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26 July 2021

Giorgio Dall'armi

General Manager

Broken Hill Operations (BHOP) – Rasp Mine

GEOTECHNICAL ASSESSMENT OF THE RASP MINE BOX CUT

Dear Giorgio,

Please find Ground Control Engineering's (GCE) report presenting a geotechnical assessment and slope design parameters for a proposed box cut for the Rasp Mine, Broken Hill NSW.

We trust that this report meets your requirements. Should you require further clarification, please do not hesitate to contact the undersigned.

Yours sincerely,

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Executive summary

Ground Control Engineering Pty Ltd (GCE) was commissioned by Broken Hill Operations (BHOP) to undertake a geotechnical assessment of a proposed box cut to replace the current access to the Rasp underground mine, currently situated at the base of the Kintore open pit.

GCE have completed a geotechnical assessment to develop slope design parameters for the box cut and provided preliminary ground support design requirements for the portal batter and upper sections of the decline linking the boxcut with the current Rasp underground workings.

The location for the boxcut was selected by BHOP based on operational factors. The location sites the boxcut excavation in historic surface waste rock and backfill material placed during the mining of the nearby historic BHP and Blackwood open pits. The boxcut location is also near historic underground, sand-filled workings., The location of the old workings has been estimated using original survey mining plans. The preferred location for the boxcut does not intersect the known underground workings apart from the Wilson and Darling Shafts located on what will be the western wall of the boxcut. These shafts originally connected the underground workings to the surface; however, it is understood these shafts were filled after abandonment. A known limitation with the underground historic data is accuracy and completeness of the available records. Investigative methods including probe hole drilling in the vicinity of the shafts and review of historic information is required.

Box cut slope design

Four geotechnical units (FILL, WEATHERED, TRANSITION and FRESH) were defined from geotechnical logging, and slope design parameters determined by empirical design and numerical modelling methods.

The upper portion of the box cut will be excavated in the FILL unit deposited as waste rock and backfill material from previous mining. The strength of this material is defined by its level of compaction, drainage characteristics and angle of repose. There are no records regarding the composition of the FILL unit and is assumed to be homogenous with respect to material properties for the purpose of this assessment.

The lower portion of the boxcut will be excavated in weathered rock (WEATHERED unit). The WEATHERED unit describes rock in a state of weathering ranging from extremely weathered to highly weathered with pervasive fracturing. The strength of the WEATHERED unit is variable, ranging from very low strength to low strength rock.

Slope design parameters for the box cut slopes are provided in the table below.

Bench Number	Geotechnical unit	Maximum batter angle	Maximum batter height in material	Bench width	Maximum slope angle in material	Maximum slope height
1	Fill	35°	10m	10m	29°	18m
2	FILL / WEATHERED CONTACT	40°	10m	10m	NA	10m
3	WEATHERED	54°	10m	10m	34°	16.5m

Surface erosion

The annual rainfall in Broken Hill is less than 250mm per annum. Long term erosion of the boxcut batters and berms is not expected to compromise the stability of the boxcut slopes apart from minor narrowing of the berms and the forming of erosion channels on the batter slopes in FILL unit. Broken Hill occasionally experiences high intensity rainfall events which may result in increased boxcut slope erosion. Measures to control long term erosion should be adopted by Rasp and access to the benches in the FILL unit should be maintained if remedial works are required. The boxcut design incorporates wide berms to account for potential erosion of the berm crests over the longer term, however, erosion protection is recommended for permanently exposed boxcut slopes and benches.

Seismic loading

The Rasp Mine experiences irregular, low level seismic activity in part due to historic and current mining activity in the area. A preliminary assessment of seismic loading on the boxcut slopes was undertaken during this analysis. A peak ground acceleration (PGA) value of 0.15 was applied to the analysis according to the Geoscience Australia NSHA18 hazard map, the map depicts the mean PGA for a 10% probability of exceedance in 50 years. The results of the analysis predict stable boxcut slopes when a seismic coefficient of 0.15g is applied to the model. Such an event is unlikely to trigger failure of the de-watered slopes but should warrant a detailed inspection for possible remediation. Any TARP that is developed for ground conditions for the boxcut should include seismic activity.

Portal batter design

The portal face is expected to be excavated in the WEATHERED unit. Ground conditions are expected to be “very poor” to “poor”. GCE recommend that the final portal ground support design and initial decline support design is finalised once the portal batter is established.

Decline design and ground conditions

The decline will commence in the WEATHERED or TRANSITION rock unit, the expected ground conditions for the initial decline development are expected to be “very poor” to “poor”, consistent with the assessment of the rock units in this report. Ground conditions are expected to improve as the decline progresses towards less weathered rock units. An improved level of data pertaining to ground conditions along the decline path is recommended to refine the rock mass characterisation information which will facilitate the prediction of ground conditions ahead of the decline face.

The ground conditions for the decline will be managed according to the requirements of the Rasp Principal Hazard Management Plan (PHMP) – Ground or Strata Failure. Adverse ground conditions that fall outside the scope of the PHMP will be managed by exception.

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1 Introduction

Ground Control Engineering Pty Ltd (GCE) was commissioned by Broken Hill Operations (BHOP) to undertake a geotechnical assessment and provide slope design parameters for a proposed box cut to replace the current access to the Rasp underground mine, currently situated at the base of the Kintore open pit.

The proposed location for the boxcut sites the excavation in historic surface waste rock and backfill material placed during the mining of the nearby BHP and Blackwood open pits. The boxcut location is also near historic underground, sand-filled workings. The location of the old workings has been estimated using historic survey mining plans. The location for the boxcut does not intersect the known underground workings apart from the Wilson and Darling Shafts located on what will be the western wall of the boxcut. These shafts originally connected the underground workings to the surface; however, it is believed that these shafts were filled after abandonment. A known limitation with the underground historic data is accuracy and completeness of the available records. Investigative methods including probe hole drilling in the vicinity of the shafts and review of historic information is required.

2 Scope of Work

The scope of work for this report was based on discussions between GCE and Rasp Mine technical management and comprised the following items:

1. Produce a conceptual boxcut design based on the BHOP preferred location.
2. Assess the condition of the slopes in the nearby areas to the proposed boxcut location.
3. Review of drill core from the geotechnical drilling programs to identify the base of the historic fill material and rock units.
4. Geotechnical analyses to define the site geotechnical conditions, determine slope design parameters and provide a ground support guidance for the decline portal.

The results of the 2018 and 2019 geotechnical logging and testing has formed the basis of the following assessment methods undertaken for this report:

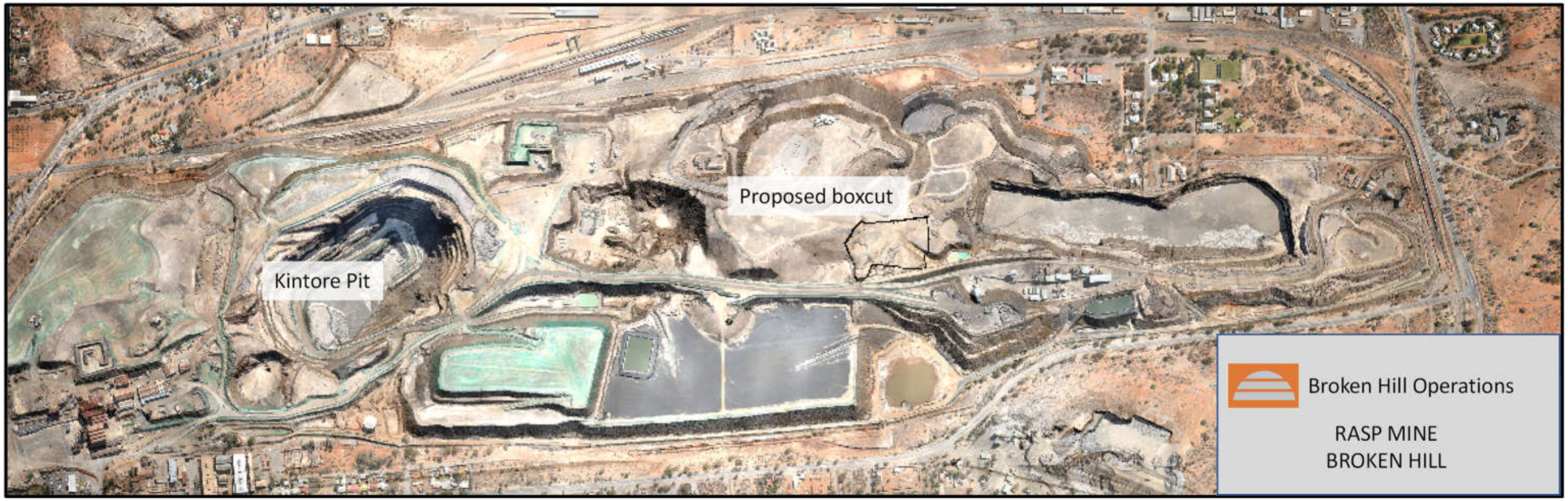
1. Empirical analysis of overall wall angles (derived from Rock Mass Rating (RMR) values), from the geotechnical logging of drill holes from the 2018 and 2019 box cut drilling programs.
2. Two-dimensional limit equilibrium modelling to assess the Factor of Safety (FOS) of design slope configurations.
3. Empirical assessment of anticipated ground conditions for the upper sections of the proposed decline to determine preliminary ground support requirements.

2.1 Project description

Broken Hill Operations (BHOP) operate the Rasp Mine in Broken Hill NSW. The mine is an underground operation situated approximately in the centre of the Broken Hill Line of Lode. The access to the underground mine is via a portal constructed in the base of the Kintore open pit which was completed in the 1991. BHOP plan to convert the Kintore Pit into a tailings facility which will require an alternative access to the underground workings.

Figure 1 shows the location of the current portal location and proposed boxcut excavation

Figure 1 Kintore pit and box cut design outline within existing topography.



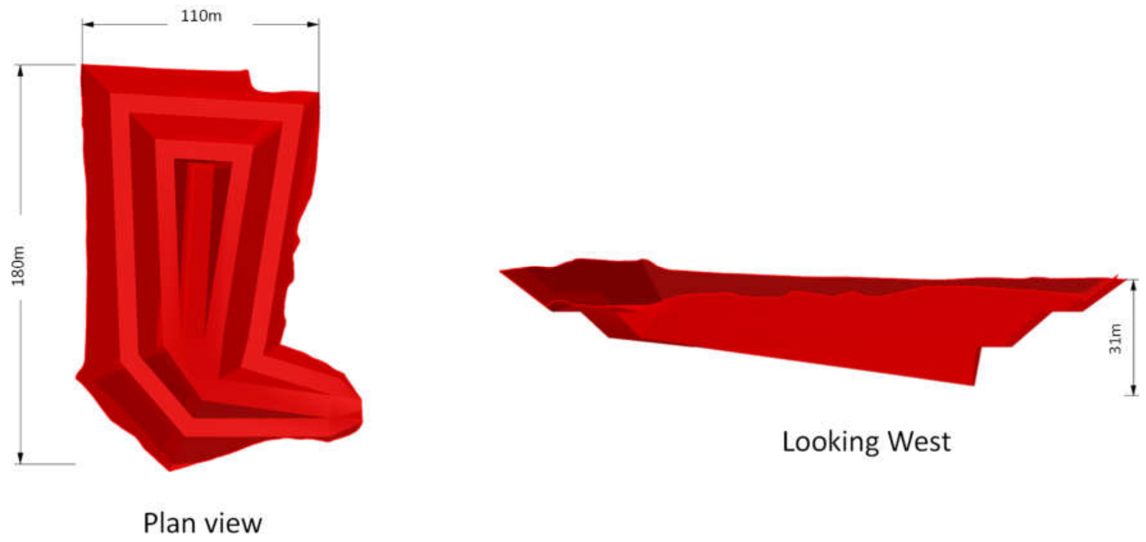
2.2 Boxcut dimensions

The proposed boxcut design dimensions are shown in Table 1 and Figure 2. The width of the box cut is constrained by the location of Rasp mine infrastructure on the eastern side of the boxcut and the mine boundary

Table 1 Boxcut design dimensions

Boxcut Dimension	Unit	No
Length	m	180
Width	m	115
Maximum depth	m	31
Excavation volume	m^3	191,000

Figure 2 Boxcut design dimensions, plan view and looking west.



2.3 Information sources

The following reports and data were provided to GCE for this assessment:

<u>Geotechnical logging and testing</u>

- BHOP Geotechnical logs and core photographs from the 2018 and 2019 box cut drilling programs:
    - 2018 Program
        - MLDD 3873
        - MLDD 3874
        - MLDD 3875
        - MLDD 3876
        - MLDD 3877
        - MLDD 3878
        - MLDD 3879

- 2019 Program
  - MLDD4132
  - MLDD4133
  - MLDD4134
  - MLDD4135
  - MLDD4136
  - MLDD4137
  - MLDD4138
  - MLDD4139
  - MLDD4140
- Trilab, 2018, 4 triaxial test results (3 consolidated-undrained (CU) triaxial tests).

Models and surfaces provided by BHOP

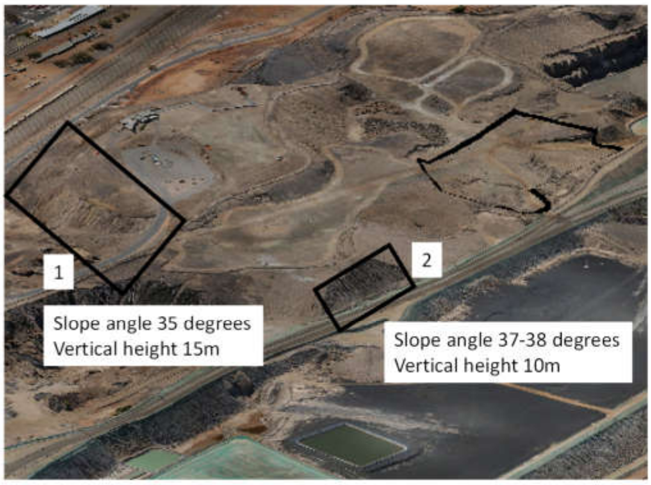
- Surpac files showing location of historic underground workings
- Aerial survey data of the mine lease.

Back analysis of existing slopes in the area

There are several historically stable slopes in the immediate area of the boxcut that were constructed using waste rock and fill material during the mining of the Blackwood Pit Figure 3 shows the location of the fill slopes in relation to the proposed boxcut location.

Figure 3 Existing fill slopes in the boxcut area

Plan view



Perspective view
(Looking north - east)

2.4 Limitations

The geotechnical data collected from the drilling programs was analysed to define the boundaries between fill material, weathered rock, and fresh rock and to determine the insitu strength properties of the rock units.

Insitu strength testing of the fill material was considered, however due to the depth of the material and the variable nature of deposition, insitu strength testing was considered an unsuitable method for determining the material properties of the fill material. The material properties adopted for assessing the fill material have been derived from GCE's experience with waste rock and sandfill material behaviours, from back-analyses of the performance of historic fill sites on site.

Access restrictions and depth of fill cover limited the extent of the drilling program in the western area of the boxcut area. Several holes were drilled in this area without definitively intersecting rock due to the depth of fill cover.

The location of the old workings in the vicinity of the proposed boxcut location were digitised from historic mining plans by BHOP. The accuracy of this information cannot be verified or guaranteed without probe drilling or accessing the workings.

The location for the boxcut does not intersect known underground workings apart from the Wilson and Darling Shafts located on what will be the western wall of the boxcut. These shafts originally connected the underground workings to the surface; however, it is believed that these shafts were filled after abandonment. The location of the Wilson and Darling Shafts is shown in Figure 4.

Figure 4 Wilson and Darling Shaft locations – plan view

3 Geotechnical data collection

3.1 2018 and 2019 Geotechnical drilling programs

Seven diamond drill holes were completed in 2018, followed by 9 diamond drill holes in 2019, spaced over the boxcut surface area. The purpose of the drilling was to locate the base of the historic fill material that overlies the surface of the intended boxcut location and to characterise the weathering profile of the rock below the historic fill material. The details of the drill holes are provided in Table 2. The information gained from the geotechnical logging also formed the basis of the empirical analyses that was used in the determination of the portal batter and initial decline ground support design. a plan view of the hole locations is shown in Figure 5.

Table 2: 2018 /2019 Geotechnical drilling program – drill hole details

Hole ID	Depth (m)	Dip	Easting (m)	Northing (m)	RL (m)
MLDD3873	45.0	-90.0	9888.6	2351.0	10334.6
MLDD3874	36.0	-90.0	9989.4	2333.6	10325.0
MLDD3875	42.6	-90.0	9985.0	2177.8	10324.6
MLDD3876	44.4	-90.0	9935.2	2085.4	10335.5
MLDD3877	53.6	-90.0	9802.2	2259.7	10354.0
MLDD3878	42.0	-90.0	9771.0	2365.0	10352.0
MLDD3879	42.0	-90.0	9782.4	2426.0	10344.8
MLDD4132	41.0	-90.0	9842.4	2526.1	10343.3
MLDD4133	40.9	-90.0	9806.8	2524.2	10343.0
MLDD4134	40.1	-90.0	9807.2	2499.1	10343.2
MLDD4135	40.0	-90.0	9806.3	2477.5	10343.0
MLDD4136	40.1	-90.0	9806.9	2524.7	10342.9
MLDD4137	40.3	-90.0	9844.6	2500.1	10340.7
MLDD4138	41.0	-90.0	9876.1	2485.0	10342.1
MLDD4139	40.3	-90.0	9879.8	2501.7	10341.8
MLDD4140	40.9	-90.0	9886.0	2548.7	10335.8

Figure 5 Plan view of diamond drill investigation holes

Laboratory testing – Rock samples

Seven representative samples from the WEATHERED zone were taken from three of the drill holes and submitted for unconfined compressive strength (UCS) and triaxial testing. The results are summarised in Table 3 and Table 4 and presented in Appendix A

Table 3: UCS test results from 2018 geotechnical drilling

Hole ID	Sample Interval		UCS (MPa)	Failure mode
	From (m)	To (m)		
MLDD3874	24.7	24.9	16.0	Shear on bedding plane
MLDD3875	30	33.0	13.4	Multiple fracturing
MLDD3876	21	21.25	24.3	Fracture along core axis
MLDD3876	30	30.2	16.5	Shear on bedding plane

Table 4 Triaxial test results from 2018 geotechnical drilling

Hole ID	Sample Interval		Friction angle (°)	Cohesion (KPa)
	From (m)	To (m)		
MLDD3874	18.7	19.0	49.7	270.9
MLDD3876	31.4	31.6	32.2	92.4
MLDD3877	48.6	48.8	51.4	240.1

4 Geotechnical model

Based on the information obtained from the geotechnical core logging and review of digital models, GCE have divided the rock mass into geotechnical units. Four geotechnical units have been defined and slope design parameters determined based on the orientation of the box cut walls and geotechnical characterisation of the rock mass. By using this approach, zones of the rock mass with similar geotechnical properties and anticipated slope performance can be grouped together.

Table 5 lists the geotechnical units and their prevalence in the geotechnical drill holes.

Table 5: Geotechnical units as logged in the drill holes

Geotechnical Unit	Metres Logged
FILL	118
WEATHERED unit - Extremely Weathered to Highly Weathered rock	238.46
TRANSITION unit - Highly Weathered to Moderately Weathered rock	160
FRESH rock	15.9

4.1 Rock mass quality

The box cut will be excavated in slopes comprising material from the FILL and WEATHERED units with the upper batter (approximately 15m) excavated predominantly in the FILL unit and the lower batter and portal face excavated in the WEATHERED unit. The boxcut is not expected to intersect the TRANSITION or FRESH rock units.

The boundaries of the units were defined using information from the recent drilling programs. The spatial distribution of the drilling data was limited by access to the area where the western wall and end wall of the boxcut is planned to be excavated. For this assessment, the material properties for the east, west and end wall of the boxcut are considered homogenous.

Further characteristics to note include:

- The upper batter will be excavated entirely in the FILL unit deposited from previous mining. The strength of this material is defined by its level of compaction, drainage characteristics and angle of repose. The FILL unit is assumed to be homogenous with respect to material properties.
- The WEATHERED unit is characterised by material affected by ground water and oxidation. The unit is of very low to low strength.
- Several fragmented and highly fractured zones were intersected in all the drill holes in each of the (natural) units. These zones were characterised by sheared, low strength material in various states of weathering.

4.2 Ground water and surface water

The geotechnical drilling program intersected several intervals where ground water was present indicated by saturated material in the core. These areas were located at the interface between the FILL unit and WEATHERED units. It is likely the saturated layer was the product of a perched water table rather than a natural water table.

The perched water table is not expected to adversely affect slope stability as the ground water in the area drains through the old workings and is collected in the current Rasp underground workings. However, provisions for dewatering infrastructure (e.g. dewatering bores and depressurisation holes) should be made to manage groundwater and surface water flows during excavation of the boxcut and to reduce deterioration and weakening of the slopes due to water ingress.

This assessment does not consider surface water flows or flood bunding around the box cut. A hydrological assessment of inflows (both groundwater and storm water) into the box cut is recommended to accurately assess drainage requirements and manage water flowing into the decline.

As a minimum, good drainage infrastructure that prevents surface water running over slopes and pooling on berms will be required.

5 Geotechnical design

5.1 Design criteria

Mine slope design is essentially governed by two factors:

1. The consequences of failure; and
2. The degree of inherent uncertainty.

To accommodate these two design factors, it is common practice to apply an appropriate Factor of Safety (FOS) and/or Probability of Failure (POF) to the design geometry of mine slopes. An example of FOS and POF design criteria is provided in Table 6. These design criteria have been developed from a combination of Western Australian, Department of Mines, Industry Regulation and Safety.

Table 6: Examples of design criteria for open pit walls

Wall Class	Consequence of Failure	Design FOS	Design POF	Pit Wall Examples
1	Not serious	Not applicable		Walls not carrying major infrastructure) where all potential failures can be contained within containment structures
2	Moderately serious	1.2	10%	Walls not carrying major infrastructure
3	Serious	1.5	1%	Walls carrying major mine infrastructure (e.g. treatment plant, ROM pad, tailings structures)
4	Serious	2.0	0.30%	Permanent pit walls near public infrastructure and adjoining leases

For this analysis, a FOS of 1.5 was applied to reflect that the boxcut will be life of mine, permanent infrastructure.

5.2 Empirical assessment

Rock mass rating (RMR)

GCE have completed an empirical assessment of the rock mass comprising the WEATHERED and TRANSITION units using the geotechnical logging data processed into Rock Mass Rating (RMR), then Mining Rock Mass Rating (MRMR), to determine general slope angles. This approach is based on rock mass quality and assesses the likelihood of shear failure through the rock (rather than along structures). This has proven to be a highly effective approach for small to intermediate pit slopes where the method is based on numerous similar case studies. Table 7 and

Table 8 show RMR values determined from assessment of the logging data.

Table 7 Core logged based on RMR

RMR Range	Description	Metres logged
≤ 20	Very Poor Rock	35
21 to 40	Poor Rock	86
41 to 60	Fair Rock	58.3
61 to 80	Good Rock	39.3
81 to 100	Very Good Rock	3

Table 8: RMR statistical data for each geotechnical unit

Geotech Unit	RMR				
	Minimum	25% Quartile	Median	75% Quartile	Maximum
WEATHERED	0	39	50	58	79
TRANSITION	0	56	65	73	83

<u>Mining rock mass rating (MRMR)</u>

MRMR values were derived for the WEATHERED and TRANSITION units and used to guide the determination of inter-ramp slope angles (IRSA) for the lower pit walls comprising the WEATHERED and TRANSITION units using the method of Haines and Terbrugge (1991). Median data was used to assess the design to account for the small number of data points available for the assessment (Table 9).

Table 9: MRMR statistical data

Geotechnical Unit	MRMR				
	Minimum	25% Quartile	Median	75% Quartile	Maximum
WEATHERED	0	11.3	23.5	40.0	34.4
TRANSITION	0	11.7	24.8	57.2	57.2

The Haines and Terbrugge design chart utilises MRMR values to determine inter ramp slope angles (IRSAs) based on a number of case studies comprising pit slopes in rock. For this case, the Haines and Terbrugge design chart is applied to the bottom 10m bench which will be excavated in the WEATHERED unit. Overall stope stability will be addressed in Section 5.3

IRSAs for Factor of Safety 1.5, using the median value MRMR are shown in Table 10.

Table 10: IRSA using Haines and Terbrugge design chart

Geotechnical Unit	MRMR Median	Slope Height (m)	IRSA (Haines & Terbrugge)
WEATHERED	23.9	16	42°

5.3 Slope stability modelling

Representative sections were modelled using “Slide” 2D limit equilibrium software by Rocscience to identify slope design configurations that met or exceeded the FOS criteria.

The material properties for all units remained fixed for all slope configurations (Table 11). The Bishop simplified and GLE/Morgenstern-Price methods were used to assess for circular failure. Results are presented in Appendix B

Table 11: Material properties for Slide modelling

Geotechnical Unit	Strength Type	Unit Weight (kN/m^3)	Strength Parameters	
			Cohesion (kPa)	Friction Angle
FILL	M-C	20	5.0	36°
WEATHERED	M-C	24	92	32°
TRANSITION	M-C	24	270	50°

Notes: M-C – Mohr-Coulomb

Figure 6 show the overall model geometry for permanent slopes and Figure 7 shows detailed model geometry for the east wall of the boxcut at the portal face.

Figure 6 Slide model configuration for permanent slopes

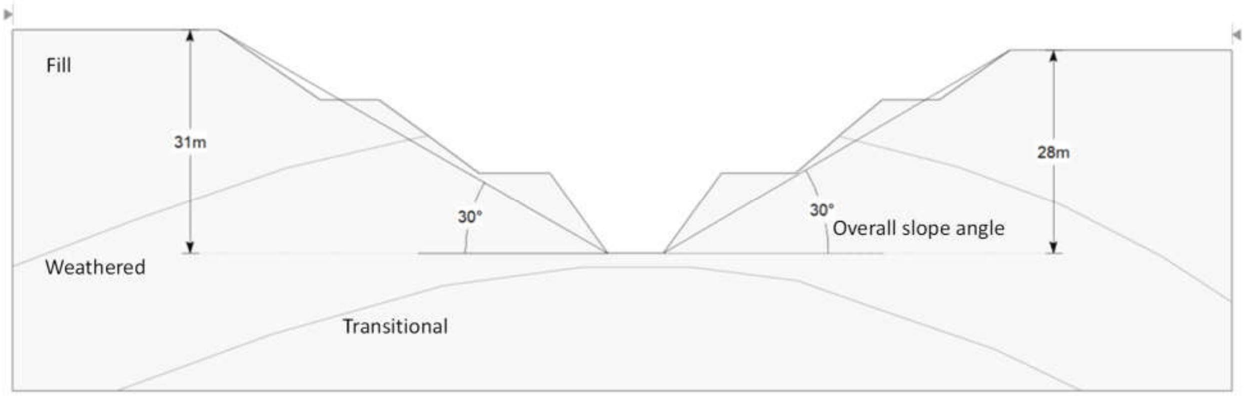
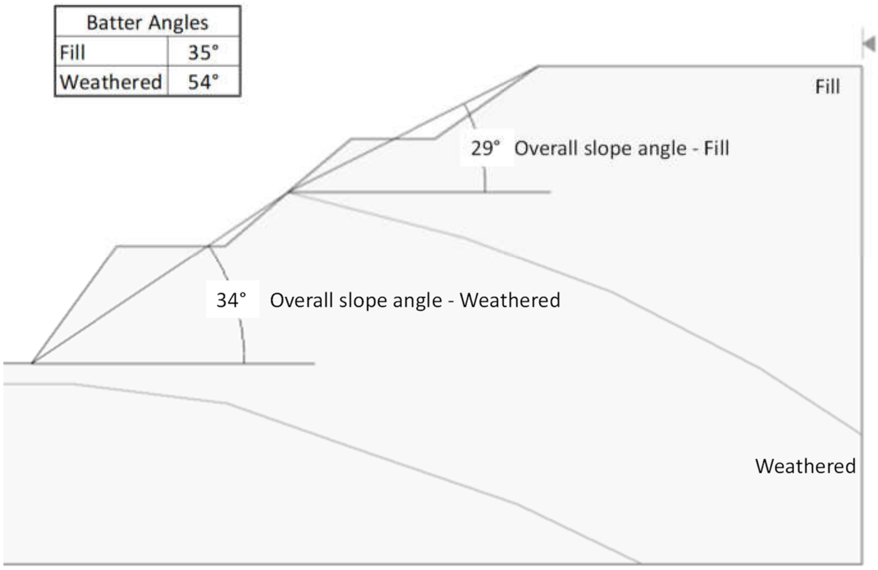


Figure 7 Detailed model geometry



<u>Discussion on modelling results;</u>

The results of the modelling indicate an overall slope angle of 30 degrees or less meets or exceeds the Factor of Safety criteria of 1.5

<u>Slopes in the FILL unit</u>

Based on the assumed geotechnical conditions, the modelling indicates stable slopes in the FILL unit at the proposed slope configuration.

<u>Slopes in combination of FILL and WEATHERED units</u>

Slopes constructed in both the FILL and WEATHERED units are expected to be stable at the proposed slope configuration.

<u>Slopes in the WEATHERED unit</u>

The results of the modelling indicate the slopes in the WEATHERED unit are expected to be stable at the proposed slope configuration.

<u>Portal batter face</u>

It is expected that the portal batter will be excavated in the WEATHERED unit. The stability of the portal batter may be compromised if FILL unit is present above the crown of the portal. Further detailed geotechnical assessment and a specific ground support design corresponding to the ground conditions encountered, will be required for the portal and portal batter face once it is exposed. It is important to note that the depth and overall shape of TRANSITION and WEATHERED units is based on limited information.

Two-dimensional modelling cannot account for confinement of slopes from the side walls (by the end wall) and the end wall (by the side walls). As such, it could be considered that the FOS results may be slightly higher if this confinement of abutting walls are incorporated into the modelling.

The model results are presented in Appendix B.

Seismic loading

The Rasp Mine experiences irregular, low level seismic activity in part due to mining activity in the area. A preliminary assessment of seismic loading on the boxcut slopes was undertaken during this analysis. A peak ground acceleration (PGA) value of 0.15 was applied to the analysis according to the Geoscience Australia NSHA18 hazard map, the map depicts the mean PGA for a 10% probability of exceedance in 50 years. The results of the analysis predict stable boxcut slopes when a seismic coefficient of 0.15g is applied to the model. Such an event is unlikely to trigger failure of the de-watered slopes but should warrant a detailed inspection for possible remediation. Any TARP that is developed for ground conditions for the boxcut should include seismic activity.

Surface erosion

The annual rainfall in Broken Hill is less than 250mm per annum. Long term erosion of the boxcut batters and berms is not expected to compromise the stability of the boxcut slopes apart from minor narrowing of the berms and the forming of erosion channels on the batter slopes in FILL unit. Broken Hill occasionally experiences high intensity rainfall events which may result in increased boxcut slope erosion. Measures to control long term erosion should be adopted by Rasp and access to the benches in the FILL unit should be maintained if remedial works are required. The boxcut design incorporates wide berms to account for potential erosion of the berm crests over the longer term, however, erosion protection is recommended for permanently exposed boxcut slopes and benches.

6 Portal batter design

The portal face is expected to be excavated in the WEATHERED unit. Ground conditions are expected to be "very poor" to "poor" GCE recommend that the final portal ground support design and initial decline support design is finalised once the portal face is established and ground support is installed. Due to expected poor ground conditions, controlled perimeter blasting is recommended to avoid damaging the drive profile during the construction of the portal.

For 'very poor" ground conditions (Q<1), the portal face and wall should be supported with the following elements:

- 75 mm FRS (fibre reinforced shotcrete), strength UCS 40 MPa after 28 days over mesh. The FRS should cover the entire portal face and wrap over the portal bench by at least 2m and a minimum of 10m of wall coverage back from the face.
- The portal face should be cable bolted using 10m length, twin strand cable bolts at 2m centres. Cable bolts may be drilled slightly upwards at less than 5 degrees from the horizontal.
- Install 9m long spiling bars at approximately 300mm centres around the portal arch. Overlap 1.5m between spiling rounds.
- Ground improvement techniques including soil nailing and pressure grouting may be required for the portal batter if very poor ground conditions are encountered. This work should be undertaken before establishing the ramp to the portal batter face.

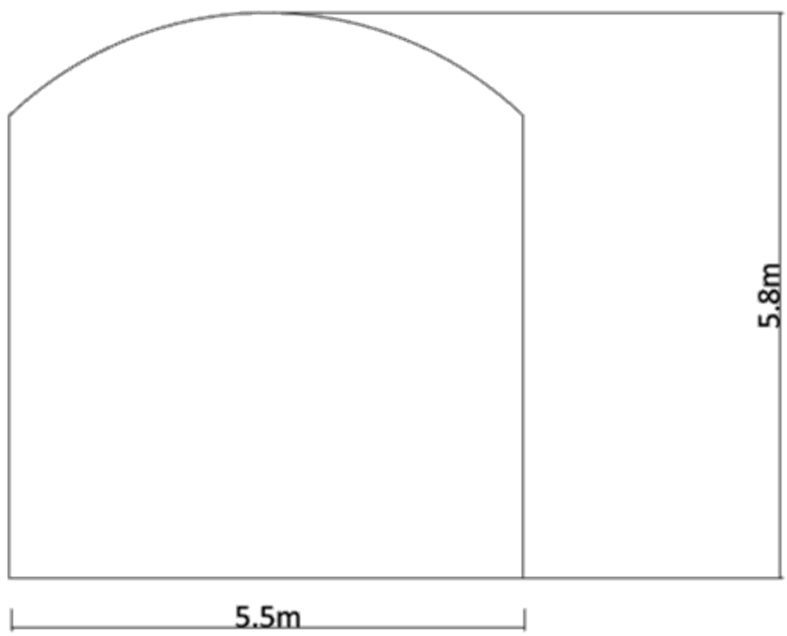
The proposed portal face design is shown in Appendix C. The support guidelines should be re-evaluated once the portal face is established.

7 Initial decline design

7.1 Decline ground conditions

The decline will be excavated using the same arched profile that is in use for the Western Min decline, the dimensions of the decline are shown in Figure 8.

Figure 8 Decline excavation profile for the decline



The decline will commence in the WEATHERED unit, the expected ground conditions for the initial decline development are expected to be "very poor" to "poor", consistent with the assessment of the rock unit in this report. Ground conditions are expected to improve as the decline progresses through the TRANSITION and FRESH rock units. An improved level of data pertaining to ground conditions along the decline path is recommended to refine the rock mass characterisation information for the decline path which will facilitate the prediction of ground conditions ahead of the decline face.

7.2 Decline ground support

Rasp have a comprehensive system for managing ground conditions during development which is detailed in the Principal Hazard Management Plan – Ground or Strata Failure. It is expected that the procedures for managing ground conditions and ground support methodology will be applied to the decline. Unexpected changes in ground conditions will be managed by exception which may require, specific ground support design.

The ground support configurations that will be applied to the decline are shown in Appendix D.

8 Summary of findings

8.1 Box cut slope design parameters

The recommended slope design parameters for the box cut slopes are presented in Table 12 and are to be read in conjunction with the comments that follow the table. They have been reached using a combination of geotechnically derived results from the following methods:

- Empirical assessment
- 2D slope stability modelling

Table 12 Summary of slope design parameters

Bench Number	Geotechnical unit	Maximum batter angle	Maximum batter height in material	Bench width	Maximum slope angle in material	Maximum slope height
1	Fill	35°	10m	10m	29°	18m
2	FILL / WEATHERED CONTACT	40°	10m	10m	NA	10m
3	WEATHERED	54°	10m	10m	34°	16.5m

The following comments are critical to application of the slope design parameters presented above:

- Dewatered slopes are recommended to ensure the long-term stability of the box cut. Provision for depressurised walls (de-watering holes may be required) and surface drainage should be made.
- The slope design parameters are appropriate for good final wall blasting techniques (i.e. pre-split and/or trim blasted) and good slope management (e.g. scaling walls). Note: pre-split blasting may not be the best method in the weathered, low strength ground due to the damage potential from explosive energy directly against the final walls.
- Routine geotechnical inspections of batters and berms, and the commissioning of a slope movement monitoring system (i.e. a system of prisms set up along berm crests and routinely surveyed by mine surveyors).
- A preliminary seismic loading analysis indicates stable boxcut slopes when a seismic coefficient of 0.15g is applied to the model. Such an event is unlikely to trigger failure of the de-watered slopes but should warrant a detailed inspection for possible remediation. Any TARP that is developed for ground conditions for the boxcut should include seismic activity.
- Long term erosion of the boxcut batters and berms is not expected to compromise the stability of the boxcut slopes apart from minor narrowing of the berms and the formation of erosion channels on the batter slopes in FILL unit. Broken Hill occasionally experiences high intensity rainfall events which may result in increased boxcut slope erosion. Measures to control long term erosion should be adopted by Rasp and access to the benches in FILL unit should be maintained if remedial works are required.
- Erosion protection is recommended for the portal batter and bench to prevent damage to the portal batter surface support.

8.2 Portal face design

- The portal face will be excavated in the WEATHERED unit. Ground conditions are expected to be "very poor" to "poor". GCE recommends that the final portal ground support design and initial decline support design is finalised once the portal face is established.
- Preliminary ground support requirements for "very poor" and "poor" to "Fair" rock mass quality are provided in Section 5.

8.3 Decline design and ground conditions

The decline will commence in the WEATHERED or TRANSITION rock unit, the expected ground conditions for the initial decline development are expected to be "very poor' to 'poor", consistent with the assessment of the rock units in this report. Ground conditions are expected to improve as the decline progresses towards less weathered rock units. An improved level of data pertaining to ground conditions along the decline path is recommended to refine the rock mass characterisation information which will facilitate the prediction of ground conditions ahead of the decline face.

The ground conditions for the decline will be managed according to the requirements of the Rasp Principal Hazard Management Plan (PHMP) – Ground or Strata Failure. Adverse ground conditions that fall outside the scope of the PHMP will be managed by exception.

Appendix A Laboratory test results

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UNIAXIAL COMPRESSIVE STRENGTH TEST REPORT

Test Method: AS 4133.4.2.1 & AS 4133.1.1.1

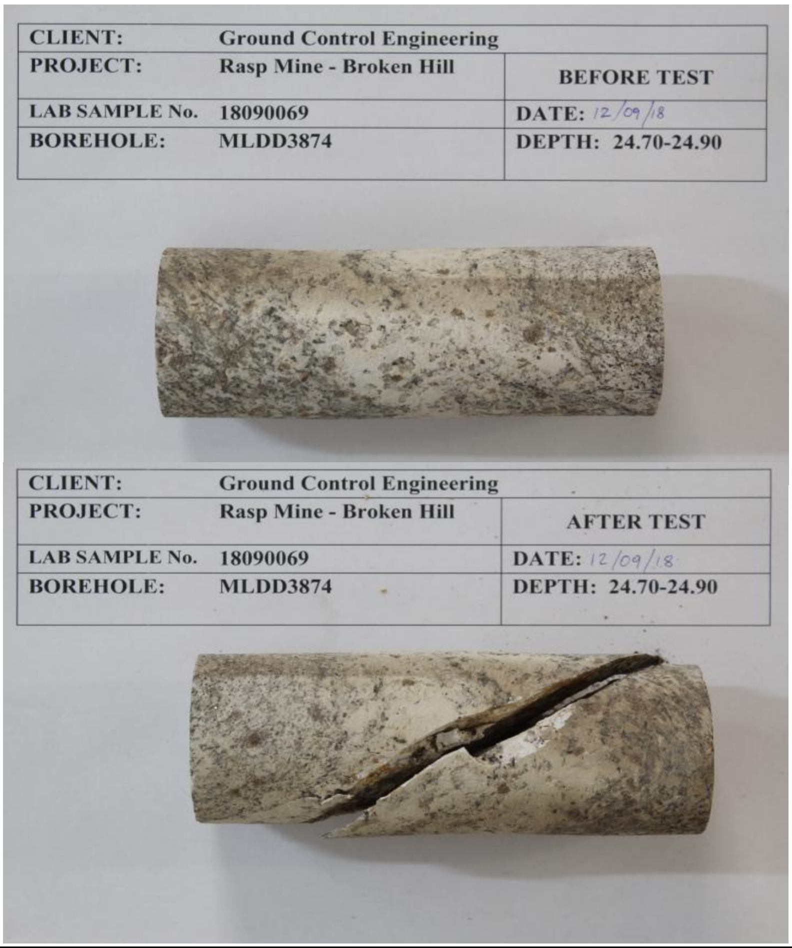
Client	Ground Control Engineering	**Report No.**	18090069-UCS
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date**	12/09/2018
		Report Date	13/09/2018
Project	Rasp Mine - Broken Hill		
Client ID	MLDD3874	**Depth (m)**	24.70-24.90
Description	-		
Sample Type	Single Individual Rock Core Specimen		

TEST DETAILS

Average Sample Diameter (mm)	60.5	Moisture Content (%)	0.2
Sample Height (mm)	159.9	Wet Density (t/m^3)	2.76
Duration of Test (min)	5:23	Dry Density (t/m^3)	2.75
Rate of Loading (MPa/min)	2.97	Bedding (°)	60
Mode of Failure	Shear	Test Apparatus	Kelba 1000 kN Load Cell
Rupture Angle (°)	65		

UCS (MPa) **16.0**

Before and After Testing Photo's



NOTES/REMARKS:
Stored and tested as received
Sample/s supplied by the client

Photo's not to scale

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory
N. Maddison

Laboratory No. 9926

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UNIAXIAL COMPRESSIVE STRENGTH TEST REPORT

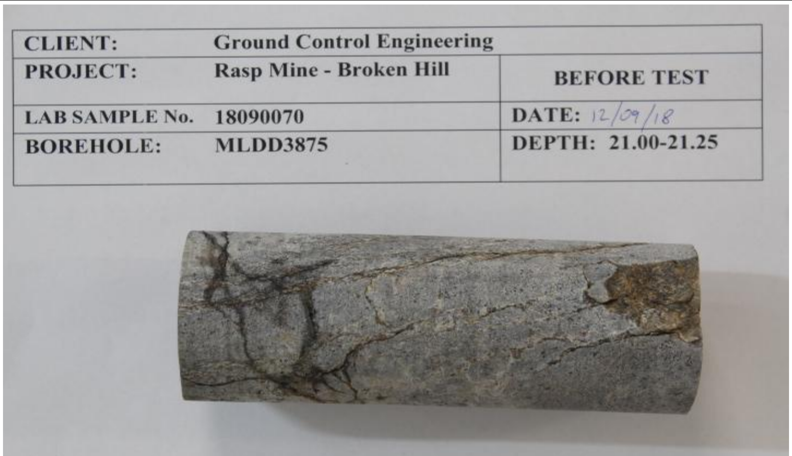
Test Method: AS 4133.4.2.2 & AS 4133.1.1.1

Client	Ground Control Engineering	**Report No.**	18090070-UCS
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date**	12/09/2018
		Report Date	13/09/2018
Project	Rasp Mine - Broken Hill		
Client ID	MLDD3875	**Depth (m)**	21.00-21.25
Description	-		
Sample Type	Single Individual Rock Core Specimen		

TEST DETAILS

Average Sample Diameter (mm)	60.9	Moisture Content (%)	0.2
Sample Height (mm)	164.4	Wet Density (t/m^3)	2.85
Duration of Test (min)	25:05	Dry Density (t/m^3)	2.84
Rate of Displacement (mm/min)	0.10	Bedding (°)	80
Mode of Failure	Shear	Test Apparatus	100 kN Load Cell in Compression Machine
Rupture Angle (°)	80		
UCS (MPa)	**24.3**		

Before and After Photo's



NOTES/REMARKS:
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Test Method: AS 4133.4.2.2 & AS 4133.1.1.1

Client	Ground Control Engineering	**Report No.**	18090071-UCS
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date**	12/09/2018
		Report Date	13/09/2018
Project	Rasp Mine - Broken Hill		
Client ID	MLDD3875	**Depth (m)**	32.80-33.00
Description	-		
Sample Type	Single Individual Rock Core Specimen		

TEST DETAILS

Average Sample Diameter (mm)	61.0	Moisture Content (%)	0.3
Sample Height (mm)	153.8	Wet Density (t/m^3)	2.69
Duration of Test (min)	19:53	Dry Density (t/m^3)	2.68
Rate of Displacement (mm/min)	0.10	Bedding (°)	70
Mode of Failure	Shear	Test Apparatus	Kelba 1000 kN Load Cell
Rupture Angle (°)	70		
UCS (MPa)	**13.4**		

Before and After Photo's

NOTES/REMARKS:
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UNIAXIAL COMPRESSIVE STRENGTH TEST REPORT

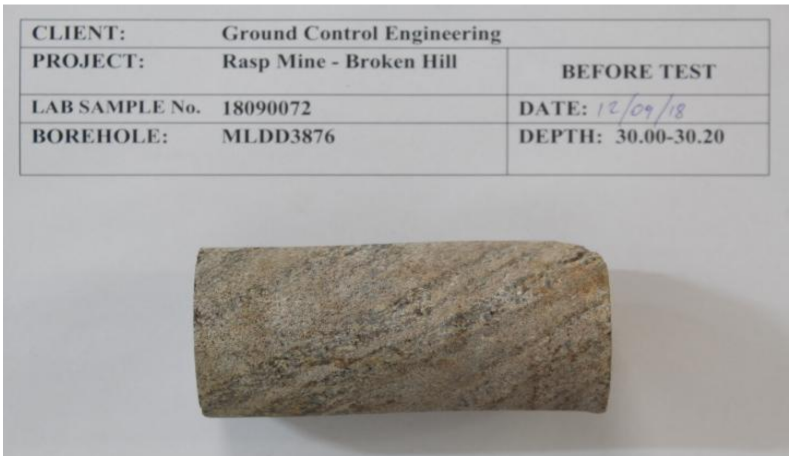
Test Method: AS 4133.4.2.2 & AS 4133.1.1.1

Client	Ground Control Engineering	**Report No.**	18090072-UCS
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date**	12/09/2018
		Report Date	13/09/2018
Project	Rasp Mine - Broken Hill		
Client ID	MLDD3876	**Depth (m)**	30.00-30.20
Description	-		
Sample Type	Single Individual Rock Core Specimen		

TEST DETAILS

Average Sample Diameter (mm)	60.8	Moisture Content (%)	0.3
Sample Height (mm)	131.6	Wet Density (t/m^3)	2.69
Duration of Test (min)	21:21	Dry Density (t/m^3)	2.68
Rate of Displacement (mm/min)	0.10	Bedding (°)	70
Mode of Failure	Shear	Test Apparatus	100 kN Load Cell in Compression Machine
Rupture Angle (°)	70		
	UCS (MPa)	**16.5**	

Before and After Photo's



NOTES/REMARKS:
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* Length to diameter ratio less than 2.5:1

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Ground Control Engineering	**Report No.:**	18090073 - CU
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date:**	28/09/2018
		Report Date:	12/10/2018
Project:	Rasp Mine - Broken Hill		
Client Id.:	MLDD3874	**Depth (m):**	18.70-19.00
Description:			

SAMPLE & TEST DETAILS

Initial Height:	128.5	mm	Initial Moisture Content:	3.1	%	Rate of Strain:	0.007	%/min
Initial Diameter:	60.7	mm	Final Moisture Content:	9.8	%	B Response:	98	%
L/D Ratio:	2.1 : 1		Wet Density:	2.34	t/m^3			
			Dry Density:	2.27	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
120 kPa	624 kPa	504 kPa	504 kPa	591 kPa	1628 kPa	33 kPa	49.774	1595 kPa	1.15 %
243 kPa	747 kPa	504 kPa	504 kPa	606 kPa	2665 kPa	141 kPa	18.917	2525 kPa	1.58 %
494 kPa	1000 kPa	506 kPa	506 kPa	584 kPa	4516 kPa	416 kPa	10.864	4100 kPa	2.21 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**212.1**	**330.7**	**270.9**
Angle of Shear Resistance Φ' (Degrees) :	**54.2**	**47.9**	**49.7**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

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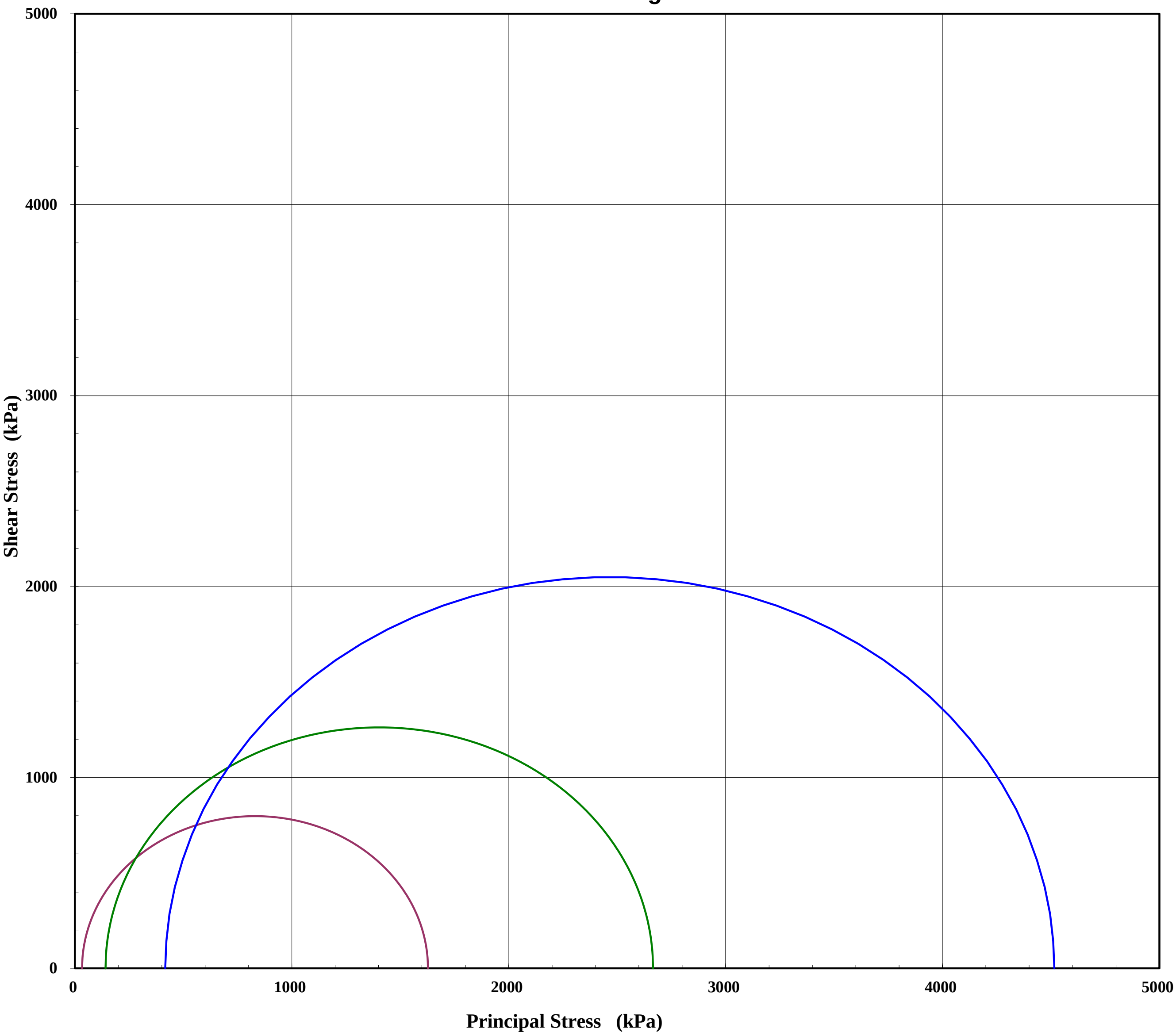
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090073 - CU

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	212.1	330.7	270.9
Angle of Shear Resistance Φ' (Degrees) :	54.2	47.9	49.7
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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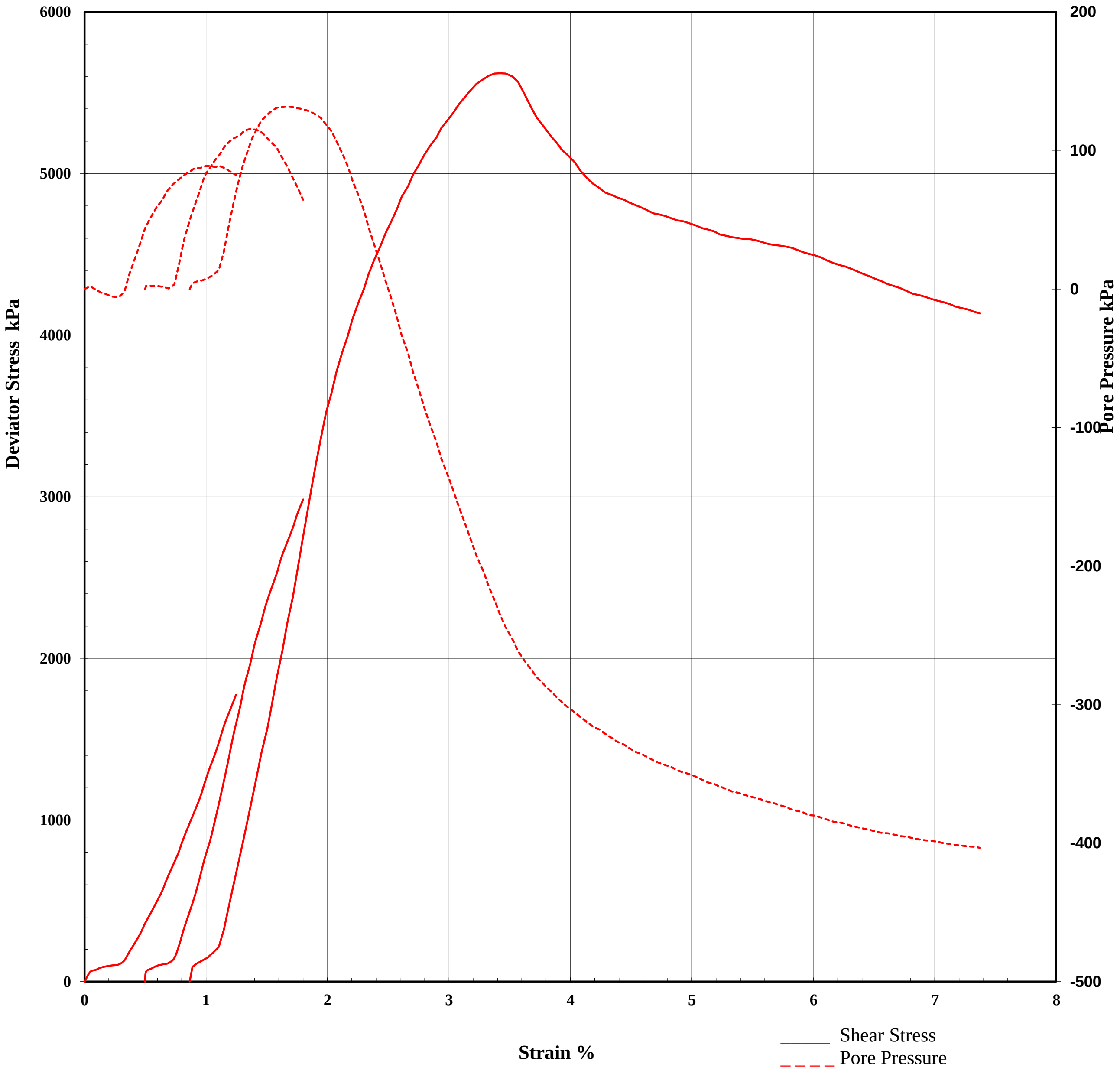
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090073 - CU

Stress/Strain & Pore Pressure/Strain Diagram



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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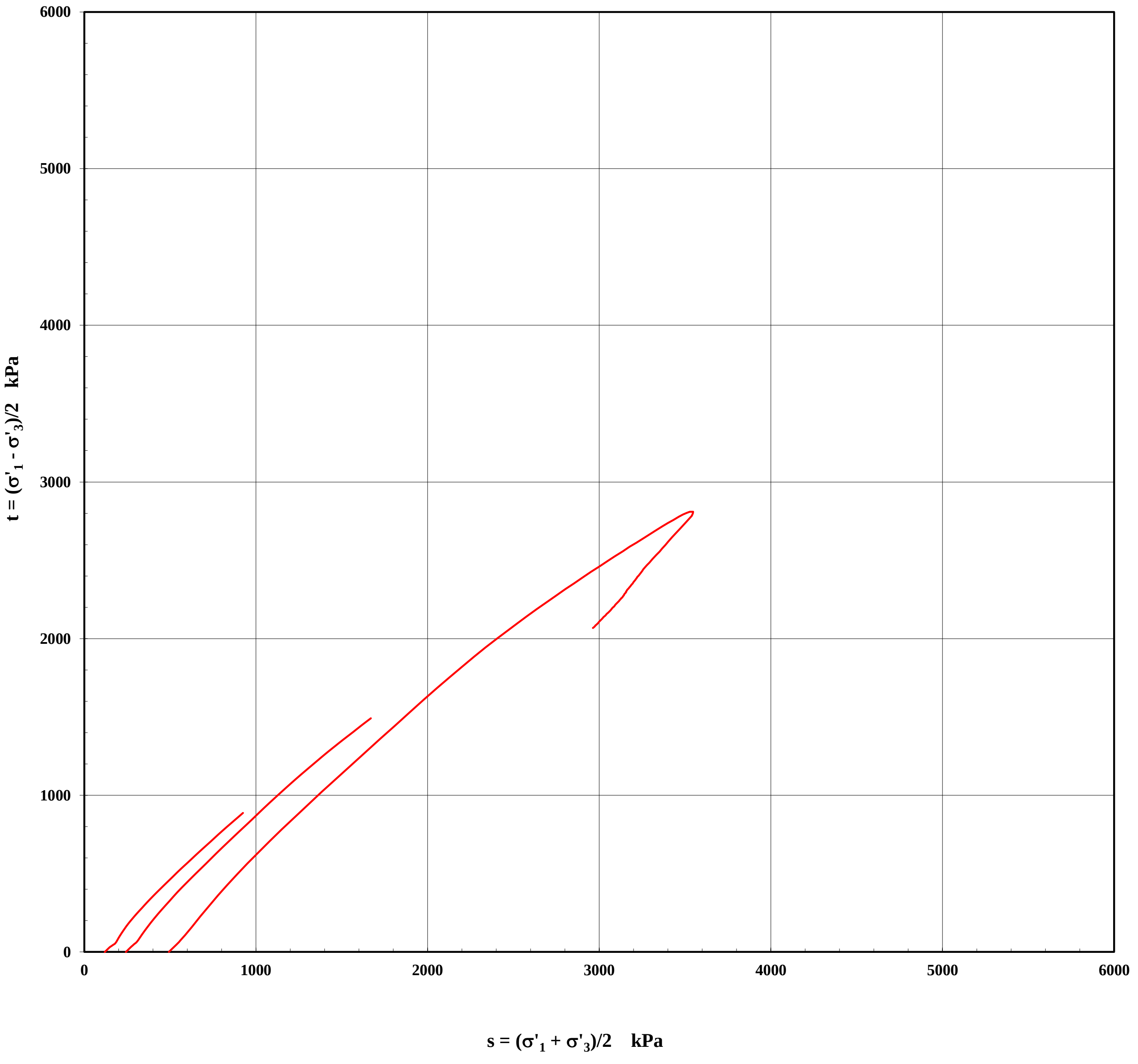
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090073 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

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Note: Graph not to scale

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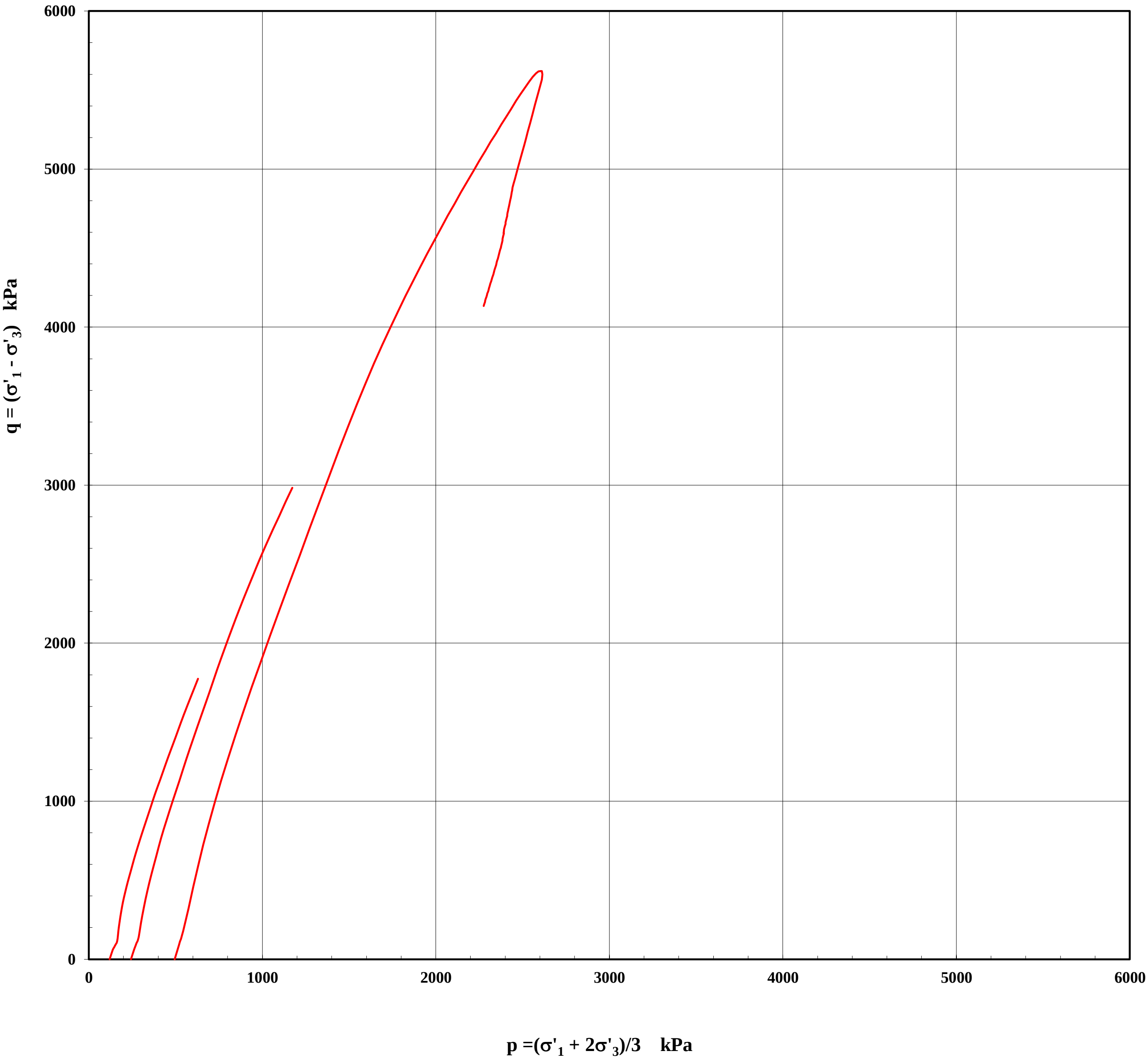
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090073 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

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Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090073 - CU

Remarks: Tested as Received

Sample/s supplied by the client

Note: Photo not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Ground Control Engineering	**Report No.:**	18090074 - CU
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date:**	26/09/2018
		Report Date:	10/10/2018
Project:	Rasp Mine - Broken Hill		
Client Id.:	MLDD3876	**Depth (m):**	31.40-31.60
Description:			

SAMPLE & TEST DETAILS

Initial Height:	125.6	mm	Initial Moisture Content:	1.1	%	Rate of Strain:	0.007	%/min
Initial Diameter:	60.7	mm	Final Moisture Content:	8.3	%	B Response:	99	%
L/D Ratio:	2.1 : 1		Wet Density:	2.23	t/m^3			
			Dry Density:	2.21	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
128 kPa	627 kPa	499 kPa	499 kPa	559 kPa	531 kPa	68 kPa	7.802	463 kPa	0.83 %
253 kPa	751 kPa	498 kPa	498 kPa	574 kPa	968 kPa	177 kPa	5.466	791 kPa	1.58 %
503 kPa	904 kPa	401 kPa	401 kPa	488 kPa	1688 kPa	416 kPa	4.054	1272 kPa	2.38 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**64.6**	**125.4**	**93.4**
Angle of Shear Resistance Φ' (Degrees) :	**36.9**	**30.1**	**32.2**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

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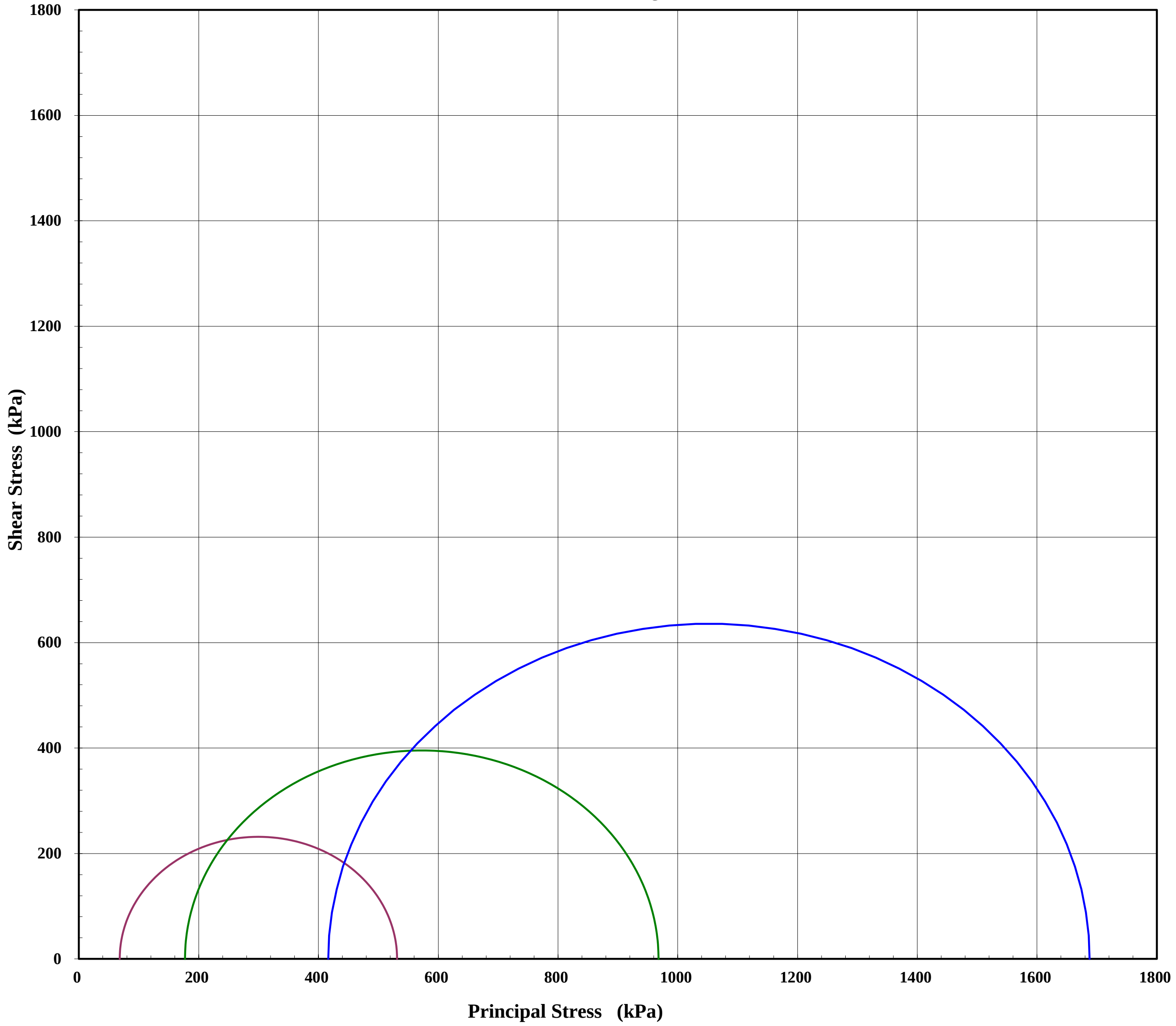
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering

Report No.: 18090074 - CU

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	64.6	125.4	93.4
Angle of Shear Resistance Φ' (Degrees) :	36.9	30.1	32.2
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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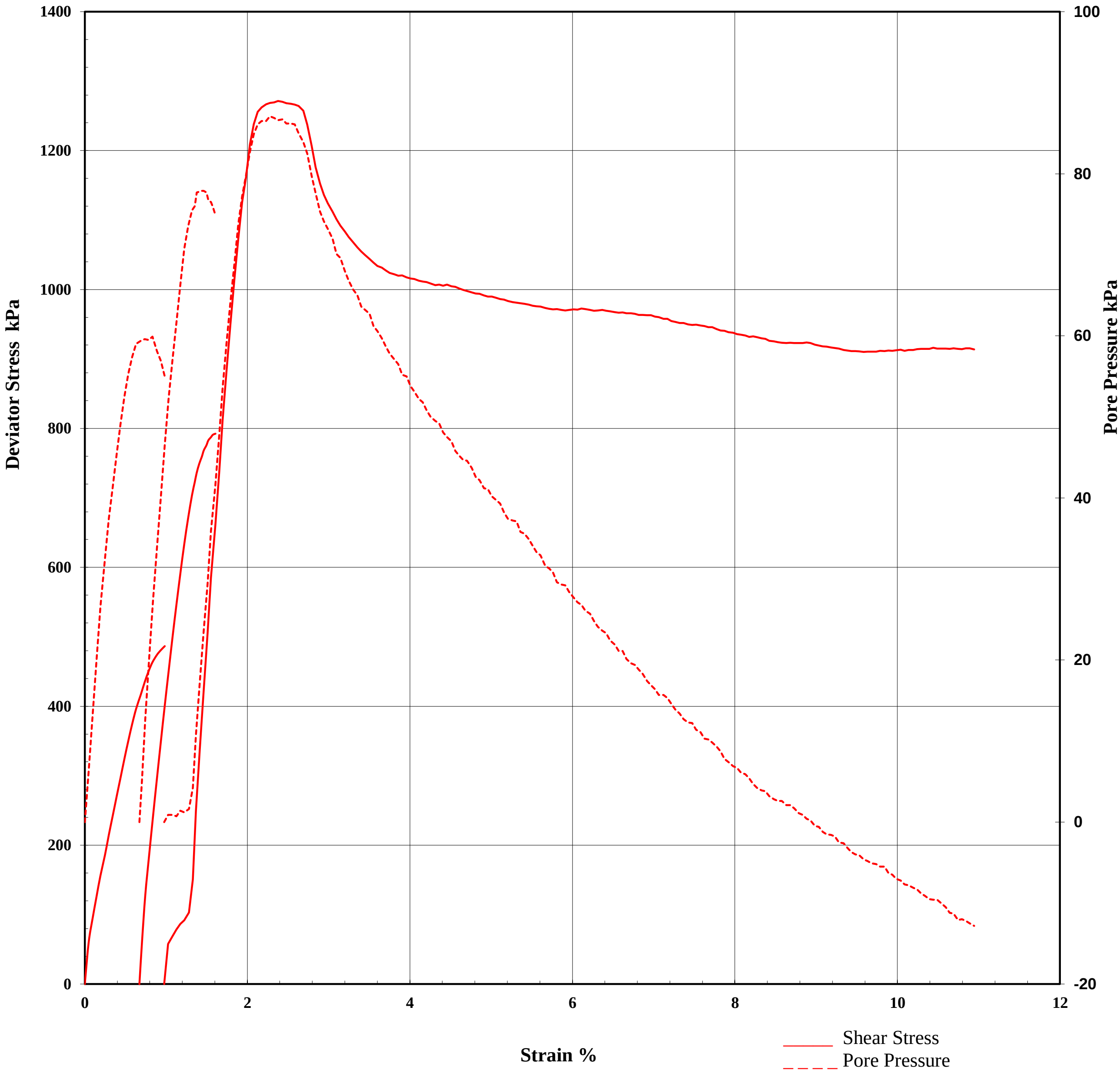
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090074 - CU

Stress/Strain & Pore Pressure/Strain Diagram



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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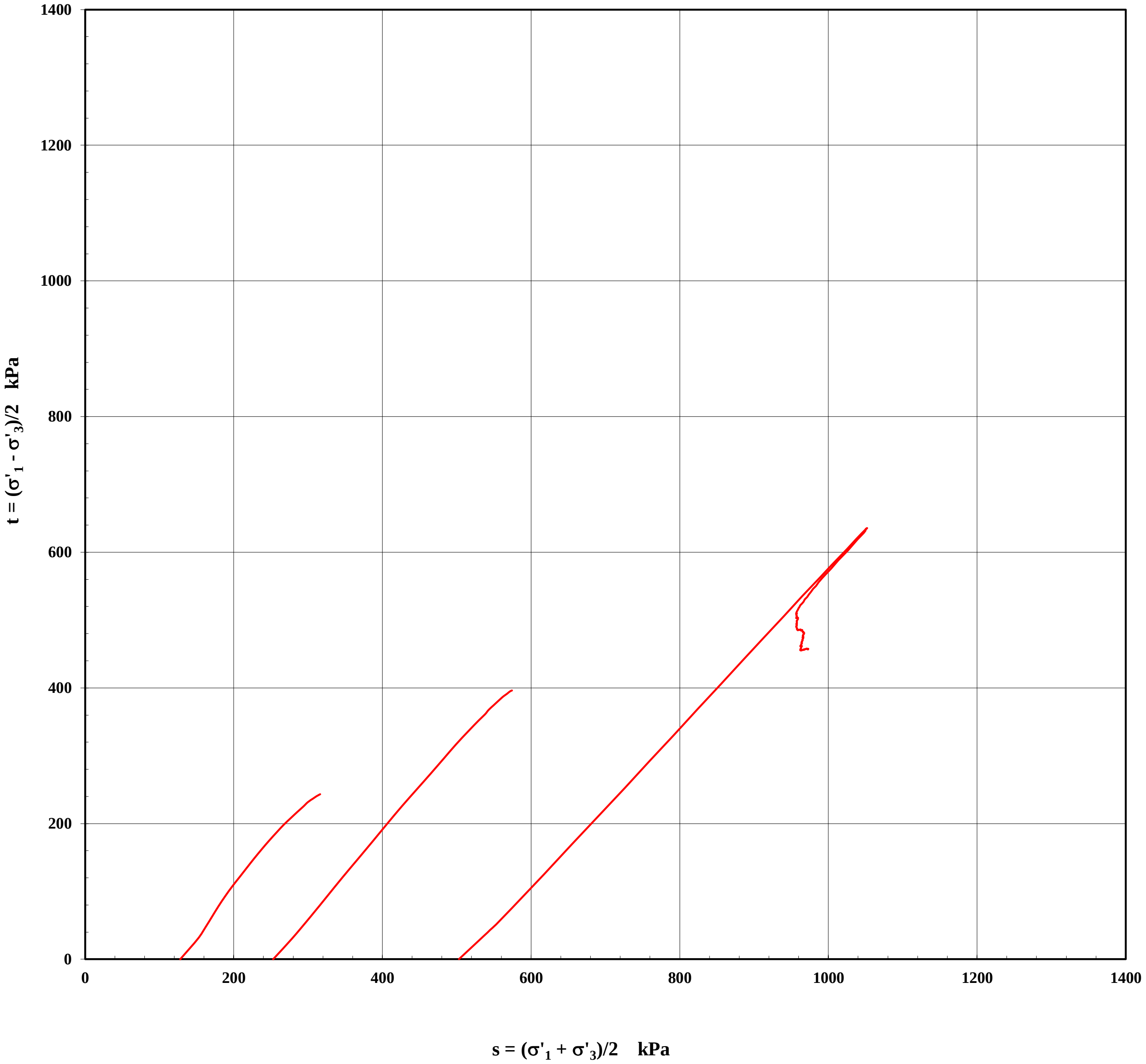
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090074 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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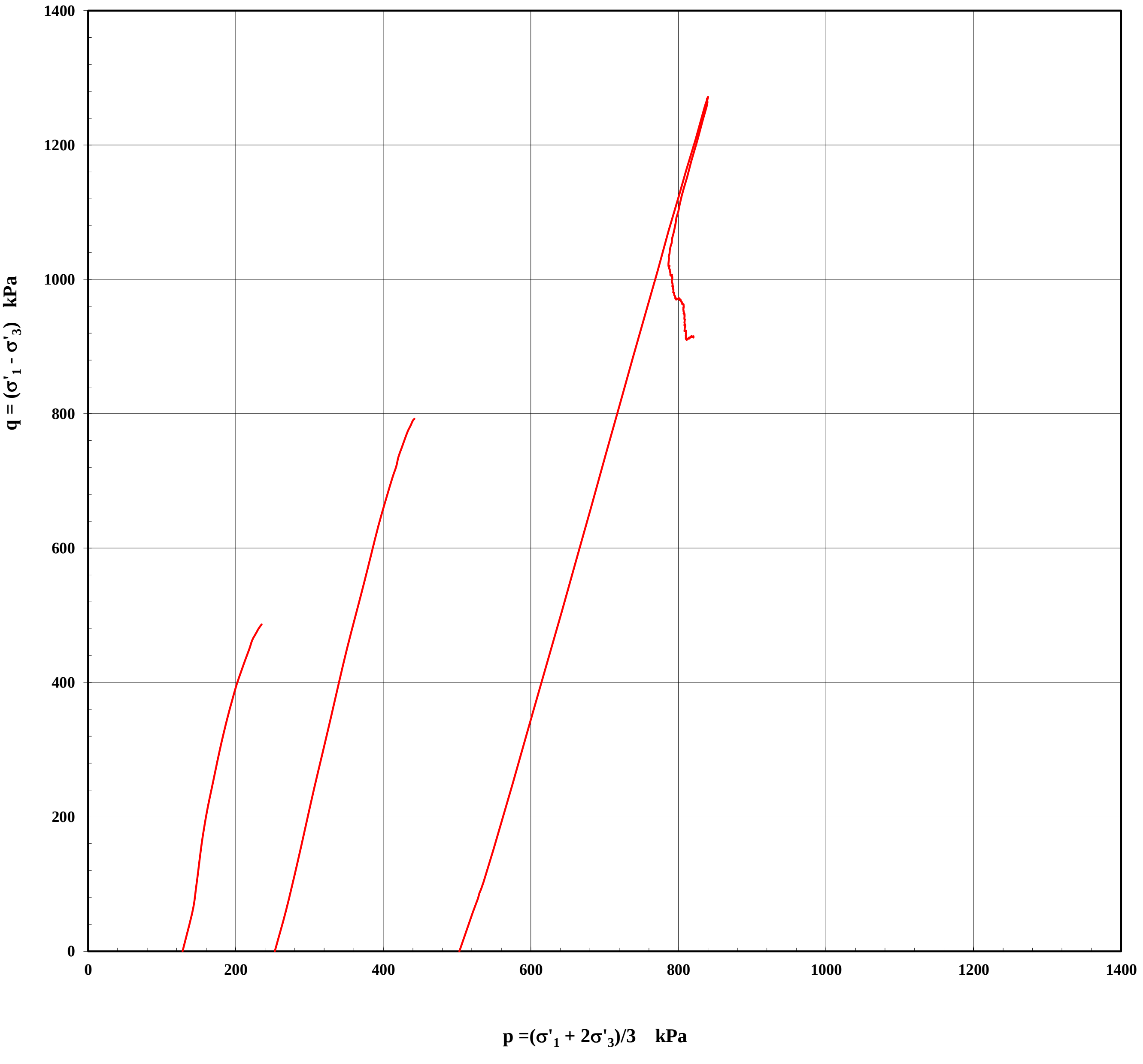
WA 6107
Ph: +61 8 9258 8323

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090074 - CU

Cambridge Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

REP03001

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

T. Lockhart

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Ground Control Engineering	**Report No.:**	18090075 - CU
		Workorder No.	0004803
Address	16 Farmer Street, Edmonton QLD 4869	**Test Date:**	25/09/2018
		Report Date:	12/10/2018
Project:	Rasp Mine - Broken Hill		
Client Id.:	MLDD3877	**Depth (m):**	48.60-48.80
Description:			

SAMPLE & TEST DETAILS

Initial Height:	126.0	mm	Initial Moisture Content:	3.1	%	Rate of Strain:	0.007	%/min
Initial Diameter:	61.3	mm	Final Moisture Content:	6.6	%	B Response:	99	%
L/D Ratio:	2.1 : 1		Wet Density:	2.47	t/m^3			
			Dry Density:	2.40	t/m^3			

Sample Type: Single Individual Undisturbed Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
127 kPa	624 kPa	497 kPa	497 kPa	517 kPa	2084 kPa	107 kPa	19.480	1977 kPa	1.14 %
252 kPa	750 kPa	498 kPa	498 kPa	466 kPa	4044 kPa	284 kPa	14.240	3760 kPa	1.61 %
505 kPa	1001 kPa	496 kPa	496 kPa	471 kPa	5490 kPa	530 kPa	10.358	4960 kPa	1.86 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**135.2**	**489.9**	**240.1**
Angle of Shear Resistance Φ' (Degrees) :	**56.5**	**45.2**	**51.4**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

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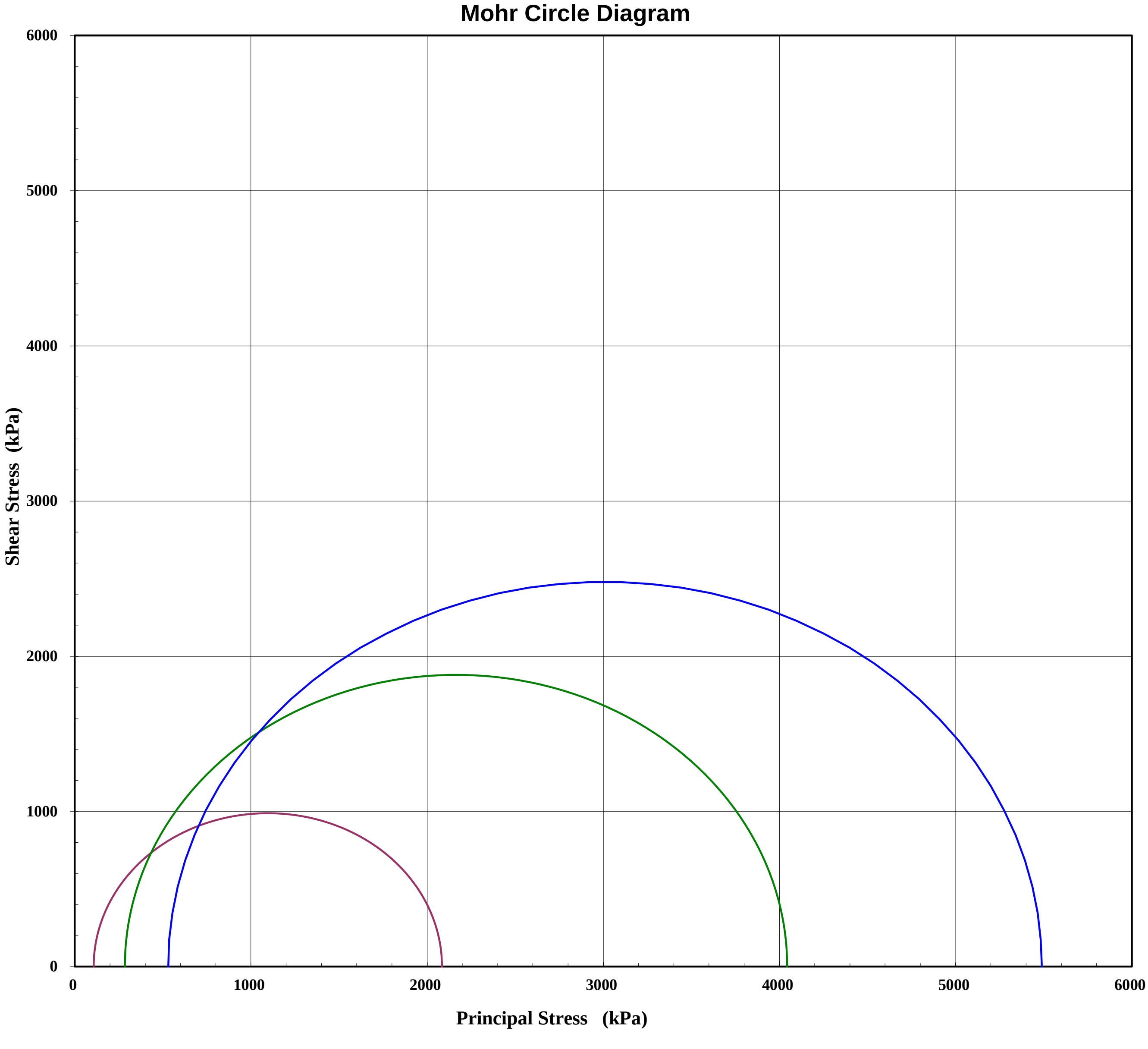
Test Method: AS1289.6.4.2

Client:	Ground Control Engineering	**Report No.:**	18090075 - CU



Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**135.2**	**489.9**	**240.1**
Angle of Shear Resistance Φ' (Degrees) :	**56.5**	**45.2**	**51.4**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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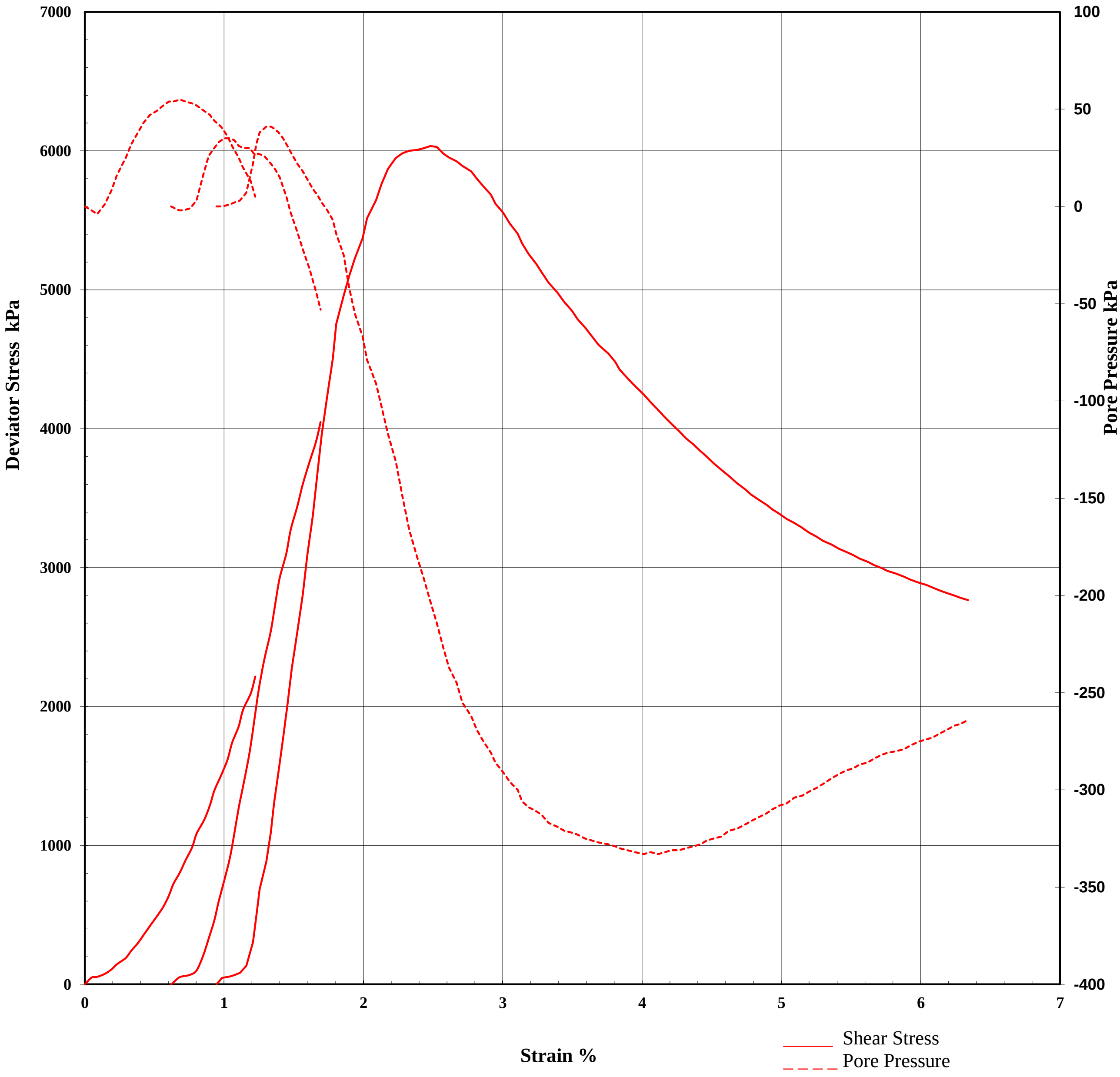
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090075 - CU

Stress/Strain & Pore Pressure/Strain Diagram



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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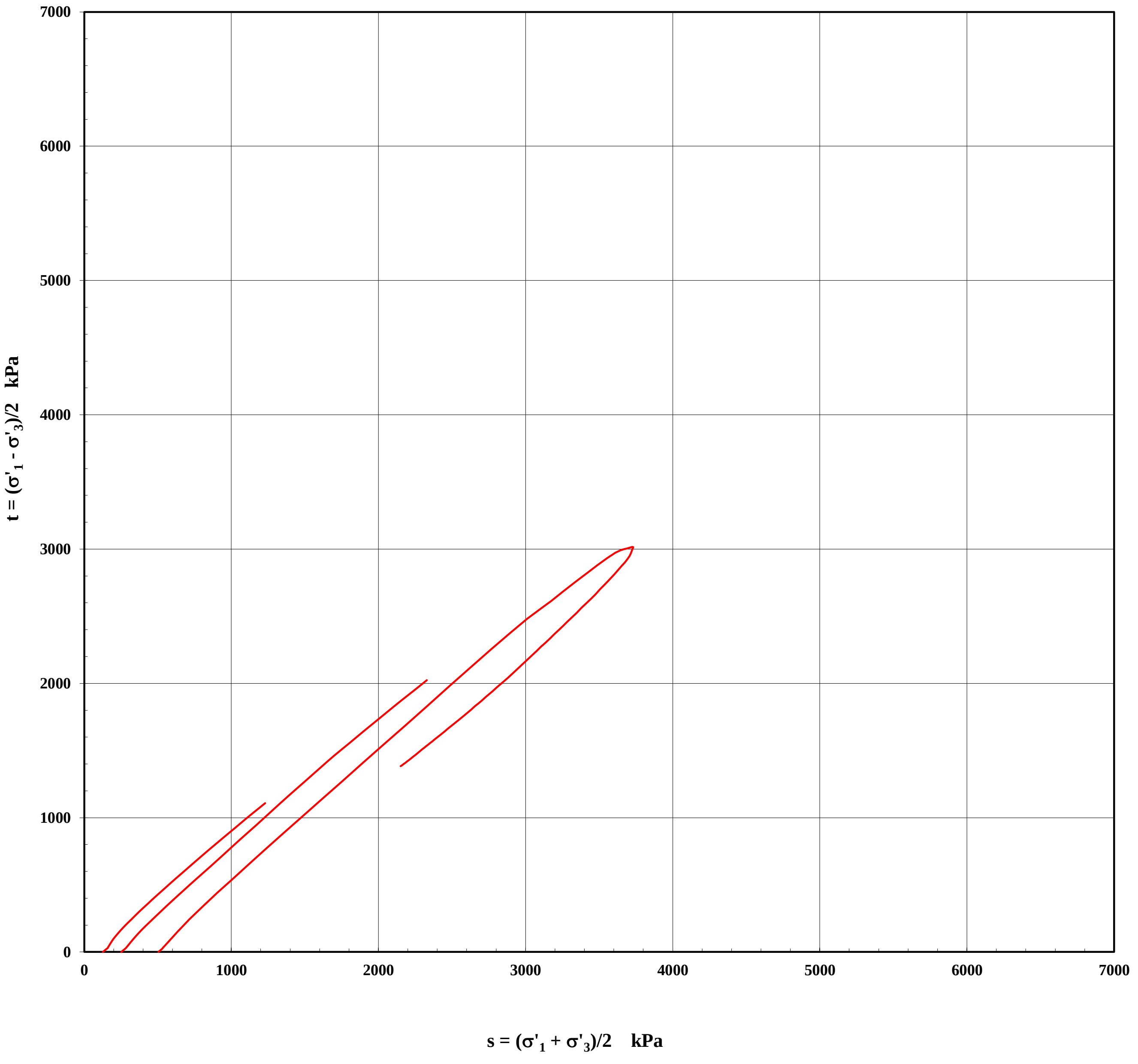
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering

Report No.: 18090075 - CU

MIT Method - Effective Stress Path



Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

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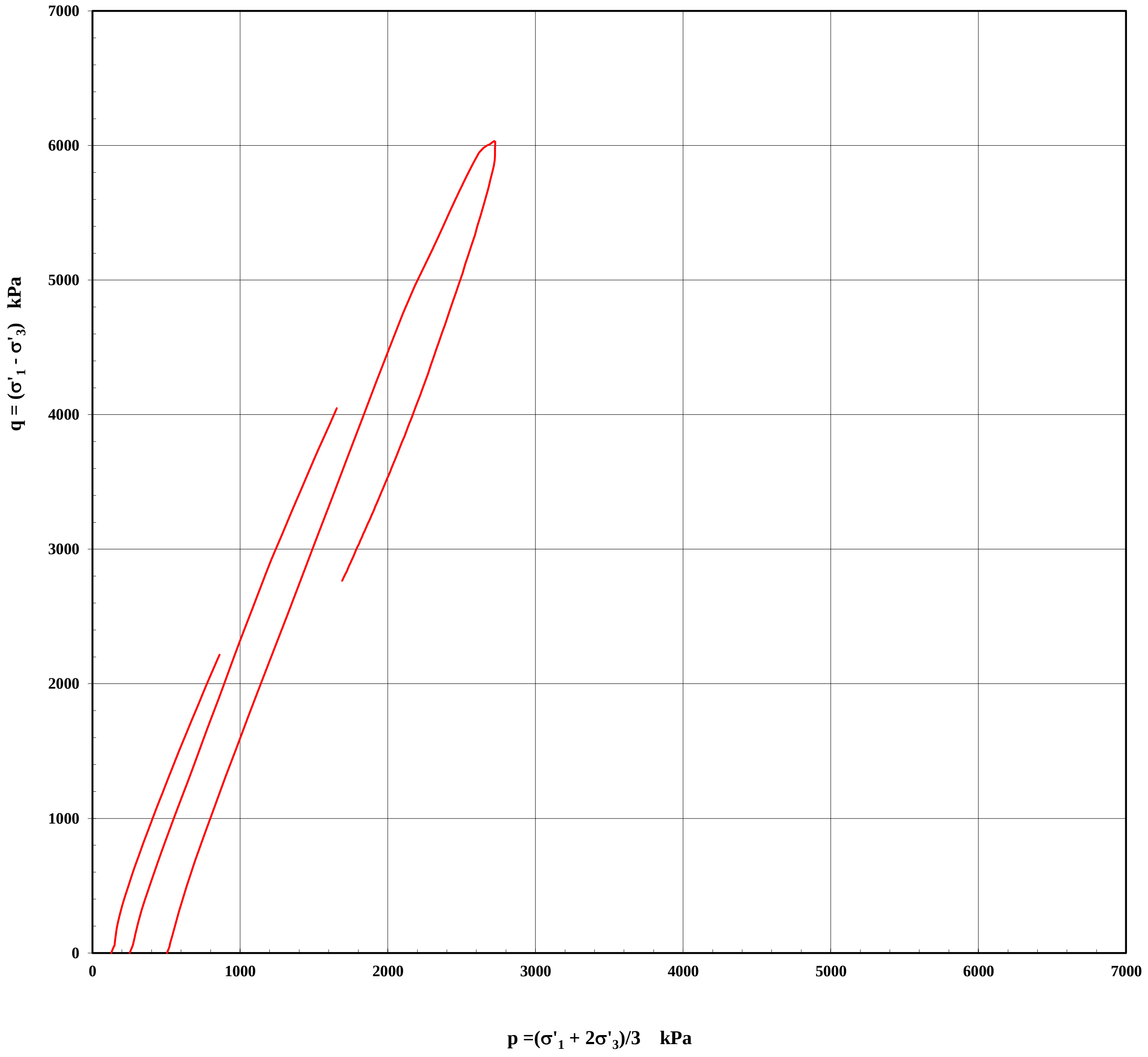
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Ground Control Engineering	**Report No.:** 18090075 - CU

Cambridge Method - Effective Stress Path



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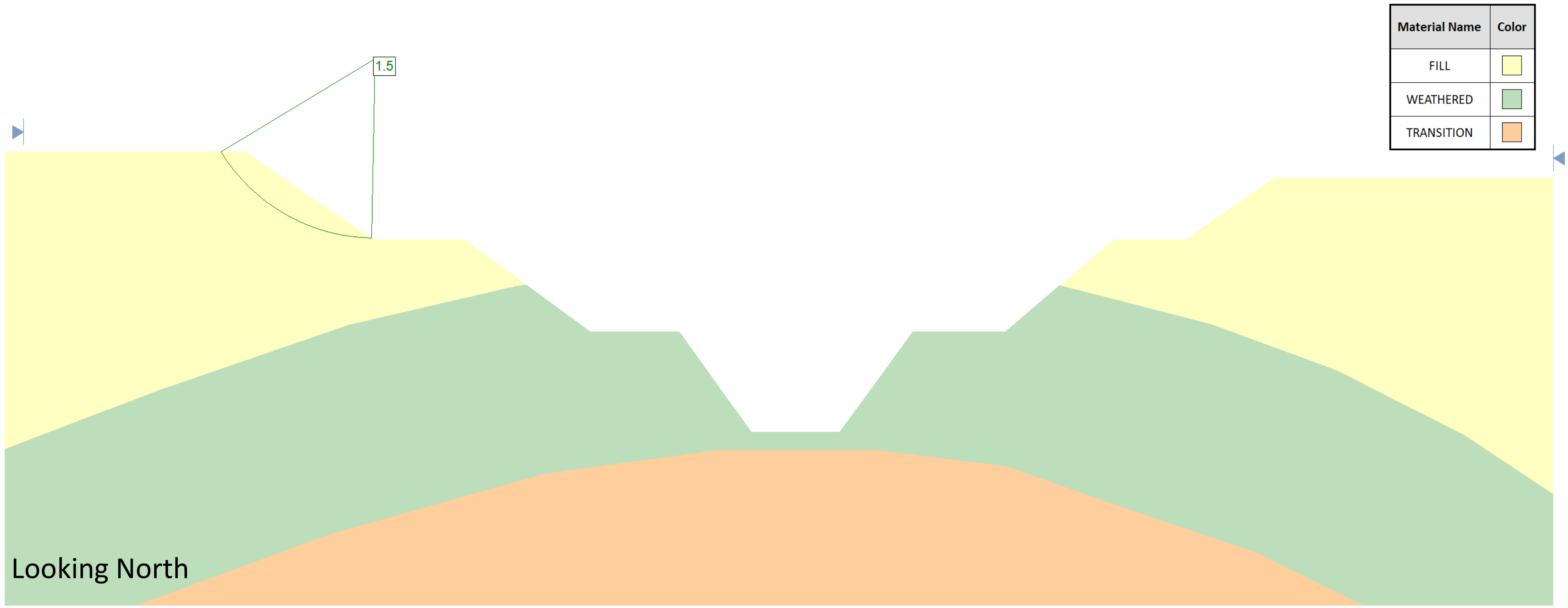
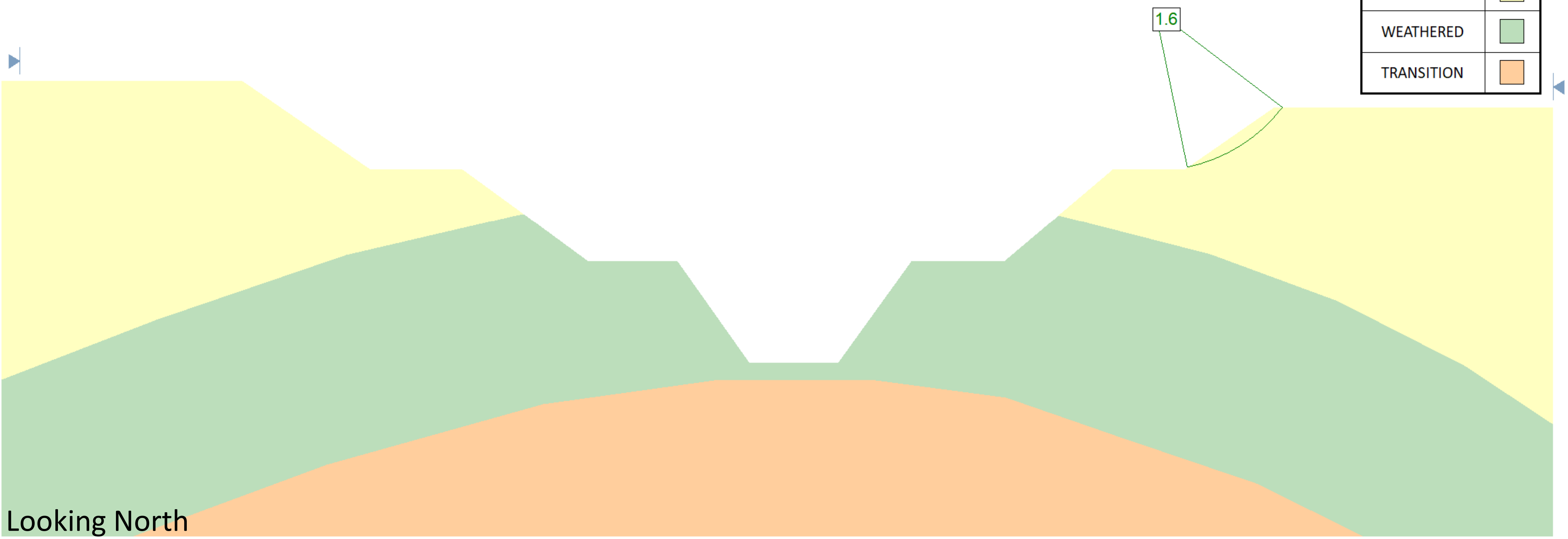
Appendix B Slide Model Results

West Wall
Model Results - Factor of Safety

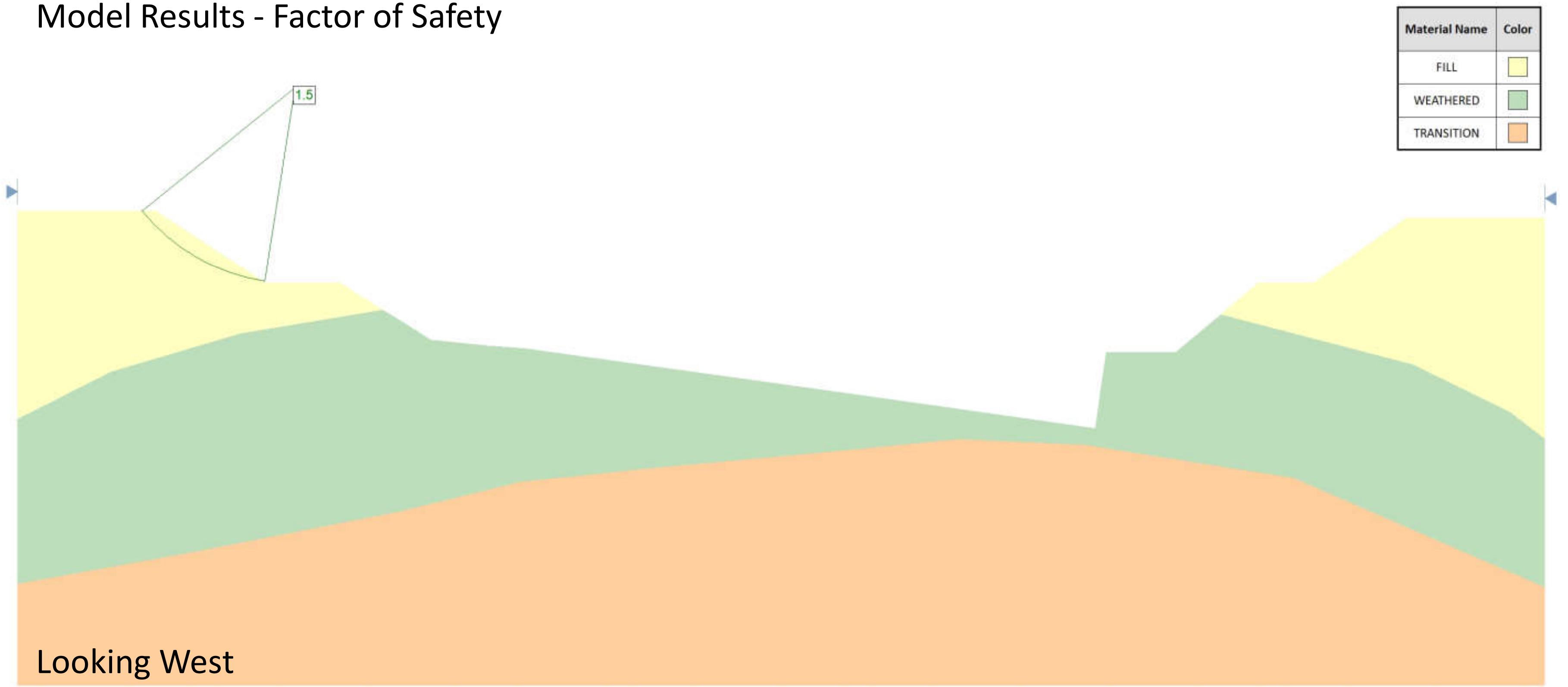


East Wall
Model Results - Factor of Safety



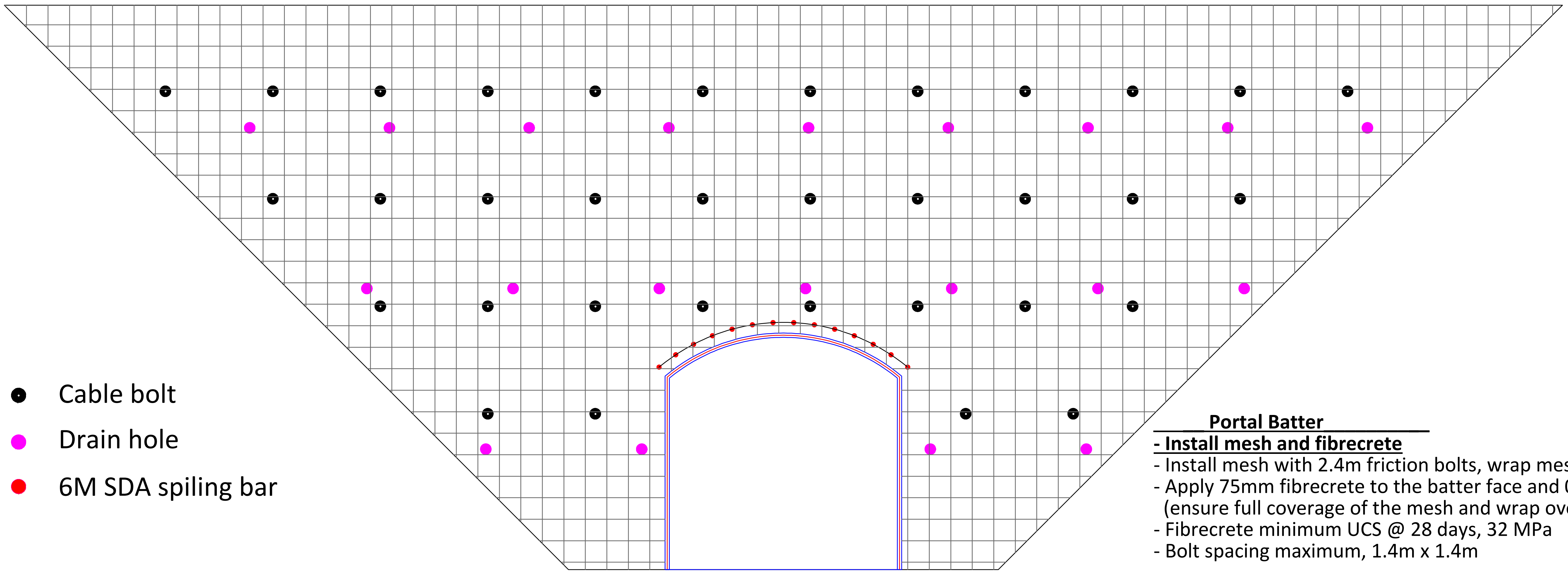
End Wall

Model Results - Factor of Safety

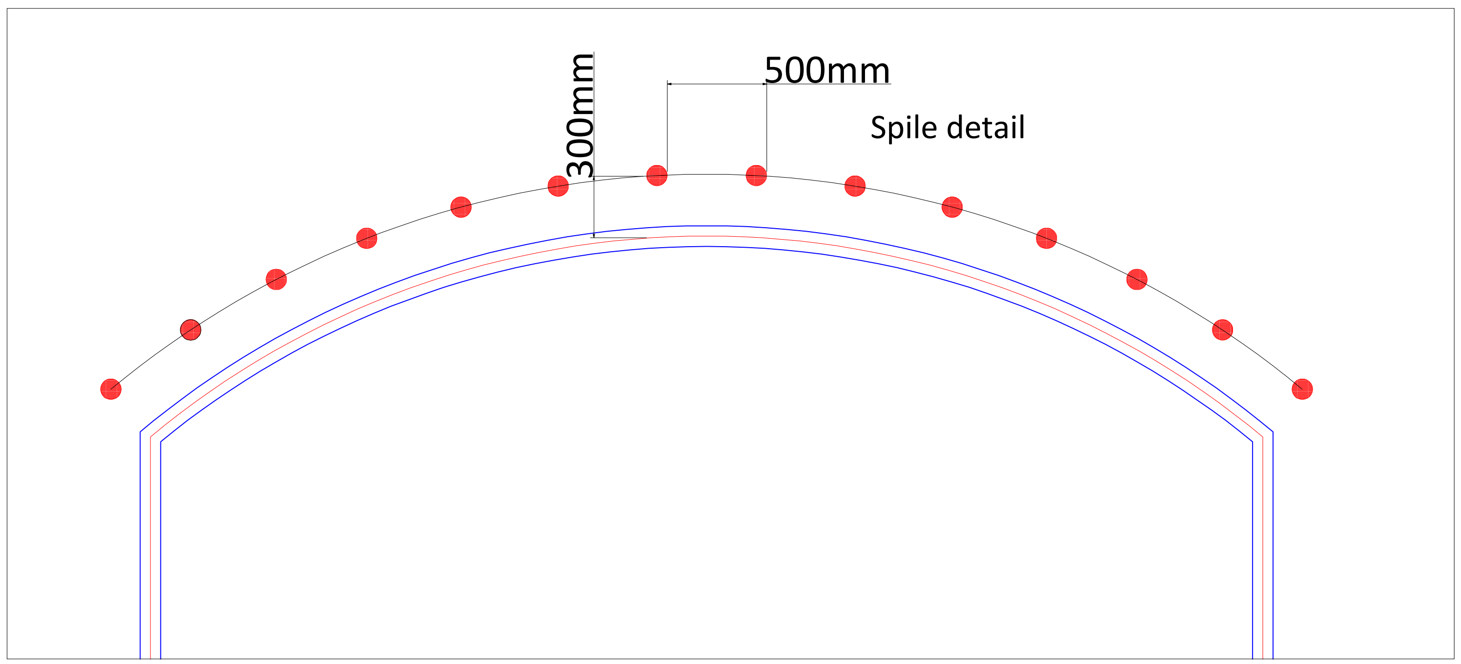


Appendix C Portal Batter Ground Support Design

PORTAL FACE GROUND SUPPORT REQUIREMENTS



- Cable bolt
- Drain hole
- 6M SDA spiling bar



Portal Batter

- Install mesh and fibrecrete
- Install mesh with 2.4m friction bolts, wrap mesh 0.5m over crest
- Apply 75mm fibrecrete to the batter face and 0.5m over crest (ensure full coverage of the mesh and wrap over crest)
- Fibrecrete minimum UCS @ 28 days, 32 MPa
- Bolt spacing maximum, 1.4m x 1.4m

- Install cable bolts
- Twin strand, 25T per strand, w:c ratio 0.35 to 0.4 (full column)
- Plate and jack 1 cable to 4T
- Length, 10m
- Spacing maximum, 2.5m x 2.5m
- Crest to top row of cable bolts, 2.0m

- Install spiling bars
- Install prior to firing decline face
- 9m long, (2 x 3m coupled R32N bars)
- Overlap between spiles - 2.0m
- Drill holes 5 degrees up.
- Grout spiles with OPC with w:c ratio 0.35 to 0.4 (full column)

- Drain holes
- Drill drain holes to 6.0m depth, drain hole diameter 45mm
- Drill drain holes 5 degrees up
- Spacing - 3.5m x 3.5m
- Top row to crest - 2.8m

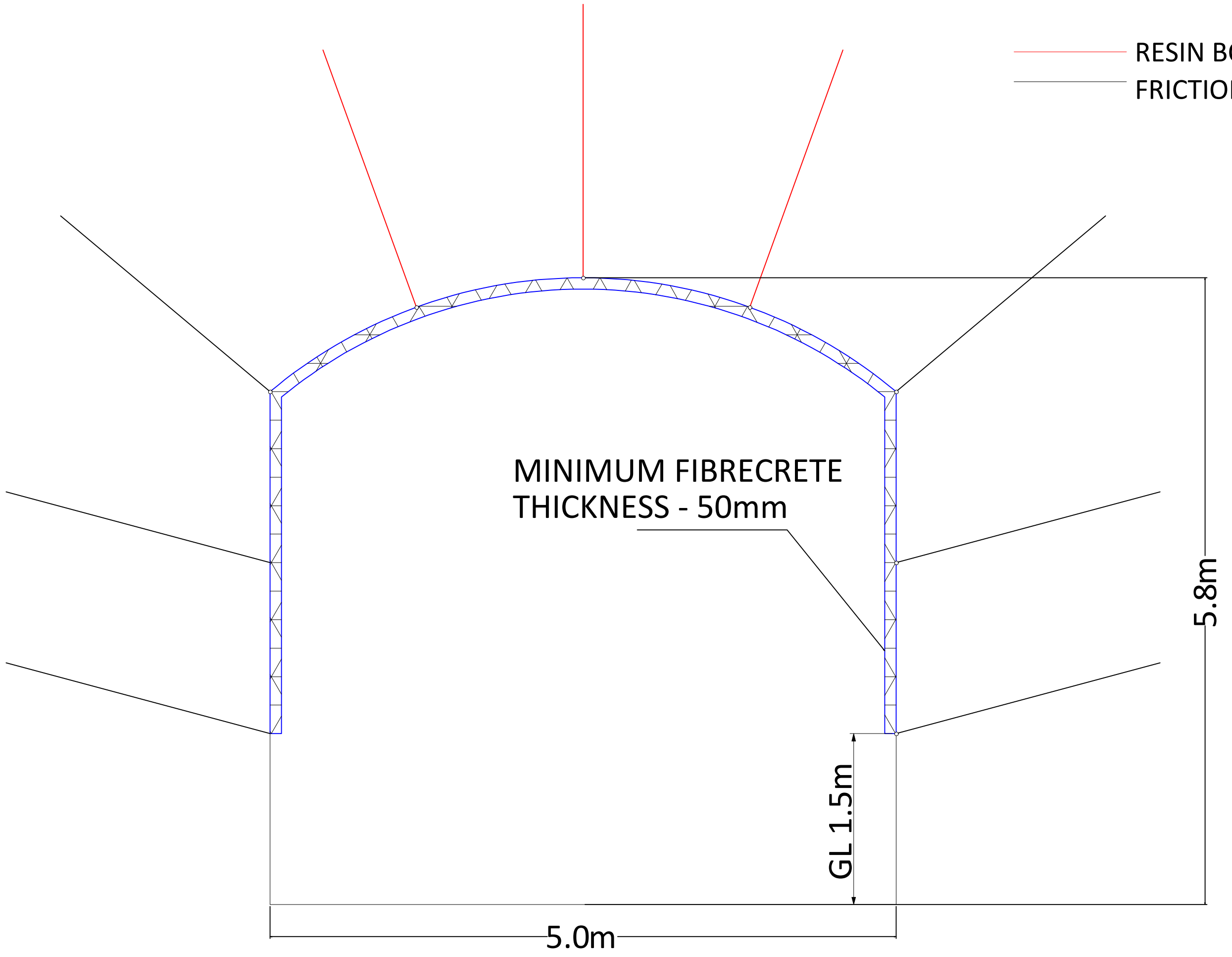
Side walls
- Mesh sidewalls with 2.4m friction bolts,wrap mesh 0.5m over crest.
- Spacing maximum, 1.4m x 1.4m
- Apply minimum 75mm fibrecrete to mesh (ensure full coverage of the mesh and wrap over crest)
- Minimum extent of sidewall coverage - 6.0m back from portal entrance.

Appendix D Decline Ground Support Designs

CBH Resources Limited

RASP MINE

PROFILE A
GROUND SUPPORT STANDARD F1



PROFILE: 5.8mH x 5.0mW ARCH
MINIMUM GROUND SUPPORT REQUIREMENTS
FOR GOOD GROUND CONDITIONS

REFER TO TARP FOR POOR GROUND CONDITIONS
IF GROUND CONDITIONS ARE POOR (PTO)

SPECIFICATIONS		
DRILLING DETAILS	HOLE DIAMETER FRICTION BOLT RESIN BOLT HOLE DEPTH COLLAR TOLERANCE ROW & RING SPACING	 45mm 32mm 2.4m 100mm 1.5m
RESIN BOLT	BOLT LENGTH NOMINAL DIAMETER MINIMUM YIELD STRENGTH	2.4m 20mm 195 KN
FRICTION BOLT	BOLT LENGTH NOMINAL DIAMETER YIELD CAPACITY - MINIMUM	2.4m 46mm 130 KN
FIXTURES	DOMED PLATES STUBBY BOLTS	150mm X 150mm X 5mm 39mm x 0.9m
FIBRECRETE	UCS (28 DAY) MINIMUM TOUGHNESS FIBRE TYPE FIBRE DOSAGE MINIMUM THICKNESS	40 MPa 400 J STEEL 40 KG/M3 50 MM

GEOTECHNICAL ENGINEER	UNDERGROUND SUPERINTENDENT	MANAGER MINING	DATE

NOT TO SCALE