CARTLEDGE
MINING AND GEOTECHNICS

EVO010006

Mt Rawdon Mine Progressive Rehabilitation Closure Plan (PRCP) Geotechnical Assessments – Tailings Storage Facility (TSF)

Report No.: Rev 0_Final
12 November 2022

EVOLUTION MINING AUSTRALIA

MT RAWDON MINE PROGRESSIVE REHABILITATION CLOSURE PLAN (PRCP) GEOTECHNICAL ASSESSMENTS – TAILINGS STORAGE FACILITY (TSF)

Cartledge Mining and Geotechnics
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Rev	Date	Author	RPEQ No.	Reviewer	RPEQ No.	Description
0	11 November 2022	Adam Kerr		Keith Mandisodza	25401	Draft
1	12 November 2022	Adam Kerr		Keith Mandisodza	25401	Final

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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 (NWRDP), 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 individual studies for all the infrastructures that were analysed. Geotechnical stability was assessed for post-closure and long-term stability as indicated by the landform modelling results. For the tailings storage facility, the geotechnical stability considered the effects of long-term erosion and weathering 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 tailings require characterisation to determine the geochemistry, rheology, and geotechnical parameters that influence the rehabilitation or management strategies and the capacity of the Site to support revegetation. The requirement of the Guidelines has been undertaken in this report in the analysis of the provided post-closure final TSF slopes.

1.1 Scope of Work

The scope of work was split into two main categories following a meeting held 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 being 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 void (pit) wall geotechnical stability and a 3D void design and consideration of the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events (where possible/practicable/relevant)*
- *The description of how the void will achieve post-closure slopes that will exhibit stability characteristics consistent with the planning and design of the post-closure mine void. Mechanisms for achieving acceptable geotechnical stability must be detailed in the plan. This includes any void filling, partial void filling, reshaping and void configuration through earthwork methods such as backfilling, regrading, buttressing, and benching. Where applicable, methods and techniques for achieving safe slopes must be detailed.*

2. Work completed by others includes:

- *TSF LOM design – ATC Williams*
- *Mine Material Management Plan – Landform, cover system and final void design and assessment – RGS Consultants 2022*
- *Progressing Rehabilitation and Closure Planning - Hydraulic Assessment – ATC Williams*
- *Long-term landform evolution (erosion) modelling of low slope angles for NWRD and TSF cover systems – RGS Consultants*

2 Background

The MRO Site is located 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 operators. Evolution Mining currently operates MRO and has been the sole operator since 2011. The operation has a life of mine that extends to 2027.

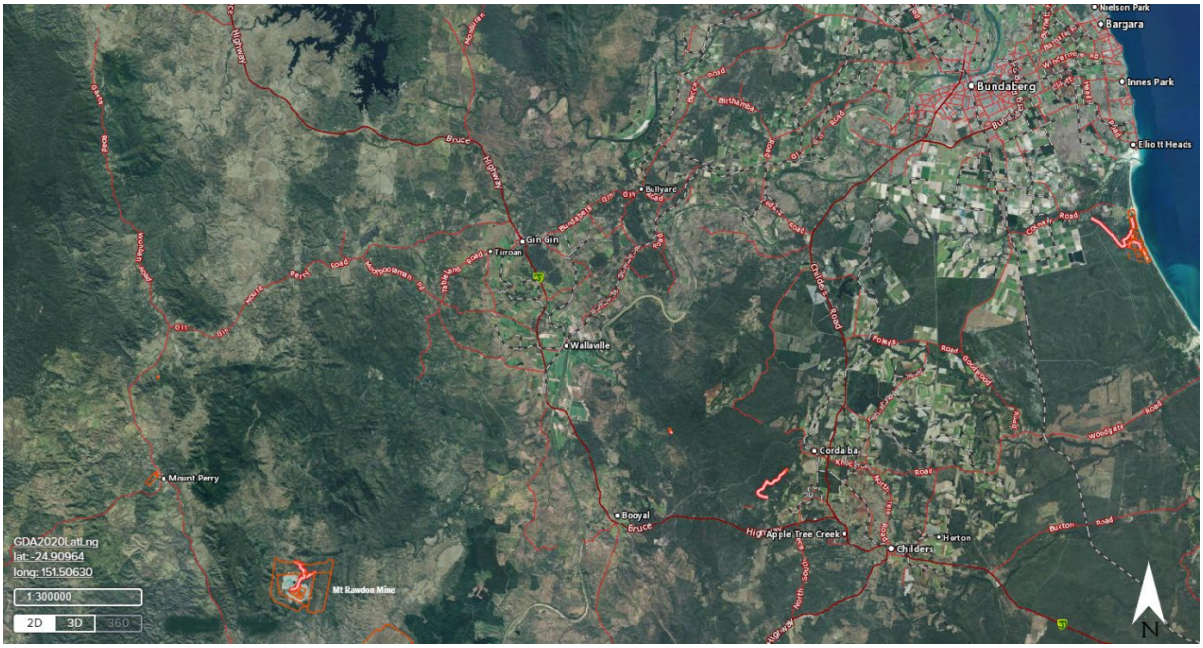

Figure 1: Mt Rawdon Operation site location

2.1 Information Provided

- TSF LOM design – ATC Williams consultants
- 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
- Assessment of long-term geochemical characteristics of Mt Rawdon tailings material-Final Report – RGS Consultants, January 2021

2.2 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.

Since the landform modelling and erosion studies were still being undertaken during the geotechnical analyses, only the final landform infrastructure was geotechnically assessed for stability. Once the landform modelling and long-term erosion analysis studies have been finalised, geotechnical investigations will be conducted on those final landforms.

3 Final Tailings Storage Facility Stability Assessment

3.1 Geotechnical Input Parameters

The input parameters considered in the final TSF analysis are provided below in Table 1 to Table 3 and are split up by their inputs into the Long-Term (LT), Undrained (UD), and Post-Seismic (PS) scenarios.

Table 1: Summary of material parameters used for the Long-Term TSF scenarios

Material	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (°)
LT Unconsolidated Tailings	Mohr-Coulomb	16	0	28
LT Consolidated Tailings	Mohr-Coulomb	18	0	32
LT Rockfill Starter Embankment	Mohr-Coulomb	21	5	38
LT Rockfill Raises	Mohr-Coulomb	20	5	38
LT Rockfill Buttress	Mohr-Coulomb	21	5	38
LT Rockfill Zone 2	Mohr-Coulomb	21	0	38
LT Clay Fill	Mohr-Coulomb	18	2	32
LT Earth Fill	Mohr-Coulomb	18	2	35
LT Surface Soils	Mohr-Coulomb	18	4	24
LT Foundation	Mohr-Coulomb	24	5	45
LT Engineered Tailings	Undrained (Phi = 0)	16	90	0

Table 2: Summary of material parameters used for the Undrained TSF scenarios

Material	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (°)	Angle (ccw to 1) (°)	Vertical Strength Ratio	Minimum Shear Strength (kPa)
UD Consolidated Tailings (0.25)	Vertical Stress Ratio	18	-	-	-	0.25	20
UD Consolidated Tailings (0.35)	Vertical Stress Ratio	18	-	-	-	0.35	20
UD Consolidated tailings (0.5)	Vertical Stress Ratio	18	-	-	-	0.05	20

Material	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (°)	Angle (ccw to 1) (°)	Vertical Strength Ratio	Minimum Shear Strength (kPa)
UD Surface Soils	Anisotropic Strength	18	5	30	0	-	-
UD Rockfill Raises	Mohr-Coulomb	21	0	38	-	-	-
UD Rockfill Starter	Mohr-Coulomb	21	0	38	-	-	-
UD Rockfill Buttress	Mohr-Coulomb	21	0	38	-	-	-
UD Rockfill Zone 2	Mohr-Coulomb	21	0	38	-	-	-
UD Foundation	Mohr-Coulomb	24	5	45	-	-	-
UD Clay Fill	Undrained	18	90	-	-	-	-
UD Earth Fill	Undrained	18	90	-	-	-	-
UD Engineered Tailings	Undrained	16	90	-	-	-	-

Table 3: Summary of material parameters used for the Post-Seismic TSF scenarios

Material	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (°)	Vertical Strength Ratio	Minimum Shear Strength (kPa)
PS Consolidated Tailings	Vertical Stress Ratio	18	-	-	0.04	0
PS Unconsolidated Tailings	Vertical Stress Ratio	18	-	-	0.04	0
PS Surface Soils	Mohr-Coulomb	20	4	24	-	-
PS Rockfill Raises	Mohr-Coulomb	21	0	38	-	-
PS Rockfill Starter	Mohr-Coulomb	21	0	38	-	-

Material	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (°)	Vertical Strength Ratio	Minimum Shear Strength (kPa)
PS Rockfill Buttress	Mohr-Coulomb	21	0	38	-	-
PS Rockfill Zone 2	Mohr-Coulomb	21	0	38	-	-
PS Foundation	Mohr-Coulomb	24	5	45	-	-
PS Clay Fill	Undrained	18	90	-	-	-
PS Earth Fill	Undrained	18	90	-	-	-
PS Engineered Tailings	Undrained	16	90	-	-	-

3.2 Modelling Methodology

Rocscience software RS2 (Version 11.017) and Slide2 (Version 9.025) were used to analyse the deformation and stability of the final TSF conditions.

Five sections in the 2020 TSF LOM Stability Assessment, completed by ATC, were replicated for this study with the updated final shell design for the TSF. These five sections are designated by their chainage in meters around the extent of the TSF, including:

- CH359m
- CH898m
- CH2059m
- CH3128m
- CH3536m

Three scenarios were analysed for each chainage section:

- Long-term drained, considering stability under steady-state seepage conditions
- Undrained, considering poor drainage
- Post-seismic, considering liquefaction of TSF material

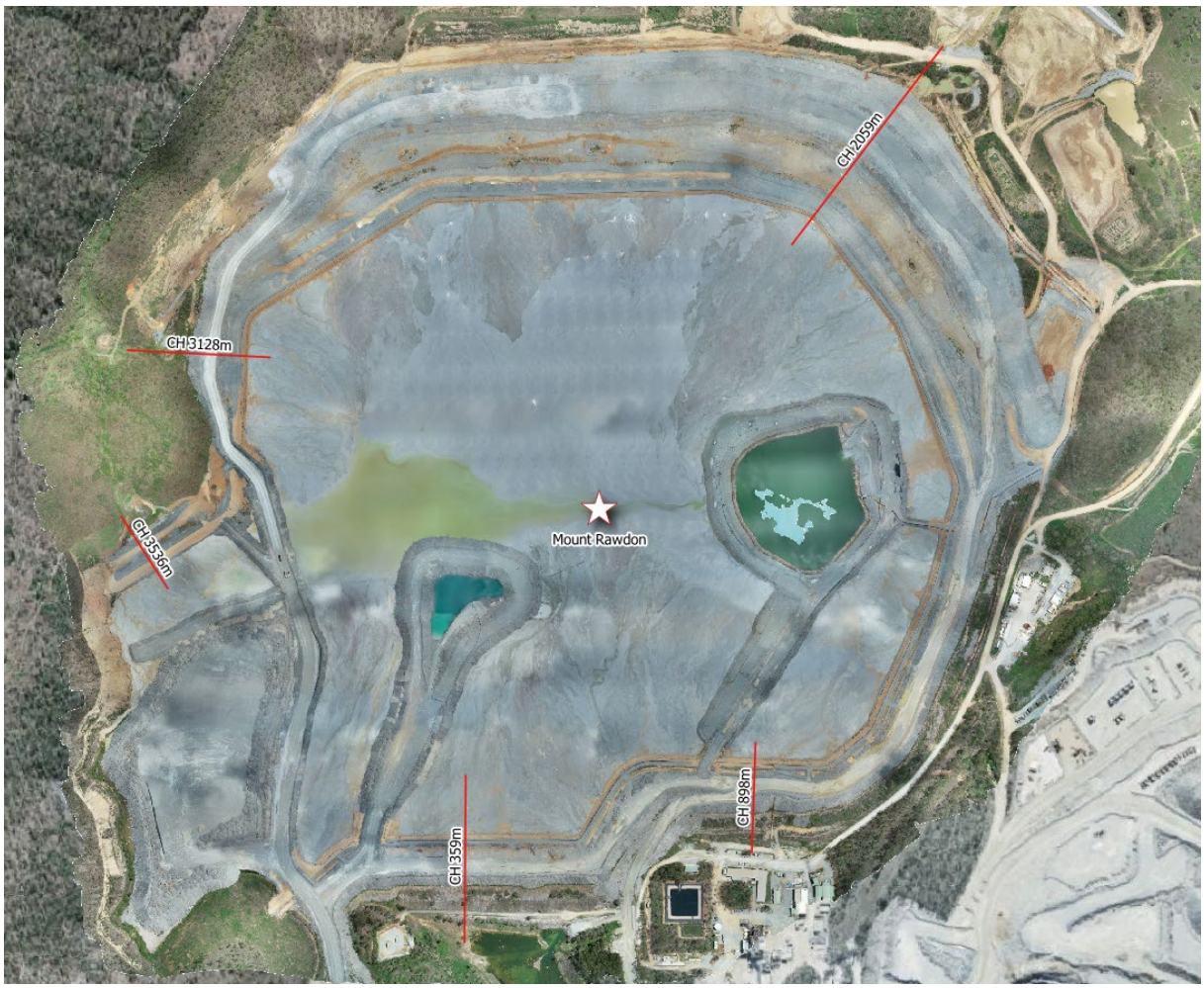

Figure 2: Aerial map highlighting sections used for 2D stability analyses

Two analysis methods were applied: the Spencer and Morgenstern-Price Global Limit Equilibrium (GLE). These methods were selected as they resolve both horizontal and vertical force equilibrium and moment equilibrium. Results were assessed for both to ensure a similar result and thus validate the failure surfaces.

3.3 Stability Assessment Criteria

The adopted assessment criteria for the slope stability analysis are based on ANCOLD guidelines (2019) for the expected range of stability conditions for the embankment.

Table 4: ANCOLD Guidelines factor of safety (ANCOLD, 2019)

Loading Condition	Recommended Minimum FoS for Tailings Dams	Shear Strength to be used for Evaluation
Long-term drained	1.50	Effective Strength
Undrained	1.30	Consolidated Undrained Strength
Post-Seismic	1.00	Post-Seismic Shear Strength

3.4 TSF Liquefaction

Previous investigations have indicated that the MRO tailings material is potentially liquefiable and flowable, which may result in lower post-liquefaction shear strength than the adopted shear strength. A post-seismic event scenario has been modelled with significantly reduced shear strength to emulate the liquefied tailings material.

3.5 Phreatic Surface

The final groundwater surface derived from the Mt Rawdon Post-Closure Groundwater Model (SLR, 2020) could not be used in the TSF study, as it does not represent realistic hydrogeological conditions in the TSF, and saturated conditions were considered instead for all sections under analysis. Groundwater surfaces were inferred and appraised from historical studies conducted for the MRO TSF.

3.6 Modelling Assumptions

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

- Material properties used in the analysis were obtained from previous studies conducted for MRO TSF and all the provided reports associated with the Site's closure planning strategy
- Modelled geometry is based on the previous 2020 TSF LOM Stability Assessment report by ATC, with the inclusion of the updated final design profile
- Final slopes were analysed based on the planned TSF at closure. There is no consideration for long-term erosion in the geometry or material parameters of the dump.
- Sections were taken on previously analysed sections from other studies for the MRO TSF since survey data for all the as-built surfaces was missing some critical stages for the facility.

3.7 Stability Analysis Results

Results for the slope stability analyses are shown below.

Table 5: Stability Analysis Results

Chainage Section	FoS (Spencer)	FoS (GLE / Morgenstern-Price)
Long-Term Stability Scenario		
CH359m	1.88	1.87
CH898m	2.50	2.51
CH2059m	2.32	2.32
CH3128m	2.41	2.40
CH3536m	1.94	1.91
Undrained Scenario		
CH359m	1.92	1.92
CH898m	2.23	2.22
CH2059m	2.27	2.27
CH3128m	1.93	1.92
CH3536m	2.16	2.14

Chainage Section	FoS (Spencer)	FoS (GLE / Morgenstern-Price)
Post-Seismic Scenario		
CH359m	1.07	1.05
CH898m	1.96	1.98
CH898m (with additional buttressing)	1.09	1.07
CH2059m	1.19	1.16
CH3128m	1.30	1.28
CH3536m	1.05	1.30

All analysed sections returned acceptable FoS results as required by the ANCOLD guidelines for long-term, undrained and post-seismic global stability conditions, shown in Table 5: Stability Analysis ResultsTable 5 above. The deformation settlement of each section was analysed for the five sections, and the results indicate settlements between 0.02 to 0.14 m, as shown in Table 6, for the different critical strength reduction factors.

Table 6: Seismic displacement results for 1:10000 event (SEE with a PGA of 0.25, Magnitude 7.5)

Section	Scenario	Critical SRF	Vertical Displacement/settlement (m)
CH359m	Post-Seismic	1.05	0.05
CH898m	Post-Seismic	0.69*	0.09
CH2059m	Post-Seismic	1.04	0.14
CH3128m	Post-Seismic	1.30	0.02
CH3536m	Post-Seismic	1.00	0.00

*The critical SRF is lower than the FOS in Table 5

3.7.1 Section Results

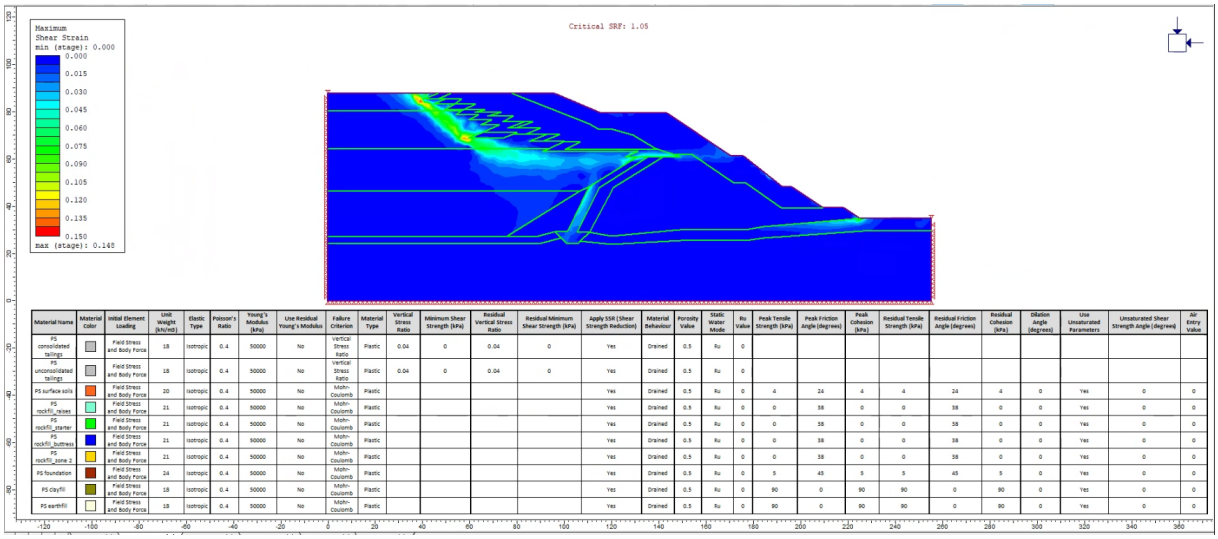

Figure 3: Section CH359m maximum shear strain and critical SRF

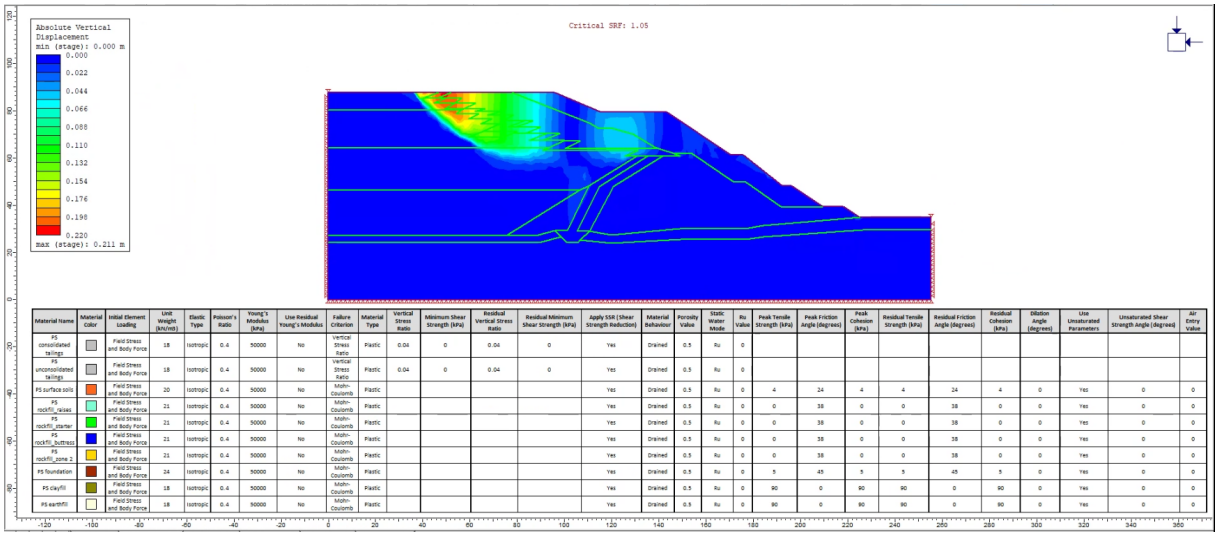

Figure 4: Section CH359m vertical displacement

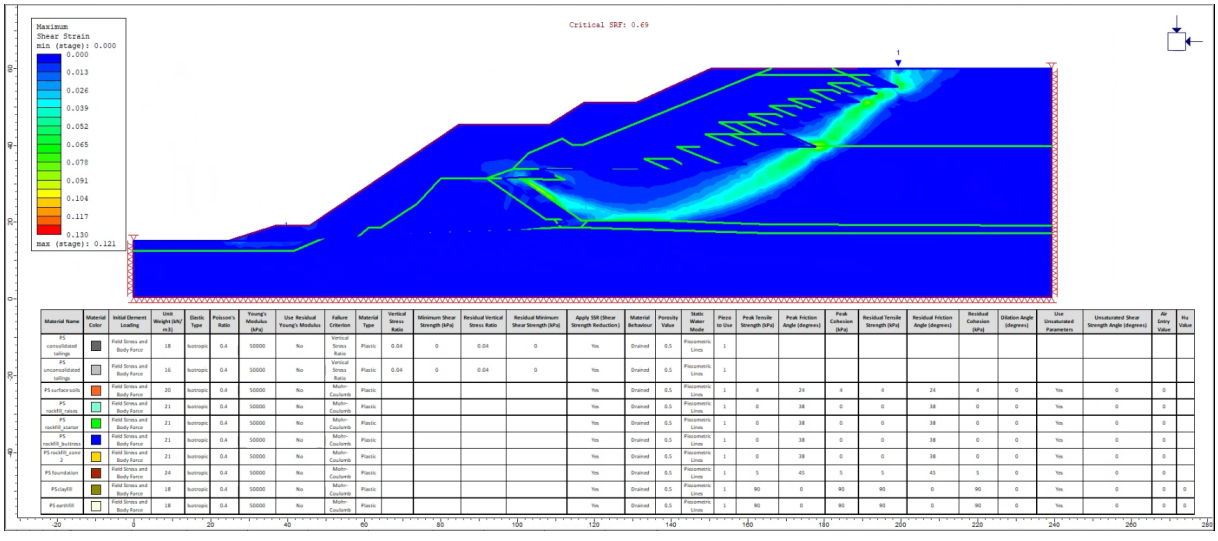

Figure 5: Section CH898m maximum shear strain and critical SRF

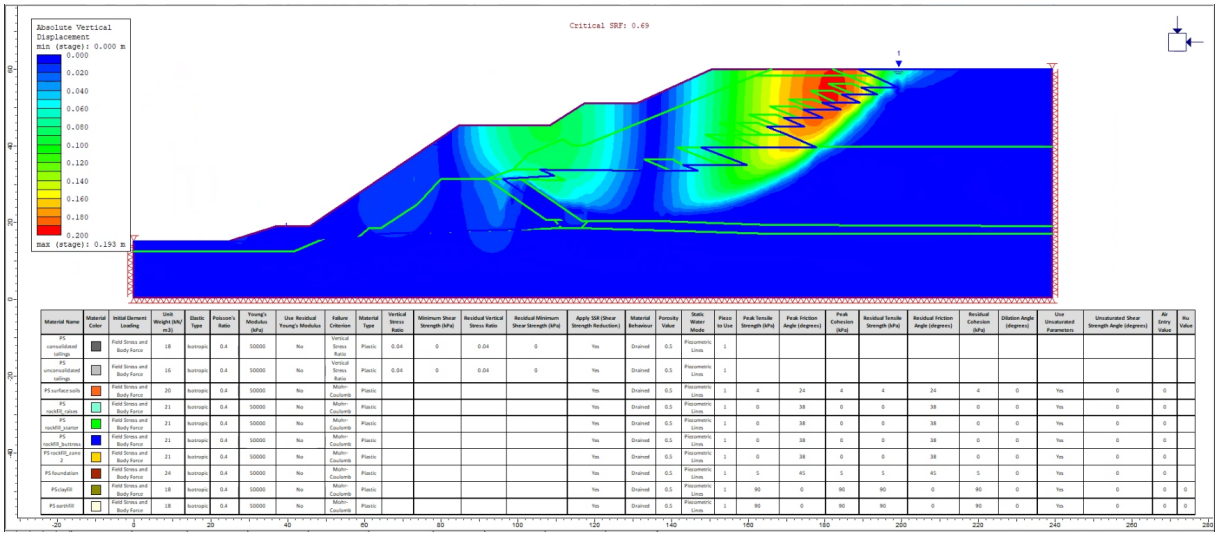

Figure 6: Section CH898m vertical displacement

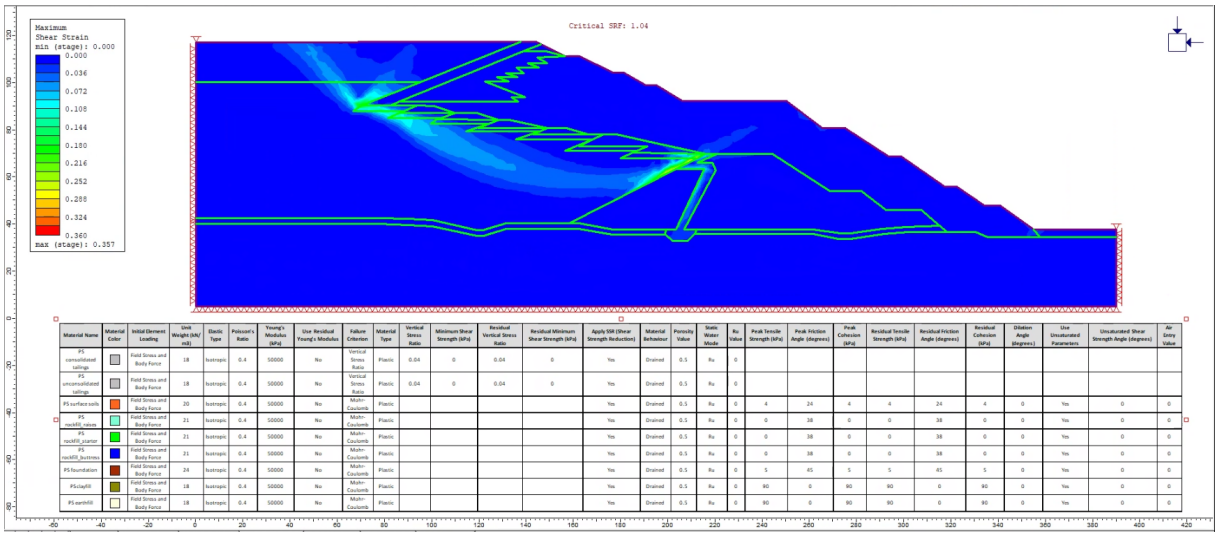

Figure 7: Section CH2059m maximum shear strain and critical SRF

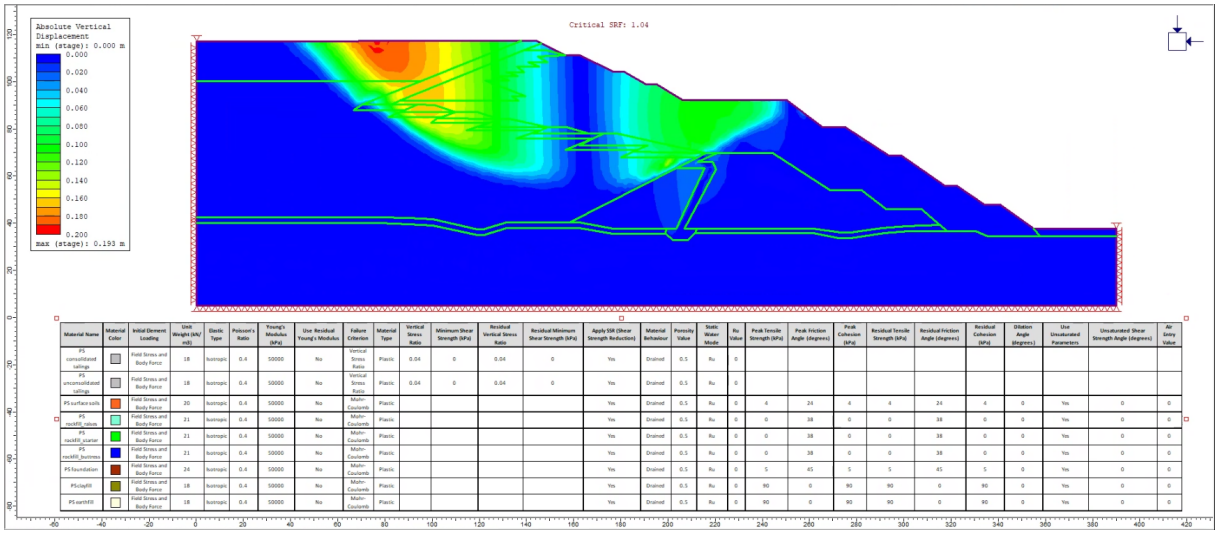

Figure 8: Section CH2059m vertical displacement

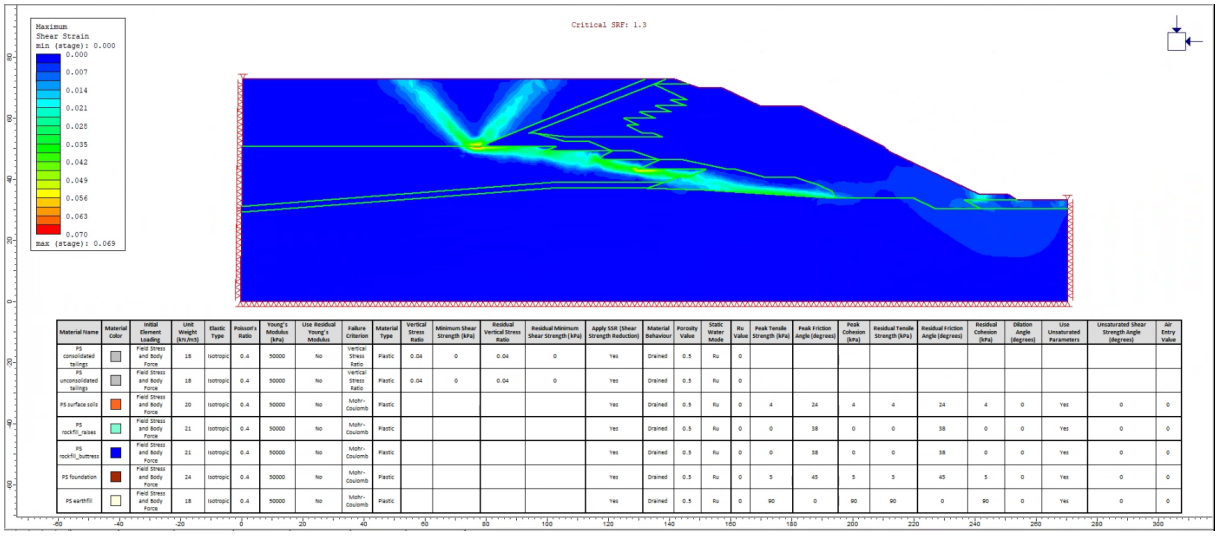

Figure 9: Section CH3128m maximum shear strain and critical SRF

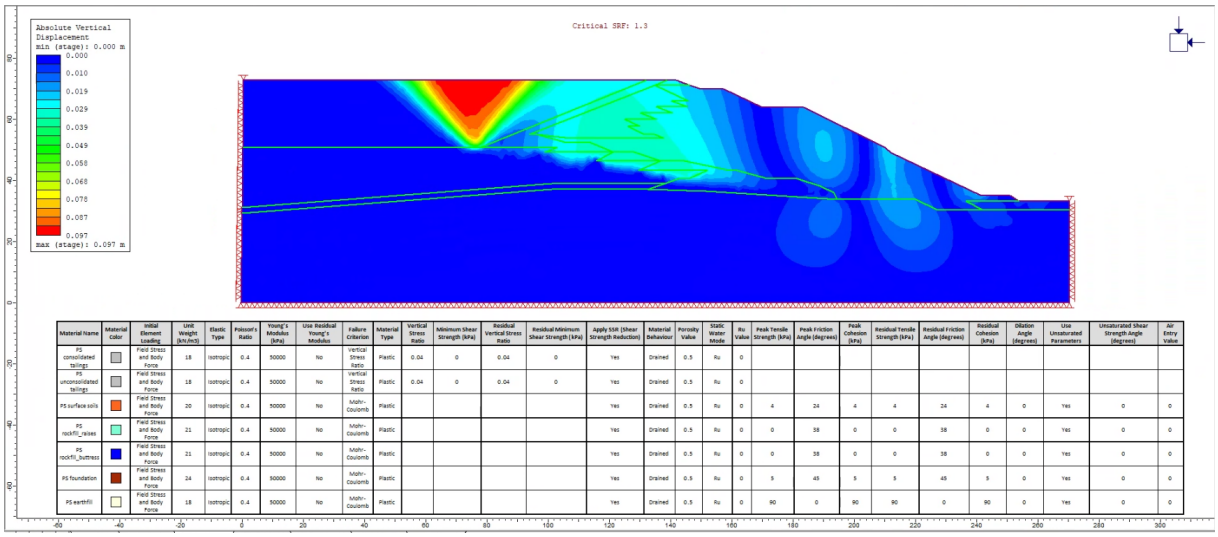

Figure 10: Section CH3128m vertical displacement

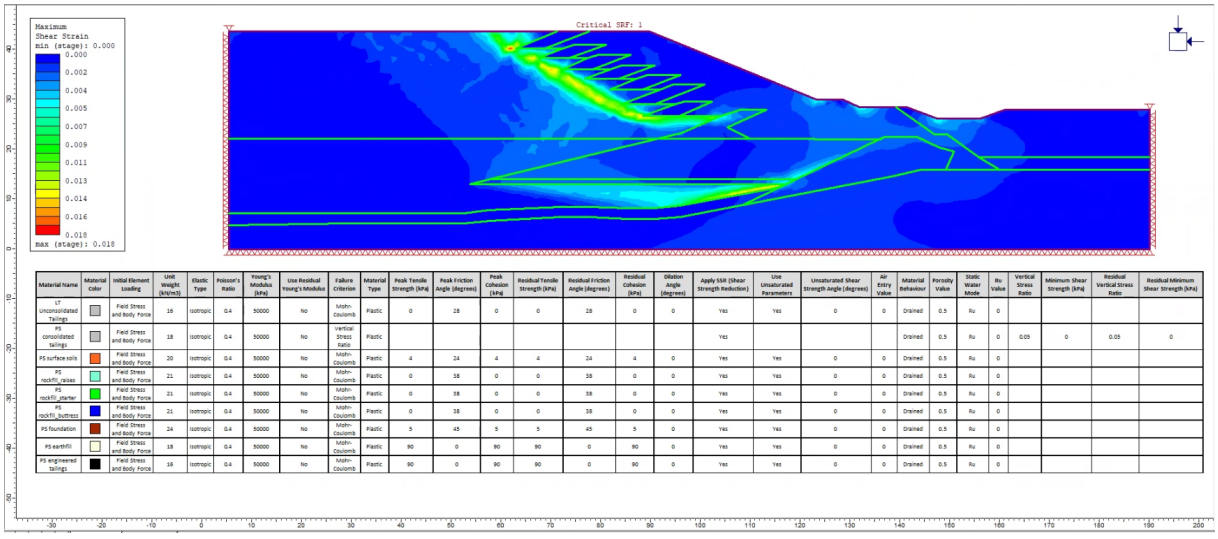

Figure 11:Section CH3156m maximum shear strain and critical SRF

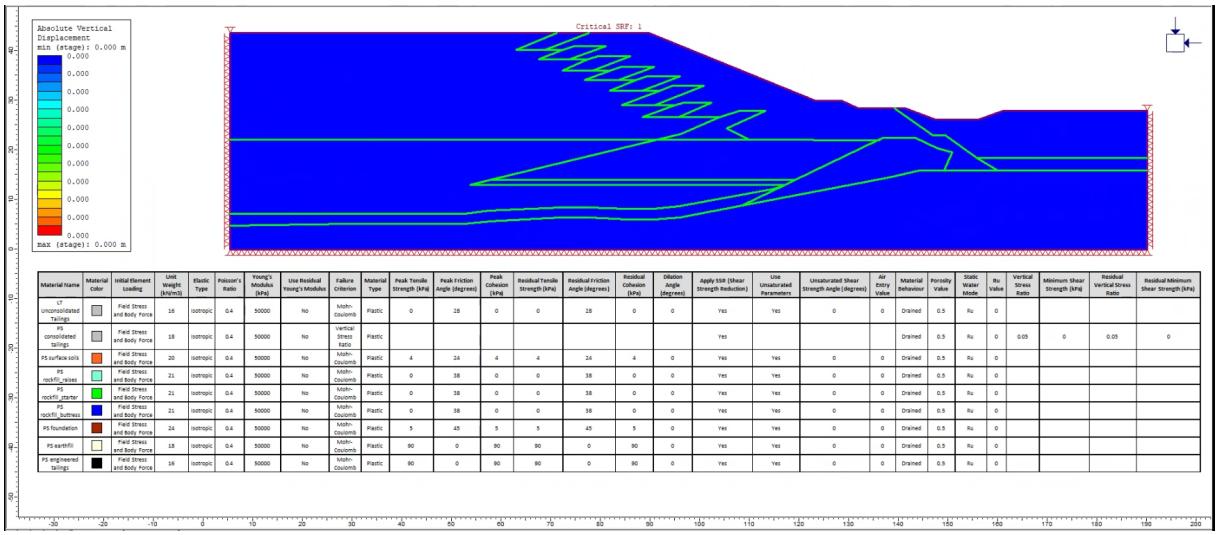

Figure 12: Section CH3156m vertical displacement

4 Recommendations

The following recommendations have been made to ensure safe operations around and to maintain the stability of the final TSF design.

- The analysed results indicate that all the sections in consideration were within the acceptable ANCOLD limits for long-term, undrained, and post-seismic recommended factors of safety
- Considering that only the final TSF shell was used in the stability and deformation analysis, it is recommended that long-term erosion effects be integrated into the final landform to ascertain the inherent effects on stability. Considering the long-term effects of erosion of the TSF, the analysed slopes in this report provide stability only for the TSF soon after operations cease and closure.
- Surface water management is considered a high priority to minimise water inflow into the TSF, as this will change the analysed conditions for long-term stability. The proposed surface water management strategies for closure should be adhered to minimise the change in proposed closure plan conditions.

5 Conclusion

A summary of the results from the stability analysis was discussed in the report. All sections analysed met the acceptable FoS criteria, demonstrating required geotechnical stability during closure and post-closure periods before the effects of erosion lead to reprofiling of the analysed final landform conditions. Changes to the profile analyses require further analyses to ascertain the inherent stability conditions.

The final TSF shell analysed for geotechnical stability does not include the effects of erosion, and results only indicate conditions during the closure period. Long-term effects need to be integrated into the analyses to investigate the associated effects on stability.

References

ANCOLD (2019), Guidelines on tailings dams – planning, design, construction, operation, and closure, July 2019

ATC Williams (2020), Mount Rawdon tailings storage facility LOM design review

Department of Environment and Science (2021), Guideline – Progressive Rehabilitation and Closure Plans, 17/03/2021

RGS (2021), Assessment of long-term geochemical characteristics of Mt Rawdon tailings material, January 2021