Appendix 6

Wyoming One Slope Stability Analysis

prepared by

AMC Consultants Pty Ltd

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Report

Wyoming One Slope Stability Analysis

Tomingley Gold Operations Pty Ltd

AMC Project 121045
10 November 2021

10 November 2021

Mr Simon Parsons
Tomingely Gold Mine Pty Ltd
68 Kings Park Road
WEST PERTH
WA 6005

Wyoming One Slope Stability Analysis

Dear Simon

This report presents the findings of the scope of work detailed in AMC proposal MP21056 Wyoming One Slope Stability Analysis dated 7 July 2021.

We trust that this letter report meets your immediate requirements and please contact the undersigned of you have any queries.

Yours sincerely
Lianne McKenzie
Principal Geotechnical Consultant

Quality control

The signing of this statement confirms this report has been prepared and checked in accordance with the AMC Peer Review Process.

Project Manager	Lianne McKenzie	10 November 2021
Peer Reviewer	Meredith Goss	10 November 2021
Author	Lianne McKenzie	10 November 2021

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1 Introduction

1.1 Background

Tomingley Gold Operations (TGO) has engaged AMC Consultants Pty Ltd (AMC) to provide geotechnical advice on the long-term stability of the as built Wyoming One (WY1) pit slopes. AMC received the request for advice in an email from Mr Simon Parsons of TGO on 12 July 2021.

Geotechnical advice on the long-term stability of the WY1 pit slopes is required for TGO's mine rehabilitation studies. Open cut mining in WY1 ceased in 2019 leaving pit slopes about 180 m high. However, access via a portal in WY1 to the TGOs operational underground mine will continue until about late 2024.

AMC understands that the proposed final rehabilitation and post mining land use for WY1 is a void that will be bunded and fenced.

1.2 Scope of work

The main aim of the work was to assess the long-term geotechnical stability of the as built WY1 pit walls that will remain as part of the current approved final rehabilitated landform.

The scope of work completed was as per AMC proposal MP21056 Wyoming One Slope Stability Analysis dated 7 July 2021 and consisted of:

- Reviewing all the available geotechnical data relevant for the assessment of slope stability in WY1, including geotechnical reports on slope performance.
- Assessing potential long-term pit slope failure mechanisms.
- Selecting critical cross-sectional locations appropriate for slope stability analyses.
- Undertaking stability analyses on the critical cross-sections.
- Reporting on the results of slope stability analyses and providing comment on long-term stability and suitability of the slopes as a final landform and if required options for slope remediation.

AMC imported wireframes supplied by TGO such as the pit design, topography and geology into the 3D visualisation software Leapfrog.

As there was an appropriate amount of existing data, no further collection of data was done to complete the scope of work. Additionally, inputs such as shear strength parameters, into slope stability analyses were based on existing data and information provided by TGO.

1.3 Previous work

In 2016 Pells Sullivan Meynink (PSM) provided mine closure advice for the east wall of the WY1 pit as it is the closest wall to the Newell Highway (PSM 2016). The advice provided was based on results of stability analyses which assessed the potential slope extent that could experience failure in the long term.

Three other geotechnical documents detail the performance of the WY1 pit slopes and these are:

- In 2018, WSP provided advice on future performance of the WY1 slopes to support safe and continual access to the pit for the underground operation (WSP 2018).
- In 2018, PSM did a rock fall analyses for the ongoing instability in the southeast corner which involves multi-bench movement and unravelling of the saprolite and weathered rock (PSM 2018).
- In 2017, PSM carried out a site visit to review the WY1 pit slopes and some cracking in the benches and berms forming the west wall were noted.

2 Available data and information

TGO has provided the following data and information for the scope of work:

- As built WY1 pit survey wireframe dated 27 December 2020 (file called wy1_working_201227).
- Survey wireframe done September 2021 (file called DTM_2m – C – TINN-VIEW).
- Survey wireframe dated 19 September 2019 (file called Wy1_surface_deceimate_300mm).
- Topography wireframe (called 2009_aam_contours_simplify).
- Dxf files showing the location of the realigned Newell Highway (Design – Newell & Kyalite Export (210421)) and mining lease (20210630_Proposed MLA).
- TGO generated geological 3D wireframes:
  - base of alluvium (wy1_base_all)
  - base of saprolite (wy1_base_sap)
  - base of oxidation (wy1_base_ox).
- Prism monitoring data as of October 2021.
- Geotechnical reports:
  - WSP Australia 2018, Tomingley Gold Mine: Geotechnical advice on slope performance Wyoming One Pit, unpublished letter, ref PS111842-GEO-LTR-001 Rev A.
  - PSM 2018, Rockfall Analyses Wyoming One, unpublished memorandum, ref PSM2029-157M.
  - PSM 2017, Geotechnical site visit October 2017 – Wyoming One Pit, unpublished letter, ref PSM2029-149L.
  - PSM 2016, Mine Closure Geotechnical Advice, unpublished report, ref PSM2029-125R.
- Draft groundwater assessment report – Jacobs Australia Pty Limited 2021, Tomingley Gold Extension Project Groundwater Assessment, unpublished report.
- The following plan and cross section detailing final rehabilitation and post mining land use:
  - Final Rehabilitation and Post Mining Land Use – 2023 Plan 4 (June 2021 MOP: Amendment 5) dated 7 June 2021 (map/plan called MOP 2021amdt5-PLAN Final Rehabilitation).
  - Cross Section A MOP – Plan 5a ((June 2021 MOP: Amendment 5) dated 7 June 2021 (cross section based on the map/plan along easting 614220 m called MOP 2021amdt5-PLAN5 a Section614220mE).

3 Performance of the pit walls

3.1 Overview

Historically, the slopes within the saprolite and weathered rock horizon have experienced stability issues in several pit areas, predominantly in the east and south walls, at both the bench and multi-bench scale. Typically, instability would occur as an initial collapse at the bench scale (up to 10 m to 15 m high) within the upper part of the saprolite at the alluvium contact or within weathered rock beneath the saprolite. After the initial collapse continual unravelling of the surrounding alluvium, saprolite and weathered rock would occur (WSP 2018).

Localised collapse in the saprolite was typically attributed to relict geological structure. It was inferred that rainfall and surface water also played a major part in the initial collapse and ongoing slumping and erosion in some area of the pit slopes.

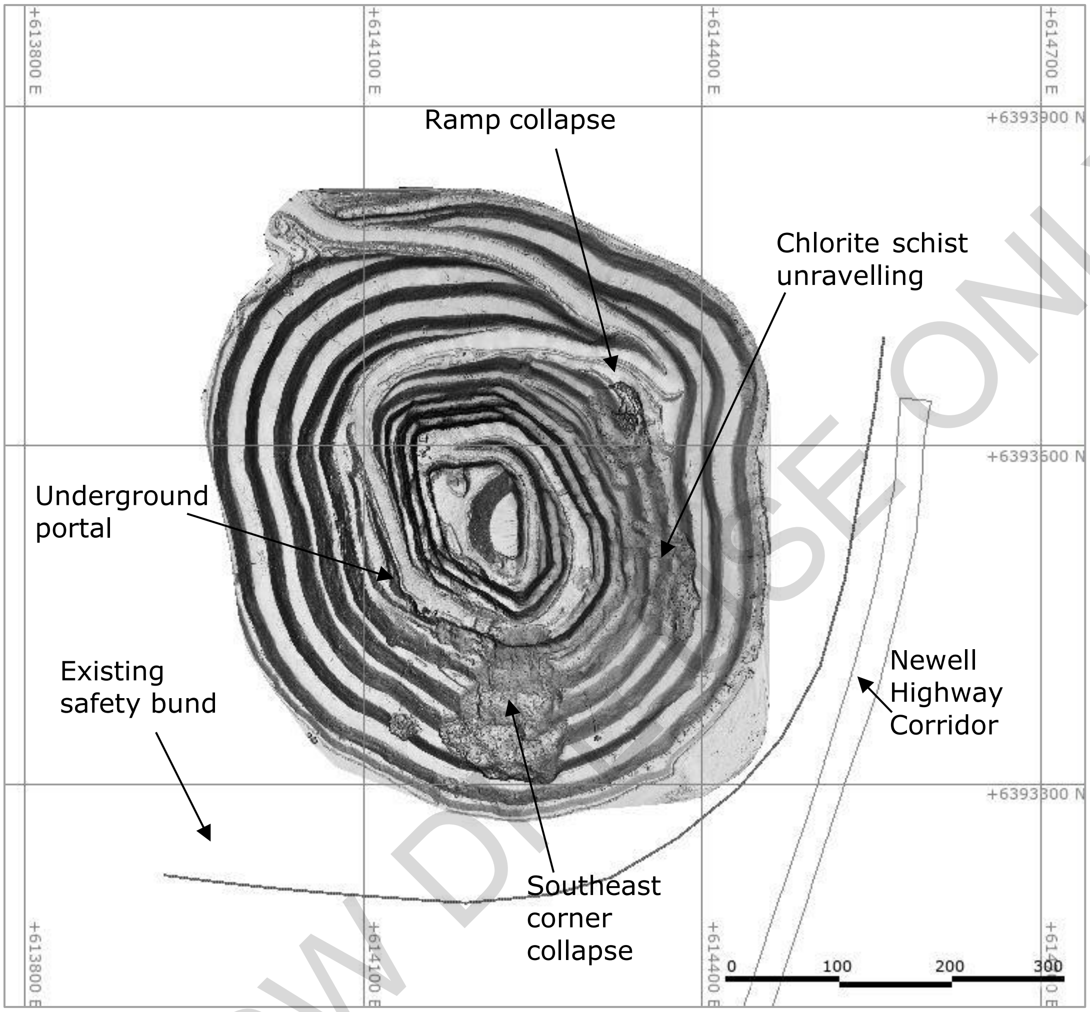
In 2018, WSP identified the following three areas of geotechnical concern within the WY1 pit:

- **Southeast collapse** involving multi-bench collapse of the saprolite and weathered rock between 240 mRL to 195 mRL that was experiencing ongoing unravelling and rock fall.
- **Chlorite schist unravelling** where minor rockfalls were occurring from the saprolite and weathered rock horizons on the east wall between 240 mRL and 195 mRL.
- **Ramp collapse** involving ongoing movement of the saprolite beneath the switchback at the multi-bench scale.

The areas of geotechnical concern are shown on Figure 3.1.

Both the southeast collapse and the chlorite schist unravelling have the potential to promote large scale instability that could impact the location of the long-term pit crest.

Figure 3.1 Geotechnical areas of concern within the WY1 pit



3.2 Southeast corner collapse

Initial collapse in the southeast corner occurred within the saprolite immediately beneath the alluvium in about December 2016. Figure 3.2 shows the initial collapse in the saprolite materials and Figure 3.3 shows the current condition of the southeast corner. Since December 2016, there has been progressive collapse of, the saprolite towards the west, the alluvium in the bench above and the weathered rock in the bench below.

Figure 3.2 Initial collapse of the saprolite in the southeast corner of WY1

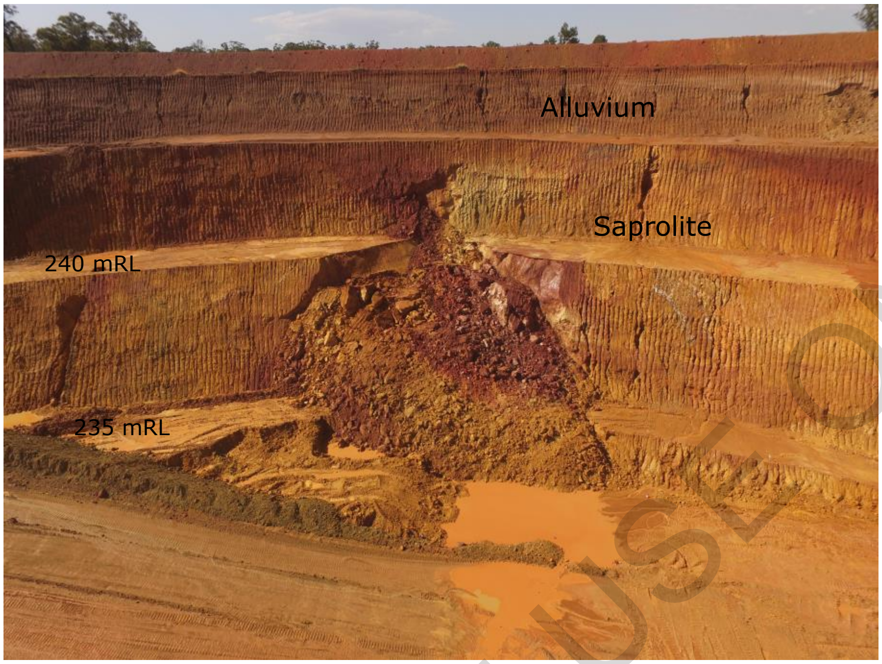
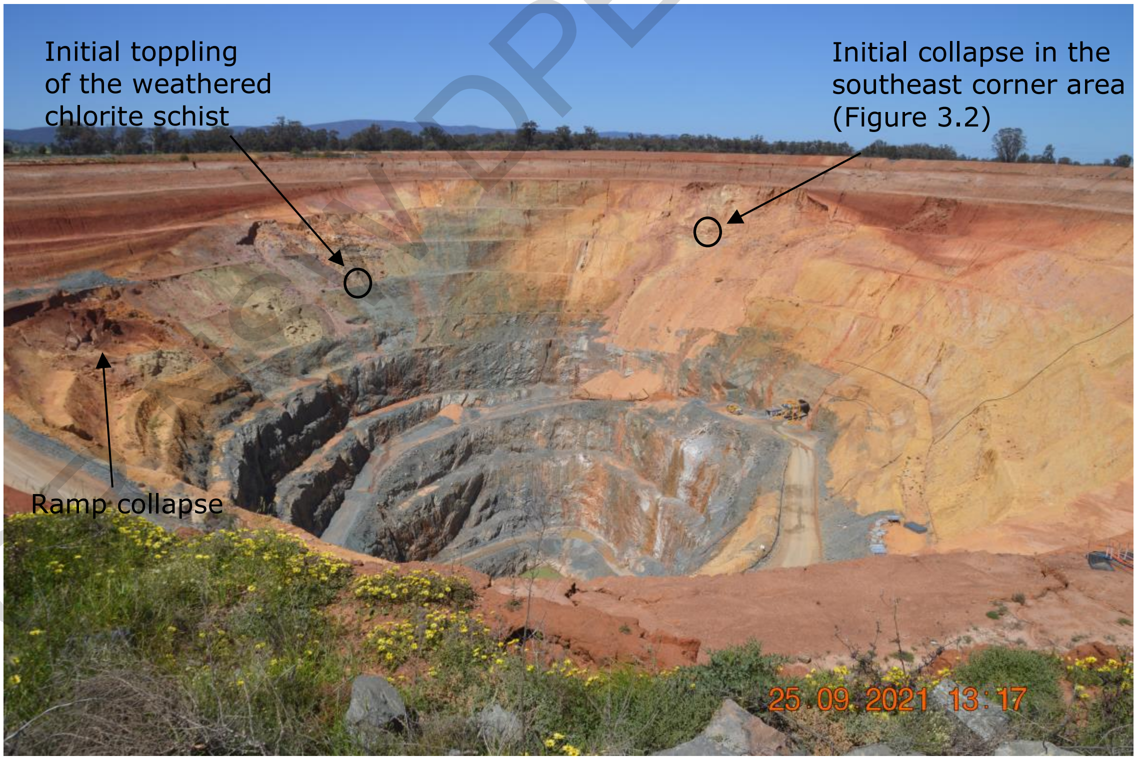


Figure 3.3 Current condition of the southeast corner and the chlorite schist in WY1



TGO has indicated that ongoing unravelling of soil and weathering rock in the southwest area results in frequents falls that typically reach the main ramp. A key contributor to the ongoing instability and material failure is rainfall with surface water promoting washing down of the loose material.

The southeast corner area is anticipated to deteriorate over the long-term and is likely to encroach further into the alluvium horizon.

3.3 Chlorite schist

Figure 3.3 shows the current condition of the east wall in the area designated as chlorite schist unravelling.

The initial collapse in this area, which occurred in about July 2017, was of the weathered rock at an RL of about 231 m. The collapse mechanism was likely to be toppling style within the chlorite schist unit that has pervasive sub-vertical foliation dipping into the wall. Further toppling of the weathered schist promoted the collapse of the saprolite above and laterally towards the north.

The unravelling of the weathered rock and collapse of the saprolite appears to be shallow structure and material strength related rather than a deep-seated instability. The main instability occurs over a lateral length of about 100 m and vertically over two benches (40 m). TGO has not noticed any cracking or movement behind the east wall pit crest that would indicate a large-scale instability was occurring.

TGO has indicated that soil and rock falls from this area are infrequent, and this is consistent with a lack of collapsed material evident on the berms below and on the main ramp. A key contributor to the ongoing instability of this areas is rainfall and surface water flow over the slope.

This area is anticipated to deteriorate over the long-term and is likely to encroach on the alluvium.

3.4 West wall

Although the west wall is not identified as an area of geotechnical concern its crest in some areas will be about 135m from the toe of the future residual storage facility (RSF2). Therefore, its long-term slope stability are important.

Overall, the west wall has performed well. However, the west wall slope within the saprolite and weathered rock horizons did experience signs of movement in June 2017. Signs of movement included cracks on several berms and movement based on prism data. Since the initial signs of movement, TGO has undertaken frequent visual monitoring as well as prisms monitoring.

A review of prism monitoring data indicated that total wall movement was not significant, refer to Section 3.5 below. Prism monitoring data is consistent with TGO's visual observations and that no signs of movement such as cracks and or extension of historical cracks have occurred.

Over the long-term the wall is expected to experience localised collapse and unravelling of the weathered rock.

3.5 Prism monitoring

A plan of the active prisms in WY1 is provided on Figure A1 in Appendix A. AMC plotted the results (time vs displacement) of key prisms to review past movement in the WY1 slopes.

Data from the following key prisms were reviewed and their plots are provided in Appendix A:

- Prisms 106, 107 and 19 are located on the slope above the southeast collapse.
- Prisms 21006, 22518, 22519, 66, 67 and 68 are located on the west wall and have previously indicated some movement.
- Prisms 25509, 25510 and 25511 are located on the east wall above the chlorite schist unravelling area.

Most prisms showed a total movement of less than 160 mm over the past two years. The available prism data does not indicate acceleration or significant wall movements that are concerning from an overall wall stability aspect. TGO has indicated that the minor increase in displacement on the 21 April 2021 was likely to be due to atmospherics and not prism movement.

4 Long-term failure mechanisms

Based on past performance of the WY1 walls, the main mechanism that will contribute to long-term stability is the ongoing deterioration of the alluvium and saprolite and rock mass style (circular mode) failures at a bench and multi-bench scale within this material. The risk of rock mass style failure occurring is increased if transient or high ground water pressures occur in the slope. Unravelling of weathered rock is also likely to occur over time.

The unravelling of the existing collapse/failed areas within the alluvium, saprolite and weathered rock is likely to continue for some time, especially after heavy rainfall events. However, it is expected that the slope will reach an equilibrium and unravelling will slow over time if water is directed away from the collapsed areas. The slopes in the collapsed areas are likely to reach their final profile sooner than long-term.

Past studies in the Tomingley pits have indicated that the alluvium and saprolite soils are highly dispersive, sodic and often non-saline (PSM 2016). Exposed or disturbed dispersive soils have a high erosion potential when in contact with water. Without implementation of management measures, such as good surface water drainage and re-vegetation, long-term erosion has the potential to lay the slopes back at nominally 20º through the alluvium and saprolite. An assessment of the long-term erosion impacts on the WY1 slopes is not part of this scope of work. AMC understand that TGO have engaged specialised soil scientists Landloch Pty Ltd to conduct this assessment.

5 Back analysis for southeast corner

5.1 Methodology

AMC undertook a back analysis to assess the material strength parameters for the saprolite in the southeast corner collapse area. A slope stability analysis of the southeast corner was then undertaken using these material strength parameters (Section 6).

The back analysis used the 2D limit equilibrium method in SLIDE[1] and a circular mechanism for collapse.

The pre-failure slope geometry was obtained from the pit slope design (wy1_v08) and the extent of the initial collapse was obtained from site photos.

Groundwater conditions at the time of the initial collapse are not known, however it is likely that the collapse was related to groundwater pressures. Therefore, a piezometric line within the alluvium horizon close to the saprolite contact that passed through the toe of the pre-collapsed slope was assumed.

5.2 Shear strength parameters

Analyses initially adopted the material properties used for the alluvium, saprolite, weathered rock and fresh rock presented by PSM in the Mine Closure Advice report (PSM 2016). Table 6.1 presents the adopted material shear strength parameters.

Table 5.1 Adopted material shear strength parameters adopted for WY1

Geotechnical Horizon	Density (kN/m^3)	Shear Strength Parameters	
		Cohesion (kPa)	Friction Angle (°)
Alluvium	20	31	13
Saprolite	22	55	29
Weathered Rock	22	55	29
Slightly Weathered and Fresh Rock	26	UCS = 70 MPa, GSI[1] = 40, mi[2] = 20	

1. Geological Strength Index
2. Intact parameter

The aim of the back analysis was to revise the material strength parameters for the saprolite horizon around the pit wall area that collapsed. The revised material strength parameters were used in slope stability analysis for the southeast corner area, refer to Section 5.3.

5.3 Results

The result of the back analysis is provided in Appendix B. The back analysed strength parameters for the saprolite material were assessed based on a Factor of Safety (FOS) of 1.0.

Results indicated that the material strength parameters for the saprolite at the southeast corner area are:

- c' = 13 kPa and ϕ' = 21°.

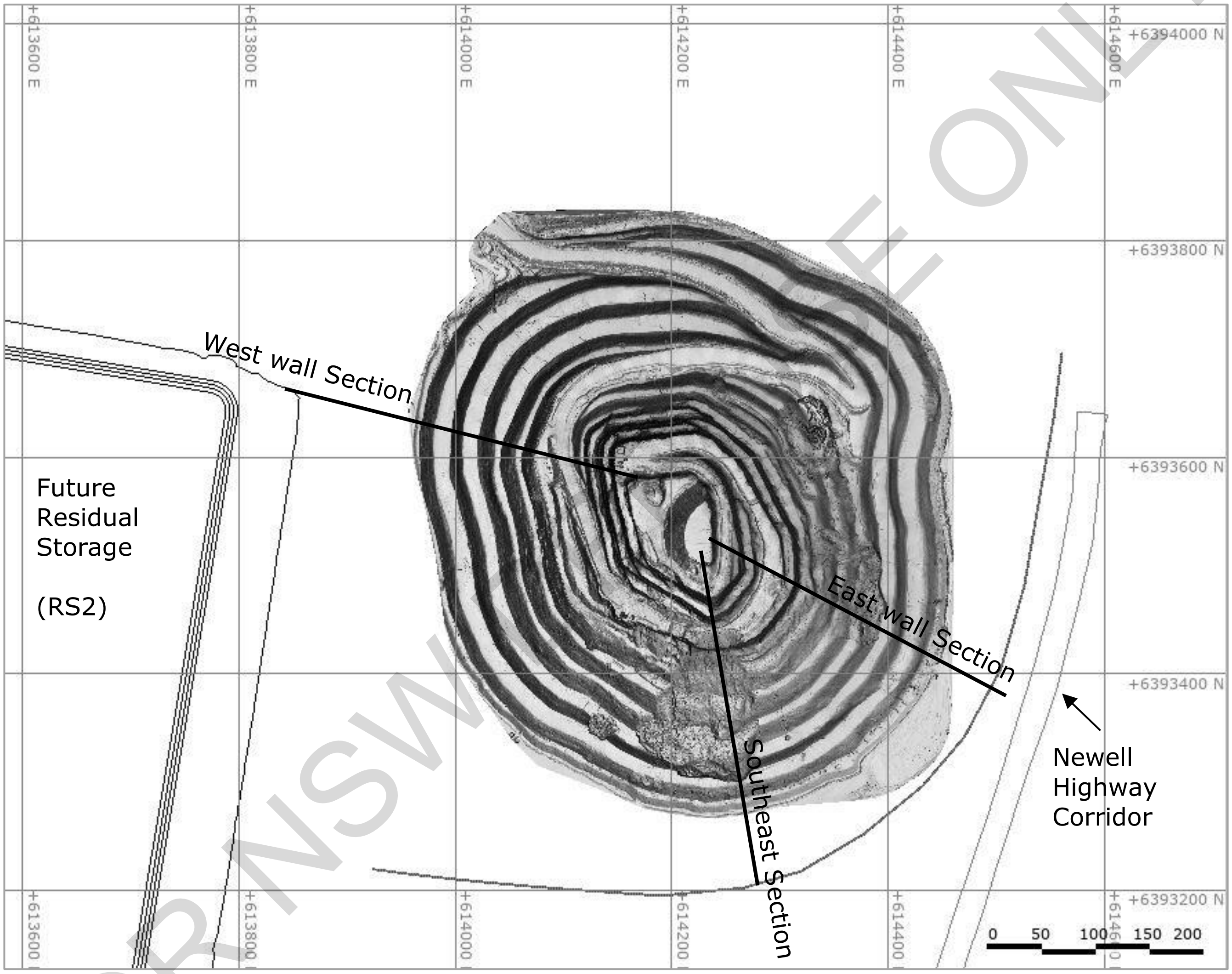
[1] Limit equilibrium analysis software developed by Rocscience

6 Slope stability analyses

6.1 Methodology and assumptions

AMC carried out limit equilibrium analyses using SLIDE to assess a Factor of Safety for the cross-sectional locations shown in Figure 6.1.

Figure 6.1 Plan showing location of analyses



The East wall and West wall section locations were analysed as failure in these wall areas could impact the re-aligned Newell Highway corridor and the RS2 respectively (Figure 6.1). The Southeast Section was analysed as due its current condition, this slope has the potential to experience a significant rock mass style failure in the long-term.

The SLIDE analysis assumed:

- A circular style failure through the alluvium, saprolite and weathered rock horizons.
- An equilibrium groundwater level of 200 mRL in the pit with a level 20 m higher in the slope. This is based on the advice provided in the Jacobs draft report.

The Jacobs report indicated that as the final void equilibrium water level in the WY1 pit will be 20 m lower that the pre-mining regional water table level, a perpetual sink is anticipated. Recovery of the water level is expected to take 42 years after end of mining.

TGOs geological 3D wireframes were used to provide the spatial location of the geotechnical horizons.

In AMCs experience and industry guidelines for open pit stability (Read & Stacey 2009) the failure path for a FOS of 1.5 proves an appropriate indication of the extent of slope that may experience failure in the long-term.

6.2 Adopted material strength parameters

Analyses adopted the material properties assessed for the alluvium, saprolite, weathered rock and fresh rock presented by PSM in the Mine Closure Advice report (PSM 2016). Table 6.1 presents the material shear strength parameters adopted.

Table 6.1 Adopted material shear strength parameters for WY1

Geotechnical Horizon	Density (kN/m^3)	Shear Strength Parameters	
		Cohesion (kPa)	Friction Angle (º)
Alluvium	20	31	13
Saprolite	22	55	29
Saprolite in southeast corner	22	13	21
Weathered Rock	22	55	29
Slightly Weathered and Fresh Rock	26	UCS = 70 MPa, GSI[1] = 70, mi[2] = 20	

1. Geological Strength Index
2. Intact parameter

6.2.1 Results

Appendix C presents the plots which show the results of the SLIDE analyses.

Table 6.2 provides the nominal FOS and comments on what the FOS values suggest regarding the current stability of the southeast, east and west wall slopes.

Table 6.2 Summary of the results of SLIDE analysis for WY1

Section Location	Nominal FOS	Comments on the results of analysis
Southeast	1.0	The current stability of the overall slope in the alluvium and saprolite is marginal. There is a potential that collapse could occur in the short-term which extends approximately 30 m back from the current crest location. Localised instability of the loose failed material sitting on benches is likely to occur.
East wall	1.3	There is a low potential for overall wall rock mass failure within the alluvium, saprolite and weathered rock during the life of mine.
West wall	1.3	

The result of slope stability analysis for the southeast corner has indicated a FOS of 1.0 for a circular failure path through the alluvium and saprolite. This suggests that the stability of the alluvium and saprolite is marginal and that there is a potential for further collapse of these materials in the short-term rather than in the long-term. The potential for collapse is increased after rainfall events. If not already done, TGO need to implement appropriate exclusions and management procedures to reduce the safety risks relating to further failure of the southeast slope.

Based on a FOS of 1.5, Table 6.3 below summarises the potential long-term crest failure distance back from the crest.

Table 6.3 Potential long-term failure distance back from the crest for WY1

Section Location	Potential long-term crest cut back based on FOS of 1.5
Southeast	64 m
East wall	36 m
West wall	23 m

AMC understand that access to WY1 and the existing underground portal may be required for possibly up to another 10 years. All the pit walls will continue to deteriorate during this time and safety risk related to this will need to be managed at an operational level. However, as analysis has identified the southeast corner area as having a marginal stability, slope remediation could be required for this wall area to remain as part of the current approved final landform. The most effective option to improve stability and reduce the potential for rock mass failure in the southeast corner will be to flatten the slope through the alluvium and saprolite.

It is recommended that long term slope stability be re-addressed if there is any significant change in pit wall conditions during the life of mine. It is also recommended that the groundwater assumptions made in this document are checked against the Jacobs final hydrogeological report.

7 Conclusion

AMC reviewed the available data to understand the existing and past performance of the WY1 walls. Based on this review, AMC identified that of the pit wall areas in WY1, the southeast, east and west wall areas have the greatest potential for large-scale rock mass style instability in the longer-term.

Slope stability analyses completed on these three wall areas suggests that a rock mass style failure mechanism through the alluvium and saprolite could occur, and potential long-term crest cut-back could be up to 23 m for the west wall, 36 m for the east wall and 64 m for the southeast wall.

Further, stability analysis of the southeast wall indicated that the existing stability of the alluvium and saprolite is marginal. This suggests that further collapse of these materials in the southeast corner area is possible in the short-term rather than the long-term. It is recommended that TGO immediately implement appropriate exclusions and management procedures to reduce the safety risks relating to further collapse of the alluvium and saprolite in the southeast slope if not already in place.

Slope remediation could be required for the southeast wall area to remain as part of the current approved final landform. The most effective option to improve wall stability and reduce the potential for rock mass style failure in the southeast corner will be to flatten the slope through the alluvium and saprolite.

It is recommended that long term slope stability be re-addressed if there is any significant change in pit wall conditions and when the Jacobs groundwater report is finalised.

References

Jacobs Australia Pty Limited 2021, Draft groundwater assessment report – Tomingley Gold Extension Project Groundwater Assessment, unpublished report.

PSM 2018, Rockfall Analyses Wyoming One, unpublished memorandum, ref PSM2029-157M.

PSM 2017, Geotechnical site visit October 2017 – Wyoming One Pit, unpublished letter, ref PSM2029-149L.

PSM 2016, Mine Closure Geotechnical Advice, unpublished report, ref PSM2029-125R.

Read, J., Stacey, P., & CSIRO (Australia). (2009). *Guidelines for open pit slope design*. Collingwood, Vic: CSIRO Publishing.

WSP Australia 2018, Tomingley Gold Mine: Geotechnical advice on slope performance Wyoming One Pit, unpublished letter, ref PS111842-GEO-LTR-001 Rev A.

Appendix A
Results of Prism Monitoring

Figure A1 **Plan showing the location of prisms in WY1.**

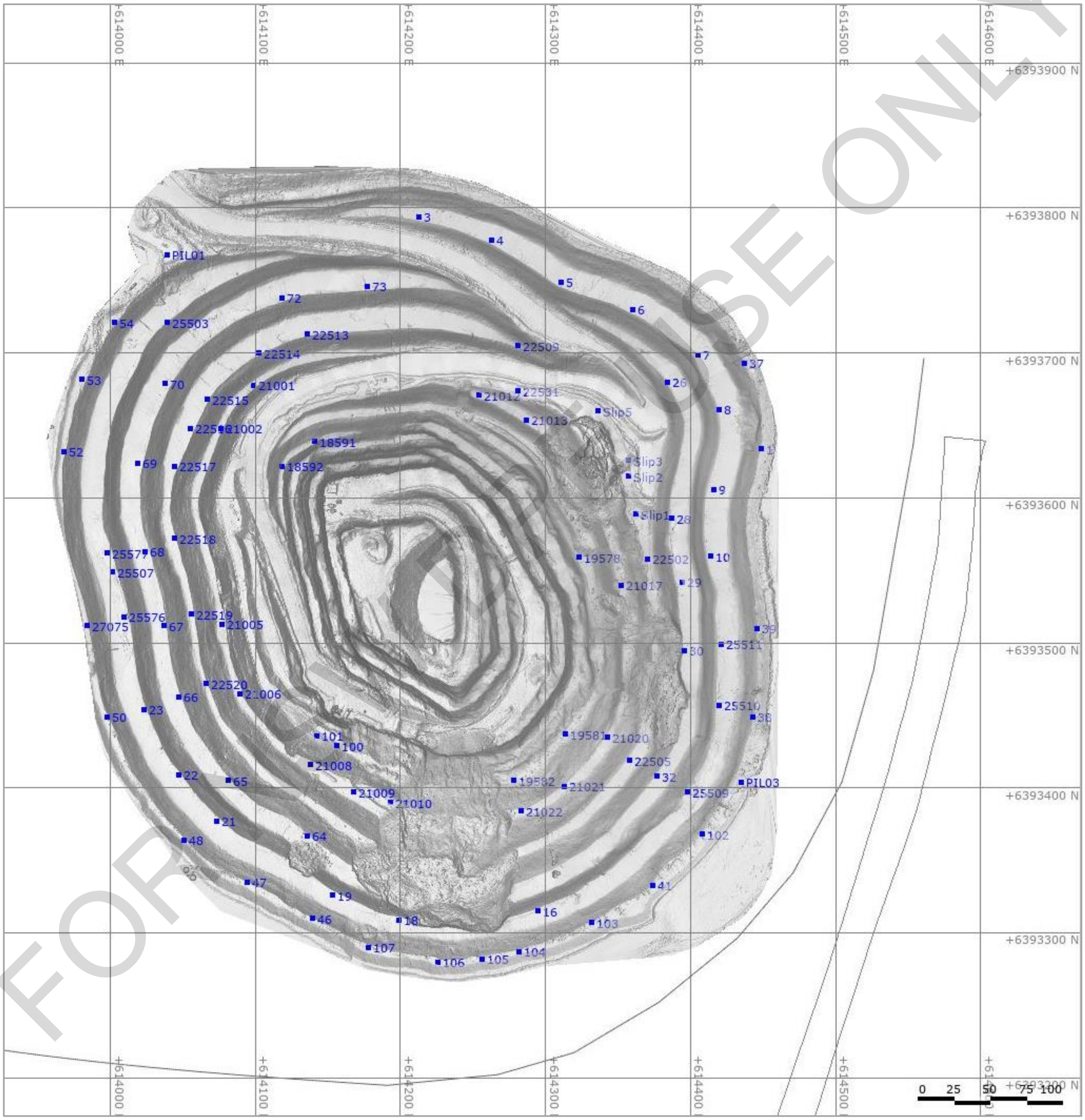


Figure A2 Time vs total displacement plot for Prism 106

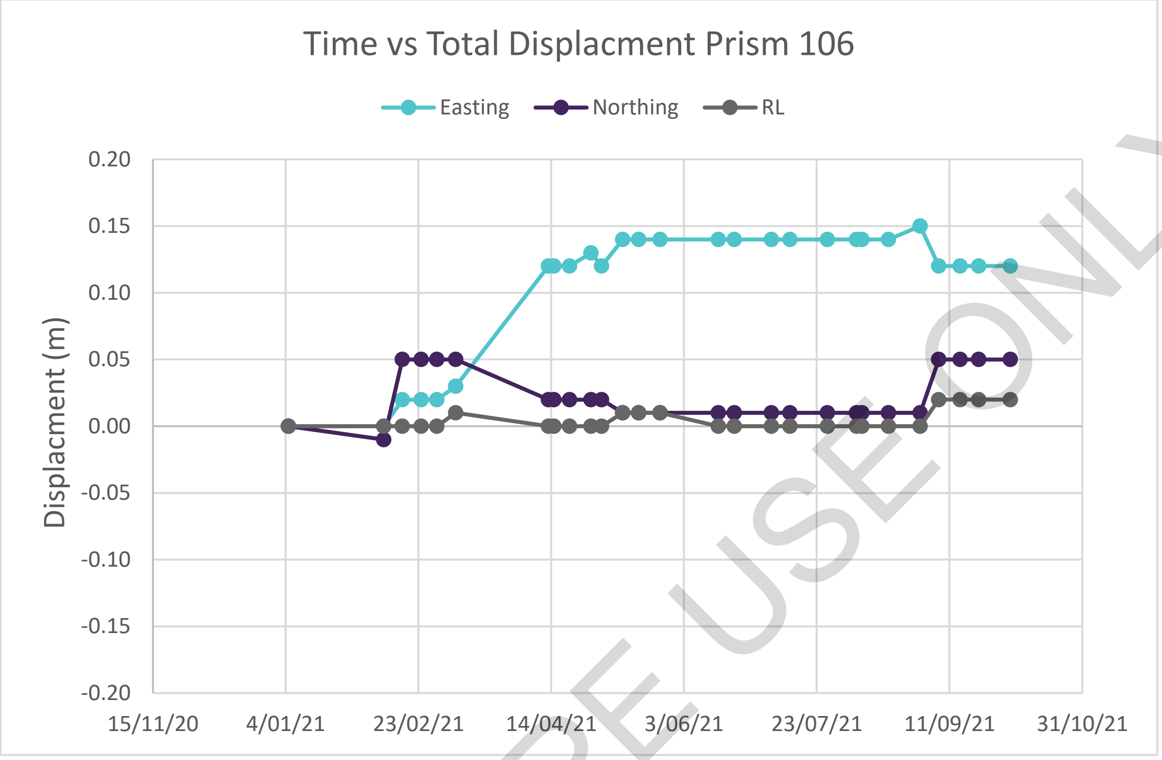


Figure A3 Time vs total displacement plot for Prism 107

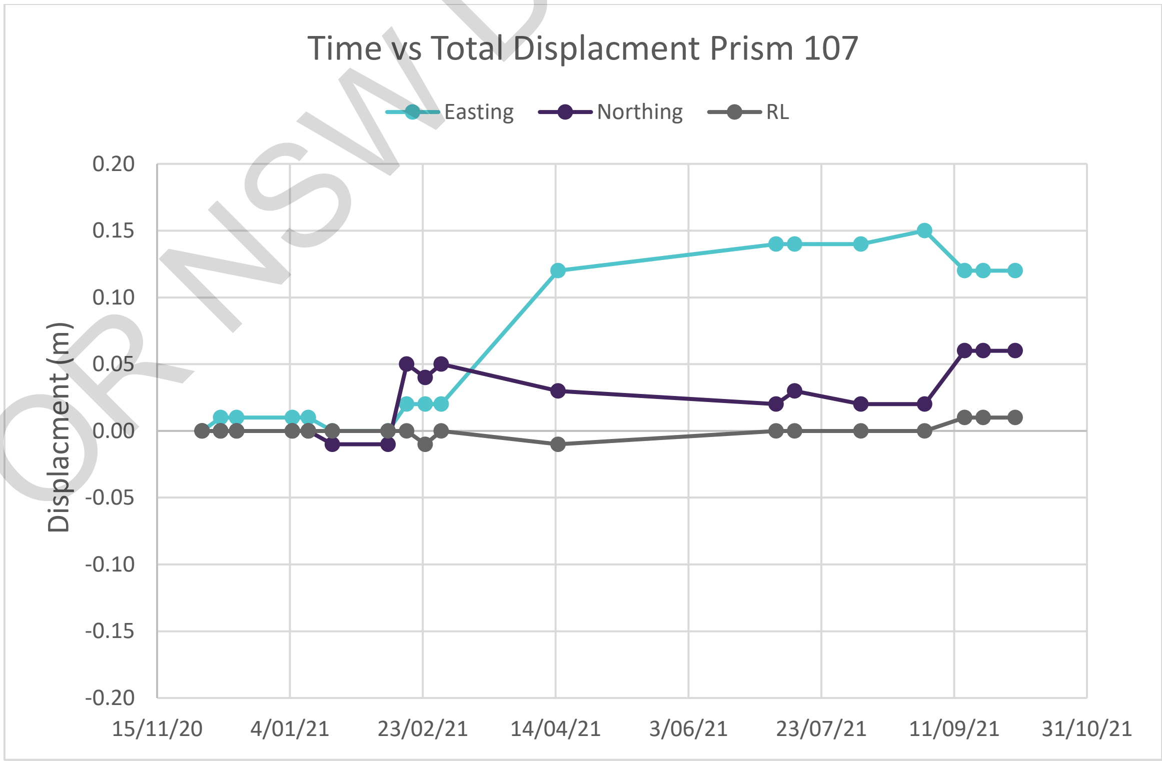


Figure A4 **Time vs total displacement plot for Prism 19**

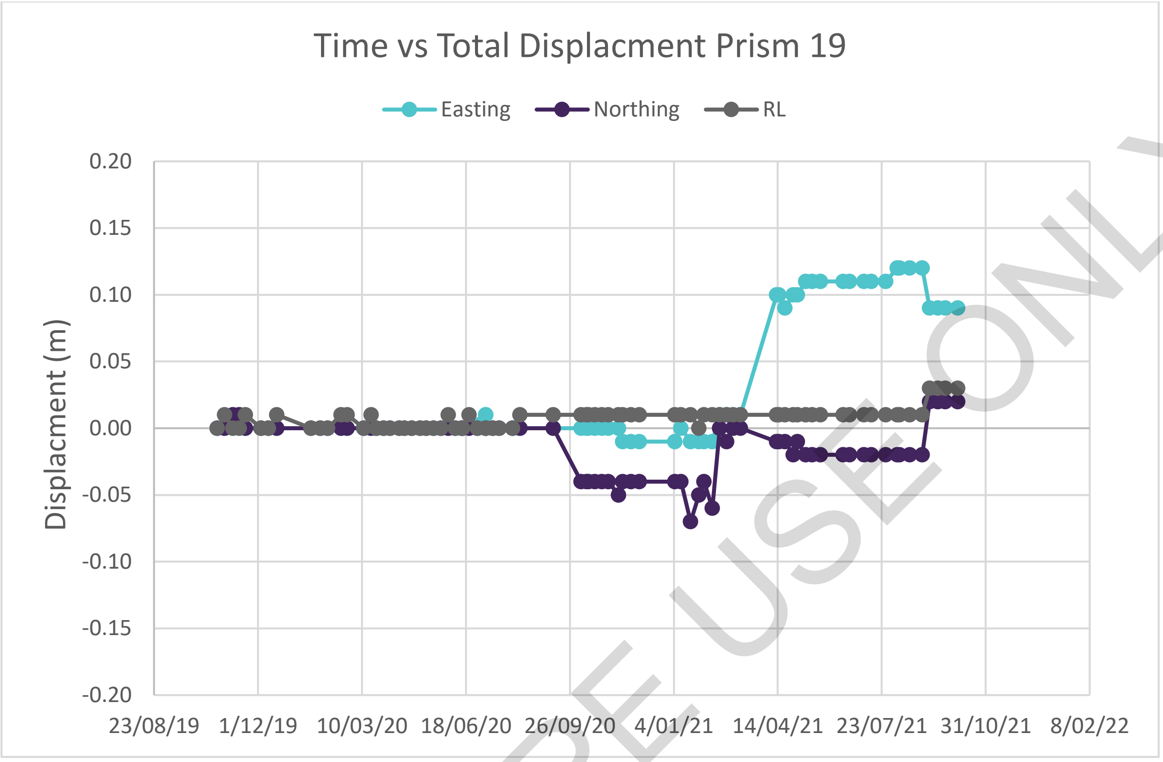


Figure A5 **Time vs total displacement plot for Prism 22518**

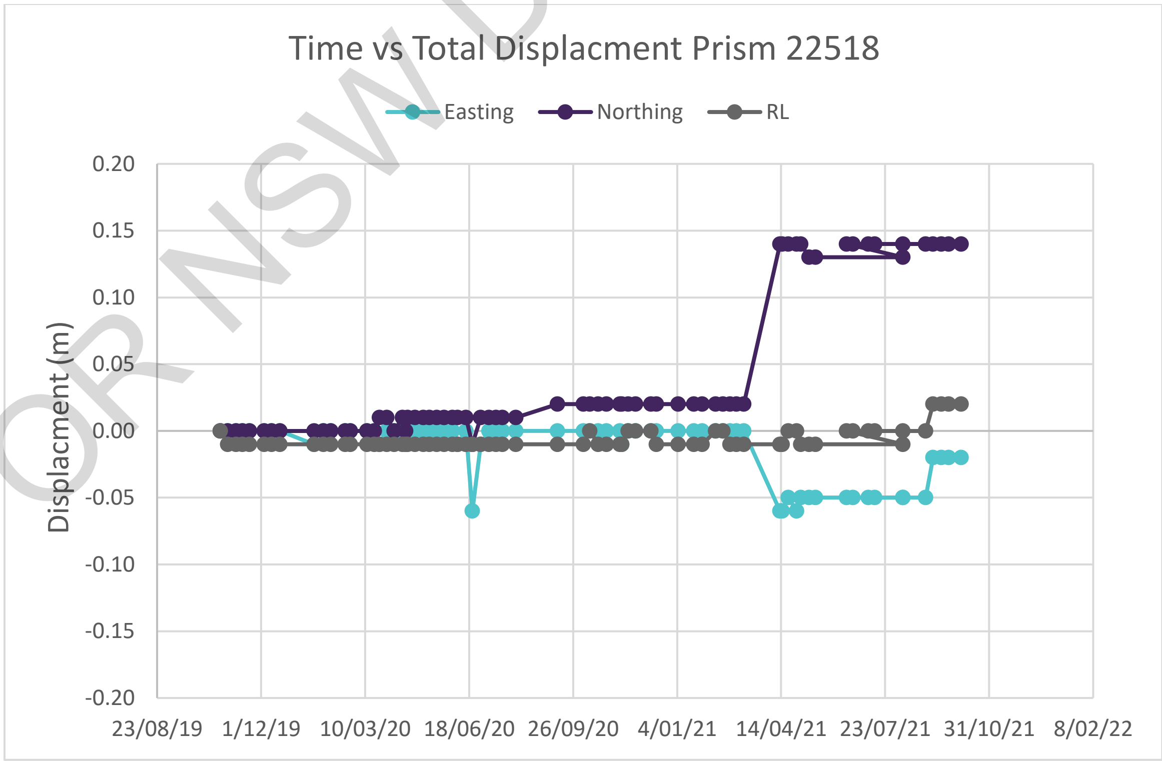


Figure A6 Time vs total displacement plot for Prism 22519

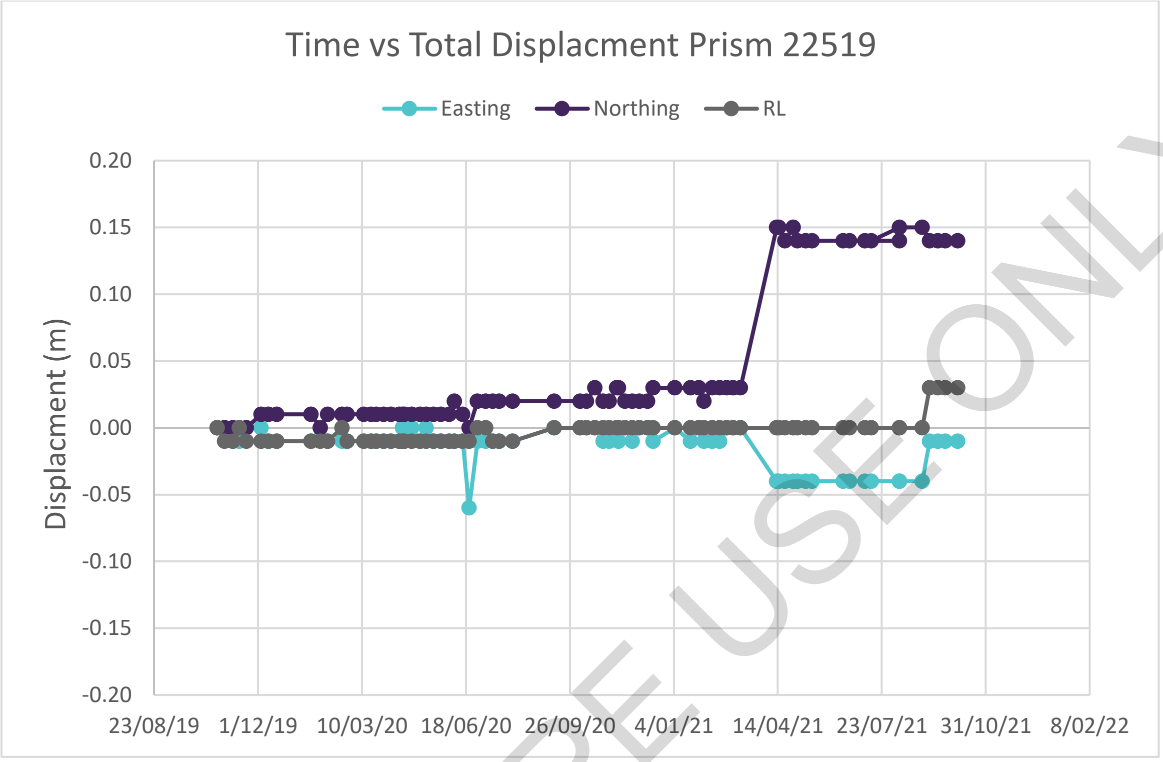


Figure A7 Time vs total displacement plot for Prism 25509

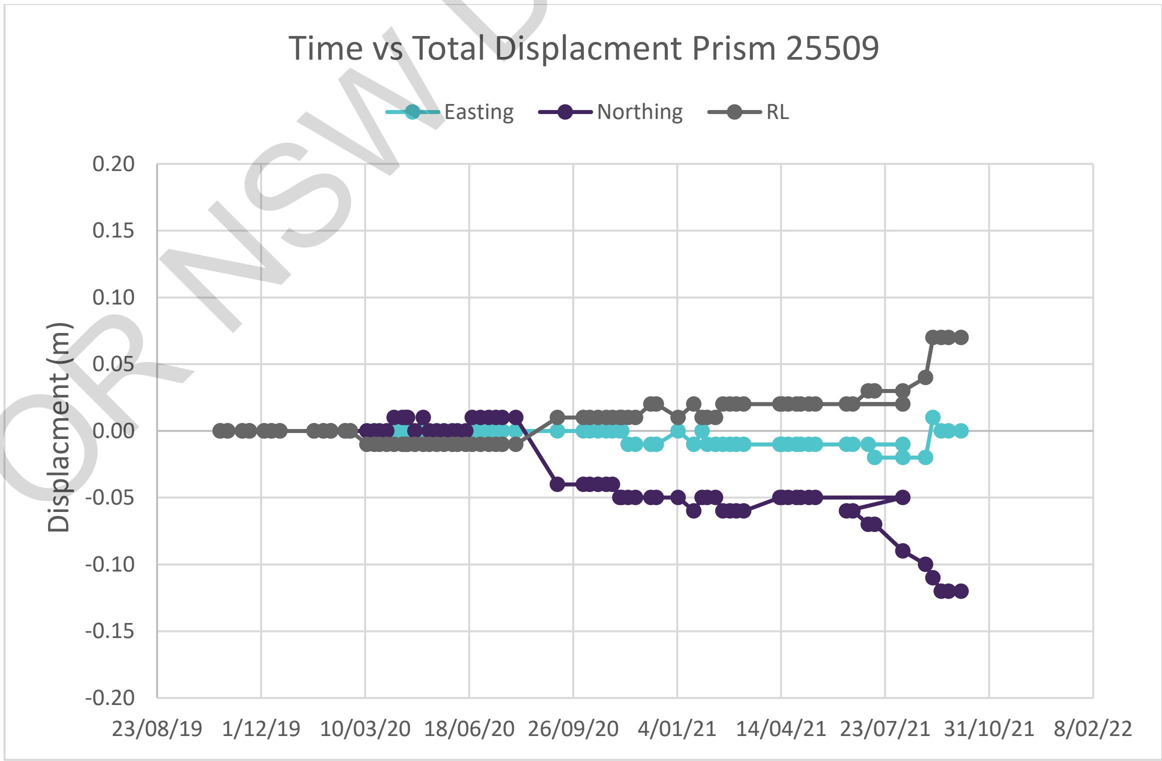


Figure A8 Time vs total displacement plot for Prism 25510

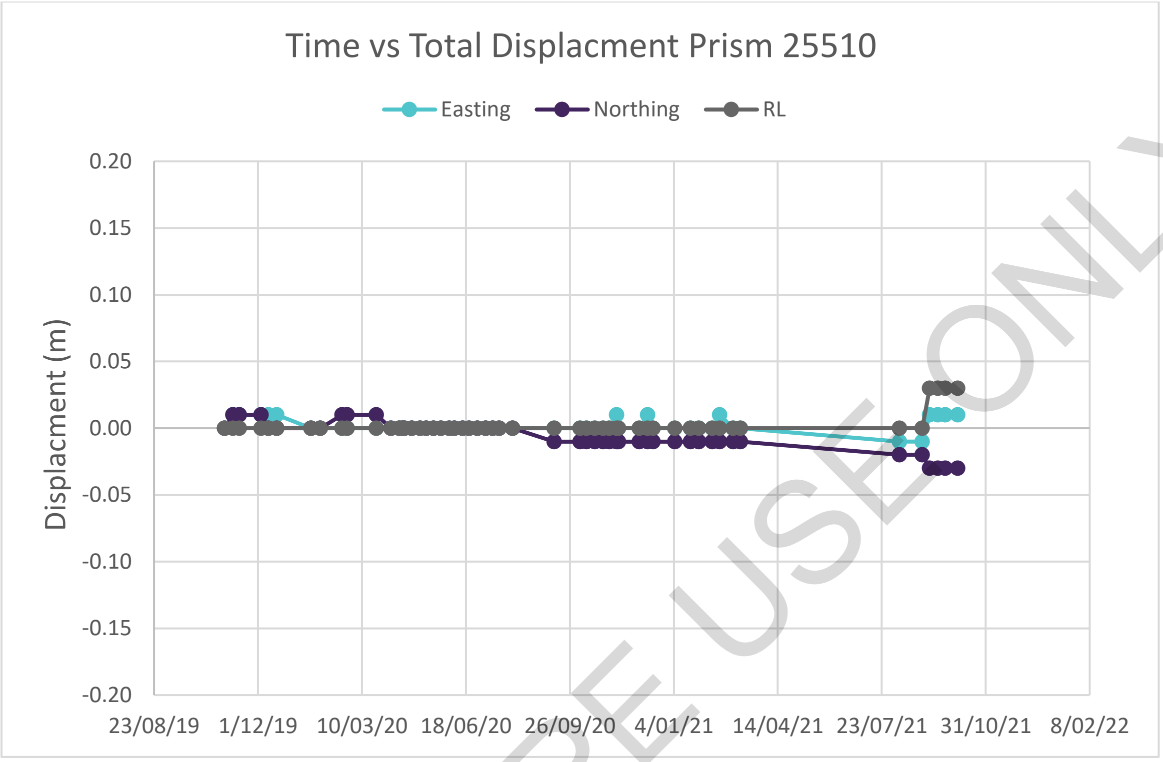


Figure A9 Time vs total displacement plot for Prism 25511

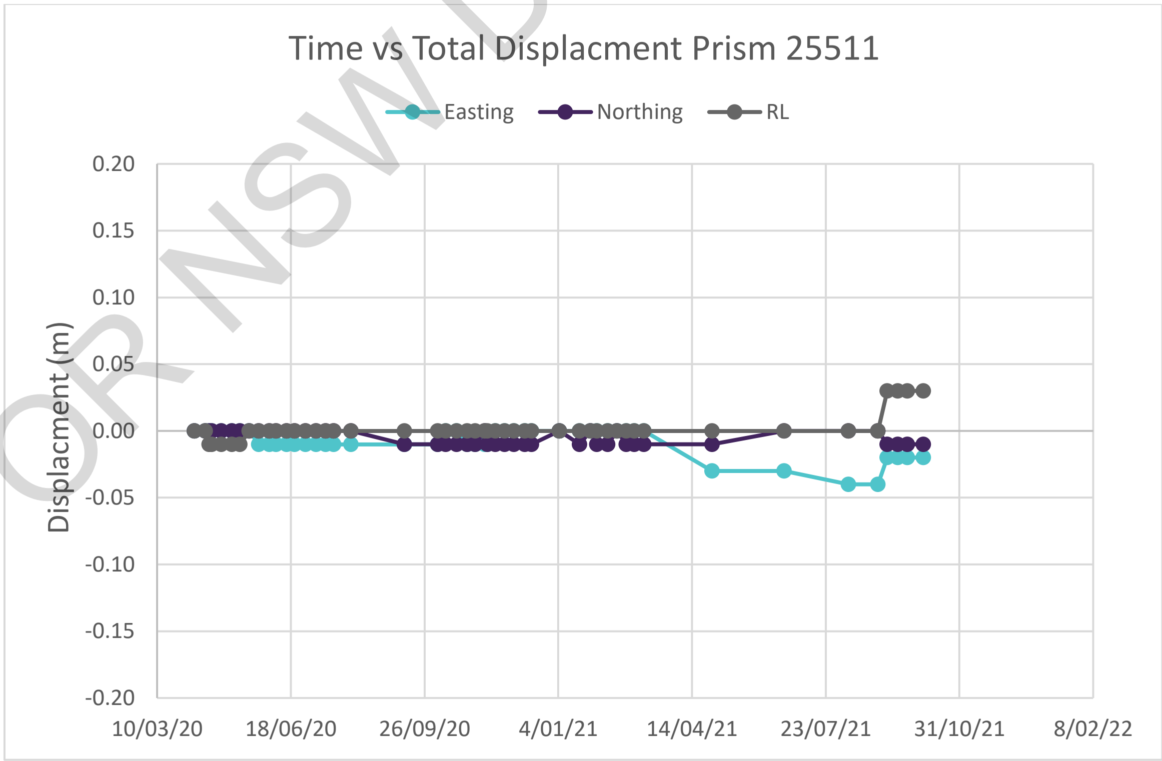


Figure A10 Time vs total displacement plot for Prism 66

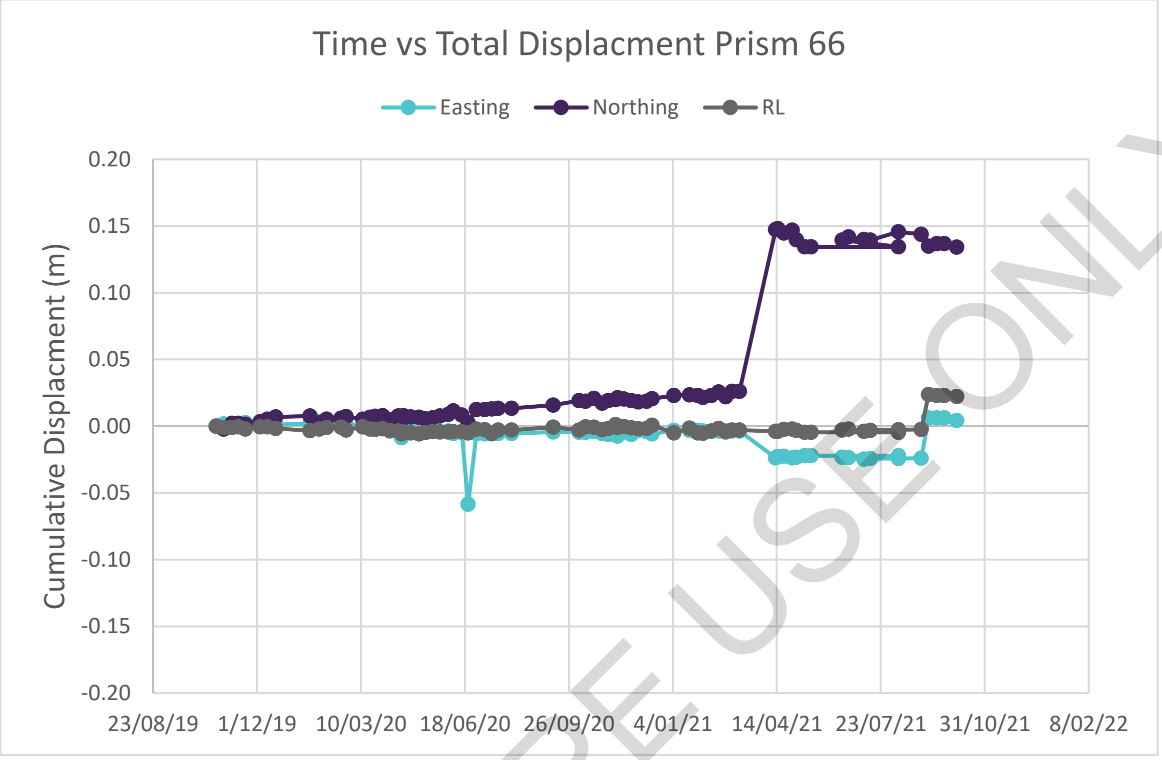


Figure A11 Time vs total displacement plot for Prism 67

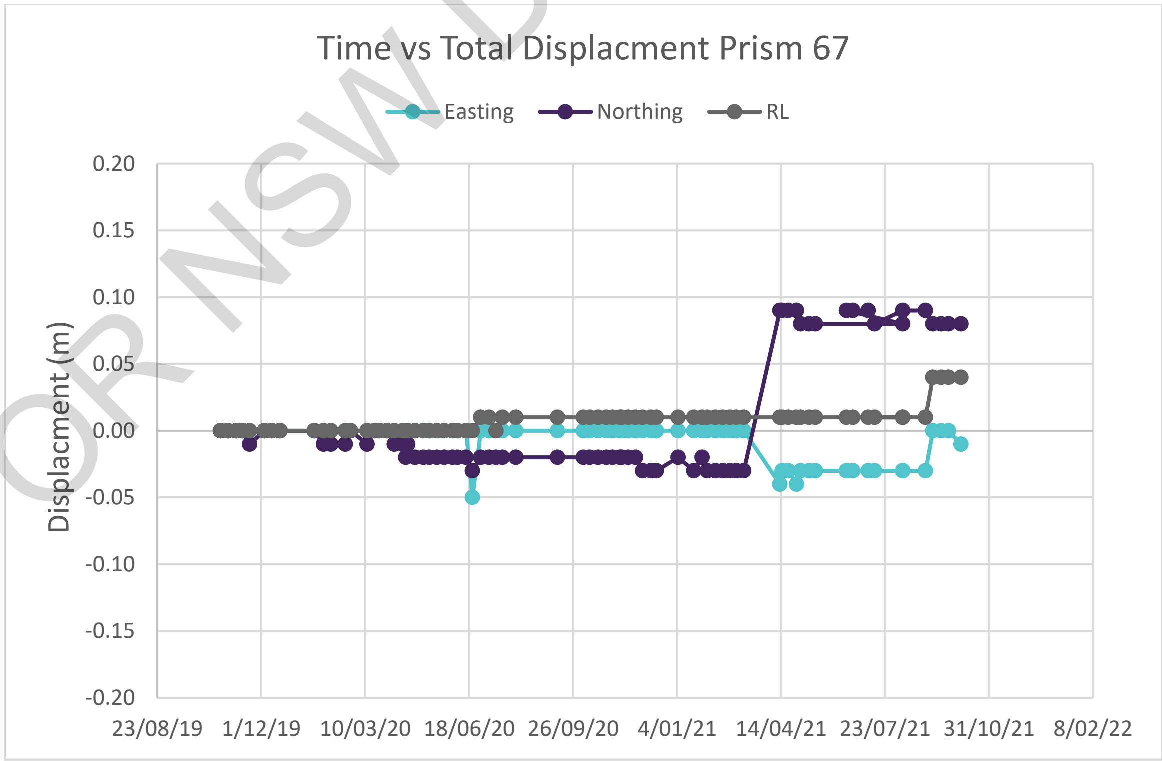
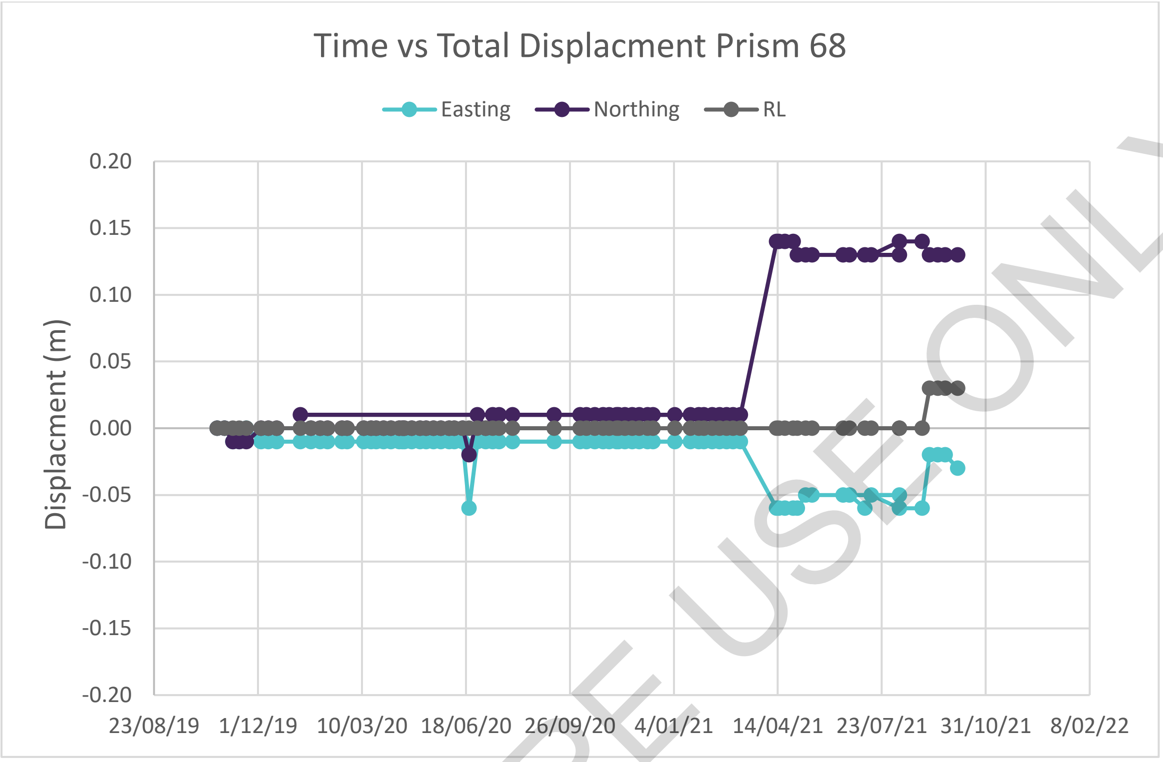
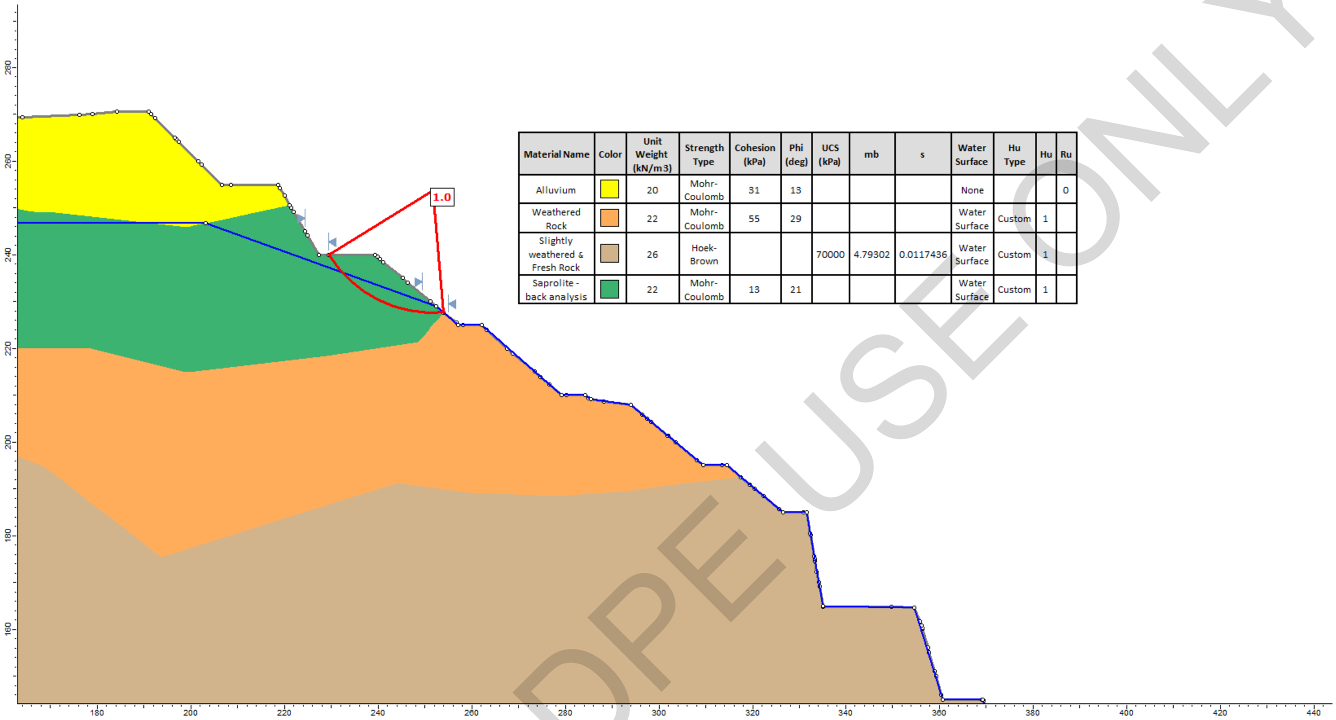


Figure A12 Time vs total displacement plot for Prism 68



Appendix B
Results of Back Analyses

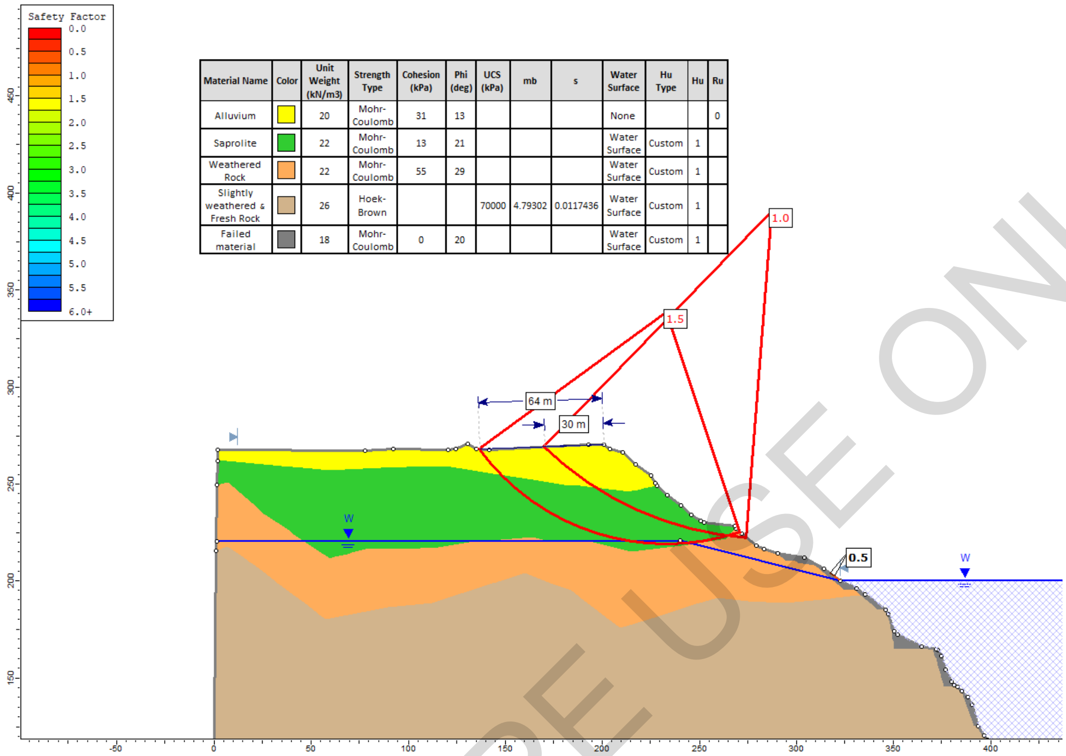
Figure B1 WY1 southeast corner results of back analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu	Ru
Alluvium		20	Mohr-Coulomb	31	13				None			0
Weathered Rock		22	Mohr-Coulomb	55	29				Water Surface	Custom	1	
Slightly weathered & Fresh Rock		26	Hoek-Brown			70000	4.79302	0.0117436	Water Surface	Custom	1	
Saprolite - back analysis		22	Mohr-Coulomb	13	21				Water Surface	Custom	1	

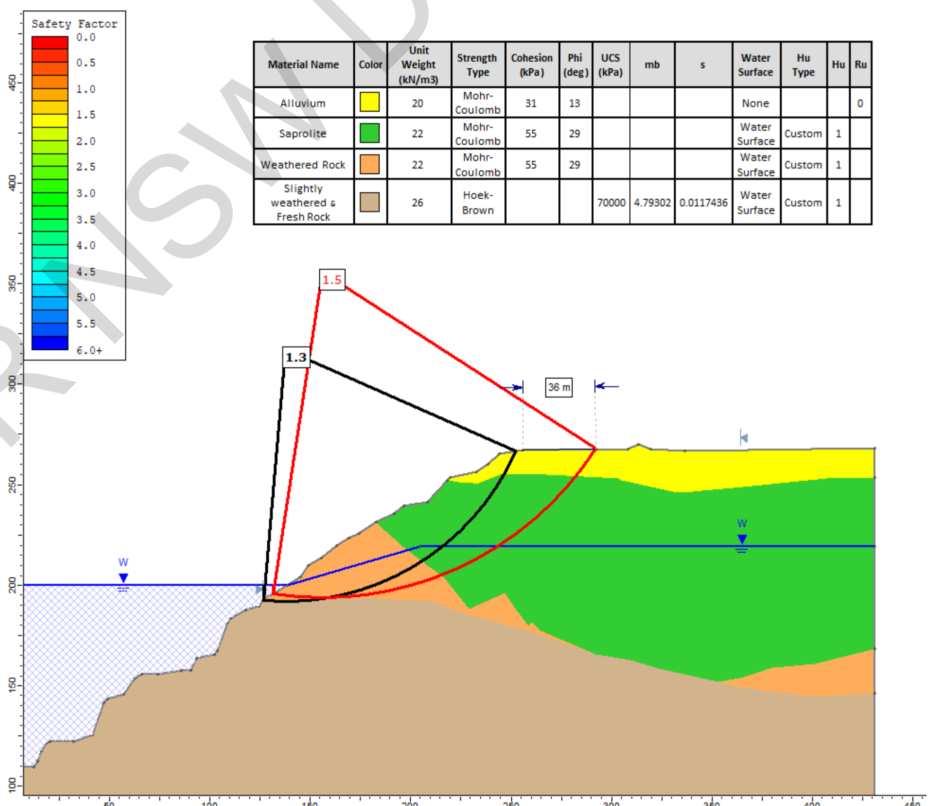
Appendix C
Results of Stability Analyses

Figure C1 SLIDE analysis results for WY1 southeast corner



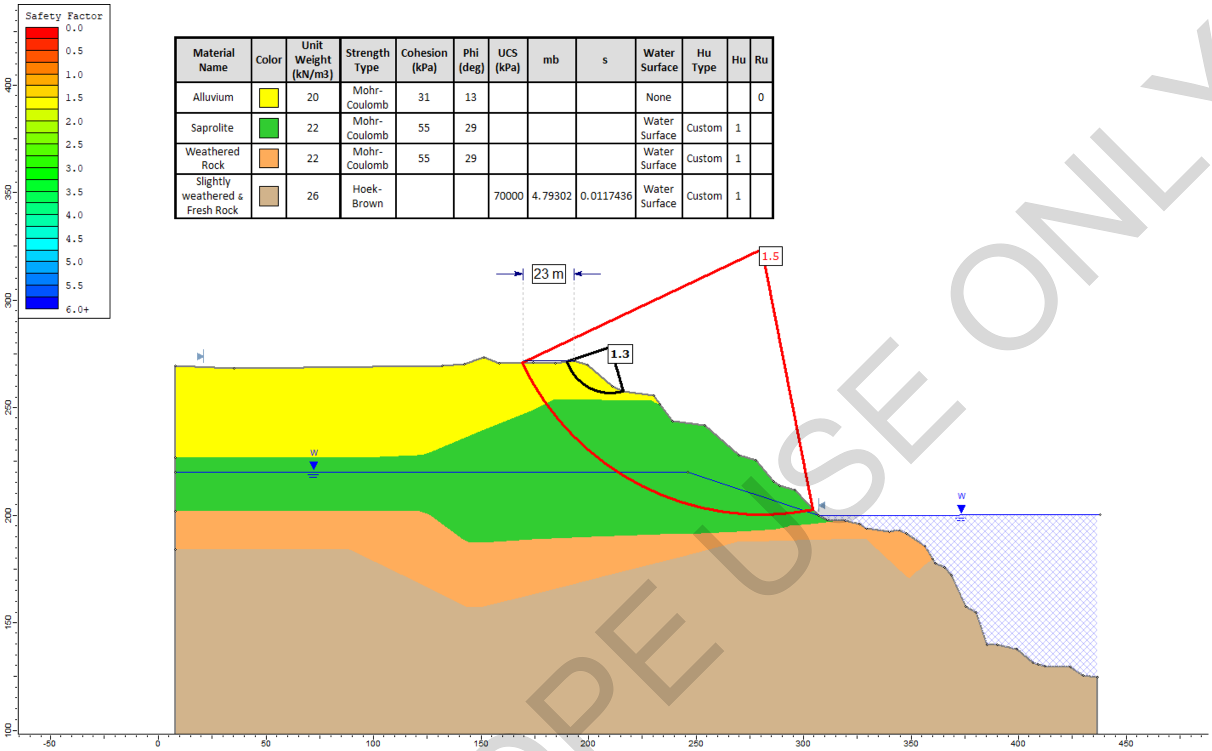
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu	Ru
Alluvium		20	Mohr-Coulomb	31	13				None			0
Saprolite		22	Mohr-Coulomb	13	21				Water Surface	Custom	1	
Weathered Rock		22	Mohr-Coulomb	55	29				Water Surface	Custom	1	
Slightly weathered & Fresh Rock		26	Hoek-Brown			70000	4.79302	0.0117436	Water Surface	Custom	1	
Failed material		18	Mohr-Coulomb	0	20				Water Surface	Custom	1	

Figure C2 SLIDE analysis results for WY1 east wall



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu	Ru
Alluvium		20	Mohr-Coulomb	31	13				None			0
Saprolite		22	Mohr-Coulomb	55	29				Water Surface	Custom	1	
Weathered Rock		22	Mohr-Coulomb	55	29				Water Surface	Custom	1	
Slightly weathered & Fresh Rock		26	Hoek-Brown			70000	4.79302	0.0117436	Water Surface	Custom	1	

Figure C3 SLIDE analysis results for WY1 west wall



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu	Ru
Alluvium		20	Mohr-Coulomb	31	13				None			0
Saprolite		22	Mohr-Coulomb	55	29				Water Surface	Custom	1	
Weathered Rock		22	Mohr-Coulomb	55	29				Water Surface	Custom	1	
Slightly weathered & Fresh Rock		26	Hoek-Brown			70000	4.79302	0.0117436	Water Surface	Custom	1	

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