CARTLEDGE
MINING AND GEOTECHNICS

EVO010009

Mt Rawdon Mine Progressive Rehabilitation Closure Plan (PRCP) Geotechnical Assessments –NWRD

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EVOLUTION MINING AUSTRALIA

MT RAWDON MINE PROGRESSIVE REHABILITATION CLOSURE PLAN (PRCP) GEOTECHNICAL ASSESSMENTS – NWRD

Cartledge Mining and Geotechnics
Report No.: Rev 0
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1 Introduction

Cartledge Mining and Geotechnics (CM&G) undertook geotechnical assessments of the Mt Rawdon Mine Operations (MRO) Open Pit, North Waste Rock Dump (NWRD), and the MRO Tailings Storage Facility (TSF) as part of the Progressive Rehabilitation and Closure Plan (PRCP) Guideline which is a critical component of the rehabilitation policy under Queensland Government's Mine Land Rehabilitation Policy (DES, 2021).

The geotechnical assessments followed previous studies for the NWRD. Geotechnical stability was assessed for post-closure and long-term stability as indicated by the landform modelling results. For the final waste dump, the geotechnical stability considered the effects of long-term erosion and weathering of the dump and the effects of significant hydrological events as outlined in the *Mount Rawdon Final Voids Study Report (SLR Ref: 620.30185-R01 Version No: v2.0 December 2020)*

According to the PRCP Guidelines, "the final landform design must include modelling predicting the long-term stability of the final landform design" (Department of Environment and Science, 2021). The requirement of the Guidelines has been undertaken in this report in the analysis of the provided post-closure final waste dump slopes.

1.1 Scope of Work

The scope of work was split into two main categories following a meeting between MRO Site representatives and CM&G Principal Engineer. The two main categories to be addressed in the scope were:

- Addressing the PRCP Guideline requirements and the DES feedback.
- Review and incorporate results from other relevant work completed by other consulting parties, i.e., TSF LOM and hydraulic studies, waste dump capping design and erosion modelling.

From these two main categories, the detailed scope of work is outlined below:

1. Address the PRCP Guideline requirements and feedback from the Department of Environment & Science, which requires the following to be captured within a high-level geotechnical report:

- *Geotechnical modelling predicting long-term stability (factor of safety, etc.) of TSF and NWRD*
- *Information about the final waste rock dump wall geotechnical stability and a 3D design and consideration of the effects of long-term erosion and weathering of the final waste rock dump and the effects of significant hydrological events (where possible/practicable/relevant)*
- *The description of how the final waste rock dump will achieve post-closure slopes that will exhibit stability characteristics consistent with the planning and design of the post-closure waste rock dump. Mechanisms for achieving acceptable geotechnical stability must be detailed in the plan. This includes excavation, reshaping and dump configuration through earthwork methods such as backfilling, regrading, buttressing, and benching. Where applicable, methods and techniques for achieving safe slopes must be detailed.*

2. As discussed, work completed by others that may or may not be relevant to this study includes:

- *TSF LOM design – ATC Williams*
- *NWRD capping design – RGS Consultants – refer to capping option 1B.*
- *Hydraulic Assessment – ATC Williams (refer to an initial report, which is being updated to reflect reshaping the TSF at closure.*
- *Long-term landform evolution (erosion) modelling of low slope angles for NWRD and TSF cover systems – RGS Consultants*

2 Background

The MRO Site is approximately 100km inland from Bundaberg in southeast Queensland, within the Burnett region. The open pit operation has existed for over twenty years and has been managed by multiple owners. Evolution Mining currently owns MRO and has been the sole operator since 2011. The operation has a life of mine that extends to 2027.

The extent of the rehabilitation works for the MRO open pit currently extends to the NWRD through the placement of clay seals along the eastern berms. These seals will progressively be implemented until pit mining activities are completed and the temporary ore stockpiles are rehandled for processing.

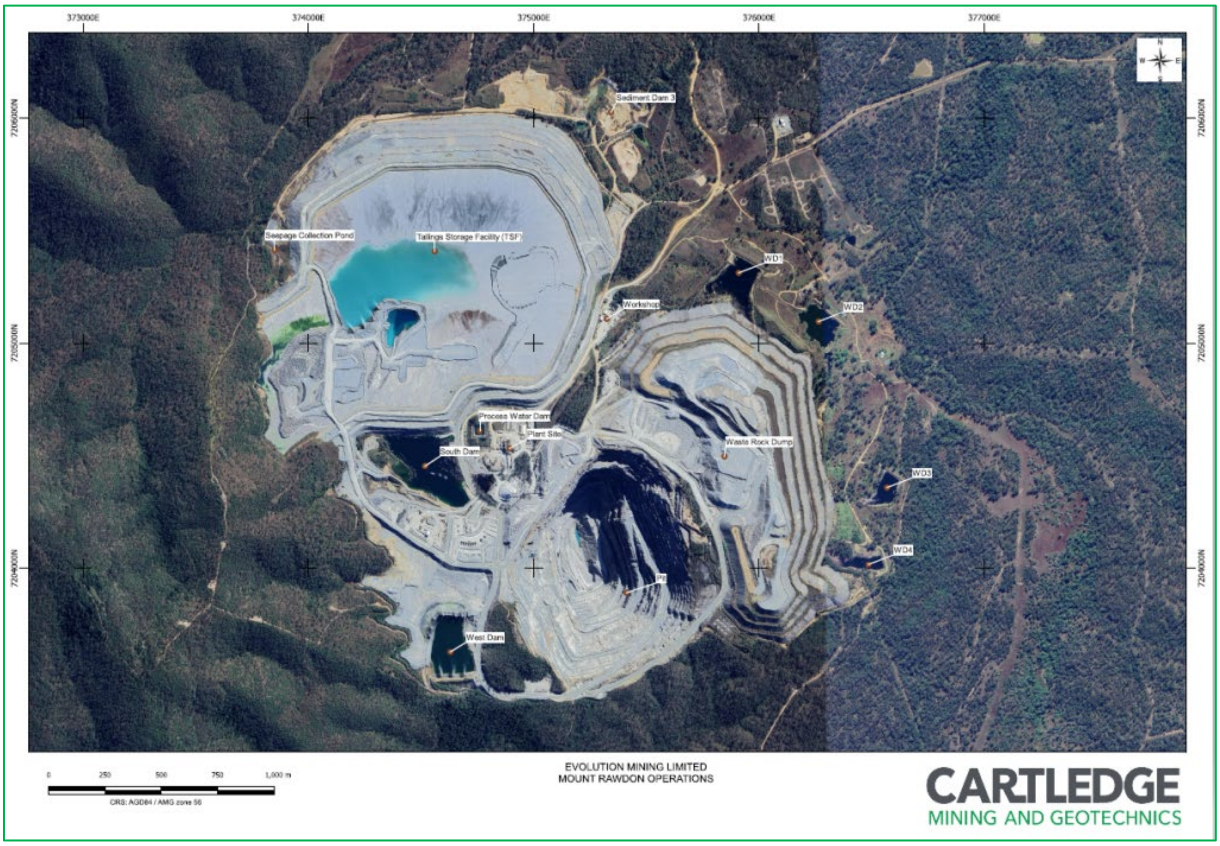

Figure 2-1: Mt Rawdon Operation site location

2.1 Information Provided

- TSF LOM design – ATC Williams consultants
- NWRD capping design – RGS consultants – refer to capping option 1B.
- Hydraulic Assessment, June 2021 – ATC Williams consultants (refer to an initial report, which is being updated to reflect reshaping the TSF at closure.)
- Long-term landform evolution (erosion) modelling of low slope angles for NWRD and TSF cover systems – RGS Consultants
- Topographic survey (original pre-mining surface)
- As-built surfaces and modelled closure surfaces (i.e., open pit, NWRD and TSF)
- TSF closure decommissioning and rehab plan – ATC Williams consultants, December 2017
- TSF conceptual closure and rehabilitation plan – RGC consultants, December 2017
- MRO Geochemical Report – RGS consultants, January 2021
- Open pit geotechnical review – PSM consultants, July 2021

- Assessment of long-term geochemical characteristics of Mt Rawdon tailings material_Final Report – RGS Consultants, January 2021
- NWRD final landform – Mt Rawdon mining
- MRO PRCP Geotechnical Assessment-Waste Dump_Final – CMG, November 2022
- MRO Erosion measurement and modelling.pdf – RGS, September 2023

3 Document Reviews

Reviewed documents in section 2.1 define different strategies and methodologies applied to analyse various aspects of the infrastructure relative to the closure requirements. Relevant information critical to the stability analysis of the infrastructure was extracted and used in the model setup for geotechnical stability assessments. MRO provided final design survey profiles at closure and post-closure, and geotechnical input parameters inferred from other studies were indicated in section 2.1.

3.1 Geotechnical Input Parameters

The input parameters considered in the final rock waste dump analysis are detailed below. Rockmass domains for the in situ material were defined by SRK Consulting (2017), and material properties (Table 1) were adopted from Itasca (2017).

Without site-specific laboratory data, parameters used in the stability analysis were collected from previous site studies and other relative reports.

For this assessment, the strength parameters for the upper 4.5 m clayey soil layer and the dry density of waste rock were sourced from previous AWA (2006) studies. In the same report, the cohesion and friction angle is set as 0 and 40°, respectively, based on the friction angle-normal stress correction proposed by Leps (1970).

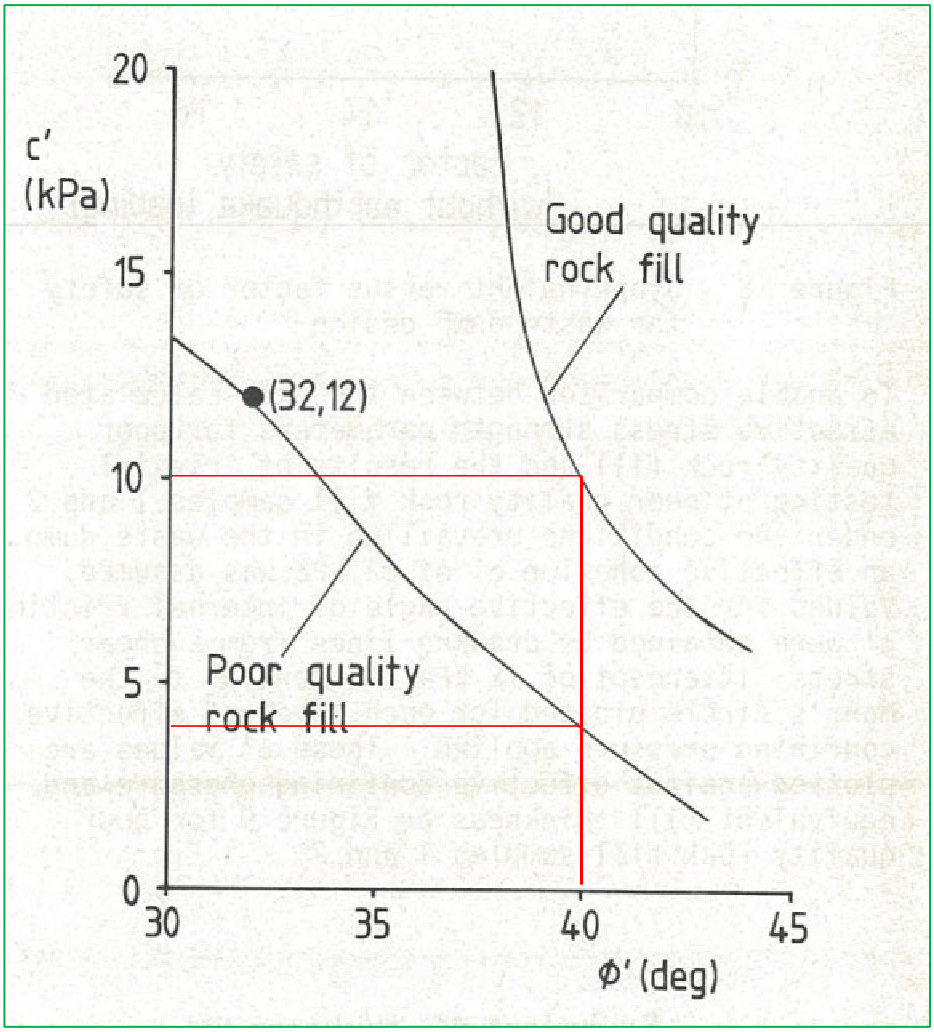

Figure 3-1: Back-calculated effective stress strength parameters (Williams & Walker, 1984)

Although the Leps chart (1970), which assumes zero cohesion, is widely employed in waste dump design, there remain ambiguities regarding cohesion in waste rock. For instance, the Australian coal industry extensively utilises categorised mining waste parameters with significant cohesion (Simmons & McManus, 2004). Furthermore, back-analysis on waste rock from an Australian Gold Mine (Williams & Walker,1984), similar to MRO, proposes an empirical chart (Figure 3-1) to delineate effective stress strength parameters. The back analysis stated that the rockfill comprising significant fines is categorised as poor quality rockfill, and the corresponding cohesion is about 3kPa.

Other research (Hawley & Cunning, 2017) conducted on a variety of rockfill materials indicates that the relationship between shear strength and normal stress can be elucidated using a power curve function:

$$\tau = a\sigma^b$$

where: τ represents shear resistance, σ represents normal stress, a and b are constants.

Section 3.8 ranked the waste dump instability hazard from NWRD as WHC III. In bottom-up spoil construction, mainly when the hazard of waste dump instability ranges from WHC I to III, the suggested rockfill shear strength constants are: $a = 2.067$, $b = 0.898$.. This function has also been incorporated into the current assessment.

From the above deduction, three distinct shear strength models for the waste rock have been applied in stability assessments, as outlined in Table 1.

Table 1: Modeling strength parameters

Material	ρ (kt/m^3)	c (MPa)	ϕ (°)	σ_{tm} (MPa)
Domain 4	26	201	37	24
Waste Rock (Leps(1970))	22	0	40	-
Waste Rock (Willams & Walker	22	3	40	-
Waste Rock (power curve)	22	$\tau = a\sigma^b$ ($a = 2.067$, $b = 0.898$)		-
Clayey Soils	18	2	30	-

Notes:
ρ – Rock Mass Density, c – Rock Mass Cohesion, ϕ – Rock Mass Friction Angle, σ_{tm} – Rock Mass Tensile Strength

Two and three-dimensional (2D and 3D) modelling were conducted for the geotechnical analysis. Irrespective of the modelling methodology, representative modelling requires careful specification of geotechnical model parameters. In contrast to the abundance of data on strength parameters, there exists a paucity of information on deformation parameters for waste rock. Young's modulus and Poisson's ratio, as studied by Simms (2020), exhibit a range of 25-100MPa and 0.3-0.4, respectively. In this report, we adopt a value of 50MPa for Young's modulus and 0.3 for Poisson's ratio. These values have been corroborated through back analysis of long-term Site deformation monitoring data.

3.2 Modelling Methodology

The PRCP Guideline (DES,2021) requires that the assessment of landforms for closure planning must include modelling that predicts the long-term stability of the final landform design.

The landform design objective must be targeted at achieving long-term stability through analysis of future stability status based on predicted and forecasted post-closure conditions. As alluded to in the preceding sections, other relative studies have been conducted for the NWRD. The methodology presented herein is only for determining the waste dump's geotechnical stability and deformation under established and analysed post-closure conditions. Recent studies conducted for the MRO NWRD have indicated that erosion will not impact the slope profiles of the waste dump post-closure due to the hard rock material properties of the volcanic rocks used in the construction of the waste dump (RGS 2023, Site correspondence). This assumption has been considered in this geotechnical analysis.

Rocscience software Slide 3 and RS3 were used to analyse the stability of the waste dump.

Material properties were first assigned by dividing the dump geometry against the initial topography of the site to determine the in-situ boundary. A subsoil clayey-sand layer was modelled based on the hydrogeological units defined in the final void study report (SLR, 2020) as a 4.5 m thick unit. Below this unit is the regolith, composed of highly weathered igneous rocks of up to 15 m (SLR, 2020). This regolith unit was assigned the rockmass domain 4 material properties, as per site-specific rockmass domaining, to align with the material properties used for the final void analysis.

The Morgenstern-Price Global Limit Equilibrium (GLE) method was adopted to report the analysed results due to its inherent capability to resolve horizontal and vertical force and moment equilibrium.

3.3 Stability Assessment Criteria

The adopted assessment criteria for the slope stability analysis are based on the overall slope scale under the high consequence of failure (Hawley & Cunning, 2009). This is summarised below based on a static and pseudo-static factor of safety values.

The location of the MRO waste dump is away from critical infrastructure and has unrestricted access, with overall slopes less than 30° and less than 250 m high. Therefore, its consequence level is moderate. However, the material input parameters adopted in this assessment are collected from previous studies and are of a low confidence level due to the inherent uncertainties, as shown in Table 2. Based on this information, the minimum FoS for static and pseudo-static analyses can be set as 1.5 and 1.15, respectively, with the maximum probability of failure (PoF) ranging between 2.5-5% and maximum allowable strain less than 0.75%.

Table 2: Typical FoS and PoF acceptance criteria values (Hawley & Cunning, 2017)

Consequence[1,3]	Confidence[2,3]	Static analysis: Minimum FoS	Static analysis: Maximum PoF[4]	Pseudo-static analysis: Minimum FoS	Maximum allowable strain[5]
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 five 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 for 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

3.4 Seismic Loading

A probabilistic seismic analysis (PSHA) was conducted at MRO in 2020. The PSHA concluded that MRO is in a low seismicity region of Australia. For the final landform analysis, the two design events considered were the operational basis earthquake (OBE) of peak ground acceleration of 0.09g and the site evaluation earthquake (SEE) of peak ground acceleration of 0.25g, both having a magnitude of 7.5 (ATC, 2020). For post-closure analysis, the SEE design event was applied to assess the stability of the final waste rock dump landform, and the corresponding seismic coefficient used in Slide 3 is 0.25.

3.5 Phreatic Surface

A phreatic surface created from the Mt Rawdon Post-Closure Groundwater Model (SLR, 2020) was used as the groundwater table for the open pit model and applied to the final landform analysis.

The analysis was conducted with the Hu value, the hydrogeological coefficient for the material type, in the Auto mode. This groundwater modelling used the stabilised groundwater elevation to assess the post-closure WRD landform stability conditions, as shown in Figure 3-2

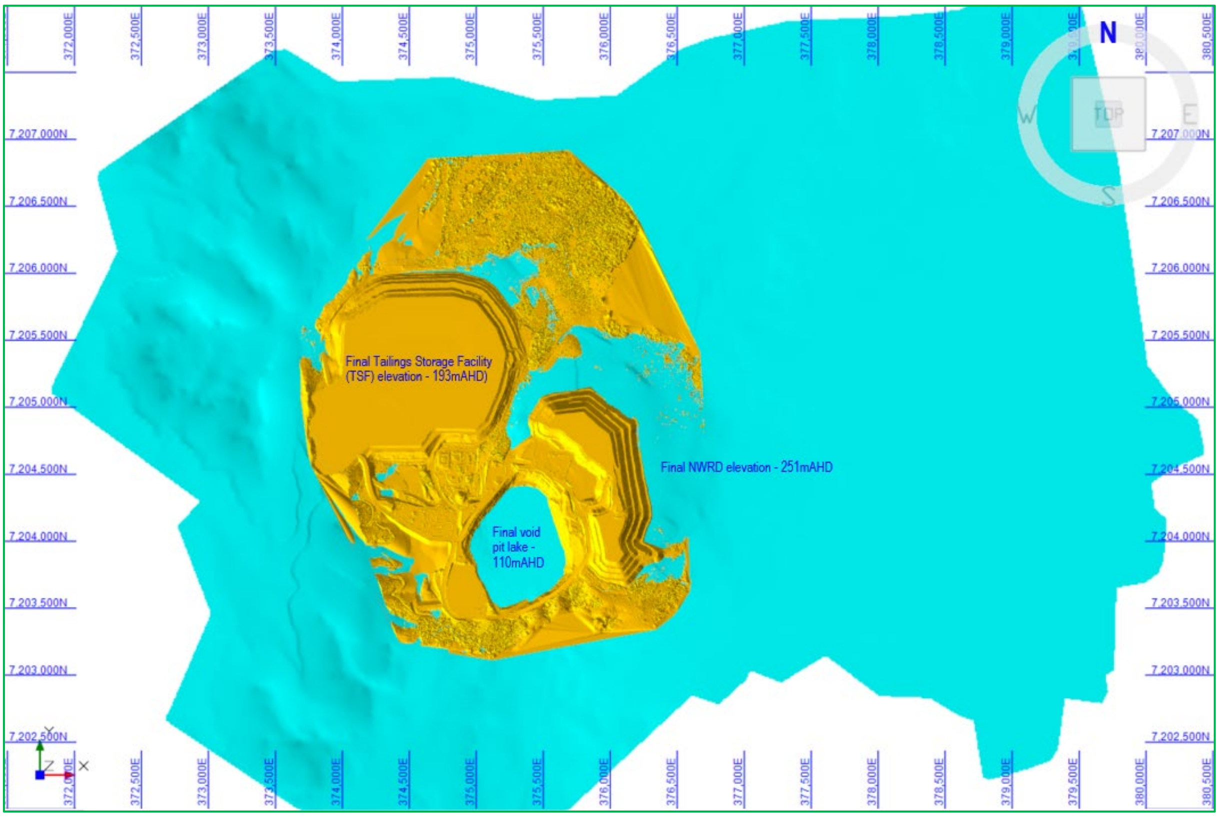

Figure 3-2: MRO Infrastructure showing the stabilised water balance after 275 years at elevation 110mAHD

3.6 Modelling Assumptions

The following design assumptions were adopted to analyse the final waste rock dump.

- Rockmass parameters were obtained from Itasca (2017).
- Waste rock parameters were collected from previous studies as presented in Section 3.1

- Final slopes were analysed based on the planned final waste rock dump slopes at closure. Long-term erosion was considered, however, without causing any profile changes to the proposed final waste dump slopes due to the material used to construct the waste dump.

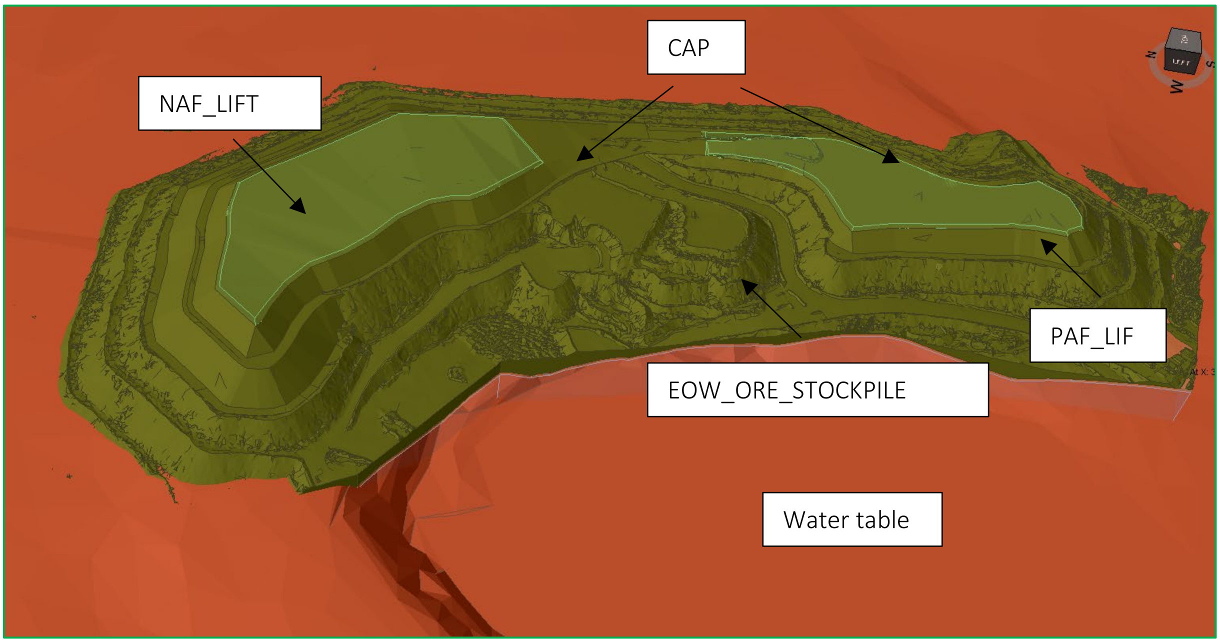

Figure 3-3: Illustration of numerical model

3.7 Stability Analysis Results

3.7.1 Limit Equilibrium Analysis (Slide3)

Two failure modes, localised and global, were identified from the Slide 3 Limit Equilibrium analysis results, as presented in Table 3 and Appendix A.

The localised failures are bench-scale, and global failures affect the overall slope. For the Mohr-Coulomb (M-C) strength function with zero cohesion under static loading, for example, the location of the localised failure in the final NWRD is depicted in Figure 3-4, with detailed failure surface information provided in Figure 3-5. The localised failure modes can be anomalous and induced by the modelled shape and geometry of the slope profile or the triangulation of the survey, with no significant impact on the overall stability of the dump.

On the other hand, global failure encompasses extensive areas and can compromise the overall stability of the dump. As outlined in Table 3, the minimum global factor of safety values determined under static and seismic loading conditions with different strength parameters fall below the prescribed criteria, except under static loading with power curve parameters. The assessment results in Appendix A indicate that most of the dump will have a factor of safety (FoS) greater than 1.5 and 1.15 under static and seismic loading, respectively.

Under static loading, identified failure surfaces are concentrated on the north side of the final NWRD and distributed depending on the material parameters. The minimum factor of safety determined via AWA's material parameters is around 1.08, indicating marginal safety. This aligns with on-site observations confirming the waste dump's stability and absence of significant failures. When raising the cohesion to 3kPa, the minimum FoS increases to above 1.30 but still falls short of the 1.5 requirement. Conversely, adopting the power curve parameters developed by Hawley and Cunning (2017) yields a minimum factor of safety higher than 1.5.

Under seismic loading, a minimum factor of safety values under all scenarios is less than 1.15, indicating potential instability during earthquakes. Most of the failure occurs on the north wall middle bench where the phreatic surface intersects the wall. The situation in the results determined via AWA's parameters is the worst, with the failure surface almost extending across the whole north wall of NWRD.

Table 3: Minimum FoS obtained from stability analysis results with different material parameters

Material parameters	Scenario	(GLE/Morgenstern-Price)*	Target FoS under acceptance criteria‡
Mohr-Coulomb (Zero Cohesion)	Static	1.08	1.4 -1.5
	Seismic	0.66	1.1 -1.15
Mohr-Coulomb (3kPa Cohesion)	Static	1.31	1.4 -1.5
	Seismic	0.85	1.1 -1.15
Power curve	Static	1.73	1.4 -1.5
	Seismic	1.24	1.1 -1.15

Notes:

* Results show the global lowest calculated FoS. No FoS <1.5 for static or <1.15 for dynamic scenarios was found to create deep-seated instabilities

‡ Hawley & Cunning, 2017

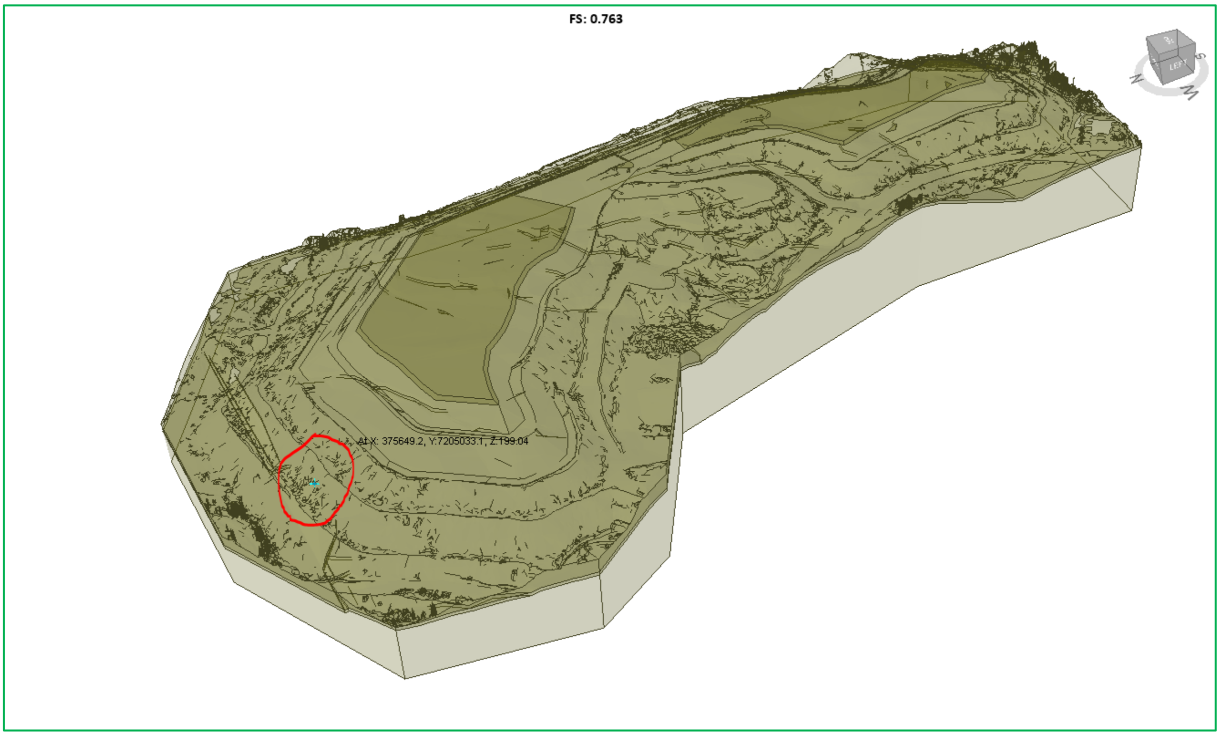

Figure 3-4: Localised minimum failure surface of Mohr-Coulomb with zero Cohesion under static conditions

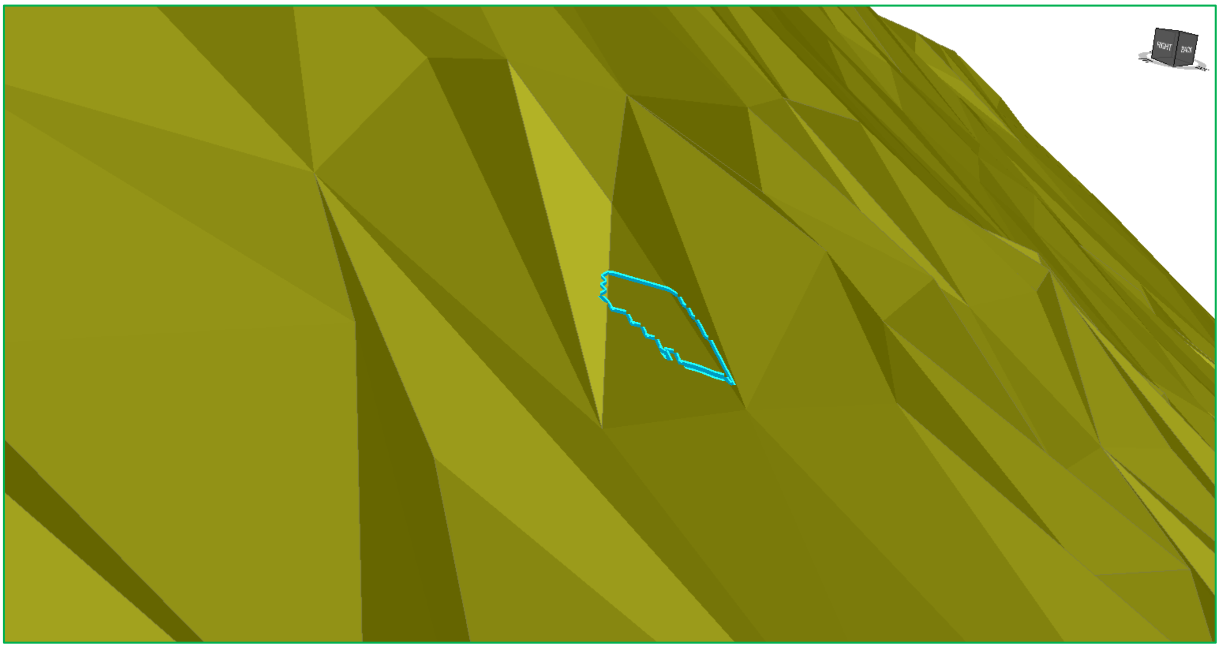

Figure 3-5: Details of the localised minimum failure surface of Mohr-Coulomb with zero Cohesion under static conditions

From the above discussion, typical NWRD failure surfaces are located on the north wall, especially the lower bench where the phreatic surface intersects the wall, and the NAF lift 5. Considering the localised areas where there is a marginal factor of safety, buttressing these areas can be implemented to enhance the factor of safety for long-term stability.

3.7.2 Deformation Analysis (RS3)

The deformation analysis results are illustrated in Figures 3-6, 3-7, and 3-8, revealing calculated vertical and E-W displacements of 500mm and 1200mm, respectively. These displacements are relatively comparable to the corresponding InSAR monitoring, which recorded values of 176mm and 329mm in the same direction during a two-year monitoring period between May 2021 and December 2023.

The time required for soils to achieve primary settlement varies considerably due to factors like particle size distribution, moisture content, loading conditions, and site-specific characteristics. Typically, sandy soils settle relatively rapidly owing to their granular composition and ability to accommodate deformation. However, primary settlement time frames can fluctuate from months to several years based on the abovementioned variables and the applied load's magnitude.

Assuming 65% settlement has occurred with the current emplaced dump material, based on ongoing monitoring data, the projected settlement under post-closure conditions will be approximately 510mm, assuming no other changes to configuration and surcharge loads, which closely aligns with the numerical result of 500mm for the final dump long-term deformation. Thus, the adopted Young's modulus value in this report closely represents site conditions under relative uncertainties and sensitivities. However, this will require further monitoring and investigation to validate the input parameter.

The maximum displacements occur on the northeast slope, coinciding with the stability analysis results. With maximum total displacements measuring 1300 mm. The analysed deformation implies no long-term stability concerns for the waste dump. Consequently, no significant deformations are anticipated to trigger landslides adversely.

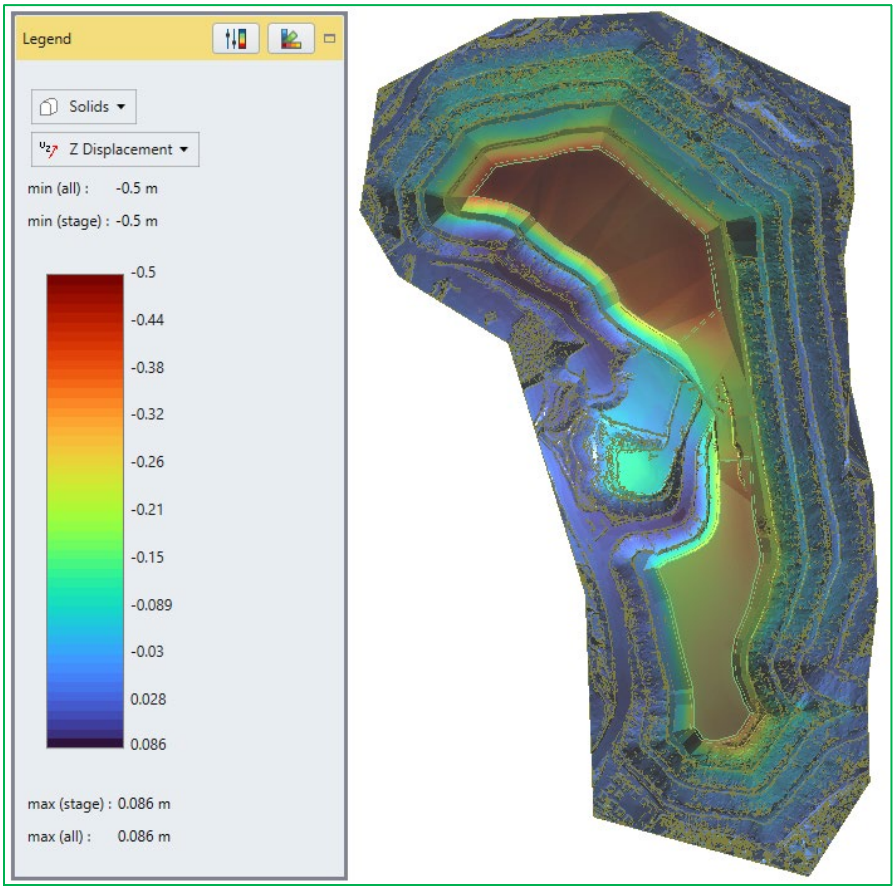

Figure 3-6: Vertical deformation of final waste dump

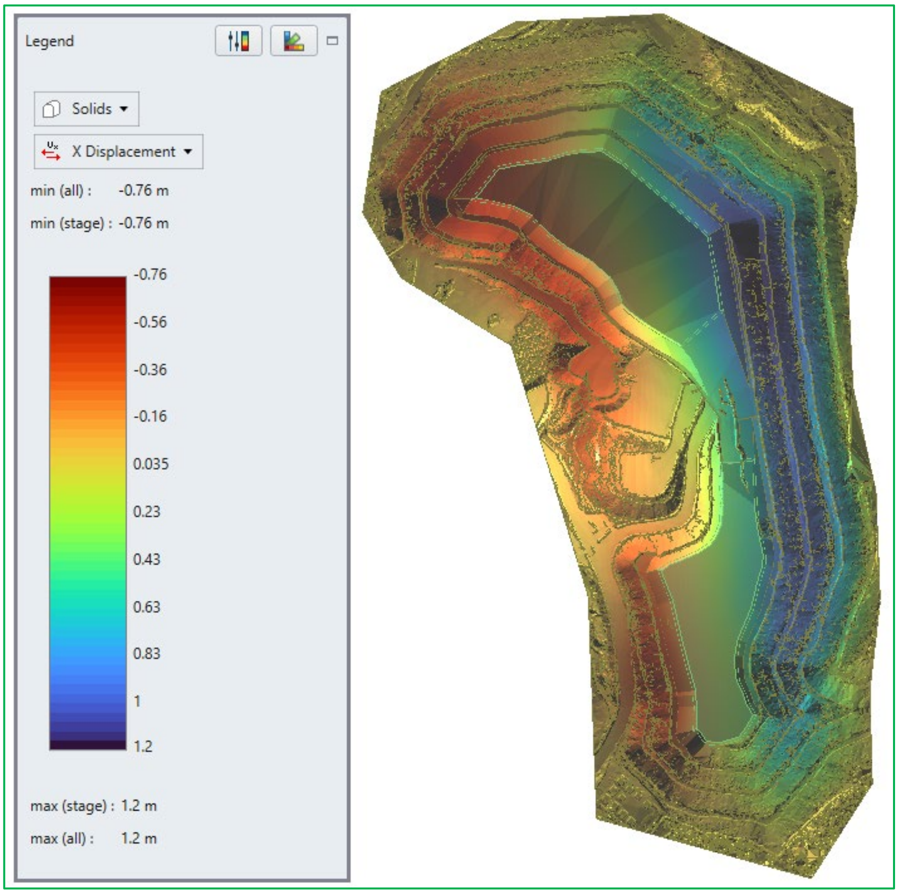

Figure 3-7: E-W deformation of final waste dump

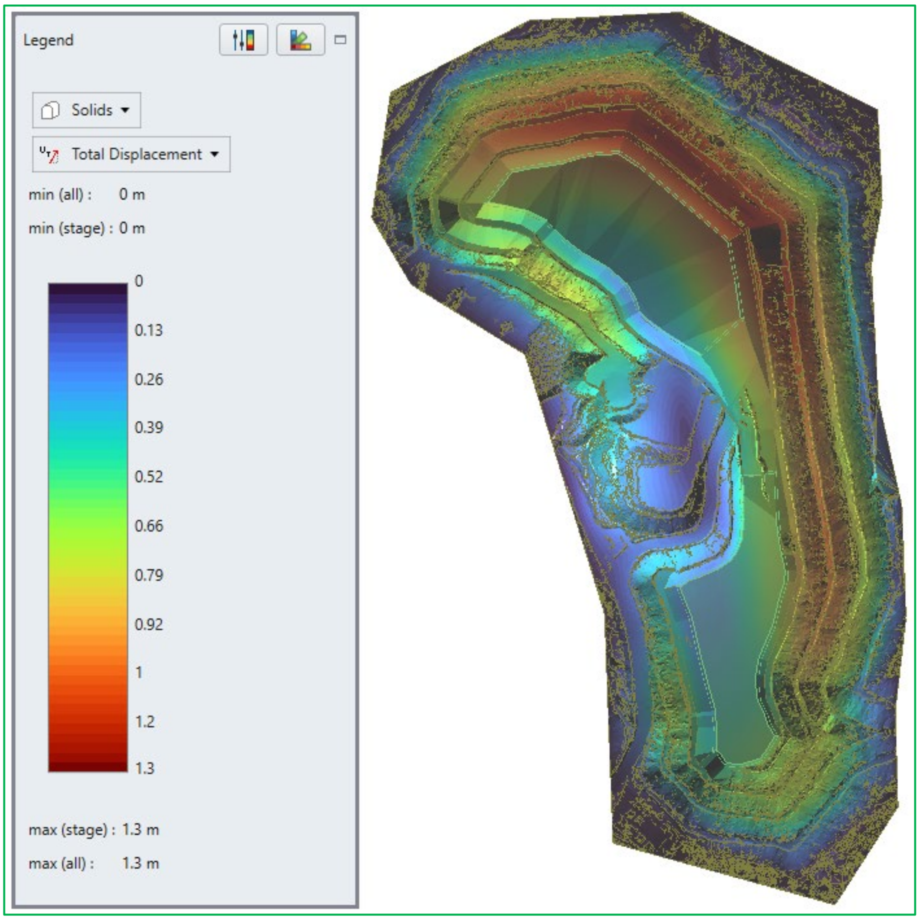

Figure 3-8: Total deformation of final waste dump

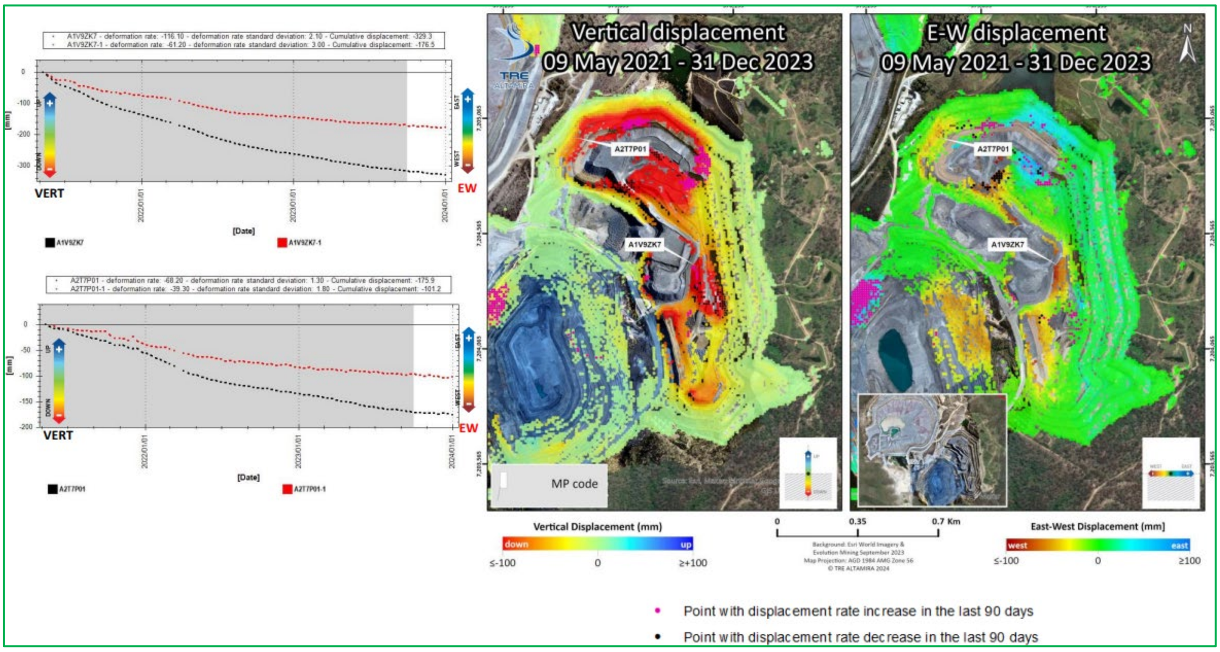

Figure 3-9: Measured vertical and E-W displacement of waste dump between 2021 and 2023.

3.8 Waste Dump Stability Rating (WSR)

The final waste dump model elements were incorporated into the Waste dump and stockpile stability rating and hazard classification system (Hawley & Cunning, 2017).

This system requires the evaluation of 22 key factors or attributes that are thought to affect stability. These factors have been organised into seven groups. Numerical ratings are assigned to each factor, and the sum of these ratings defines the waste dump and stockpile stability rating (WSR) (Figure 3-10).

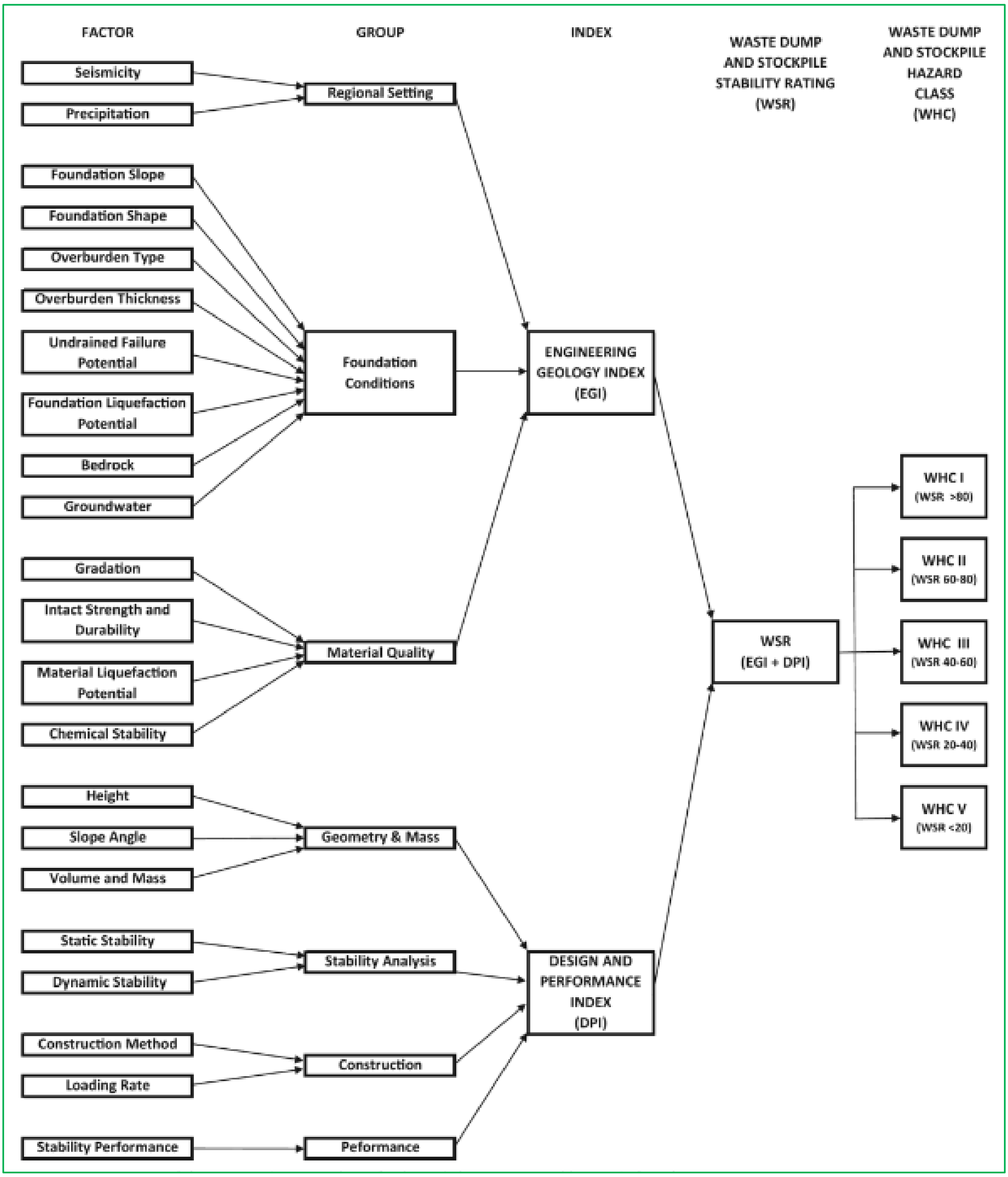

Figure 3-10: Structure of the waste dump stability rating and hazard classification system

The waste dump stability rating was scored against all factors to resolve the Engineering Geology Index (EGI) and the Design and Performance Index (DPI).

Table 4: Waste Dump Stability Rating and Hazard Classification System

Index	Group	Factor	Value	Rating
Engineering Geology Index (EGI)	Regional Setting	Seismicity	OBE – 0.09 g SSE – 0.25 g	1.5
		Precipitation	1000-2000mm	2
	Foundation Conditions	Foundation Slope	Flat (<5°)	5
		Foundation Shape	Planar or concave on gentle slopes	1.5
		Overburden Type	Typically highly weathered with minor partially weathered rock	3
		Overburden Thickness	3-5 m	1
		Undrained Failure Potential	Moderate	-5
		Foundation Liquefaction Potential	Low	-2.5
		Bedrock	Type D	3
		Groundwater	Moderate	1.5
	Material Quality	Gradation	Coarse-Grained	7
		Intact Strength and Durability	Very Strong to Extremely Strong (100-130 MPa)	8
		Material Liquefaction Potential	Low	-2.5
		Chemical Stability	Relatively Low	2.5
Design And Performance Index (DPI)	Geometry and Mass	Height	Moderate – 115 m	2
		Slope Angle	Moderate - 27°	2
		Volume and Mass	Large - 38 Mm^3	1
	Stability Analysis	Static Stability	<1.1	0
		Dynamic Stability	<1.0	0
	Construction	Construction Method	Method IV	6
		Loading Rate	Low	5
	Performance	Stability Performance	Very Good	15

Table 5: Waste Dump Stability Rating Summary

	Rating	Group Score	Index Score
Engineering Geology Index (EGI)			
Regional Setting	Neutral	3.5	25.5
Foundation Condition	Neutral	7.0	
Material Quality	Good	15.0	
Design and Performance Index (DPI)			
Geometry and Mass	Medium	5.0	31.0
Stability Analysis	-	-	
Construction	Very Favourable	11.0	
Performance	Very Good	15.0	

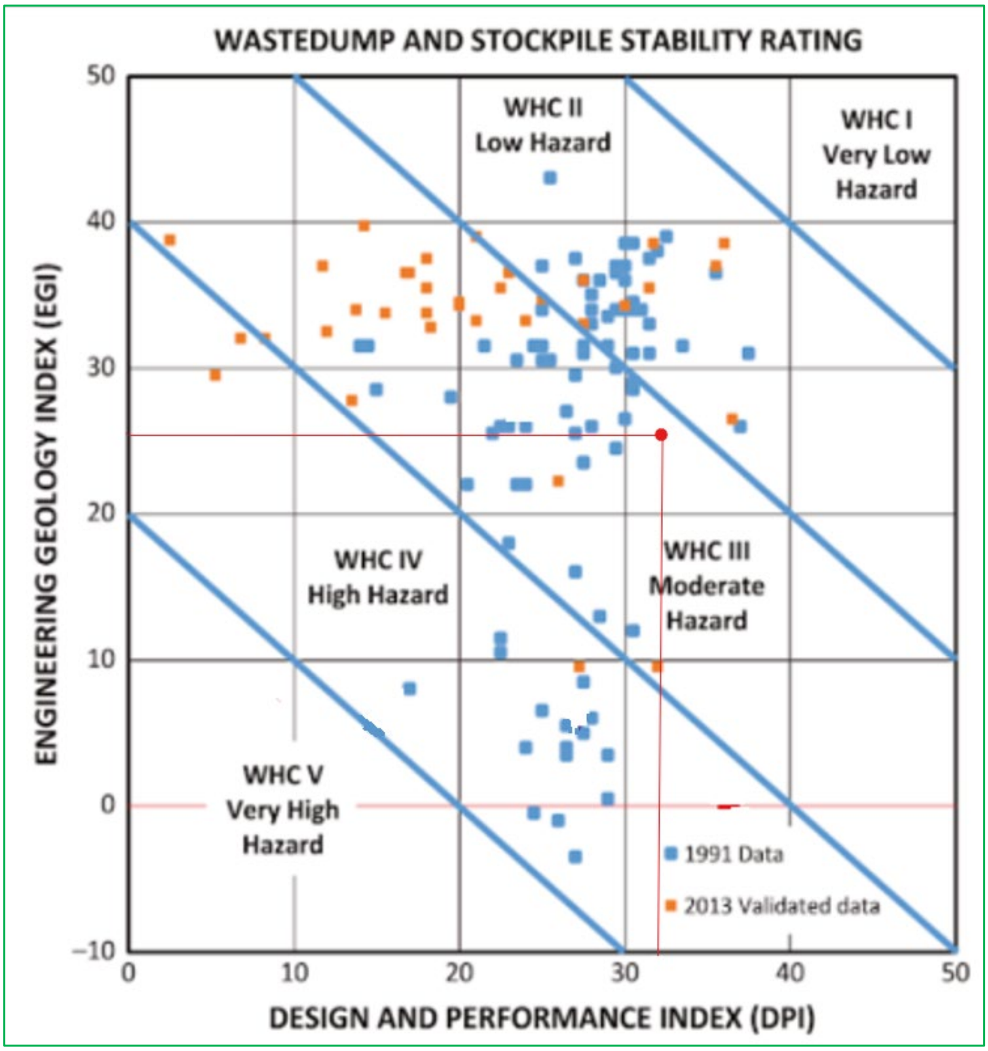

Figure 3-11: Waste dump stability and hazard chart showing MRO NWRD stability rating (red dot)

As per the WRS classification system (Hawley & Cunning, 2017), the intersection of the EGI and DPI results places the MRO final waste dump within the moderate hazard classification (red dot). Guidelines for the investigation and characterisation, analysis and design, and construction and operation phases are described below.

Applying this to post-closure conditions, as per the WRS guidelines, a moderate hazard classification should require adherence to the following:

Moderate site preparation may include diversions and underdrainage; limited foundation instrumentation to verify performance; runout/rollout mitigation measures, if required; moderately constrained construction sequence; control of fill quality and placement as necessary; loading/advance rate restrictions; standard instrumentation and visual monitoring with well-defined TARPs; periodic (minimum annual) inspections by an experienced geotechnical specialist.

4 Recommendations

The following recommendations have been made to ensure safe operations around the final waste rock dump for long-term stability conditions:

- Static and pseudo-static stability analyses indicated that the dump would meet the design requirements under the design acceptance criteria in Table 2, using the power curve function as proposed in the Guidelines for Mine Waste Dump and Stockpile Design (Hawley & Cunning, 2017). However, other methods used for sensitivity analysis, including input parameters used in historical stability studies, did not meet the design acceptance criteria (DAC) adopted. From this analysis, it can be concluded that the dump's stability and deformation characteristics are sensitive to the model input parameters, and hence, site-specific investigations to validate the parameters will be essential.
- For localised areas, mainly in the north wall, that obtained a factor of safety less than the criteria. Buttressing these areas is recommended to enhance long-term stability.
- CConsidering that long-term erosion effects will not impact the dump profile conditions and degrade the material strength properties due to the nature of the rock material used during construction, the provided waste dump profile changes long-term will be insignificant. Hence, the analysed results provide an acceptable stability condition for NWRD.
- Surface water management and drainage will be critical controls for rainfall events and the ensuing surface runoff. Proper planning, design and implementation of such structures will facilitate good surface water management as a long-term strategy.
- One of the most sensitive components of this model is the hydrogeological surface modelling of the long-term groundwater trends used for the analysis. As stated, the surface used was provided by external consultants. Variations in this model will be significant to the geotechnical stability of the dump; hence, sensitivities to the phreatic surface variations will be required to assess the long-term stability impacts.

5 Conclusion

A summary of the results from stability and deformation analyses was discussed in the report. In a set of sensitive analyses, the results produced by the parameters adopted and from historical reports and literature review indicate sensitivities to material input parameters. In contrast, the power curve strength parameters derived from established waste dump design guidelines met the design criteria. It is imperative to acknowledge the limitations of relying solely on literature-based assumptions. To mitigate uncertainties and enhance accuracy, site investigation and laboratory testing will be recommended to validate the input parameters (Hawley & Cunning, 2017). Continuous instrumentation and visual monitoring with well-defined Trigger Action Response Plans (TARPs) are crucial to ongoing safety protocols. Any anomalies detected during periodic inspections conducted by experienced geotechnical specialists must be promptly addressed in accordance with established guidelines outlined in the TARPs. By integrating these measures, waste dumps' long-term stability and safety can be guaranteed.

The mechanisms to achieve acceptable stability to align with best leading practices were detailed in the report. Other supporting reporting in the closure, post-closure, and rehabilitation strategies were reviewed to ensure that the post-closure conditions analysed in the report aligned with the rest of the considered closure plan. Based on this background, the analyses demonstrated that the MRO dump would be globally stable under post-closure conditions.

Long-term erosion effects were considered less impactful on the waste dump profile and configuration changes caused by material deterioration due to the non-acid-forming (NAF) rock material used to encapsulate the waste dump. This consideration will significantly influence the overall performance of the waste dump’s stability condition long-term.

6 References

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7 Conclusion

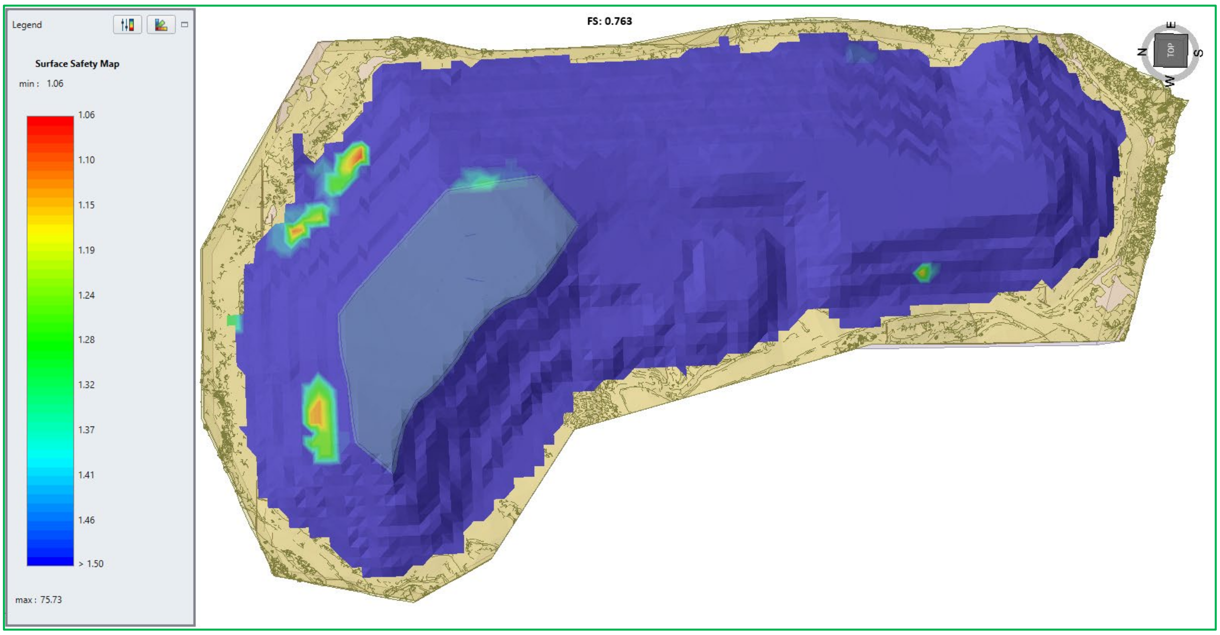

Figure 7-1: Waste dump stability safety map of Mohr-Coulomb function with zero cohesion under static loads, showing location with a factor of safety less than 1.5

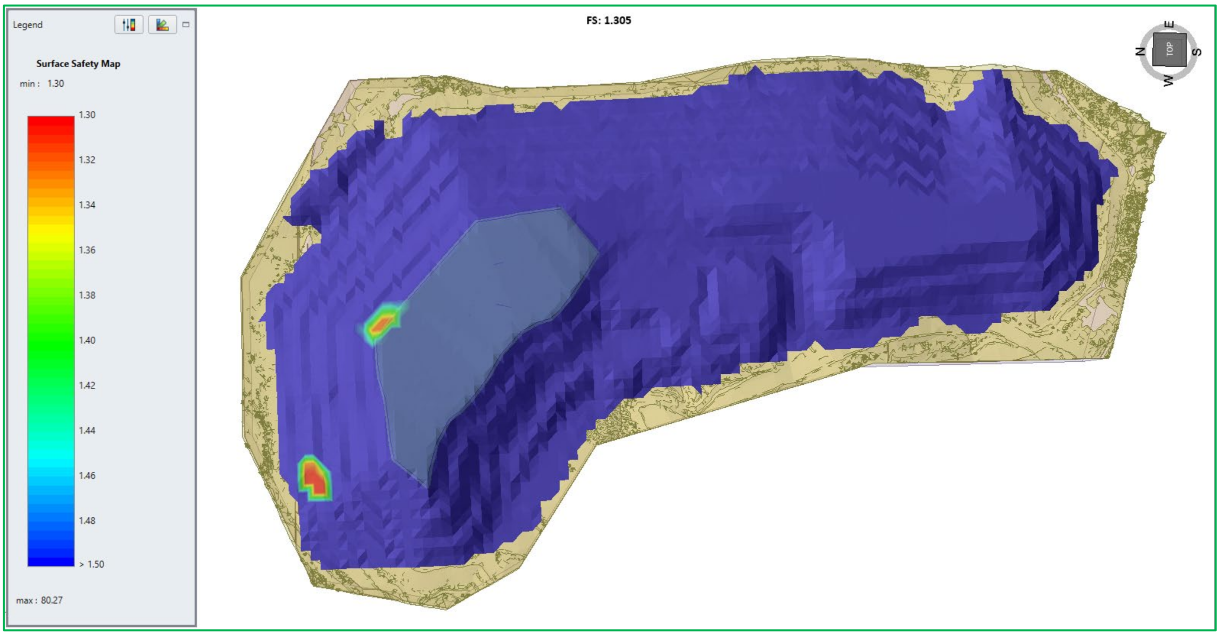

Figure 7-2: Waste dump stability safety map of Mohr-Coulomb function with 3kPa cohesion under static loads, showing location with a factor of safety less than 1.5

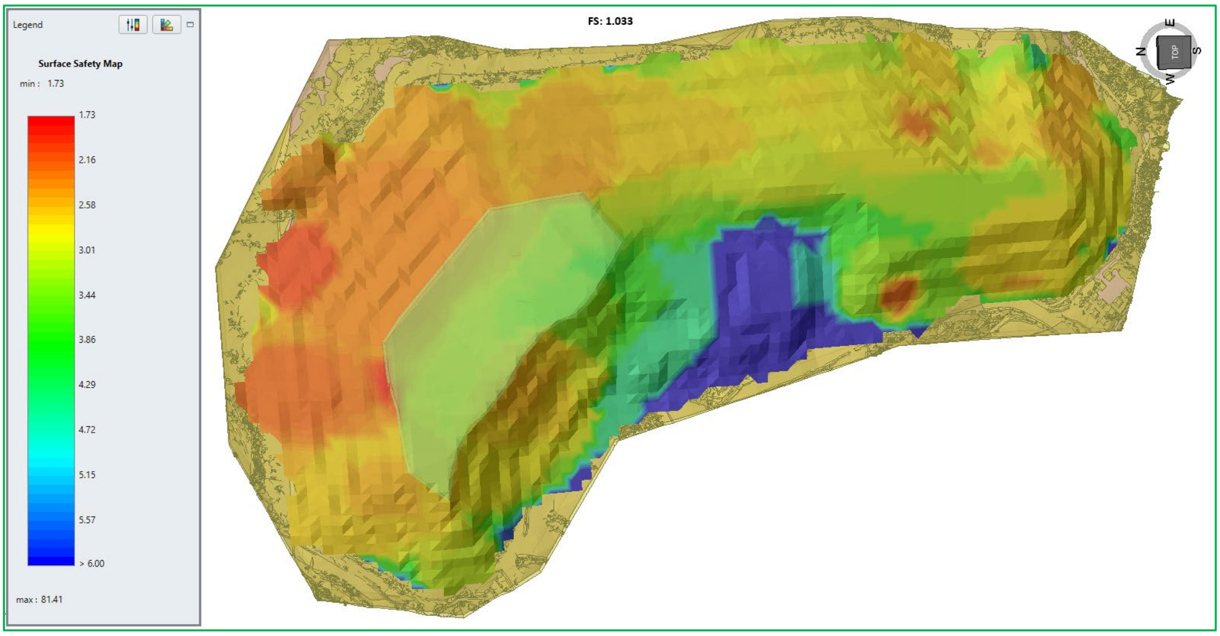

Figure 7-3: Waste dump stability safety map of power curve under static loads, showing location with a factor of safety less than 6.0

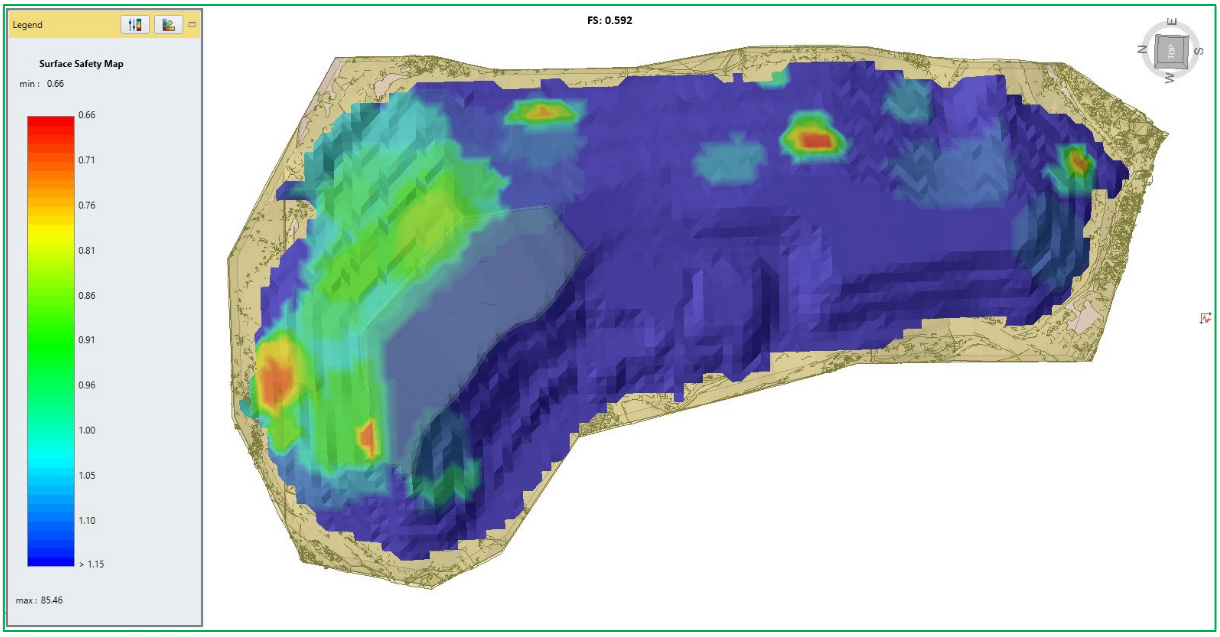

Figure 7-4: Waste dump stability safety map of Mohr-Coulomb function with zero cohesion under seismic loads, showing location with a factor of safety less than 1.15

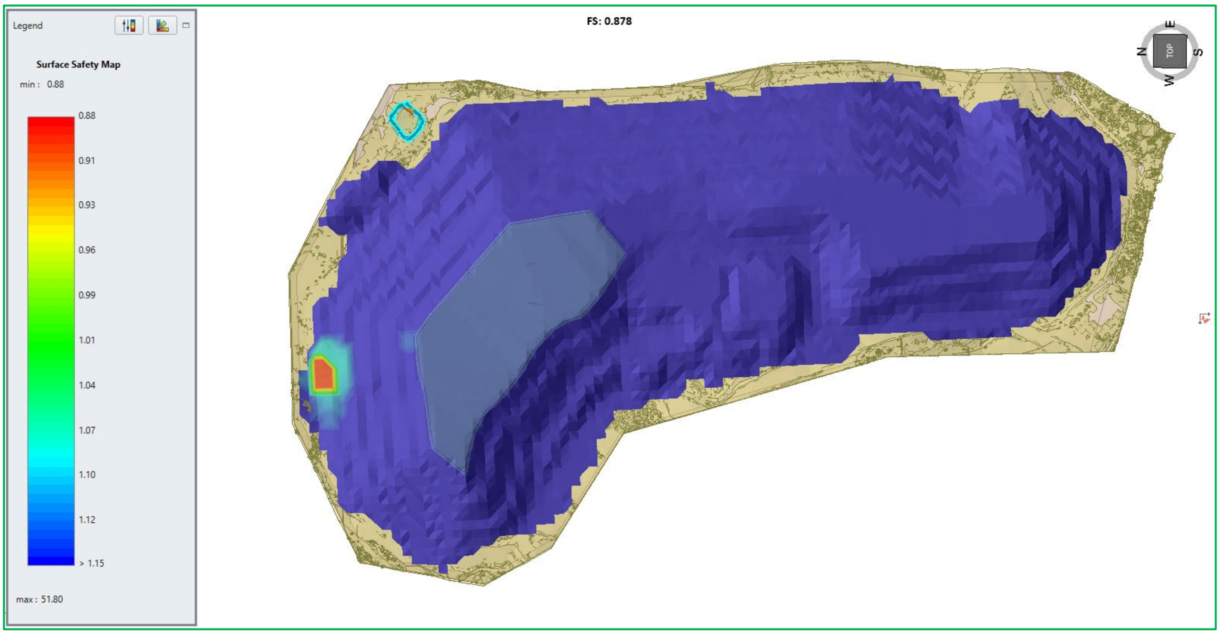

Figure 7-5: Waste dump stability safety map of Mohr-Coulomb function with 3kPa cohesion under seismic loads, showing location with a factor of safety less than 1.15

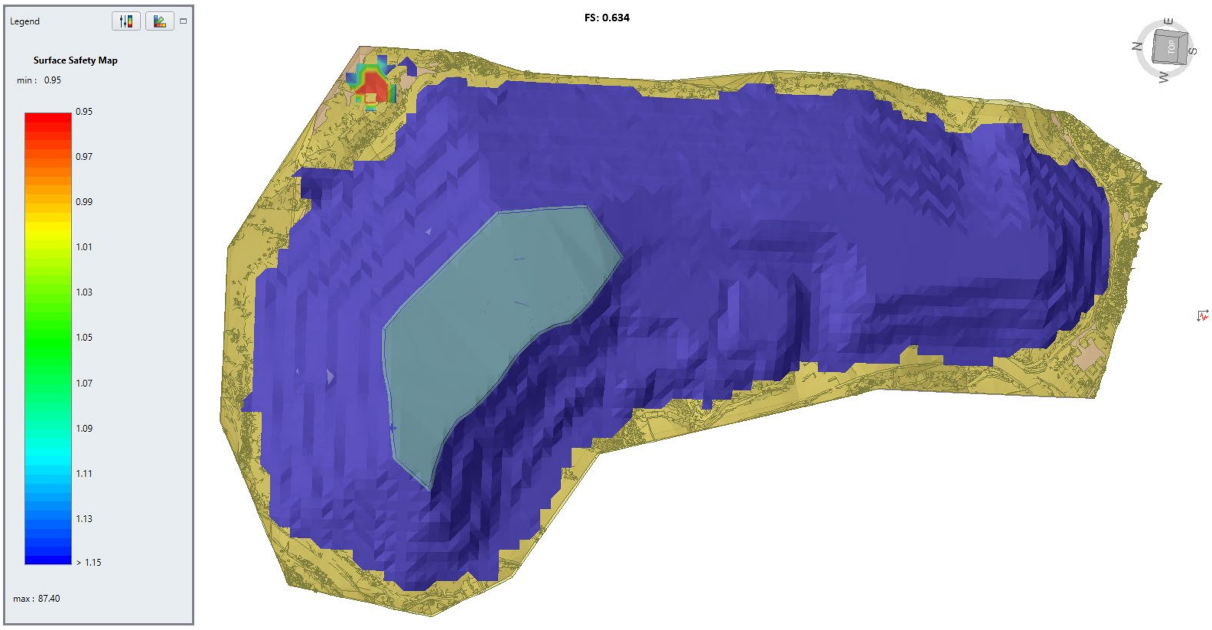

Figure 7-6: Waste dump stability safety map of power curve under seismic loads, showing location with a factor of safety less than 1.15