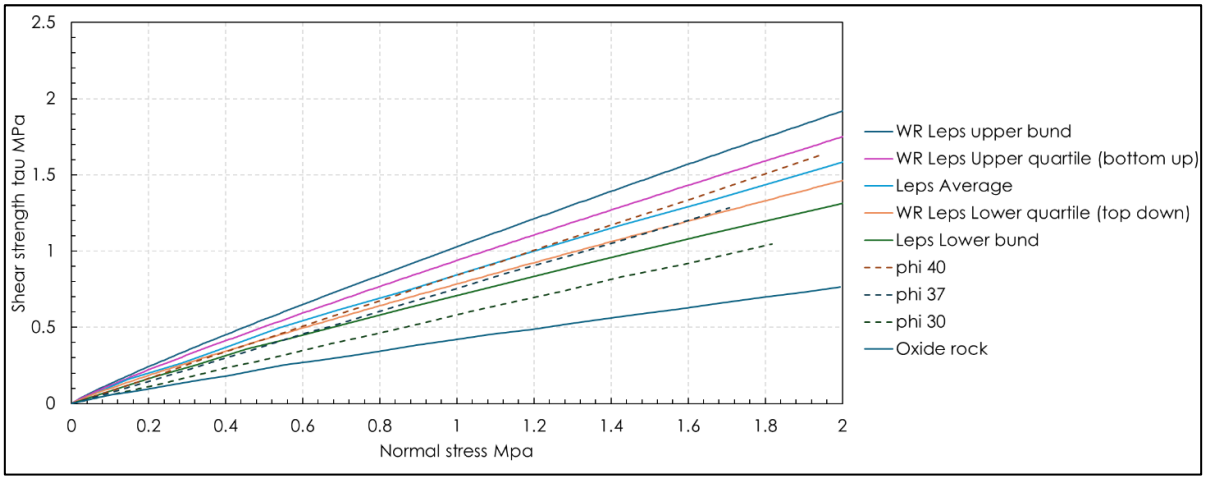


Figure A1: Waste rock shear strength curves. Data from (Leps, 1970) with recent testing data added (Hawley and Cunning, 2017).

The strength envelope derived from Leps' work and subsequent studies showed that at low pressures, rockfill materials have a high internal friction angle and negligible cohesion. However, as confining pressures increase, the compressibility of the granular matrix leads to a reduction in the internal friction angle, resulting in a non-linear shear strength function. This function was validated by additional large-scale measurements of frictional strength of rock dump materials from mines in the Chilean Andes, further supporting the non-linear stress-dependent friction angles applicable to rock dumps. Leps' work and following research concluded that:

- Characterising waste rock material for geotechnical stability modelling must consider the non-linear nature of the shear strength curve.
- Key influencing factors include density, particle strength, and confining stress.

- Leps' work provides foundational understanding for developing accurate and reliable stability models for waste dumps.

- Effective models should incorporate both intrinsic and state parameters of the materials.

Based on the curves shown in Figure A1, industry guidelines (Hawley and Cunning, 2017) provide suggested rockfill shear strength functions based on the facility method of construction, its instability hazard, and physical characteristics, as shown in Table A1, also used by (Cartledge, 2024).

Table A1: Suggested rockfill shear strength parameters (Hawley and Cunning, 2017).

Waste dump Construction method	Shear strength function (τ and σ in kPa)	Leps (1970) envelope (incorporating recent data) (Figs. 5.9 and 5.10)	Waste dump instability hazard
Top down spoil construction	$\tau = 1.446\sigma^{0.898}$	Lower bound	Very high to high (WHC IV and V)*
Top down spoil construction	$\tau = 1.576\sigma^{0.899}$	Lower quartile, between low and average rockfill (typical to model top down construction greater than 75 m high)	Moderate to low (WHC I to III)*
Bottom up spoil construction	$\tau = 1.899\sigma^{0.898}$	Upper quartile, between average and high rockfill (typical to model bottom up construction)	Very high to high (WHC IV and V)*
Bottom up spoil construction	$\tau = 2.067\sigma^{0.899}$	Upper bound	Moderate to low (WHC I to III)*

Specific to the NWRD, it has been reported that the inner PAF core of the facility was covered by constructing external NAF batters built at the angle of repose using competent rock ranging from gravel (~20 mm diameter) to boulders (up to 1 m diameter). The nominal PSD is D80 > 250 mm, as stated in the background review. Visual inspections suggest variability in particle size distribution across the section, and internal comments from MRO staff on the construction method indicate that while the inner NAF core of the NWRD was built bottom-up, the external NAF batters were constructed by end-dumping coarser rock to enhance the physical and erosional stability of the external batters.

When characterising the material properties for geotechnical stability modelling of mixed fills, it is essential to consider the composition of the mixture, method of construction, and its variability in terms of PSD, which typically includes rockfill, overburden, and fine particle accumulation from the end-dumping construction method, as illustrated in Figure A2. The behaviour of mixed fills will vary depending on the relative proportions of these components.

Mixed fills composed predominantly of rockfill will exhibit characteristics similar to rockfills provided there is significant contact between individual rockfill blocks, and the overburden material is contained within the voids of the rockfill. Conversely, mixed fills primarily composed of overburden materials will behave more like overburden, especially if there is minimal contact between the rockfill blocks. This can lead to properties that closely reflect those of the overburden. Therefore, when selecting material properties for design purposes, it is crucial to conservatively consider the relative proportions of rockfill and overburden.

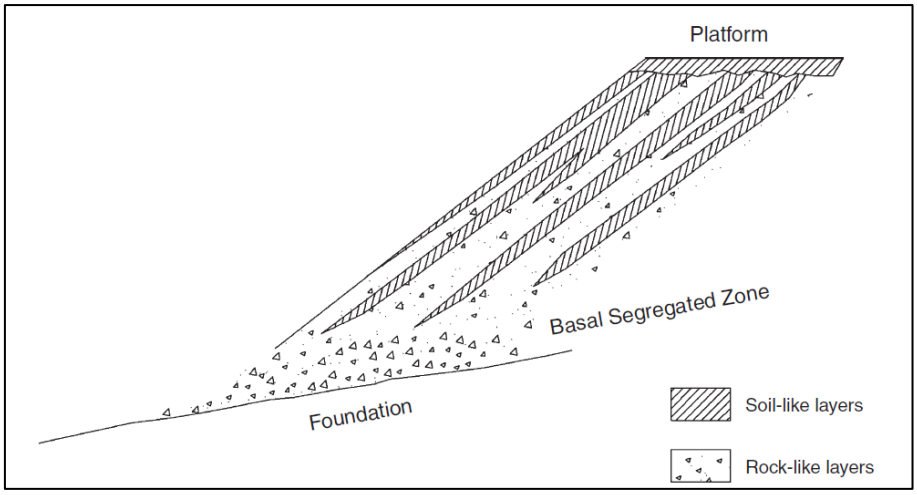


Figure A2: Typical stratigraphy of an end-dumped waste dump (Hawley and Cunning, 2017).

Previous geotechnical stability assessments for the NWRD, such as (Cartledge, 2024), were based on a bottom-up mine construction method for the entire NWRD facility and a moderate instability risk. This led to the use of the upper limit of the Leps curves, which is reasonable under an operational framework due to the moderate consequence and low likelihood of material flow, as well as the minimal reach of critical infrastructure due to the coarse nature of the waste rock. However, in a closure framework where the geotechnical instability of the NWRD has the potential to affect the top-tier cover system, a conservative approach in selecting material parameters is necessary due to uncertainties in the construction method of the NWRD and the cross-sectional variability in PSD of the batters. The landform design objective must be targeted at achieving long-term stability (DES, 2021).

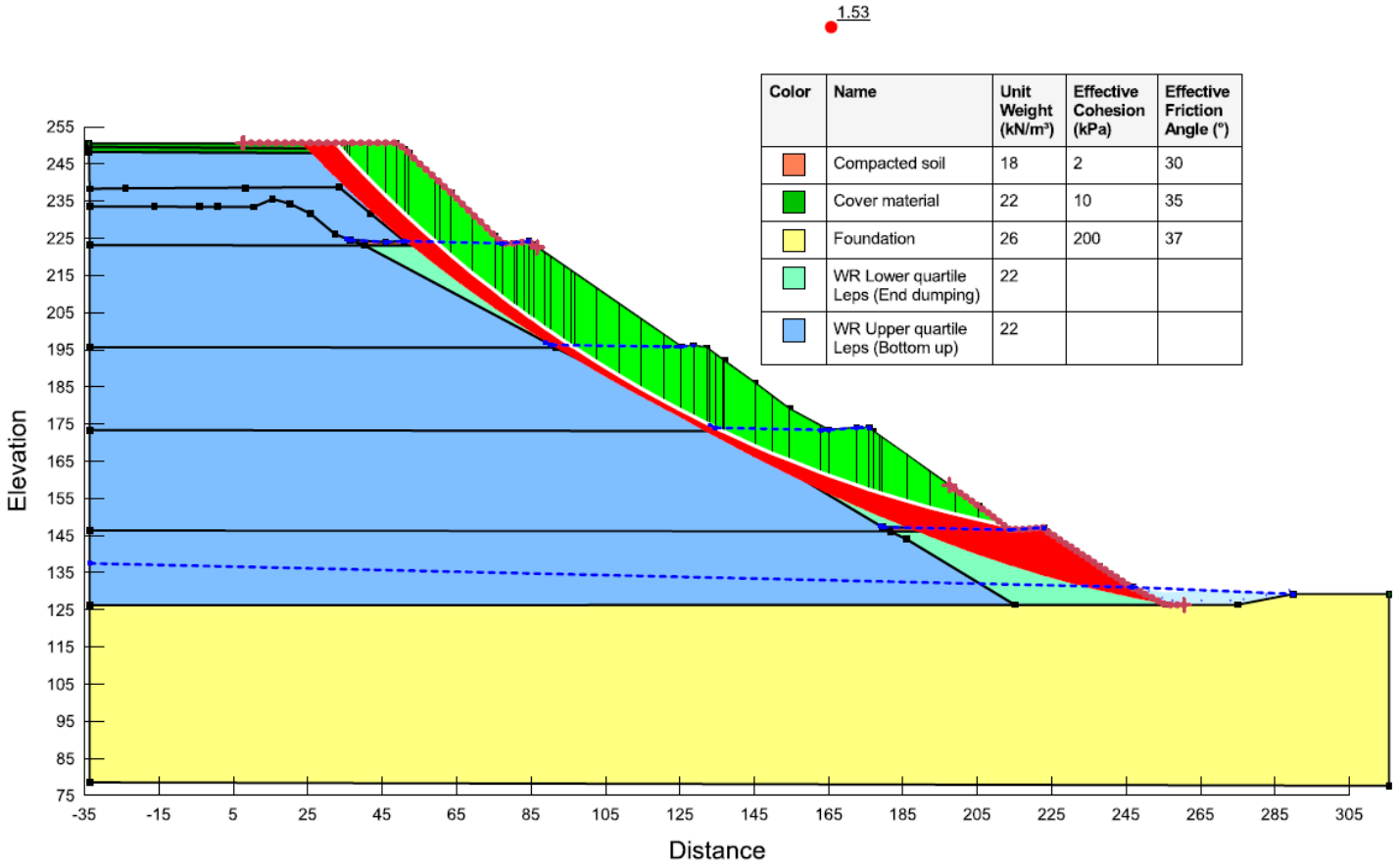
Furthermore, based on the findings and observations of the recent site visit, described in the main document, it was confirmed that the outer slopes were constructed by a top-down method of construction. These observations support the need for a conservative approach in assessing material parameters to ensure the long-term stability of the NWRD, considering the top-down method of construction with a low consequence of failure in the framework shown in Table A1.

Appendix B

Stability Sections

Appendix B – NWRD Stability Assessment

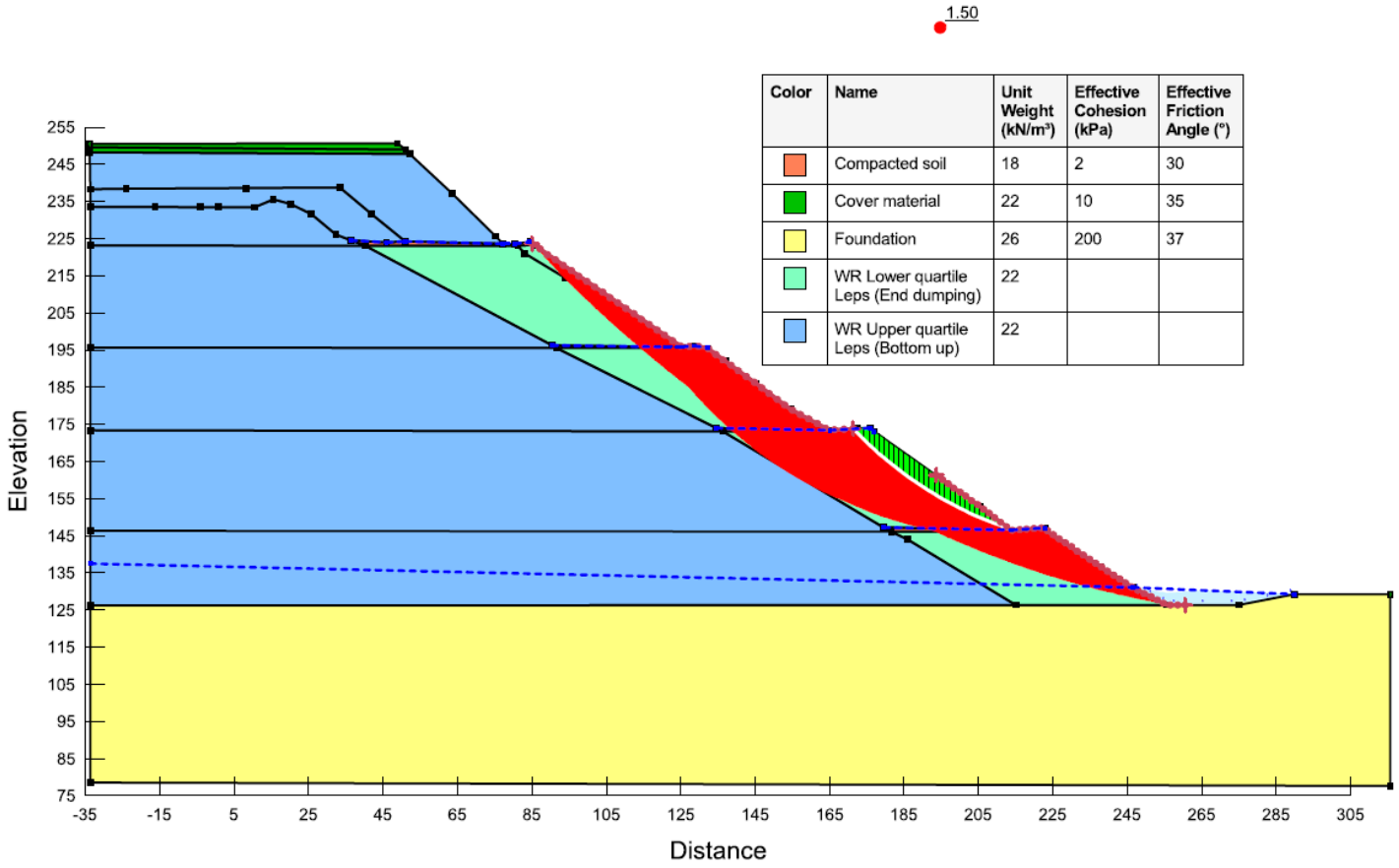
Mount Rawdon Operations



Section A 2% Berm

Lower quartile Leps - Drained

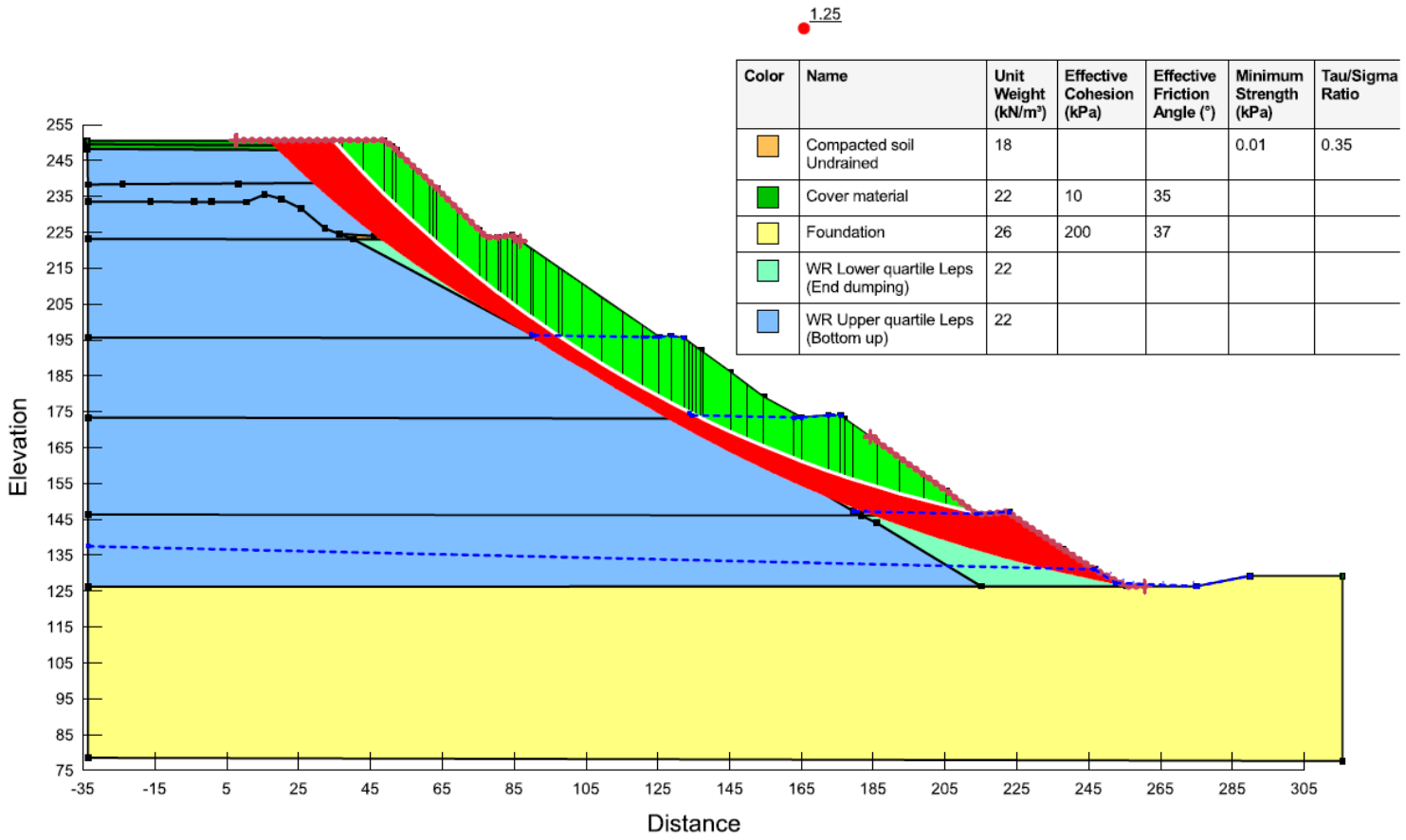
Global



Section A 2% Berm

Lower quartile Leps - Drained

Local



Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Minimum Strength (kPa)	Tau/Sigma Ratio
	Compacted soil Undrained	18			0.01	0.35
	Cover material	22	10	35		
	Foundation	26	200	37		
	WR Lower quartile Leps (End dumping)	22				
	WR Upper quartile Leps (Bottom up)	22				

Section A 2% Berm

Lower quartile Leps - Undrained

Global PS

okane