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SUBSIDENCE REPORT FOR THE MAVIS DOWNS SOUTH BORD AND PILLAR PROJECT

Prepared for MetRes Pty Ltd

REPORT NO: Millennium23-R3

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List of Abbreviations

AHD	- Australian Height Datum
D	- Disturbance Factor
E_i	- Laboratory Modulus
E_{rm}	- Rock Mass Modulus
FoS	- Factor of Safety
GGPL	- Gordon Geotechniques Pty Ltd
GSI	- Geological Strength Index
UCS	- Uniaxial Compressive Strength

Glossary

Bell out	An area of coal extraction, where ground support is not installed.
Bord	A roadway developed in an underground mine.
Empirical	Based or acting on observation and experiment, not on theory.
Floor	Strata immediately below the extracted seam.
Inbye	Direction towards the coal face.
Modulus	The ratio between applied stress and resultant strain.
Outbye	Direction away from the coal face.
Overburden	Sequence of strata above the extracted seam.
Pillar	Coal that is not extracted within the underground workings.
Roof	Strata immediately above the extracted seam.
Secondary Coal Recovery	Mining of floor coal and bell outs.
Stratigraphy	A branch of geology that studies rock layers and layering. It is primarily used in the study of sedimentary and layered volcanic rocks.
Subsidence	Sinking or settlement of the land surface, due to any of several processes. As commonly used, the term relates to the vertical downward movement of natural surfaces although small-scale horizontal components may be

	present. The term does not include landslides, which have large-scale horizontal displacements, or settlements of artificial fills.
Strain	Relative change in the volume, area or length of a body as a result of stress. The change is expressed in terms of the amount of displacement measured in the body divided by its original volume, area, or length, and referred to as either a volume strain, areal strain, or one dimensional strain, respectively. The unit measure of strain is dimensionless, as its value represents the fractional change from the former size.
Tilt	The rate of change in vertical subsidence between two points divided by the horizontal distance between those two points.

1 INTRODUCTION

Gordon Geotechniques Pty Ltd (GGPL) was commissioned by MetRes Pty Ltd to complete a subsidence assessment, as part of the environmental approvals process to facilitate bord and pillar mining in the Mavis Downs South underground mining area (**Figure 1**).

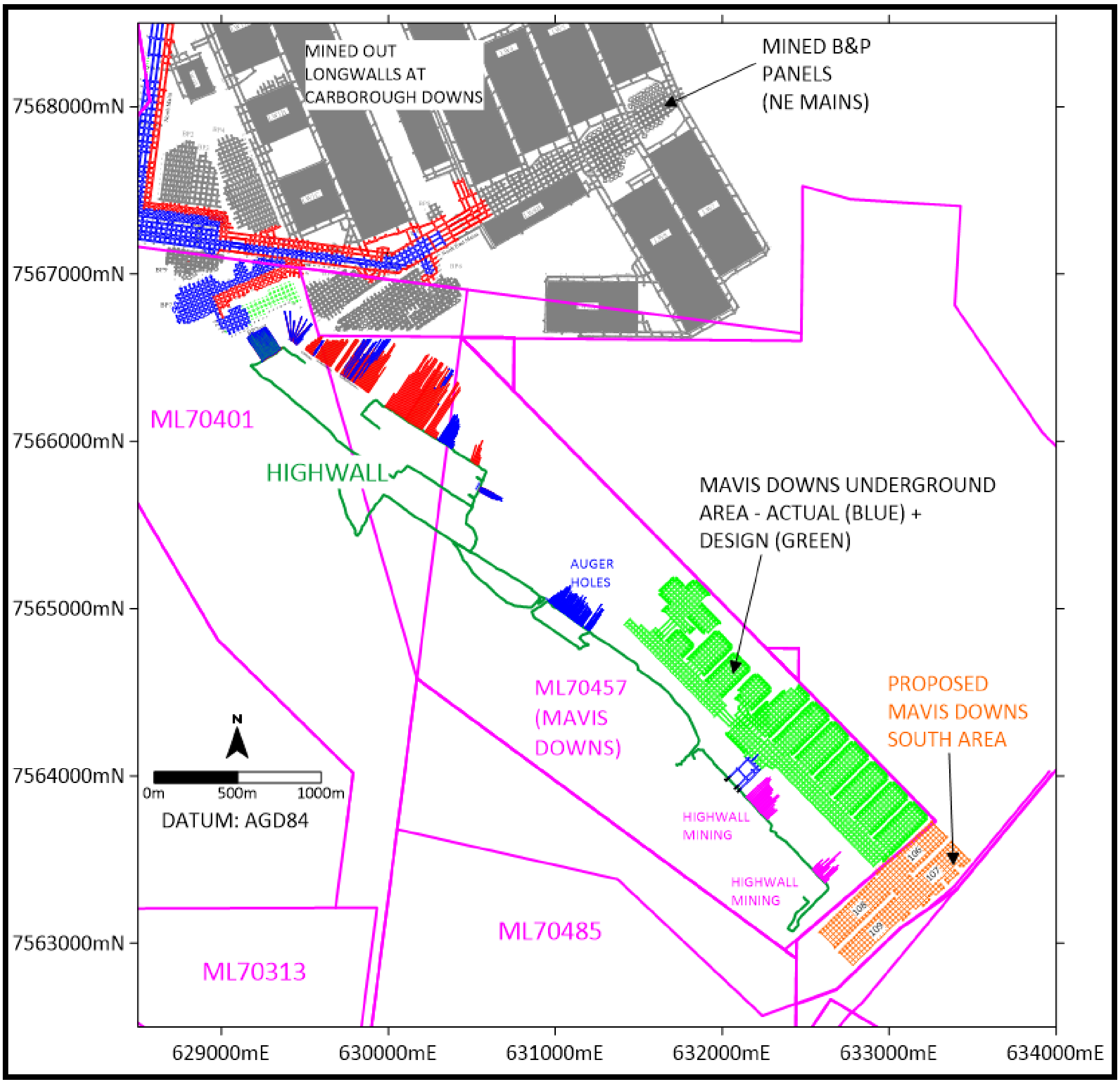

Figure 1. Location Plan – Proposed Mavis Downs South Underground Area.

The Mavis Downs South area is an extension to the current Mavis Downs underground area and would use the existing infrastructure to mine the Leichhardt Seam (**Figure 1**). GGPL previously completed a subsidence assessment for the Mavis Downs underground in 2021[1] and this assessment was also peer reviewed by

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[1] GGPL (2021). Subsidence Report for the Mavis Downs Bord and Pillar Project. Report No. Millennium21-R2.

Byrnes Geotechnical (2021[2]). The same assessment methodology has therefore been applied to the Mavis Downs South underground area.

1.1 Location

The topography above the Mavis Downs South underground area is relatively flat with a gentle fall to the southeast at a gradient of approximately 2% (**Figure 2 and Figure 3**). Ground surface elevations range from 240-245 m ASL over the Mavis Downs South underground area (**Figure 3**).

As shown on **Figure 2**, the surface above both the Mavis Downs and Mavis Downs South underground areas does not contain any significant drainage lines or any remnant or high value regrowth vegetation and there is also no significant surface infrastructure. Small, ephemeral lakes termed gilgai's formed from a depression in the soil surface may also occur in this area.

Figure 2. Mavis Downs Open Cut and Underground Areas (NW to SE).

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[2] Byrnes Geotechnical Pty Ltd (2021). Review of Subsidence Assessment Report by Gordon Geotechniques Pty Ltd. Report No. BGMD-02.

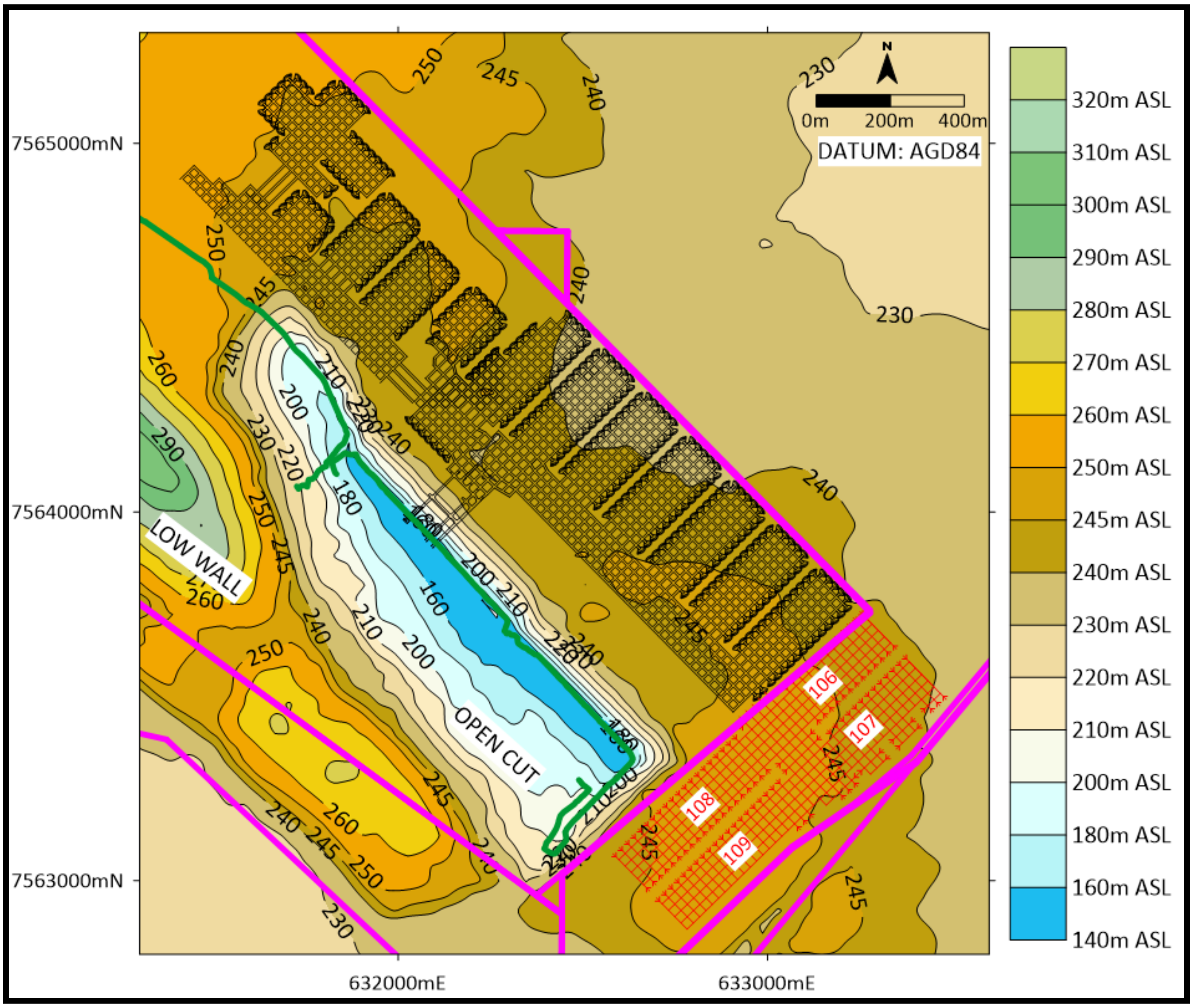

Figure 3. Surface Topography (m ASL).

1.2 Scope of Work

This report includes the prediction of the subsidence and an assessment of the subsidence effects for the proposed Mavis Downs South bord and pillar area (**Figure 1**). This includes:

- A subsidence assessment using a compression analysis of the roof, floor and coal for the proposed bord and pillar mine layout (106-109 Panels and 100 Mains) and mining method (**Figure 1**).
- Comparison of the mining methodology and geology in the Mavis Downs South area to other bord and pillar mines.
- Review of the geological model to identify any very weak units in the floor that may lead to bearing capacity failure below the coal pillars.
- Detailed description of the subsidence prediction methodology and any associated limitations and limits of accuracy.

- Discussion on the surface and subsurface subsidence effects based on the assumption that there will be no significant surface subsidence and no surface/subsurface cracking.
- Review of the potential for the formation of sinkholes.

Nick Gordon of GGPL has inspected the bord and pillar underground workings at neighbouring Carborough Downs on two occasions, as well as the initial Mavis Downs underground roadways developed from the E Pit highwall (**Figure 1**). Subsidence assessment reports have also been completed for the bord and pillar operations at Carborough Downs, Mavis Downs and Ensham.

In addition, Nick has extensive experience at a large number of partial and total extraction bord and pillar mines in QLD and NSW, having worked for the Mining Division of the Australian Coal Industry Research Laboratories (ACIRL) in the late 1980s and early 1990s.

GGPL has also provided underground geotechnical support to the Ensham bord and pillar mine in Central Queensland since pre-feasibility studies were carried out in 2005. At Ensham, the mining methodology is the same as proposed in the Mavis Downs South area, with panels developed on the advance and then floor coal and bell outs extracted on retreat (Gordon, 2016)[3].

1.3 Mining Methodology

The fundamental concept of the place change bord and pillar method proposed in the Mavis Downs South underground area is that the coal seam is divided into a regular block like array, by mining the coal to form bords or roadways (**Figure 4**). The headings are intersected at regular intervals by connecting cut-throughs (**Figure 4**).

The ***bords*** are the headings and the cut-throughs (CTs), and the ***pillars*** are the blocks of coal bounded by the bords (**Figure 4 and Figure 5**). The pillars of coal support the overlying strata as the bords are driven. Each regular array of bords is called a ***panel*** e.g. 106 Panel (**Figure 4**).

In the place change method, the bords (roadways) are excavated, where ground conditions allow, to a maximum horizontal distance of 14 m, without the installation of roof and rib support (**Figure 5**). The maximum cut out distance is determined by the distance from the second last roof bolt support to the operator of the shuttle car.

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[3] Gordon, N. (2016). Geotechnical Aspects of Place Change Mining at Ensham. COAL2016.

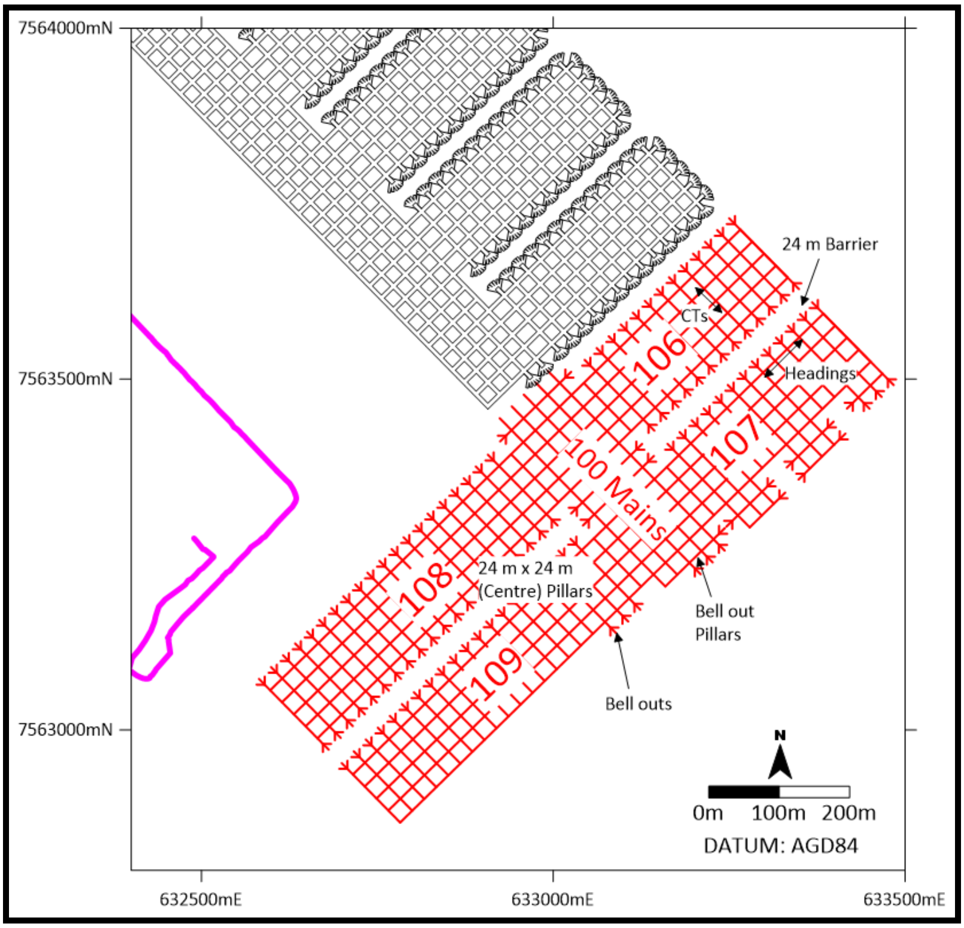

Figure 4. Bord and Pillar Layout and Terminology.

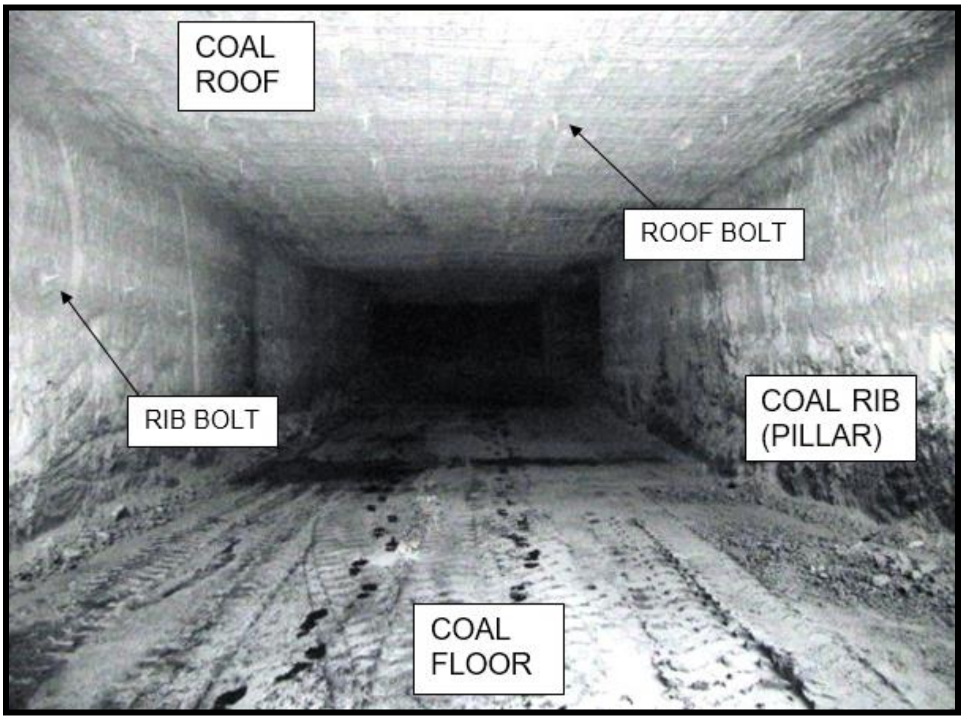

Figure 5. Supported Roadway, 6.5 m Wide and 3.5 m High (Gordon, 2016).

Excavation of the roadways is carried out using the continuous miner cutting machine, which loads the coal into a shuttle car. The shuttle car then transports and loads the coal onto the conveyor belt system. Once the roadway is excavated to the maximum distance, the continuous miner is moved to the next mining sequence.

Ground support, consisting of steel roof and rib bolts, is then installed using a bolting machine termed a multibolter (**Figure 5**). In poorer ground conditions, additional mesh and cables may also be installed.

This methodology is a non-caving mining method such that large-scale overburden fracturing and subsidence does not occur (**Figure 5**).

It is intended to develop 6 m wide roadways in the proposed Mavis Downs South underground area, at 2.8-3 m high, to form pillars with centre dimensions of 24 m x 24 m, at depths <170 m (**Figure 4**).

During secondary extraction on retreat, floor coal will be mined in these roadways and also in the unsupported bell outs on the perimeter of the panels (**Figure 4 and Figure 6**). The thickness of floor coal is determined by the depth of cover, to satisfy the pillar factor of safety and width: height design criteria (Section 3.4).

Figure 6. Roadways after Floor Coaling (Gordon, 2016).

This is the same mining methodology that has been carried out at Carborough Downs and Ensham and is also planned for Mavis Downs and Mavis Downs South (**Figure 1**). As shown in **Figure 4**, the pillar between the bell outs is of a similar size to the pillars in the main part of the panels.

24 m (solid) barriers (blocks of coal), up to 500 m long, have been designed between each panel in the Mavis Downs South underground area (**Figure 4**). These barrier

pillars are larger than the panel pillars and minimise the interaction of overburden loads between the panels.

1.4 Report Structure

Section 1 of this report introduces the Mavis Downs South project, including the proposed bord and pillar mining layout and mining methodology, and the project setting.

Section 2 details the engineering geology, stratigraphy, depth of cover and coal seam thickness.

Section 3 provides a discussion on the stability of the proposed Mavis Downs South underground bord and pillar workings.

Section 4 describes the subsidence methodology, predictions and potential subsidence effects from the Mavis Downs South underground area.

1.5 Objectives

The objective of this assessment is to predict the subsidence associated with the proposed bord and pillar mining activities within the Mavis Downs South underground area. The predictions are to be undertaken following a transparent and robust methodology that was also used for the Mavis Downs underground area.

2 ENGINEERING GEOLOGY

2.1 Geological Data

The Mavis Downs and Mavis Downs South underground areas are covered by closely spaced exploration drilling, as shown in **Figure 7**. Additional drilling has been carried out in the adjacent Carborough Downs South area, on an approximate 500 m grid spacing (**Figure 7**).

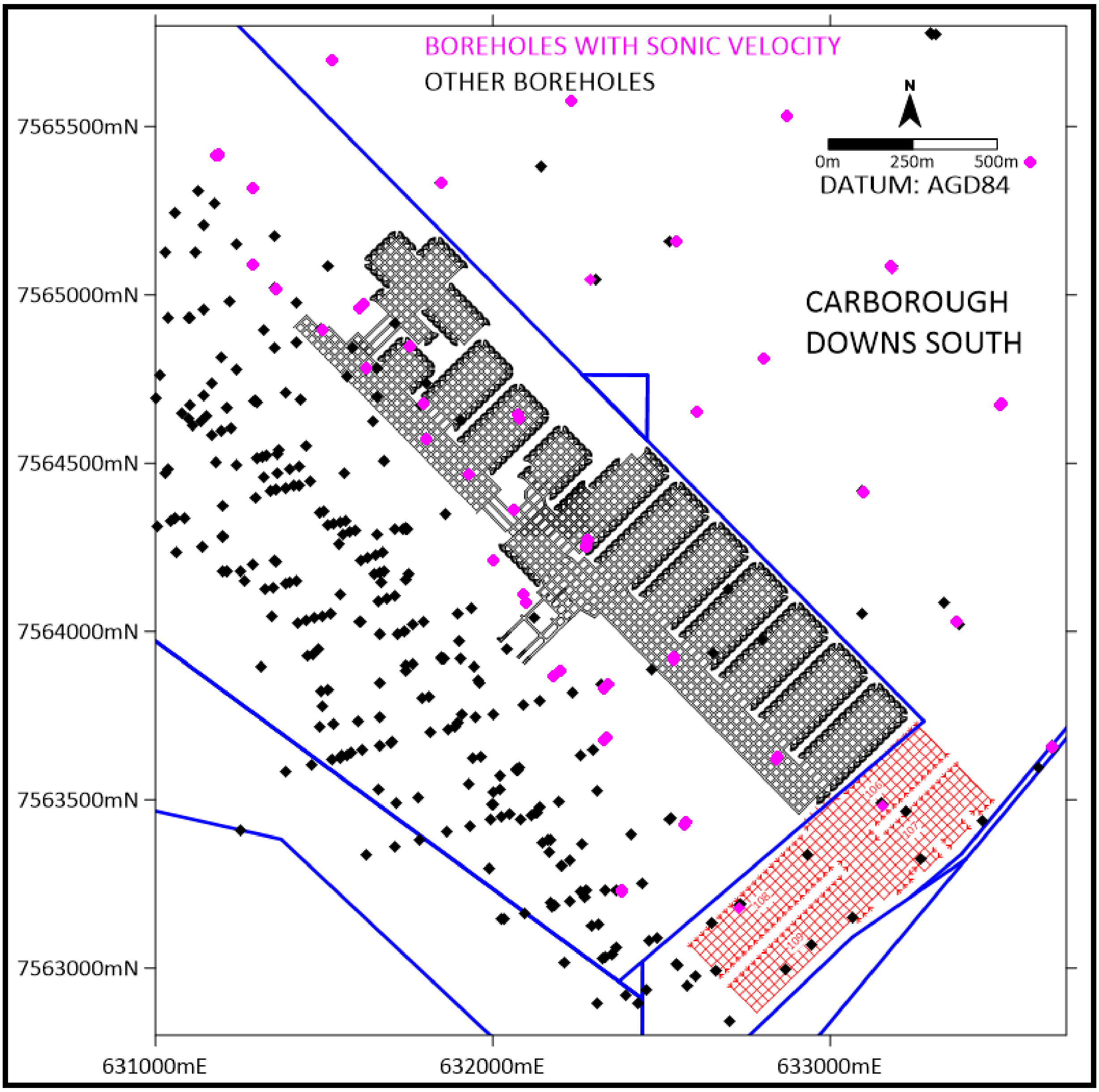

Figure 7. Location of Exploration Boreholes.

These drill holes record the geological sequence of the overburden and coal seams, as well as the sediments immediately below the Leichhardt Seam targeted for mining.

In the majority of the drill holes, geophysical logs are also available and provide additional data on the rock and coal seam properties. This includes sonic velocity logs to allow the estimation of rock strength (**Figure 7**).

This density of data in the Mavis Downs South underground area is considered to be sufficiently detailed to identify any significant changes in the roof and floor strata that would affect the subsidence predictions prepared in this report (**Figure 7**).

2.2 Geology Overview

2.2.1 Depth of Weathering

The Mavis Downs South underground area is covered by a thin veneer of weathered Quaternary and Tertiary age sediments. The depth of weathering is typically less than 25 m (**Figure 8**).

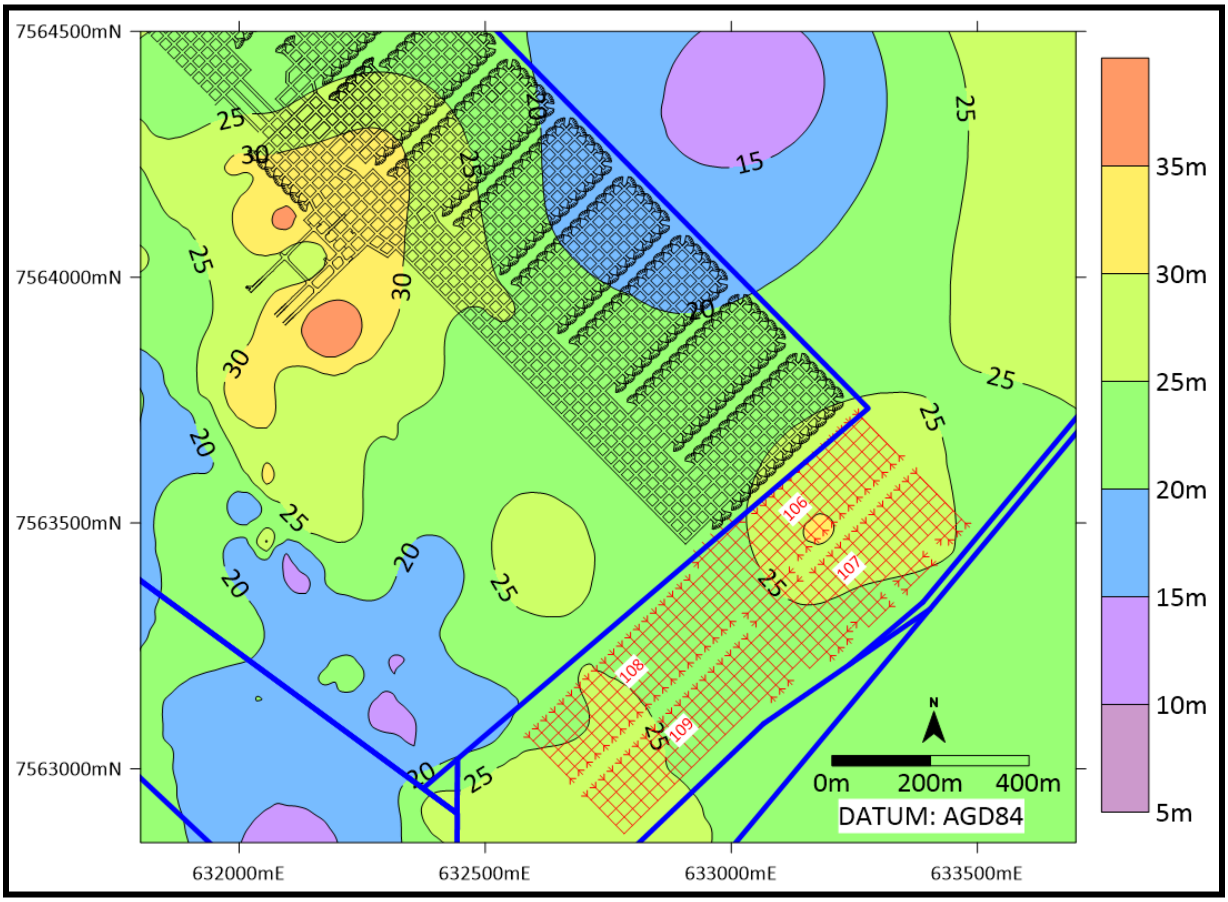

Figure 8. Depth of Weathering (m).

2.2.2 Leichhardt Seam Thickness

Below the weathered sediments, the Permian Coal Measures comprise a sedimentary sequence of interbedded coal seams, including the targeted Leichhardt Seam.

The Leichhardt Seam consists of an upper section (LU), which provides a PCI product and a lower coking section (LL). It is anticipated that the distinct marker band between the LU and LL sections can be used at Mavis Downs South for horizon control during mining operations. The combined Leichhardt Seam (LU + LL) in the proposed Mavis Downs South underground mining area is typically 4.8-5.4 m thick (**Figure 9**).

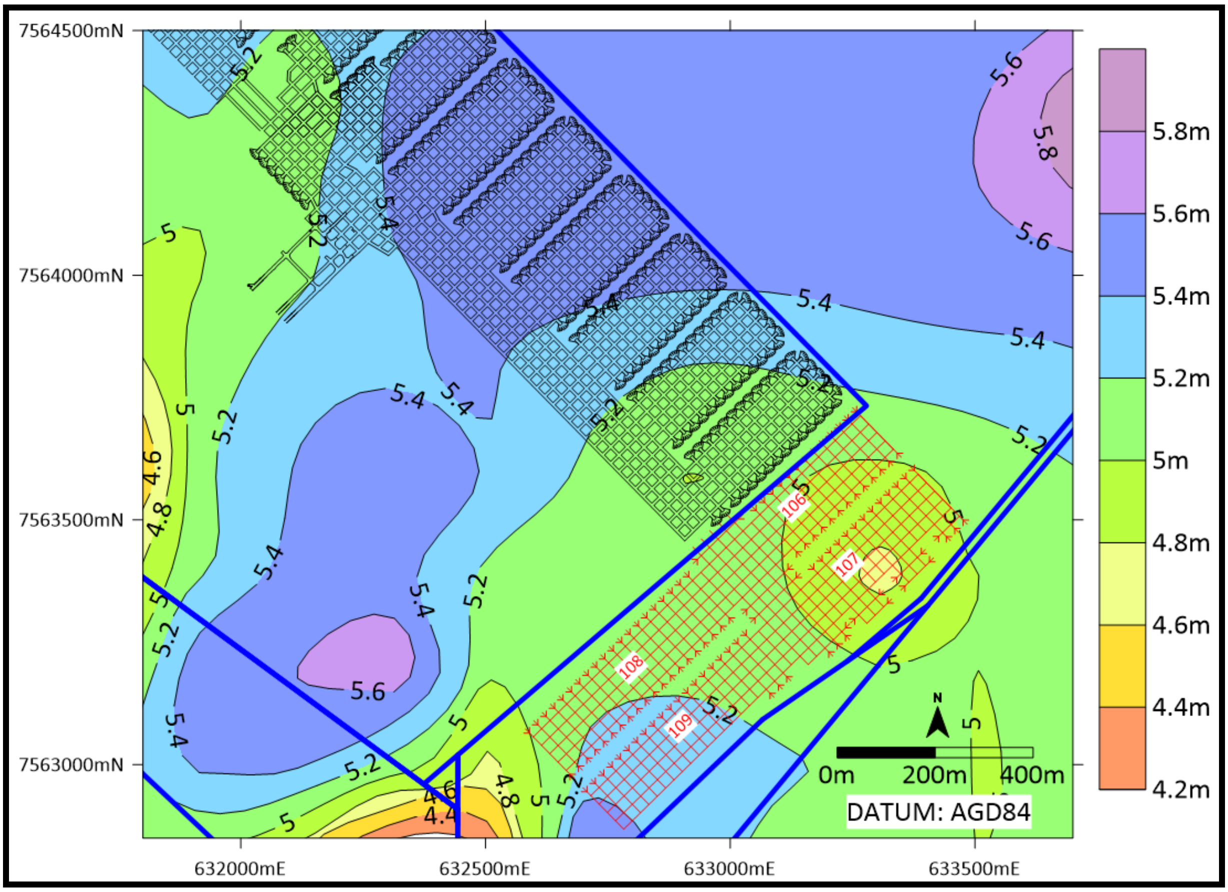

Figure 9. Leichhardt Seam Thickness (m).

Based on a 0.5 m roof coal beam left in the roof of the development roadways, the maximum available coal for extraction is 4.3-4.9 m (**Figure 10**).

2.2.3 Leichhardt Seam Depth of Cover

The proposed Mavis Downs South bord and pillar layout is located at relatively shallow depths of 60-170 m (**Figure 11**).

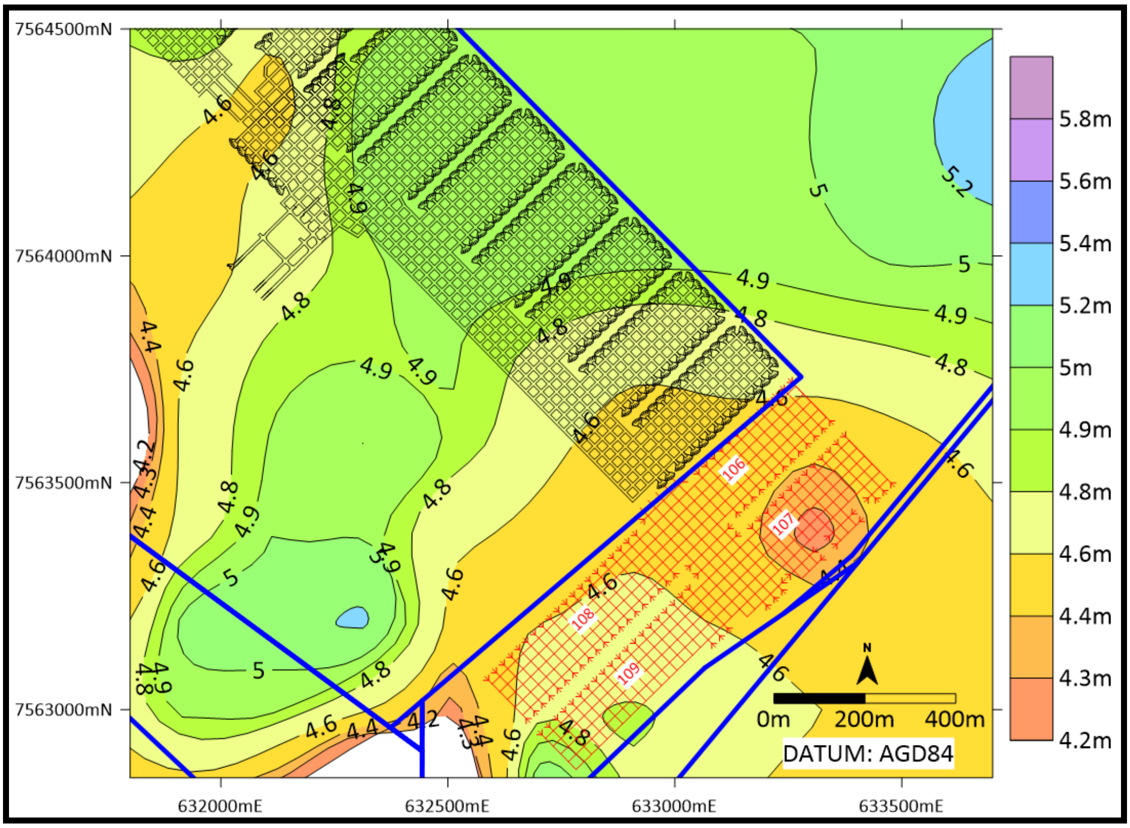

Figure 10. Available Coal for a 0.5 m Roof Coal Beam (m).

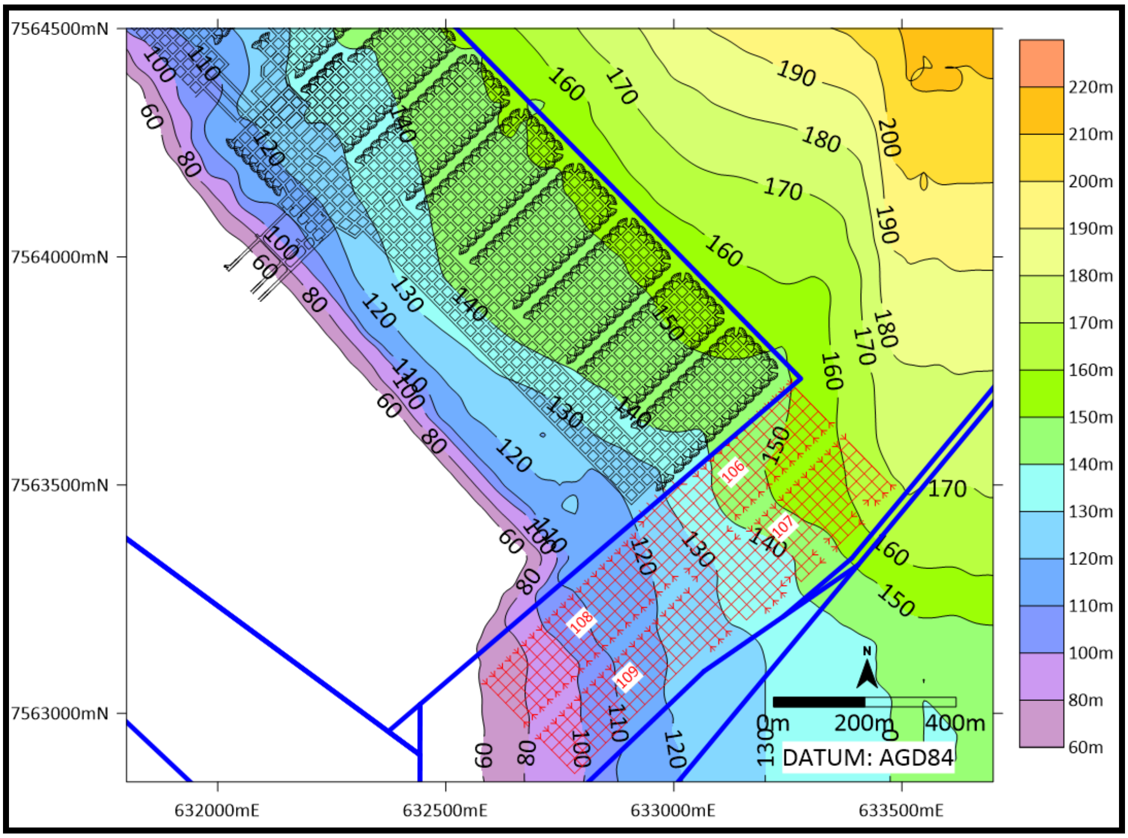

Figure 11. Depth of Cover (m).

2.2.4 Leichhardt Seam Structure

Experience at other open cut and underground mines has shown that the Rangal Coal Measures are characterised by extensive faulting. Between the faults, relatively gentle seam grades occur. The same seam characteristics and geological structure are anticipated in the Mavis Downs South underground area (**Figure 12**).

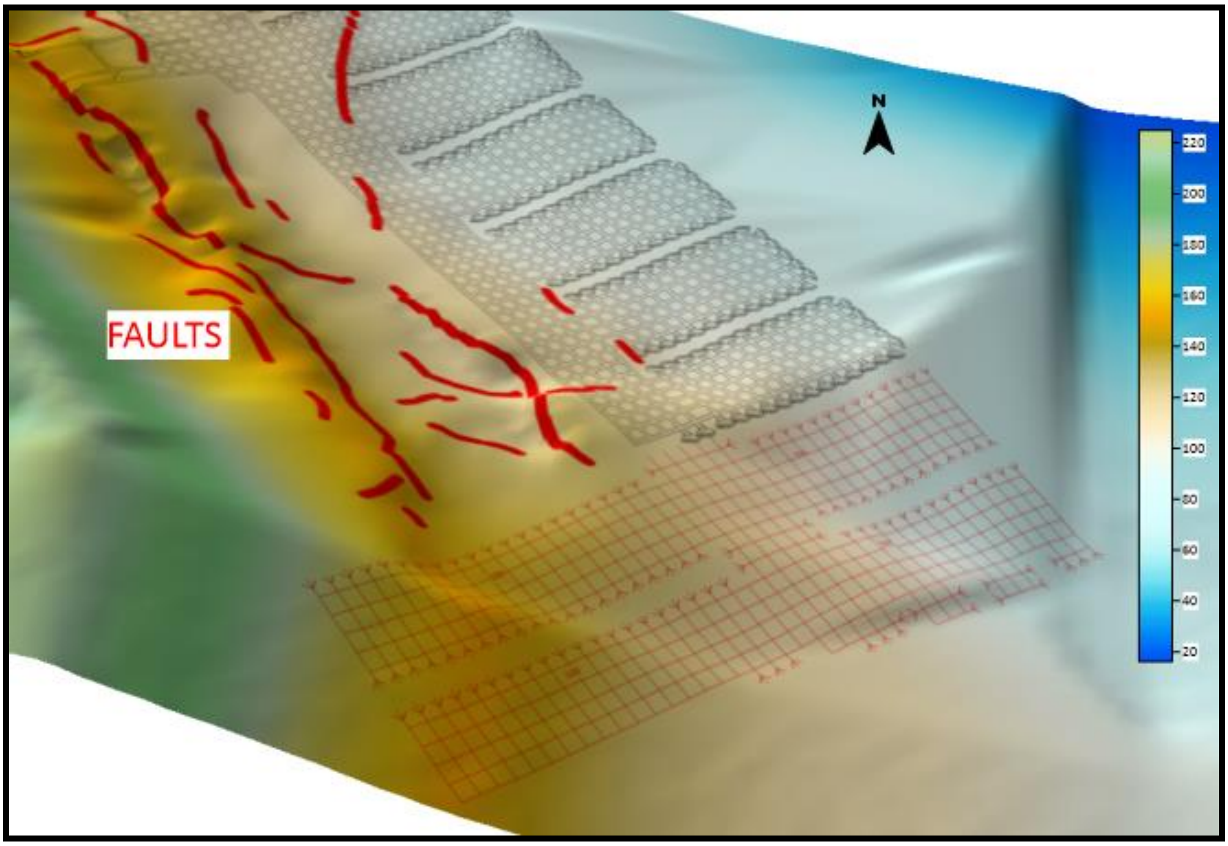

Figure 12. 3D Surface of the Leichhardt Seam Structure Floor Levels and Faults (m AHD).

3 STABILITY OF THE MAVIS DOWNS SOUTH UNDERGROUND WORKINGS

3.1 Introduction

Before addressing the subsidence effects, a discussion on the stability of the coal pillars and associated roadways in the bord and pillar panels at Mavis Downs South is required. These coal pillars are designed to be long-term stable, as a large scale pillar collapse such as occurred at Coalbrook Colliery in South Africa would lead to significantly higher levels of subsidence (Van Der Merwe, 2006[4]).

3.2 Factor of Safety

The assessment of the stability of the coal pillars at Mavis Downs South has been carried out using the industry accepted University of New South Wales Pillar Design Procedure to determine the Probability of Failure according to the design Factor of Safety (Galvin et al, 1998[5]).

3.2.1 Pillar Strength

The UNSW Pillar Power Strength Formulae were used to calculate the strength of the pillars. Tributary area loading was used to calculate the load carried by the pillars, to allow the factor of safety (FoS) to be determined as follows:

FoS = Strength of Pillar/Load on Pillar

For pillars with w/h ratios <5, the strength is defined as:

$$\sigma_p = 8.6\frac{(w_p\theta)^{0.51}}{h^{0.84}}$$

For pillars with w/h ratios ≥5, the strength is:

$$\sigma_p = \frac{27.63\theta^{0.51}}{w_p{}^{0.22}h^{0.11}}\left\{0.29\left[\left(\frac{w_p}{5h}\right)^{2.5} - 1\right] + 1\right\}$$

Where: w_p = pillar width (m)
h = mining height
σ_p = pillar strength (MPa)
θ = dimensionless aspect ratio factor

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[4] Van Der Merwe, J.N. (2006). Beyond Coalbrook: Critical Review of Coal Strata Control Developments in South Africa. Proc. 25th Int. Conf. on Ground Control in Mining, Morgantown, West Virginia.

[5] Galvin, J., Hebblewhite, B., Salamon, M. and Lin, B. (1998). Establishing the Strength of Rectangular and Irregular Pillars. Final Report, ACARP Project C5024.

The dimensionless aspect ratio is derived from Wagner's (1980[6]) hydraulic radius concept (effective pillar width) as follows:

When w/h <3:

$$\theta = 1$$

When 3≤ w/h ≤6:

$$\theta = \left[\frac{2l_p}{w_{p+l_p}}\right]^{\frac{\frac{w}{h}-3}{3}}$$

When w/h >6

$$\theta = \left[\frac{2l_p}{w_{p+l_p}}\right]$$

Where: l_p = pillar length (m)

3.2.2 Pillar Load

Tributary area loading is used to calculate the load carried by the pillars as follows:

$$Load\ (MPa) = \frac{0.025 \cdot H \cdot C^2}{w^2}$$

Where: C = pillar width (centre to centre) (m)
H = depth of cover (m)
w = pillar width (solid dimension) (m)

The panel width to depth of cover ratios are >1 in the majority of the Mavis Downs South underground area, such that the pillars experience the full tributary area load of the overlying strata.

A publication by Reed et al (2016)[7] suggested that coal pillars may exceed their peak strength before the overburden moves enough to generate full tributary area loading conditions.

However, a conservative full tributary area load assumption is considered appropriate for the pillars in the Mavis Downs South underground area (**Figure 1**).

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[6] Wagner, H. (1980). Pillar Design in Coal Mines. Journal of South African Institute of Mining and Metallurgy, 80 (1), 37-45.

[7] Reed, G., McTyer, K. and Frith, R. (2016). An Assessment of Coal Pillar System Stability Criteria Based on a Mechanistic Evaluation of the Interaction Between Coal Pillars and the Overburden. Proceedings 35th International Conference on Ground Control in Mining, Morgantown, West Virginia.

Galvin, (2016[8]) also proposed that the pillars on the perimeter of the panels do not carry the full tributary area load (**Figure 13**). These are the bell out pillars on the proposed Mavis Downs South mine plan and are anticipated to carry 70% of the overburden load, as shown in **Figure 13**.

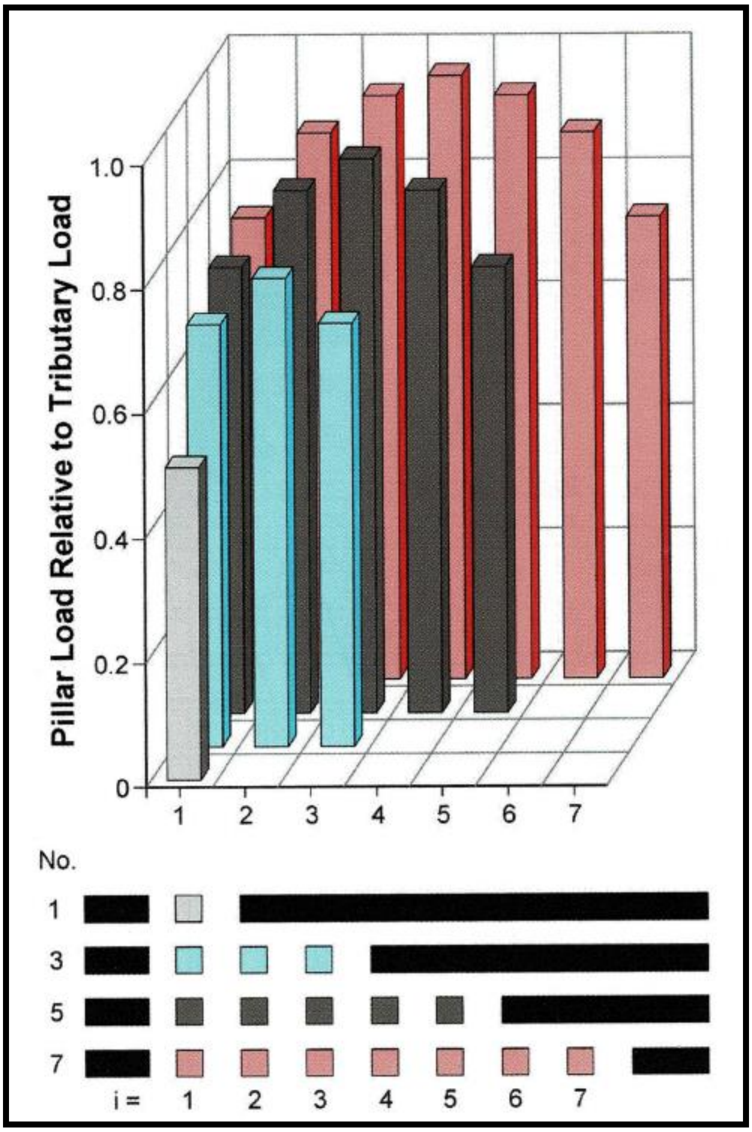

Figure 13. Influence of Panel Width on Pillar Load (Galvin, 2016).

3.3 Width: Height

As well as the factor of safety, the width: height ratio of the pillars also has to be considered in the stability of the pillars. This ratio has a significant controlling influence on the post-failure behaviour of the pillar and can vary from a complete structural collapse (termed strain softening), to a more controlled squeeze with the pillar becoming stronger as it is compressed further (termed strain hardening).

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[8] Galvin, J.M. (2016). Ground Engineering – Principles and Practices for Underground Coal Mining.

Reed et al (2016) suggest that the use of laboratory-based testing data may be flawed due to the very smooth top and bottom contacts in the test rig. This is particularly important as the transition to squat pillars is about the development of frictional based confinement within the core of the pillar. As such, published laboratory data shows substantial strain softening at width: height ratios as high as 9 (Das, 1986[9]).

Reed et al (2016) refer to the available in situ testing data for coal pillars that indicates that the post-failure modulus should transition from negative (strain-softening) to positive (work-hardening) at a width/height ratio of around 4 (**Figure 14**).

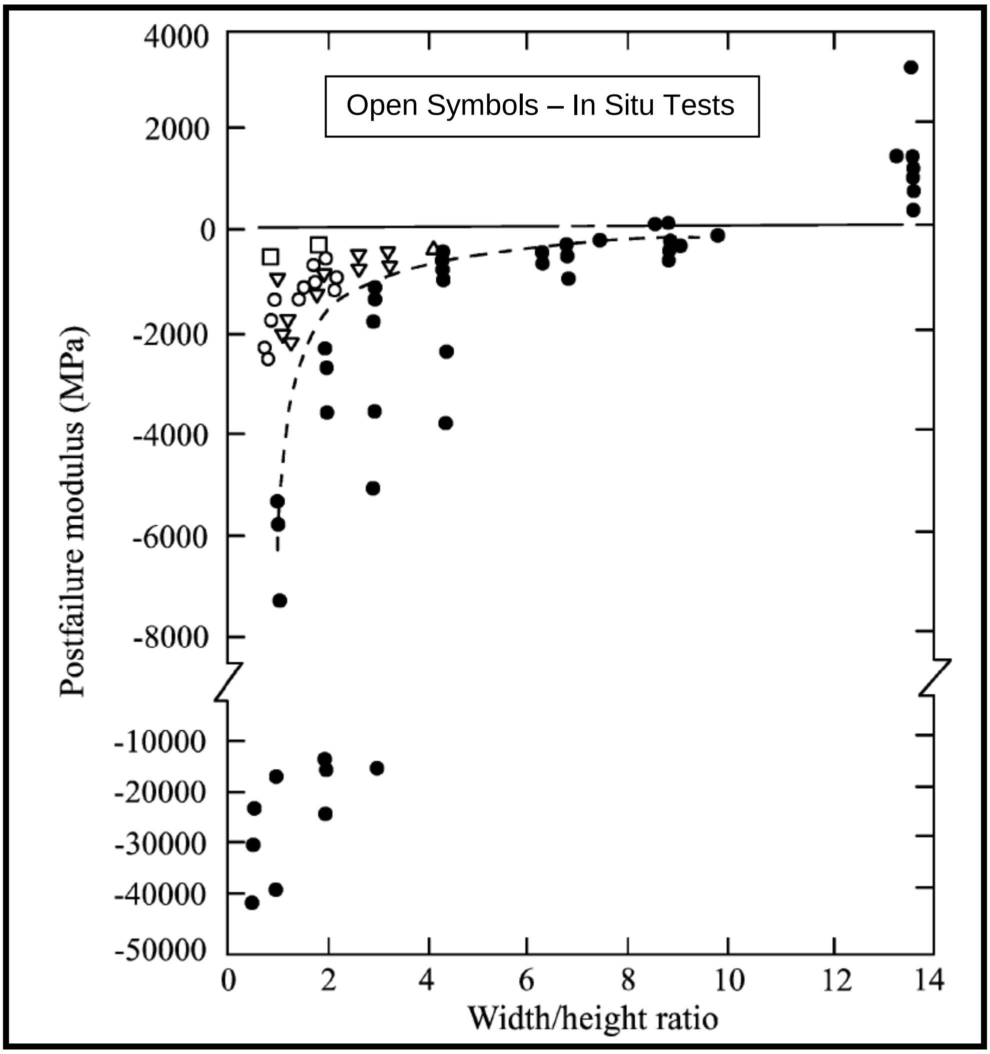

Figure 14. Post-failure Stiffness of Coal Pillars vs Width to Height (Chase et al, 1994[10]).

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[9] Das, M.N. (1986). Influence of Width/Height Ratio on Post Failure Behaviour of Coal. Int. J. Mining. Geological Engineering. No.4.

[10] Chase, F., Zipf, R. and Mark. C. (1994). The Massive Collapse of Coal Pillars – Case Histories from the United States. Proc. 13th Int. Conf. on Ground Control in Mining, Morgantown, West Virginia.

Galvin (2016) also detailed that if the pillar width to height ratio is >4, any pillar failure will be controlled and may be arrested through the application of confinement such as bolts and mesh to the pillar sides (**Figure 5**).

3.4 Criteria for Pillar Design

Hill (2005[11]) presented an empirical database of Australian and South African failed pillars, in terms of both width to height ratio and factor of safety (**Figure 15**). As shown on **Figure 15**, the failed cases typically have FoS values <1.2 and W: H ratios <3.

It should be highlighted that there has been technical debate over the validity of the pillar in the failed database with a width to height ratio of 8.16 (**Figure 15**). The implications of including this data point are that the UNSW pillar strength formulae may conservatively underestimate the pillar strength and overestimate the probability of failure.

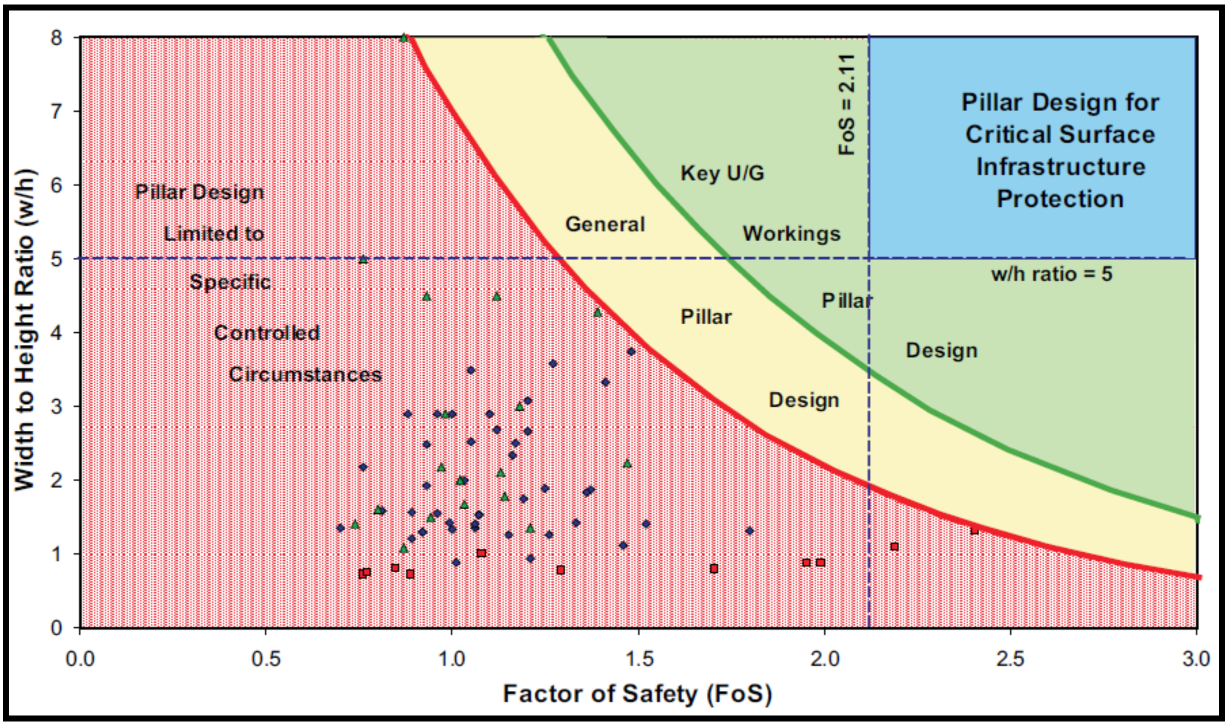

Figure 15. Design Criteria for Bord and Pillar Workings (Hill, 2005).

There is value to step away from the empirical design criteria presented in **Figure 15** and consider what may be driving the upper bound for the width to height ratio. Considering the kinematic stability of a pillar that is cut diagonally from the roof on one side, to the floor on the other is shown in **Figure 16**.

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[11] Hill, D (2005). Coal Pillar Design Criteria for Surface Protection. COAL2005 – Moving Technology – Maintaining Competence. 6th Australasian Coal Operators Conference. Brisbane, pp31-37.

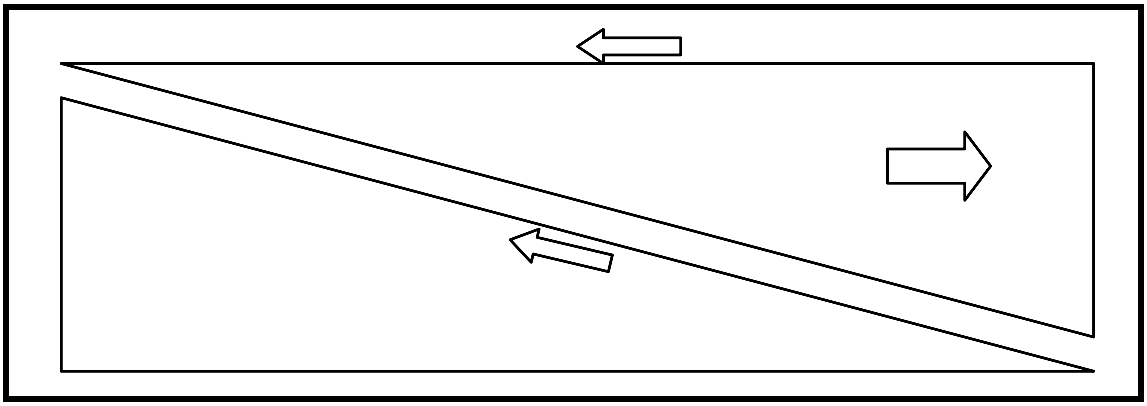

Figure 16. Kinematic Failure of Wedges.

The top wedge may be pushed sideways depending on the shear strength developed along the roof line and on the diagonal surface (**Figure 16**). If frictional restraint only is assumed then using a conservative friction angle of 20^o for unstructured coal indicates a width to height ratio of 2.75 is required to prevent shear of the coal pillar. This is consistent with the empirical database in **Figure 15**, where the majority of failed cases have width to height ratios of <2.75.

For structured coal, a lower friction angle of 15^o would be more representative, requiring a greater width to height ratio of 3.7 to prevent failure. This aspect is illustrated by Hill (2005) in **Figure 17**, where geological structure may weaken the pillar with a lower W: H ratio, hence reducing the FoS.

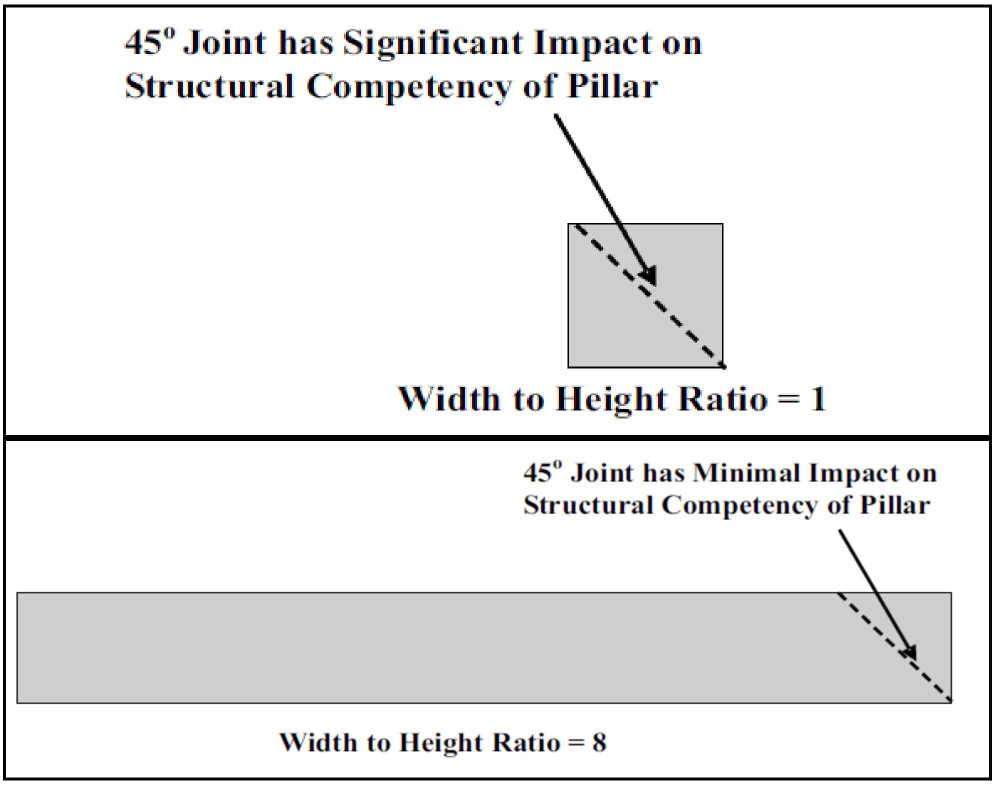

Figure 17. Impact of Geological Structure (Hill, 2005).

Based on the empirical database, as well as practical mining experience at both Ensham and Carborough Downs, a minimum FoS of 1.5 and a minimum W: H ratio of 3 in the area located to the right of the design curve, is recommended for the Mavis Downs South area (**Figure 18**). Byrnes Geotechnical (2021) also considered that these design criteria are appropriate for the Mavis Downs area and therefore are applicable to Mavis Downs South.

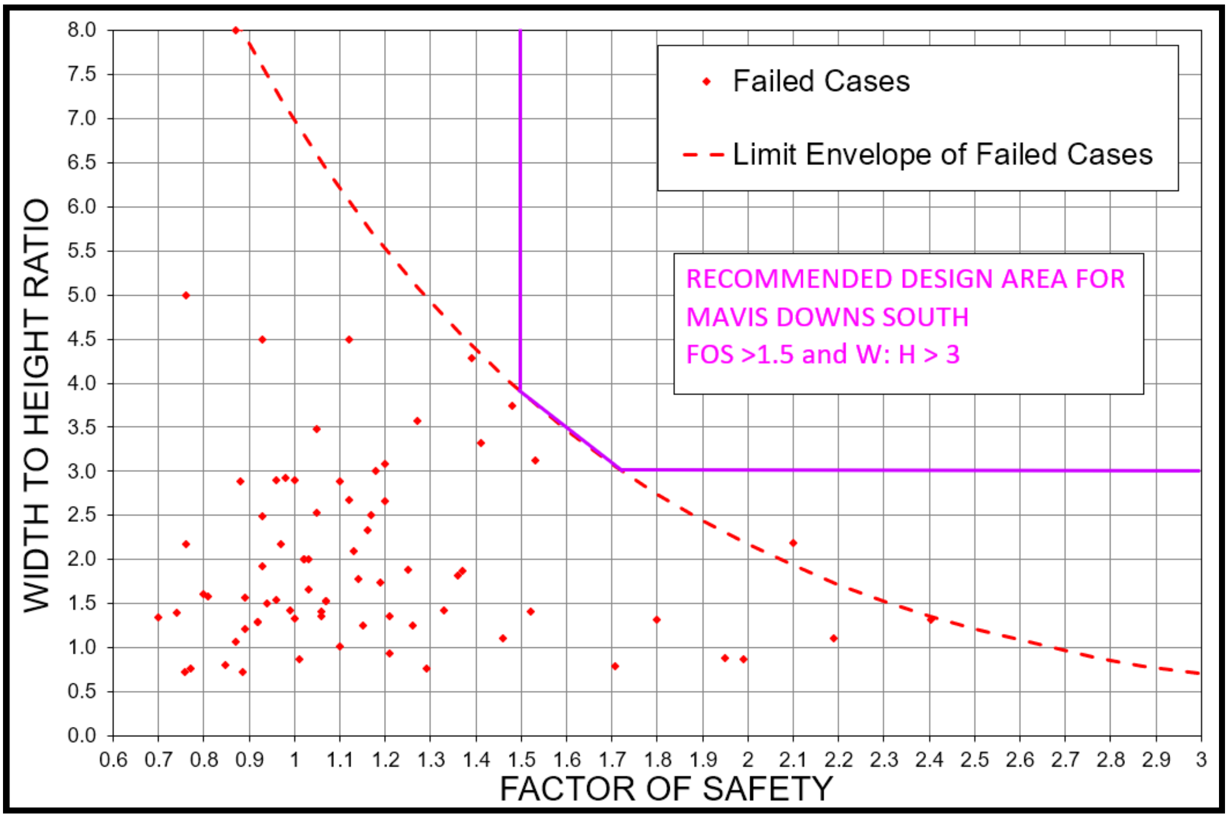

Figure 18. Factor of Safety vs Width: Height Ratio.

Gordon (2016) presented a summary of the pillar factor of safety and width: height data from Ensham (**Figure 19**). As detailed in this paper, all coal pillars at Ensham beneath the Nogoa River flood plain, must have a FoS >1.6, as part of the mine's consent conditions (Gordon, 2016).

3.5 Extraction Ratio

As shown in **Figure 20**, the extraction ratios of the bord and pillar layout in the Mavis Downs South underground area are similar to those mined at Carborough Downs and also proposed at the adjacent Mavis Downs (**Figure 1**).

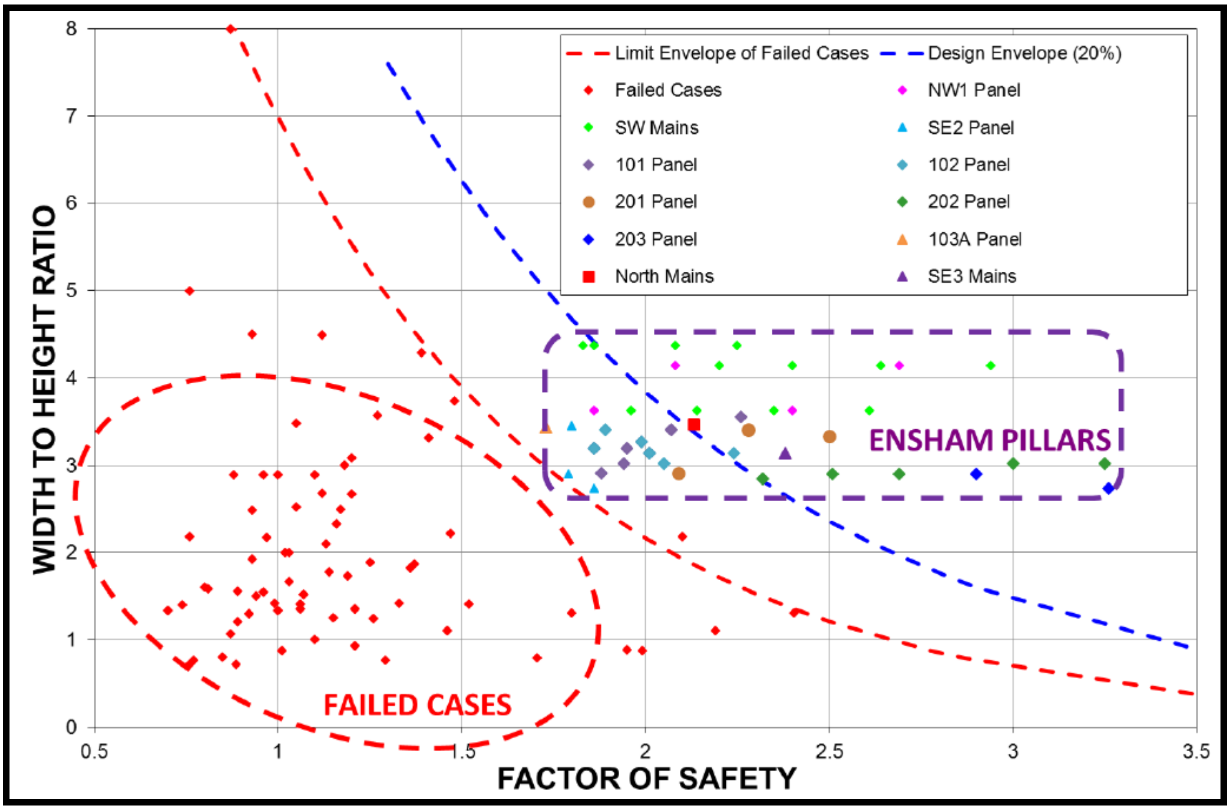

Figure 19. Ensham Pillar Data (Gordon, 2016).

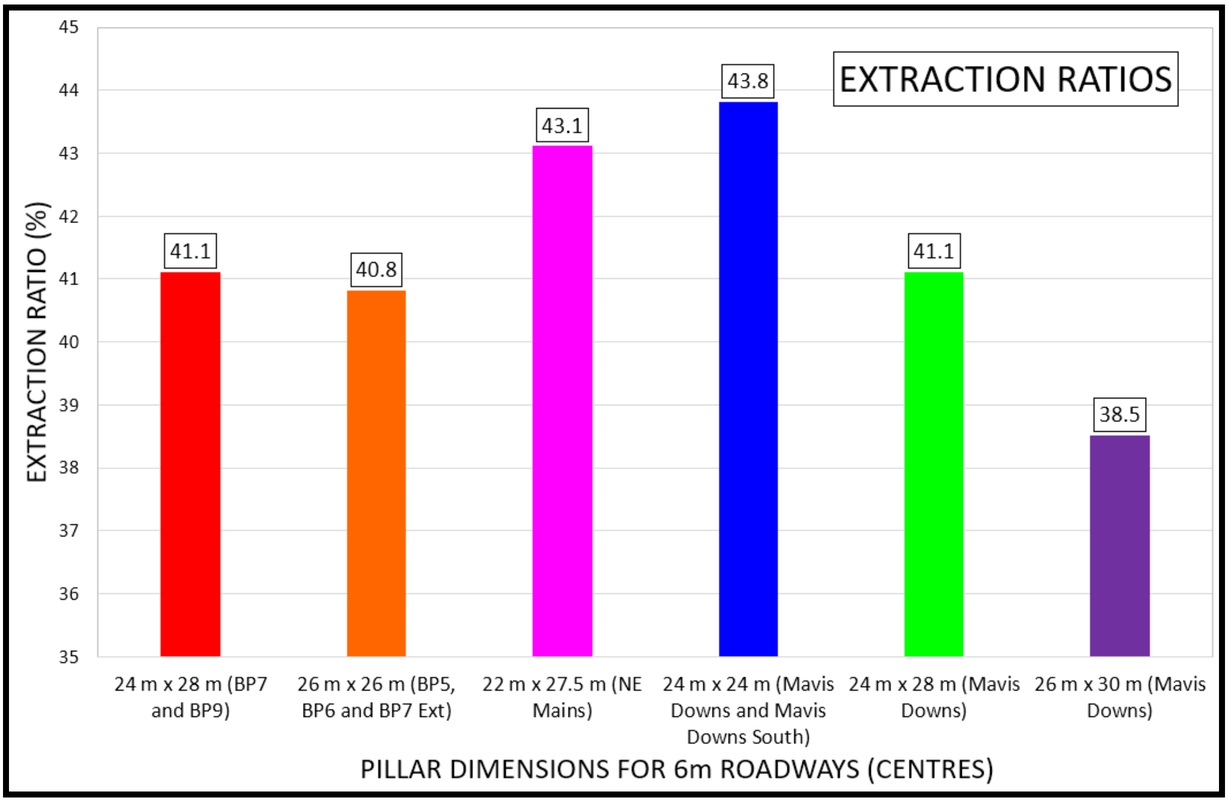

Figure 20. Comparison of Extraction Ratios.

3.6 Long Term Stability of the Overburden

Mine Advice (2018[12]) demonstrated for the Hume Project in NSW, that for the overburden above bord and pillar panels to become critically unstable and so drive the coal pillars to a collapsed state or high levels of yield, a critical level of overburden settlement is first needed to be exceeded.

If the critical level of settlement is not exceeded, then the stability of the bord and pillar workings is strongly controlled by the stability of the overburden. If however the critical level is exceeded, then the stability of the underground workings is almost entirely reliant upon the coal pillars.

The idea of evaluating global mine stability through displacement criteria, in addition to pillar loading criteria, was raised by Emeritus Professor Ted Brown during the experts review meeting of the Hume Project (Mine Advice, 2018).

With reference to the Hume Project, the predicted surface settlements are in the order of 20 mm. Published data indicates that surface settlements of at least 150 mm are required before the overburden starts to lose its stability (Mine Advice, 2018).

Based on this discussion, Mine Advice (2018) defined the term system stability according to an overburden displacement FoS, to complement that of the pillar system. In the case of the Hume Project, the system stability FoS was found to be in the order of 7 (150/20).

This displacement based FoS for the overburden provides a measure to the level of conservatism involved in making the full tributary area assumption detailed in Section 4.1.1. This discussion adds further stability arguments to pillar FoS and width: height criteria for long term stability in the Mavis Downs South underground area.

3.7 Pillar Spalling

It is noted that Canbulat (2010[13]) has published data from South African collapsed cases using the original Salamon and Munro pillar strength formula. The data has a number of pillars with FoS >1.5 that may have failed due to time dependent spalling or scaling, which reduces the width of the pillar (**Figure 21**).

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[12] Mine Advice (2018). Interpretation of the Numerical Modelling Study of the Proposed Hume Project EIS Mine Layout. Report No. HUME22/1.

[13] Canbulat I. (2010). Life of Coal Pillars and Design Considerations. In: Proceedings of the 2nd Australasian Ground Control in Mining Conference. Victoria (Australia): AusIMM; 2010. Pp. 57–66.

Frith and Reed (2019[14]) provided an explanation for this apparent conundrum of these high FoS collapsed cases. Additional failed cases from South Africa with high FoS are also included in **Figure 21**. It is noted that the majority of failed cases occur at depths <100 m. It is highlighted that the panels in the proposed Mavis Downs South underground area are at depths typically >100 m (**Figure 11**).

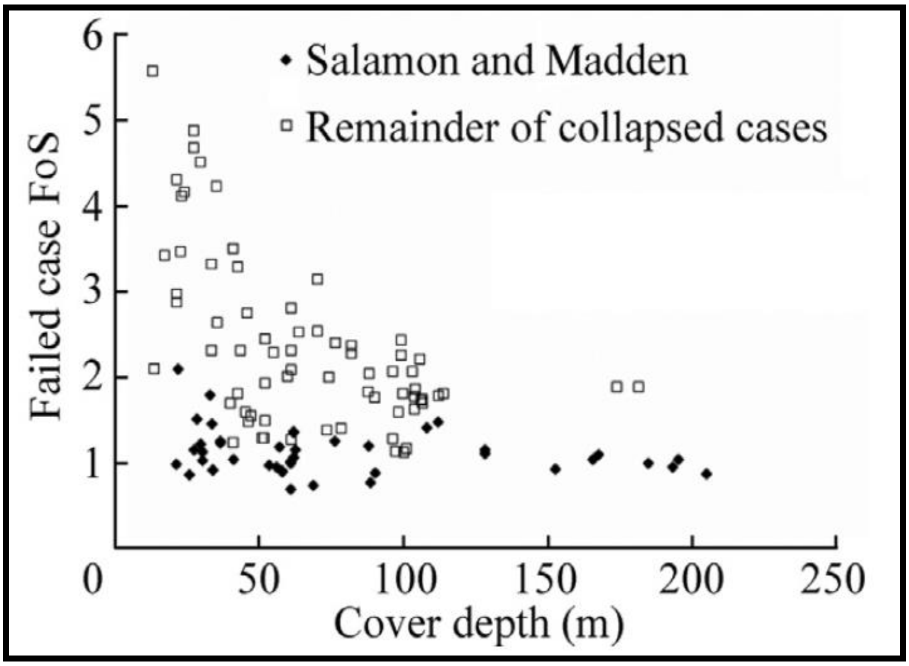

Figure 21. Factor of Safety vs Depth of Cover (Frith and Reed, 2019).

These additional cases were published by Salamon et al (1998[15]) who put forward the concept of swelling clays driving pillar scaling as a possible explanation to explain the collapsed cases. The authors did clarify however that no direct evidence appears to exist to substantiate the proposed model of pillar scaling. The same model was used by Canbulat (2010) in his analysis of the time to failure of high FoS pillars.

Frith and Reed (2019) suggested that the high FoS values in **Figure 21** may be erroneous due to the pillar strength equation used, substantially overestimating the actual coal pillar strength. They concluded that the scaling around the pillars is due to under designed pillars rather than the presence of swelling clays.

Van der Merwe (2016[16]) also presented a formula to calculate the life span of pillars, as follows:

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[14] Frith, R. and Reed, G. (2019). Limitations and Potential Design Risks When Applying Empirically Derived Coal Pillar Strength Equations to Real-Life Mine Stability Problems. International Journal of Mining Science and Technology 29 (2019) 17–25.

[15] Salamon, M.D.G, Ozba, M.U and Madden, B. J. (1998). Life and Design of Bord and Pillar Workings Affected by Pillar Spalling. J. S. Afr. Min. Metall. 1998;98(3):135–45.

[16] Van der Merwe, J.N. (2016). Review of Coal Pillar Lifespan Prediction for the Witbank and Highveld Coal Seams. The Journal of the Southern African Institute of Mining and Metallurgy. Pp. 1083-1090, Volume 116.

$$T = [d_c/(m*h^x)]^{\wedge(1/(1-x))}$$

Where: T = Time to failure (years)
h = Mining height (m)
m = 0.1799
x = 0.7549

and d_c is the critical scaling distance, which for an ultimate safety factor of 0.5 is given by:

$$d_c = w - [0.002285*H*h*C^2]^{\wedge 0.3571}$$

Where: H = Depth of cover (m)
C = Pillar centre distance (m)
w = Pillar width (m)
h = Mining height (m)

Using this approach, the proposed 24 m x 24 m (solid) pillars in the Mavis Downs South underground area at 4.5 m high and 130 m depth of cover, are stable for >35,000 years.

It should be highlighted that the database used by Van der Merwe (2016) was sourced from South African mines with a maximum solid pillar width of 10.5 m and maximum depth of cover of 102 m and hence some extrapolation of the technique is required.

Byrnes Geotechnical (2021) note the data presented shows that absolute scaling is independent of the age of the pillar, leading to the conclusion that the scaling rate must reduce with time. Byrnes Geotechnical therefore assessed that pillar scaling or spalling will not lead to pillar collapse with the pillar sizes proposed in the Mavis Downs and Mavis Downs South underground areas.

3.8 Potential For Sinkhole Subsidence

In addition to overall pillar stability, the risk of roadway (intersection) collapse such that sinkholes develop at the surface should be considered in the Mavis Downs South underground area. Significantly, it is reported in the technical literature that sinkholes are restricted to shallow mining areas and generally only reach the surface at depths **less than 50 m**[17,18,19].

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[17] Mahar, J.W. and Marino, G.G. (1982). Building response and mitigation measures for building damage in Illinois. Proceedings of Workshop on Surface Subsidence due to Underground Mining, Morgantown, West Virginia University, pp. 238-252.

[18] Whittaker, B.N. and Reddish, D.J. (1989). Subsidence: Occurrence, prediction and control, Elsevier, Amsterdam, 528p.

As shown in **Figure 11**, the depth of cover in the proposed Mavis Downs South underground area is **greater than 60 m and typically >100 m**.

Furthermore, underground mining using the same methodology as proposed at Mavis Downs South has been carried out in the Ensham bord and pillar workings at depths of 40 m, with no evidence of sinkhole subsidence occurring above the excavated roadways (Gordon, 2016).

These observations are confirmed by the following discussion on the mechanism of sinkhole subsidence and supplemented with design calculations for a potential failure to occur. Byrnes Geotechnical (2021) presented another model which confirmed similar heights of caving above roadways and wider bell outs in the Mavis Downs area.

3.8.1 Mechanism of Sinkhole Development

Whittaker and Reddish (1989) devote an entire chapter to sinkhole subsidence above bord and pillar mines. They present various analyses examining the development and propagation of sinkholes and also review the published literature, supplemented with some case examples.

Whittaker and Reddish concluded that the local geology and the natural strength of the immediate roof are important factors in assessing the potential for sinkhole development. The mining dimensions and geometry of workings are also of equal importance and should be considered in making an assessment of subsidence risks above bord and pillar mines.

One of the key issues in regards to sinkhole development through fresh rock material is the extent by which the upwards progression of a roof cavity is truncated by either lithology or natural arching (**Figure 22**). **Figure 22** shows that sinkholes develop with vertical sides rather than any form of natural arching, which will cause the effective span to decrease higher into the cavity.

This failure mechanism is commonly observed in underground coal mines and along with roof lithology acts to restrict the height of roadway roof fall cavities to typically only a few metres, rather than propagating higher as shown in **Figure 22**.

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[19] Nielen Van Der Merwe, J and Madden, BV.J. (2002). Rock Engineering for Underground Coal Mining. South African Institute of Mining and Metallurgy. Special Publications Serries 7.

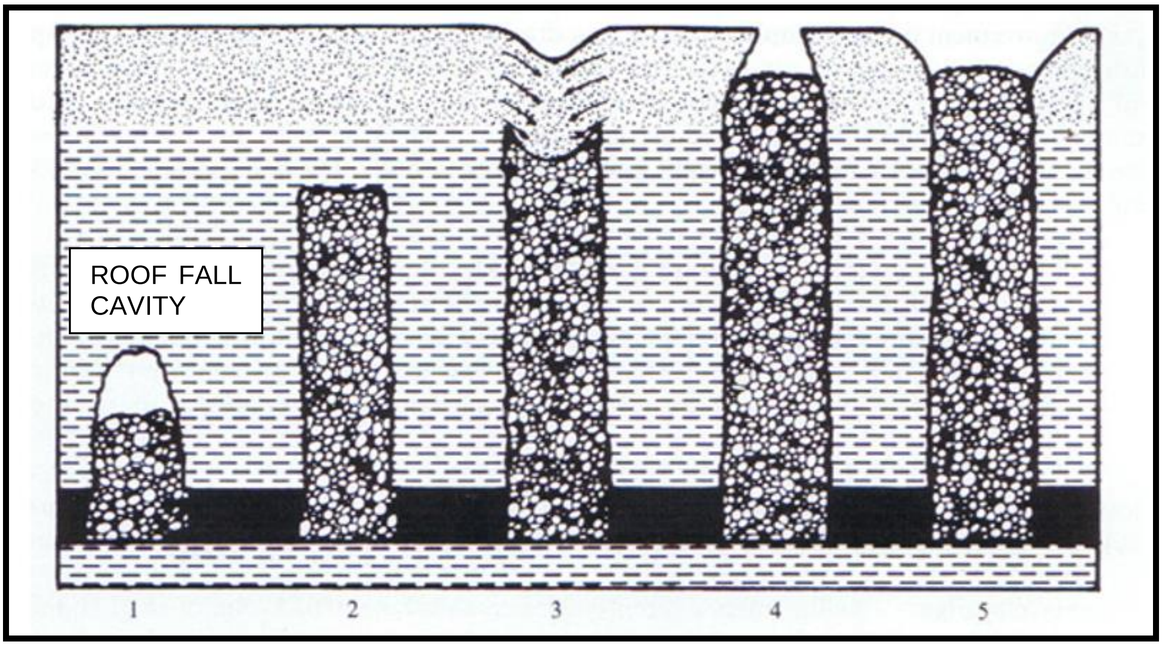

Figure 22. Illustration of Suggested Sinkhole Development Mechanism (Whittaker and Reddish, 1989).

3.8.2 Analysis of Sinkhole Subsidence

The risk of sinkhole subsidence of shallow workings to the surface has been assessed using a limiting equilibrium analysis as detailed below. The analysis is presented in Brady and Brown (2006[20]) as follows:

For **dry** conditions:

$$F_1 = \frac{2c'(a + b\cos\alpha)}{\upsilon ab\cos\alpha} + \frac{k\tan\phi'}{(2h - b\sin\alpha)} * \{\frac{h^2 + (h-b\sin\alpha)^2}{b\cos\alpha} + \frac{2}{a}[h(h - b\sin\alpha) + \frac{b^2\sin^2\alpha]}{3}\}$$

For **saturated** conditions:

$$F = F_1 - \frac{2\upsilon_w\tan\phi'}{3\upsilon(2h-b\sin\alpha)} * \{\frac{h^2 + (h-b\sin\alpha)^2 - 2d(2h - b\sin\alpha - d)}{b\cos\alpha} +$$

$$\frac{2}{3a}[3h(h - b\sin\alpha) + b^2\sin^2\alpha - 3d(2h - b\sin\alpha - d)]\}$$

where: F, F_1 = factor of safety
c' = cohesion in kPa
ϕ' = friction angle in degrees
a = intersection width 1 (metres)

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[20] Brady, B.H.G. and Brown, E.T. (2006) Rock Mechanics in Underground Mining. 3rd Edition.

b = intersection width 2 (metres)
k = average of the horizontal to vertical stresses
α = seam dip in degrees
υ = rock density in kN/m^3
υ_w = water density in kN/m^3
d = water table depth (metres)
h = thickness of fresh rock (metres)

For the Mavis Downs South underground area, cohesion (c’) and friction angle (ф’) values of 0 kPa and 30° have been used respectively, assuming the failure mode is along joints, with some surface roughness. The roadway width is 6 m and the seam dip 3°.

The stress ratio value (k) has been reduced to 1.2 for the shallower depth of cover. This value is also consistent with the in-situ stress measurements presented in Brady and Brown (2006). The analysis has been carried out for both dry and saturated conditions.

To maintain a Factor of Safety of >1 in saturated conditions, **at least 6 m** of fresh rock is required for 6 m wide roadways (**Figure 23**). In the shallowest part of the Mavis Downs South underground area, there is anticipated to be **at least 35 m** of fresh rock.

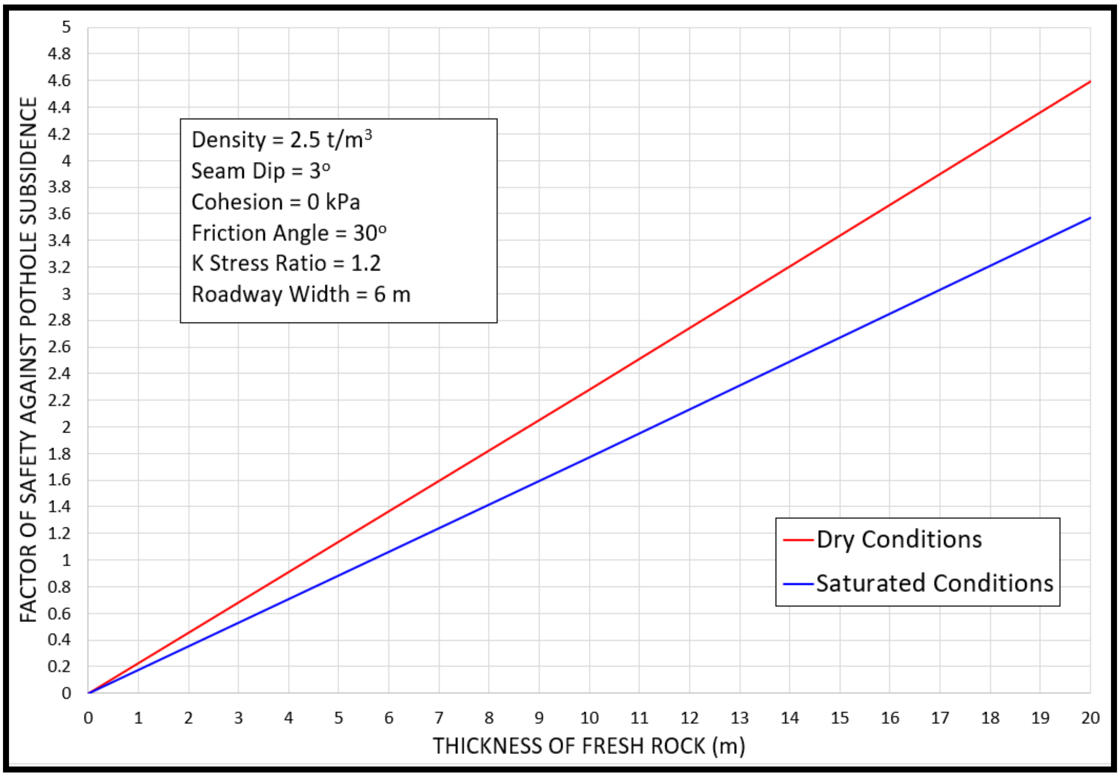

Figure 23. Limiting Equilibrium Analysis for Sinkhole Subsidence above 6 m Wide Roadways.

The larger intersection and bell out excavations also need to be considered. For a large intersection with an average diagonal span of 14 m, the side dimensions would be 9.9 m. In this case, the required thickness of fresh rock would approach 10 m in saturated conditions, applying a Factor of Safety of 1 (**Figure 24**).

For a 15 m wide bell out, this approaches 15 m of fresh rock (**Figure 24**).

Based on mining experience at shallow depths of cover at other mining operations around the world, the risk of sinkhole subsidence occurring in the Mavis Downs South underground area, where the depth of cover is typically >100 m, is considered to be without known precedent.

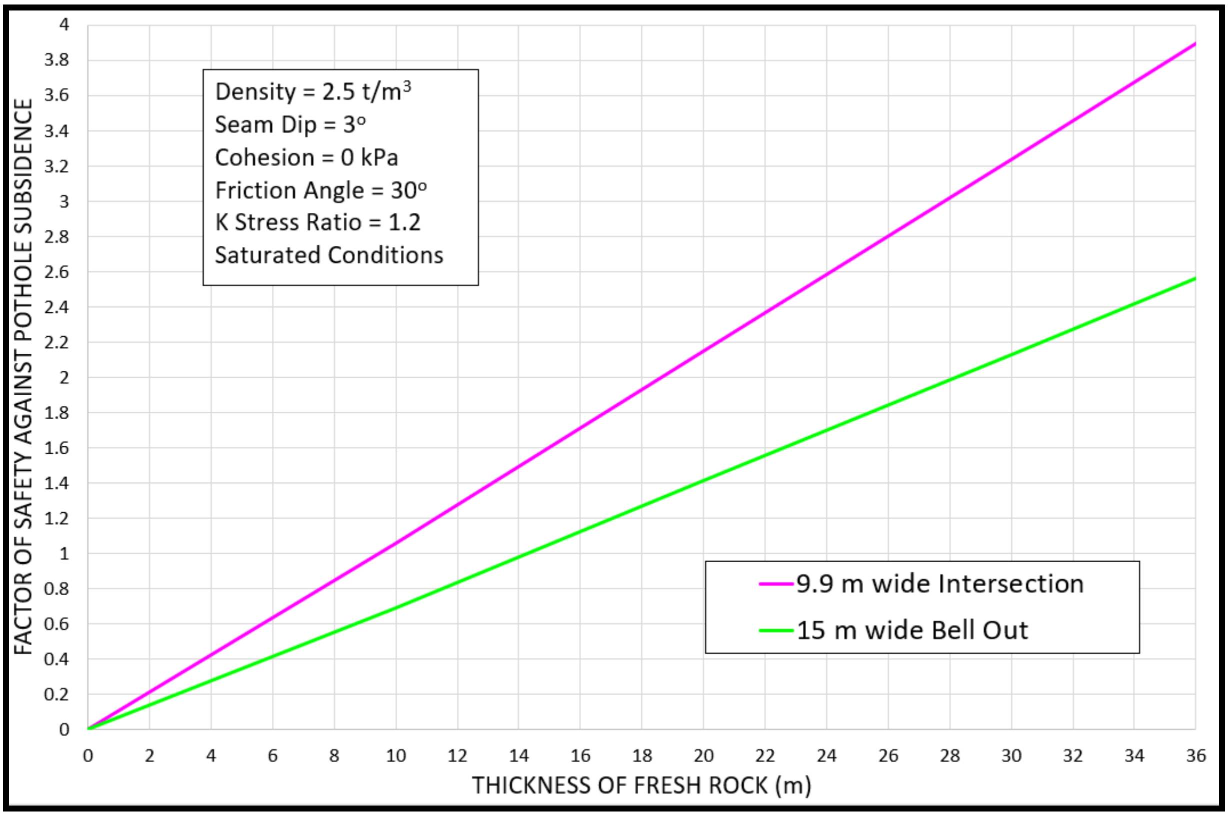

Figure 24. Limiting Equilibrium Analysis for Sinkhole Subsidence above Intersections and Bell Outs.

3.9 Mavis Downs South Underground Area

3.9.1 Panel Pillars

The stability of the pillars in the proposed Mavis Downs South underground area has been assessed, with reference to the range in depth of cover (**Figure 11**). The maximum allowable mining heights for a range of depths, to satisfy a FoS of 1.5 and W: H >3 for the 24 m x 24 m (centre) pillars planned for the underground area are summarised in **Figure 25**.

The input values used in the strata compression analysis has referenced these maximum mining heights, as detailed in **Appendix 1**. It is noted that for a 0.5 m coal roof beam, the full seam can be extracted in the Mavis Downs South underground area (**Figure 25**).

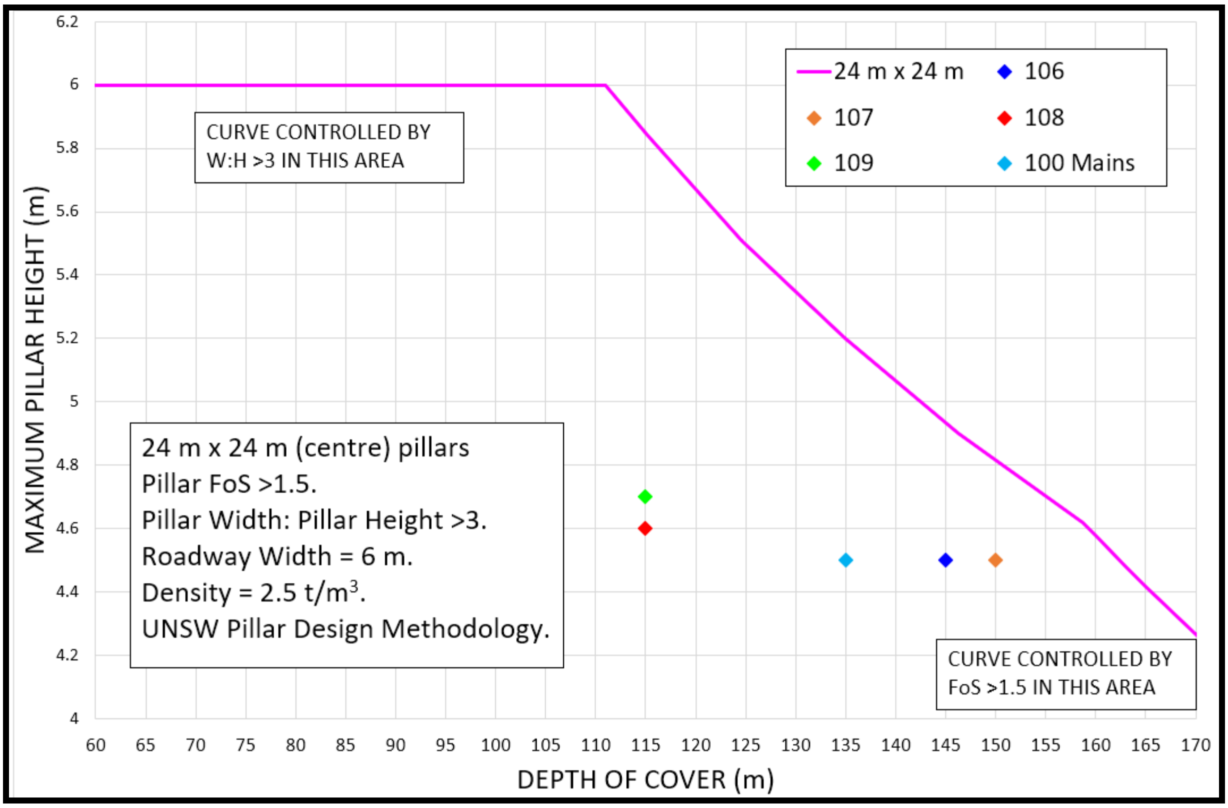

Figure 25. Maximum Pillar Height to Satisfy W:H >3 and FoS >1.5.

It should be highlighted that any rib canchs left during the floor coal mining operations to improve rib stability, have conservatively not been included in the FoS calculations (**Figure 6 and Figure 26**).

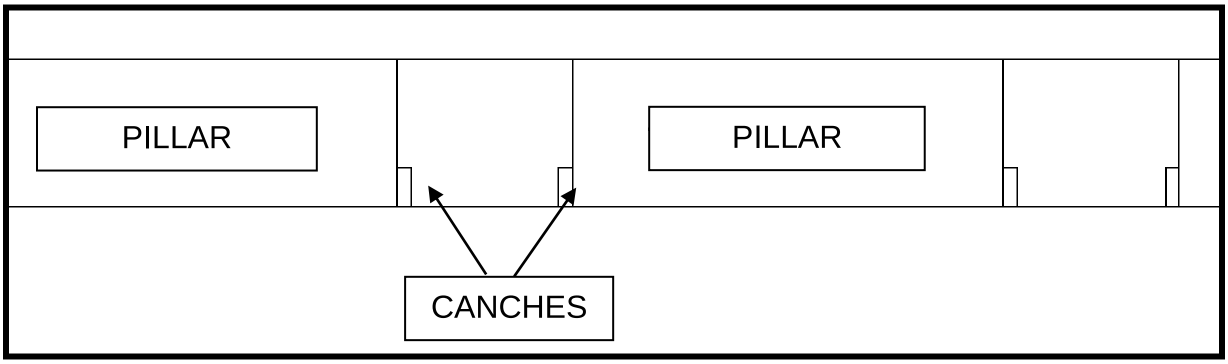

Figure 26. Rib Canches Left Around Coal Pillars.

3.9.2 Bell Out Pillars

The FoS of the bell out pillars also needs to be considered. As shown in **Figure 13**, a 70% load assumption is appropriate for these pillars located on the perimeter of the panels.

The secondary coal recovery methodology forms a regular pillar between the bell outs, which allows the application of standard pillar design formulae (**Figure 27**). The analysis of these pillars has conservatively assumed a 10 m wide roadway equivalent to the mined bell out, which equates to an average void width around the pillar of 7 m.

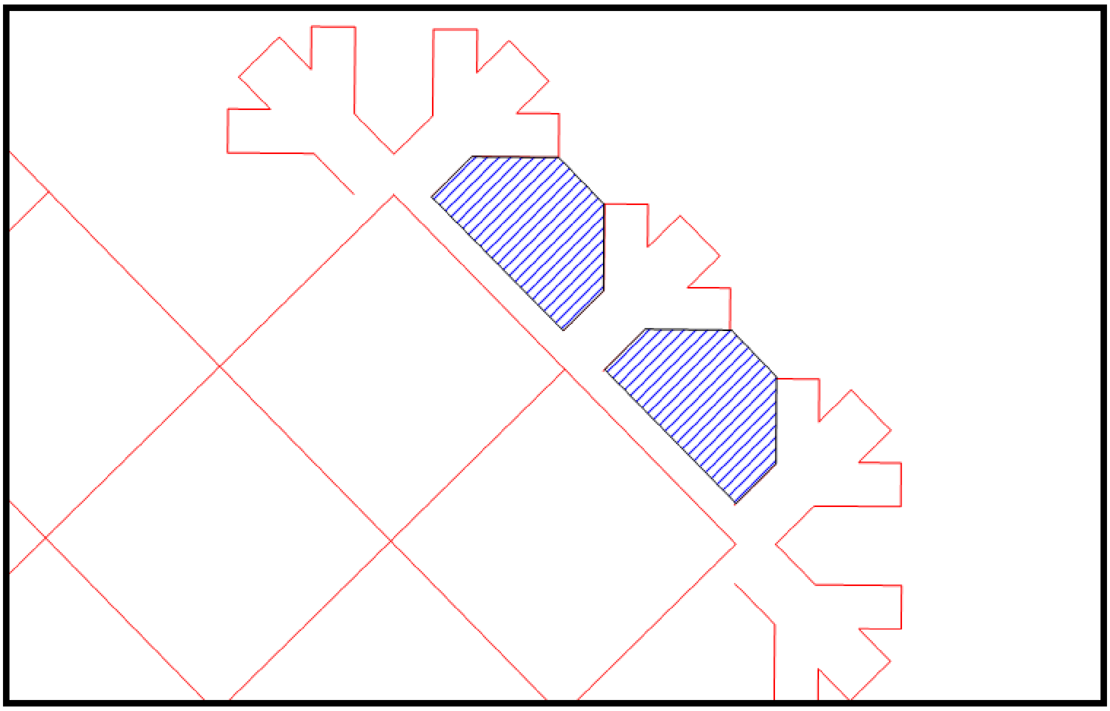

Figure 27. Bell-out Pillars.

The size of this bell out pillar has been calculated using the hydraulic radius approach of Wagner (1980), where the effective width (w_e) is given by:

$$w_e = 4A/P$$

where: A is the pillar solid area and
P is the pillar perimeter distance.

The effective width of the bell out pillar developed on 24 m centres with 6 m wide roadways in the Mavis Downs South area, decreases to 15.2 m. Even at 4.5 m high and 170 m deep, the bell out pillar with an effective width of 15.2 m still has a FoS of 1.57.

3.9.3 Barrier Pillars

Barriers with a minimum FoS of 2.11 and width: height ratios >5 are recommended for long-term stability at Mavis Downs South. The solid coal barriers between panels have been designed at 24 m (solid) (**Figure 4**). At a 4.5 m extraction height, these barriers have a W: H ratio >5 and FoS values of 2.21 for a 50 m long section of the barrier, at 150 m depth of cover.

At this stage, the mine plan shows a large barrier to the highwall >130 m. At 110 m depth of cover, the factor of safety for a 50 m long section of this barrier, at 4.5 m high, is very high at 9.8.

It is important that any modification to the barrier pillar width is reviewed from a geotechnical perspective and also considers potential inrush sources such as water and gas. GGPL considers that the requirement for barriers between panels developed with FoS values >1.5 and width: height ratios >3 is dominantly related to gas and water inflow hazards.

4 SUBSIDENCE PREDICTION METHODOLOGY AND RESULTS

4.1 Methodology

4.1.1 Subsidence Behaviour

Unlike longwall mining, where the subsidence is comprised of two main components namely sag subsidence and strata compression, in the proposed Mavis Downs South underground area, the subsidence will be due to strata compression alone. This results in very low levels of surface lowering and minimal associated surface effects due to the associated very low tilts, curvatures and strains.

Before the compression analysis of the roof, floor and coal can be carried out, the potential for bearing capacity failure of weak floor strata below the coal pillars should also be assessed. A commentary is also included on the effect of flooding the workings after mining is completed.

4.1.2 Bearing Capacity Failure of the Floor Beneath the Pillars

For completeness, the strength of the floor below the Leichhardt Seam should be considered when designing pillar panels in the Mavis Downs South underground area.

Several years ago, in the Newcastle coalfield in NSW, the stone floor beneath the pillars failed in a panel designed with factors of safety >2.11. In this area, very soft layers (<1 MPa) were present in the immediate stone floor below the seam. The overburden consisted of thick conglomerate, which was able to span over more than 50 m.

The bearing capacity failure potential of the floor beneath the pillars in the Mavis Downs South underground area has been analysed using the following formula:

$$\text{Bearing Capacity of the Floor (MPa)} = \text{UCS}/2*(4.14159+0.5*W/T)$$

Where:
W = Pillar Width (m)
T = Thickness of Weak Floor (m)
UCS = Floor Strength (MPa)

The factor of safety for floor failure is the bearing capacity of the floor divided by the stress on the pillar.

With reference to the average floor strength in **Figure 28**, strength values >6 MPa are indicated in the proposed Mavis Downs South underground area. These values have been determined using the strength/sonic velocity correlation presented in **Figure 30**.

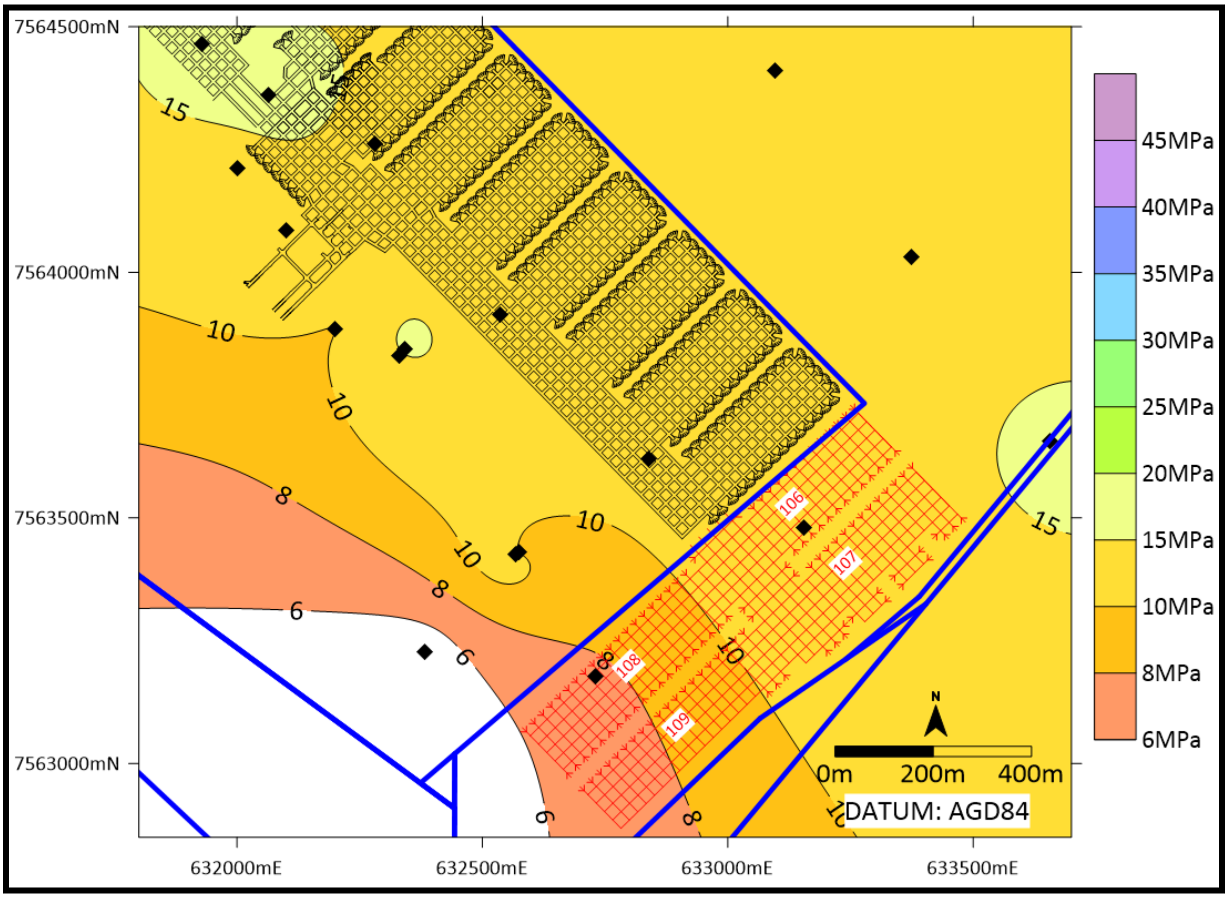

Figure 28. Average Strength of the 0-0.5 m Stone Floor Horizon (MPa).

Byrnes Geotechnical (2021) also concluded that there are no low strength horizons in the immediate stone floor in the Mavis Downs area (**Figure 29**). A low strength horizon was identified by Byrnes Geotechnical in the underlying strata associated with a coal seam but this horizon is located well below the Leichhardt Seam in the Mavis Downs area (**Figure 29**).

For the typical floor strength in excess of about 10 MPa, with the possibility of a 4 m thick layer 6 MPa, bearing capacities of 32 MPa or 19.2 MPa respectively are indicated below the 24 m x 24 m (centre) pillars. The maximum vertical stress under the pillars in the Mavis Downs South area for the proposed pillar size (expressed as uniformly distributed loads) is about 7-8 MPa. It is highlighted that in shallower part of the area where the floor is weakest, the vertical stresses are <4 MPa.

Based on these calculations, it is assessed that the stability factors are high and pillar-punching or “squeezes” are unlikely.

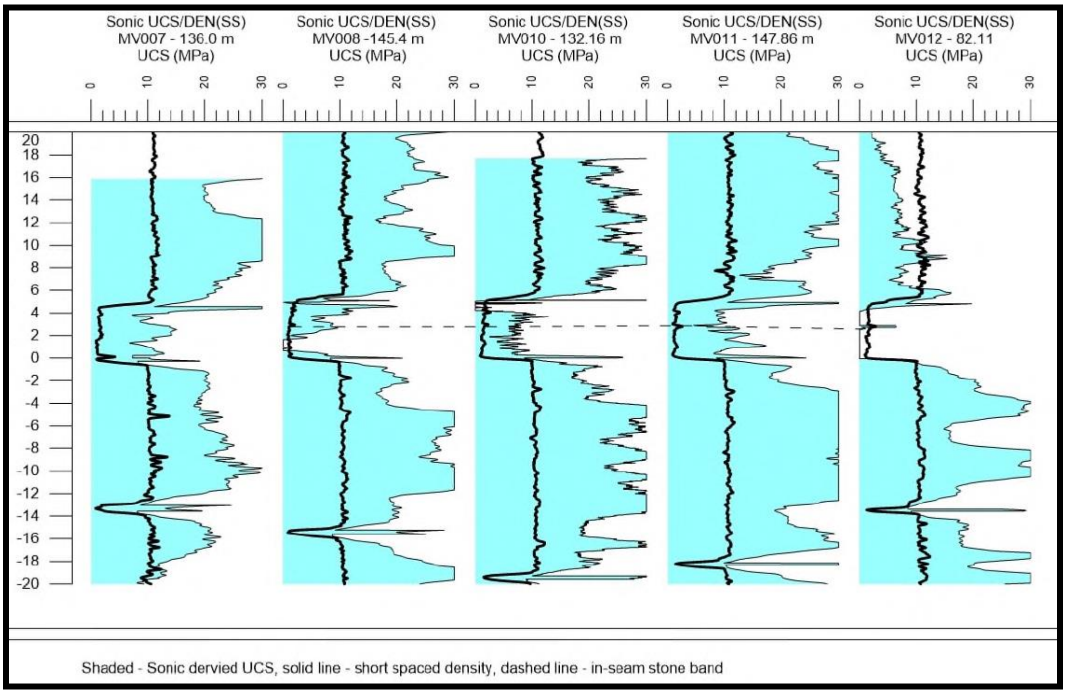

Figure 29. Density and Sonic Derived Strength Logs – Mavis Downs Area (Byrnes Geotechnical, 2021).

4.1.3 Flooding Workings

In the longer term, the flooding of old panels in the Mavis Downs South underground area also needs to be considered. Galvin (2008[21]) discusses this aspect in more detail and suggested that flooding of mine workings could influence pillar load in two ways:

1. The water pressure acting on the roof of the workings would function as a hydraulic jack to unload the pillars or
2. The overburden may be fully saturated over the full water head, effectively reducing the density, resulting in lower loads on the pillars.

Both these mechanisms have a positive impact on the stability of old workings.

The other aspect that needs to be considered is the effect of water on the strength of the pillar system. Galvin (2008) details that water can reduce friction on fracture planes and roof/floor interfaces. The water can also accelerate the degradation of clay rich minerals in the roof, floor and coal seam.

As detailed by Byrnes Geotechnical (2021), the buoyancy effect of water will reduce the vertical load on the pillars by up to 40% and hence increase the factor of safety. This effect is calculated using the formula:

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[21] Galvin, J. (2008). Geotechnical Engineering in Underground Coal Mining – Basic Principles of Pillar Behaviour and Design. ACARP Report.

Effective Stress on Pillar = Total Stress on Pillar – Pore Pressure due to Flooding

The effective stress on the pillar is therefore 1.5 (2.5-1) or 60% (1.5/2.5) of the total stress. The extent of the increase in stability will depend on any strength loss in the coal and the surrounding strata, which may be around 10-15%.

It should be highlighted that the Leichhardt Seam and immediate roof and floor strata in the Mavis Downs South area do not contain significant puggy or water sensitive material that could degrade over time. Byrnes Geotechnical (2021) also concluded failure of the floor due to transient strength reduction effects is unlikely as the groundwater recovers.

There is a case of a pillar collapse in a flooded bord and pillar iron ore mine in France. Conversely, many of the mines in the Newcastle Coalfield of NSW have been flooded for years without adverse effect on stability.

Galvin cautions that careful consideration needs to be given to the possible adverse effects on stability by dewatering the workings, as there is a history of pillar collapses soon after being dewatered.

4.1.4 Strata Compression

The induced surface deformation due to strata compression has been estimated analytically by calculating the combined pillar, roof and floor compression using modulus values. This is discussed in the following sections.

4.1.4.1 Strength of the Stone Roof and Stone Floor

For the proposed pillars in the Mavis Downs South underground area, the influence into the roof and floor is one pillar width. As such, the average strength of both the stone roof and stone floor above and below the Leichhardt Seam for a distance of 18 m has been determined from the geological model based on the planned 18 m x 18 m (solid) pillar size (Section 1.3).

To assist in determining the strength of the roof and floor strata in the Mavis Downs South area, a strength: sonic velocity correlation has been determined from the Carborough Downs South (previously called Moorvale West) data presented by IMC (2007[22]). It is noted that this correlation is also similar to other areas in the Rangal Coal Measures (**Figure 30**).

The average strength of the roof and floor intervals typically ranges from 25-35 MPa and 15-25 MPa respectively (**Figure 31 and Figure 32**). The data points used to generate the contours are also shown on these figures.

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[22] IMC Consultants Pty Ltd. (2007). Geotechnical Assessment of the Moorvale West Resource. Report No. IMC01104.

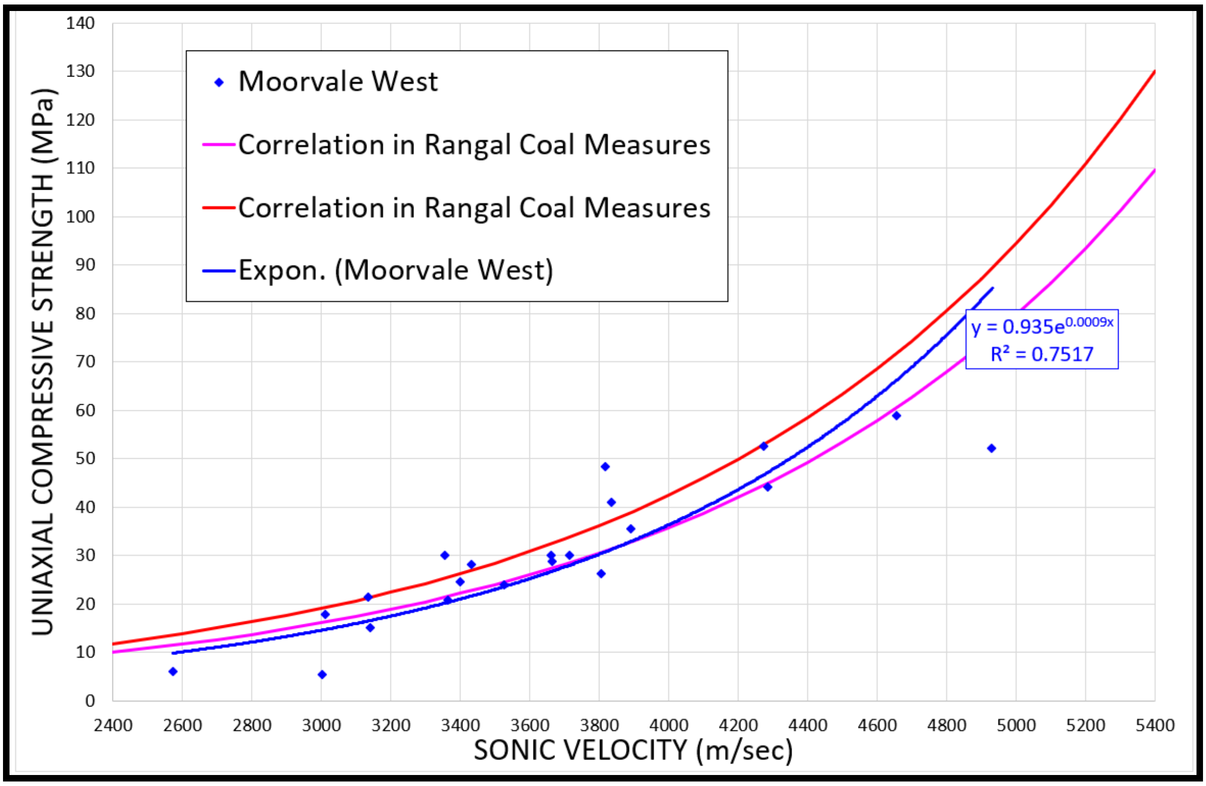


Figure 30. Strength: Sonic Velocity Correlation.

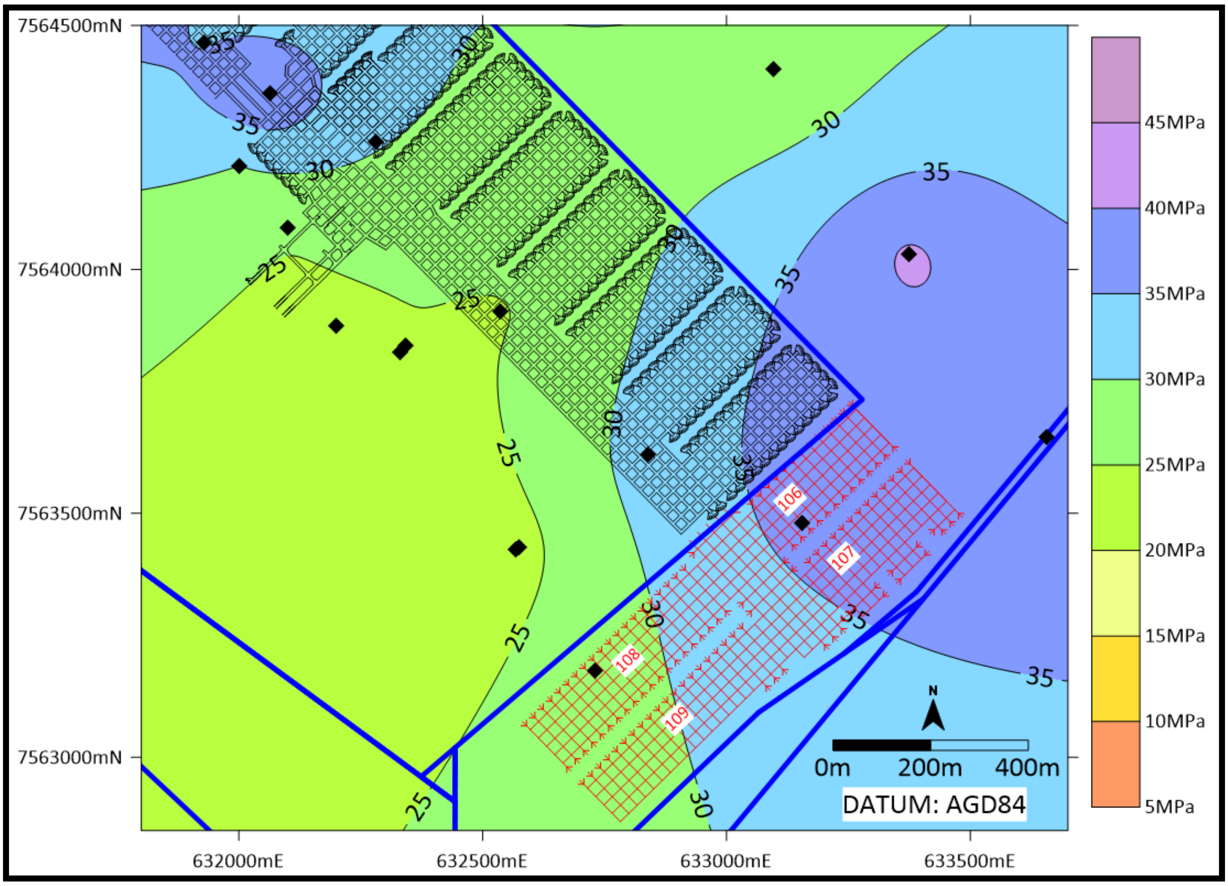


Figure 31. Average Strength for the Stone Roof 0 m to 18 m Interval (MPa).

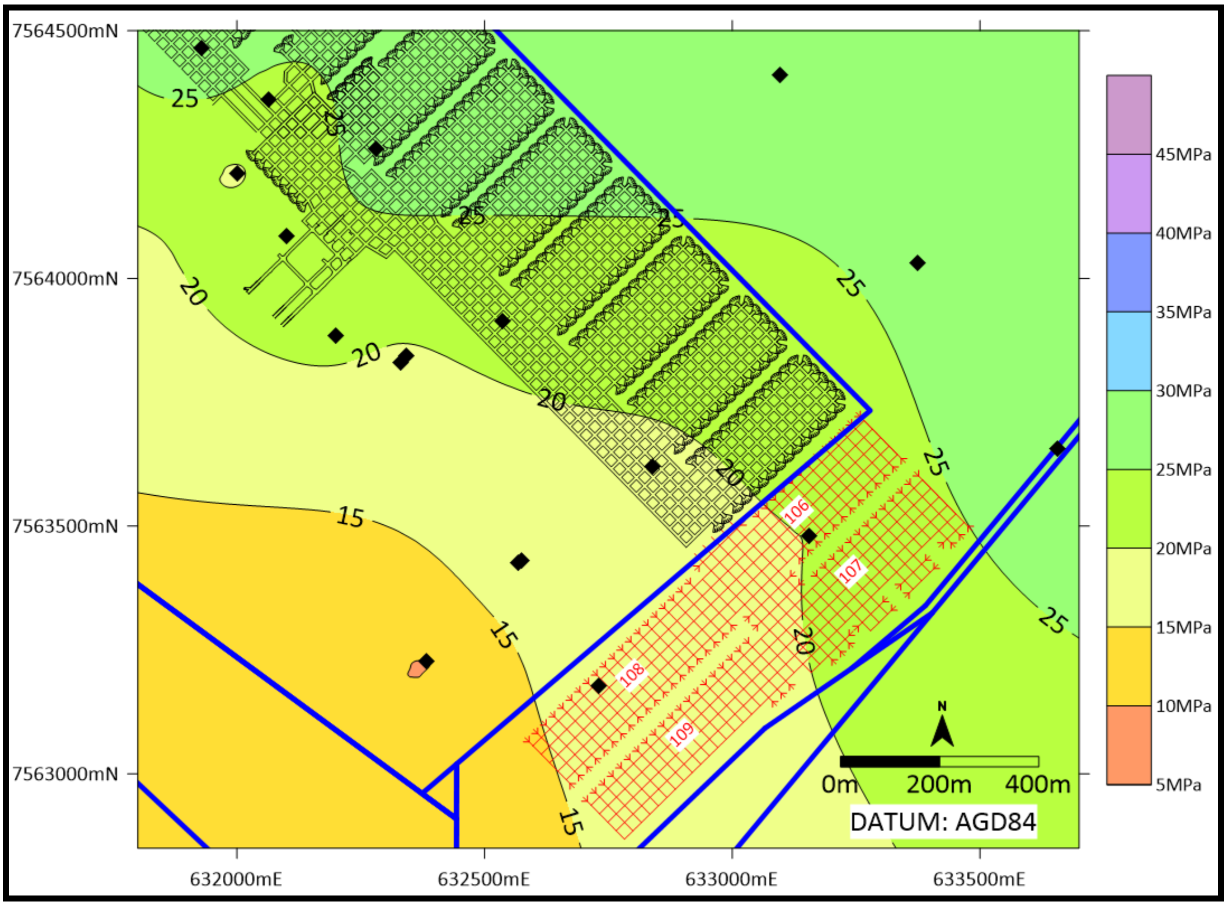


Figure 32. Average Strength for the Stone Floor 0 m to 18 m Interval (MPa).

4.1.4.2 Coal Modulus

An in-situ modulus value of 1500 MPa has been used for the Leichhardt Seam based on published coal seam modulus data (Seedsman et al, 2009[23]).

4.1.4.3 Compression Analysis

As part of the strata compression analysis, these strength values are converted to a laboratory modulus value based on a typical Bowen Basin correlation of:

Laboratory Modulus (GPa) = 300 * Strength (MPa)

The methodology of Hoek and Diederichs (2006[24]) was then used to reduce the roof and floor laboratory modulus values (E_i) to rock mass values (E_{rm}), to consider the discontinuities in the rock mass.

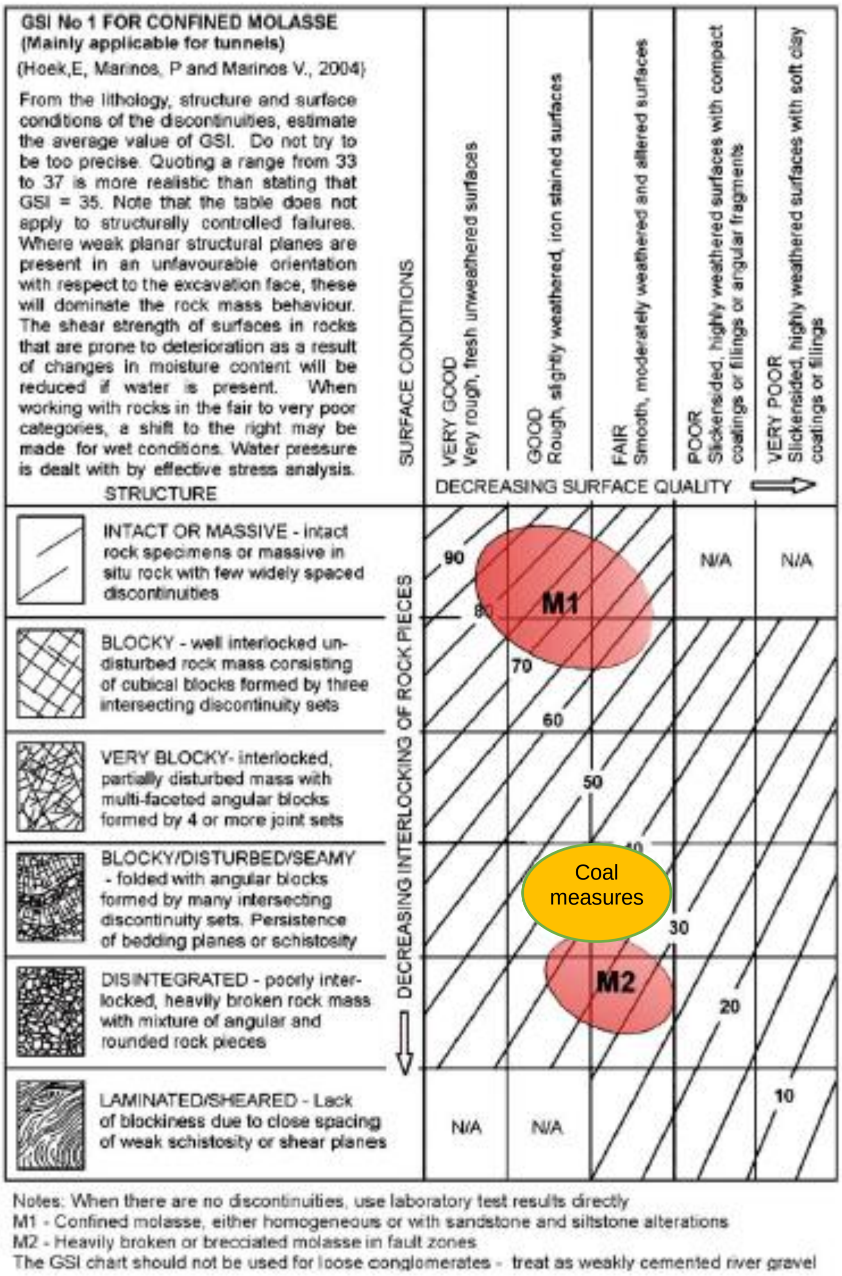
---

[23] Seedsman, R.W., Gordon, N. and Aziz, N (2009). Analytical Tools for Managing Rock Fall Hazards in Australian Coal Mine Roadways. ACARP Project C14029.

[24] Hoek, E. and Diederichs, M. (2006). Empirical Estimates of Rock Mass Modulus. International Journal of Rock Mechanics and Mining Sciences, 43, 203-215.

$$E_{rm} = E_i * \{0.02 + (1\text{-}D/2)/\ (1 + \exp((60+15D–GSI)/11))\}$$

The laboratory modulus values are reduced using a Disturbance Factor (D) of 0 and representative Geological Strength Index (GSI) values for the roof and floor (**Figure 33**).



GSI No 1 FOR CONFINED MOLASSE
(Mainly applicable for tunnels)
(Hoek,E, Marinos, P and Marinos V., 2004)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

Notes: When there are no discontinuities, use laboratory test results directly
M1 - Confined molasse, either homogeneous or with sandstone and siltstone alterations
M2 - Heavily broken or brecciated molasse in fault zones
The GSI chart should not be used for loose conglomerates - treat as weakly cemented river gravel

Figure 33. Determination of the Geological Strength Index (GSI).

Based on the lithological and bedding characteristics of the roof and floor strata in the Mavis Downs South underground area, GSI values of 50 and 45 have been applied to the roof and floor respectively. It is noted that the Millennium Open Cut

Geotechnical Management Plan (2019[25]) quotes similar GSI values for these intervals in D and E pits of 47 and 55 respectively.

Byrnes Geotechnical (2021) also highlight the sensitivity of the compression results in the Mavis Downs area to the GSI value adopted.

The pillar compression is then calculated as follows using the methodology of Poulos and Davis (1974)[26] for analysing rigid footings:

$$\text{Compression}_{\text{pillar}} = (\sigma_C * h)/E$$

Where: σ_C = Vertical stress change (MPa)
h = Pillar height (m)
E = Young's modulus of coal pillars (MPa)

The compression of the roof and floor is calculated as follows:

$$\text{Compression}_{\text{roof or floor}} = I_P*(\sigma_C * w/2)/E$$

Where: σ_C = Vertical stress change (MPa)
I_P = Influence Factor (for a rigid footing) = 1.4
w = Pillar width (m)
E = Young's modulus of roof or floor (MPa)

The change in vertical stress on the pillars can be estimated as:

$$\sigma_C = \text{Tributary Area Stress} - \text{Virgin Stress}$$

4.2 Prediction of Subsidence Effects for the Mavis Downs South area

The compression analysis has been carried out in the Mavis Downs South underground area at the average depth of cover above each panel pillar and bell out pillar, using the average roof and floor strength values shown in **Figure 31 and Figure 32**.

The extracted mining height in both the panel pillars and bell out pillars has assumed 0.5 m of roof coal (**Figure 10**). These heights have also considered the design criteria FoS of 1.5 and width: height >3 (**Figure 25**).

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[25] Millennium Mine (2019). Geotechnical Management Plan. Document Number MO-MIN-MNP-M008 – June 2019.

[26] Poulos, H.G. and Davis, E.H. (1974). Elastic Solutions for Soil and Rock Mechanics.

Based on this analysis, the predicted subsidence above the panel pillars following secondary coal recovery in the Mavis Downs South area is <50 mm (**Figure 34**). This reduces to <30 mm above the bell out pillars, as they do not carry the full tributary area load on the perimeter of the panels (**Figure 13 and Figure 34**).

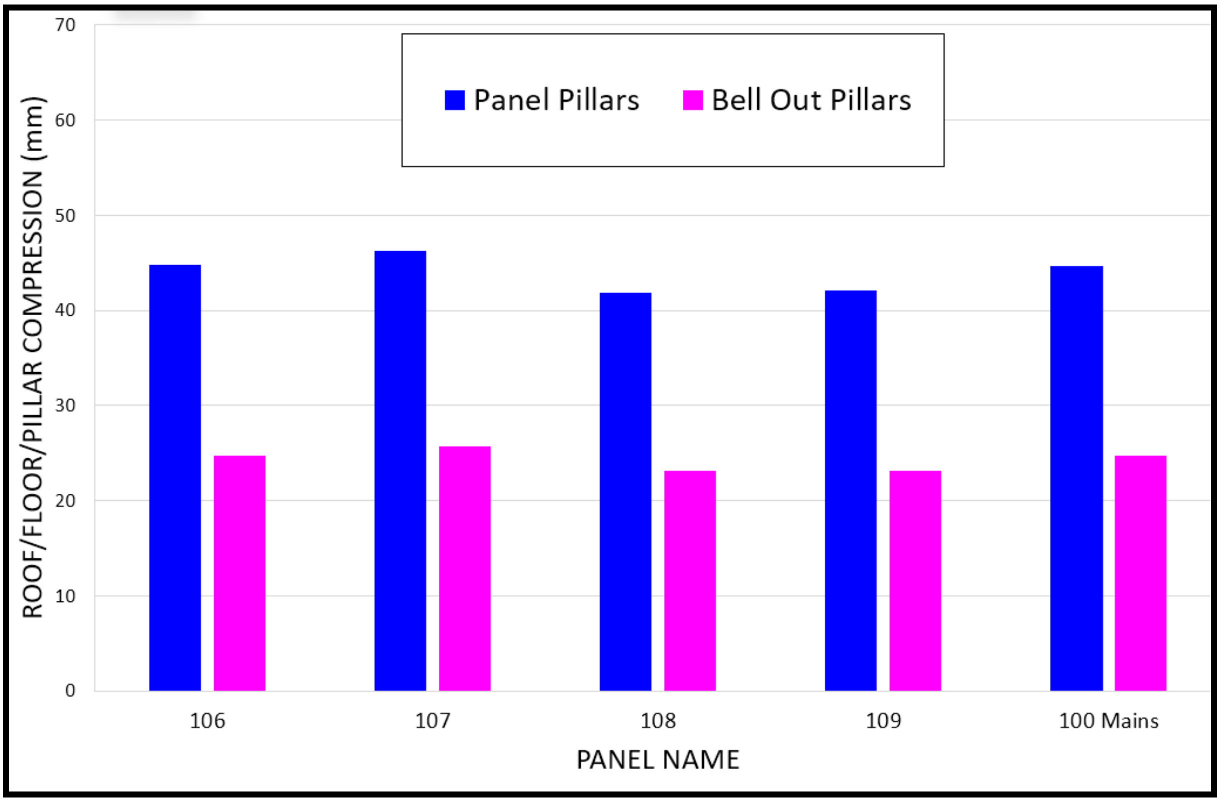

Figure 34. Subsidence above the Panel and Bell Out Pillars.

These subsidence values are well within the guidance published by the IESC (2015)[27], which states that seasonal variation can be as high as 50 mm or more due to changes in moisture content.

Due to the non-caving method proposed in the Mavis Downs South underground area, these very low subsidence values are also not anticipated to extend outside the mining lease. As shown in **Figure 1**, the proposed mine plan has been designed 20 m or greater from the lease boundary.

Fixed Real Time Kinematic (RTK) GPS monitors with an accuracy of ±5 mm have recently been installed over the planned Mavis underground workings above the East Mains and 101 Panel to confirm the predicted low levels of subsidence.

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[27] Independent Expert Steering Committee (2015). Monitoring and Management of Subsidence Induced by Longwall Coal Mining Activity. Report to the Department of the Environment.

4.2.1 Surface Cracking

McTyer and Sutherland (2011[28]) reported that a surface crack of 30 mm width developed above the rib line of 3 North Panel and across a public access path, only after subsidence exceeded 300 mm at the Tasman bord and pillar mine in NSW. No surface cracking developed in areas where the subsidence was <300 mm.

The lack of any surface cracking or ground disturbance observed above other Bowen Basin bord and pillar mines is consistent with this experience in NSW.

Based on these observations and experience in other mining areas, surface cracking is not predicted above the proposed Mavis Downs South underground area, due to the predicted low levels of subsidence of <50 mm (**Figure 34**).

The main surface feature in the Mavis Downs South area, as detailed earlier, are the small ephemeral lakes formed from a depression in the soil surface in expanding clay soils (gilgai’s). These features could be mistakenly associated with surface subsidence due to underground mining.

4.2.2 Sub-surface Cracking

The nature of the proposed mining method in the Mavis Downs South underground area indicates that the surface subsidence will be due to elastic compression of the strata (Section 4.1.4). The proposed bord and pillar mining methodology does not create areas of caving, which could result in fracturing of the overburden and additional levels of subsidence unless their pre-mining characteristics were documented.

This is confirmed by experience in NSW at Clarence Colliery, which uses partial extraction bord and pillar methods at the north western edge of the Blue Mountains Heritage Area. As detailed by Hill and White (2017[29]), there have been no exceedances of the 100 mm subsidence limit and interaction with the overlying perched groundwater system since partial extraction started in 2003.

4.2.3 Limitations of the Subsidence Predictions

Based on the available data for the proposed Mavis Downs South underground area, there are no localised features or variations in the geology, geotechnical conditions or surface topography that are considered likely to result in any significant deviations from the subsidence predictions presented in this report.

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[28] McTyer, K. and Sutherland, T. (2011). The Duncan Method of Partial Pillar Extraction at Tasman Mine, 11th Underground Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2011, 8-15.

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5 CONCLUSIONS

The key conclusions from this report include:

1. The nature of the mining method generating only elastic compression of the strata indicates that sub-surface cracking in the overburden above the proposed Mavis Downs South underground area is not expected.

2. Due to the low levels of subsidence and associated strains and tilts, no surface cracking is predicted above the Mavis Downs South underground area. This is consistent at other comparable bord and pillar mines in Queensland and NSW.

3. Due to the nature of the bord and pillar mining method, low levels of subsidence, of **less than 50 mm**, are predicted in the Mavis Downs South area as a result of elastic compression of the strata. This magnitude of subsidence is less than the natural ground movements of **up to 50 mm or more** that can occur (IESC, 2015). The low levels of subsidence are not anticipated to extend outside the mining lease.

4. The formation of significant depressions in the surface topography, where ponding of the surface drainage may occur, are not anticipated in the Mavis Downs South underground area due to the predicted low levels of subsidence. This is also consistent with other comparable bord and pillar mines in Queensland and NSW, where ponding has not been observed.

5. Based on mining experience at other bord and pillar mines, the risk of sinkhole subsidence occurring in the Mavis Downs South underground area, where the depth of cover is greater than 60 m, is considered to be without known precedent.

Yours truly,

N.G.Gordon.

Nick Gordon
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6 APPENDIX 1. SUBSIDENCE DATA FOR EACH PANEL – MAVIS DOWNS SOUTH

Panel	Average Depth (m)	Extraction Height in Panel at Average Depth (m)	Extraction Height in Bell Out at Average Depth (m)	Average 0-18 m Roof Strength (MPa)	Average 0-18 m Floor Strength (MPa)	Strata Compression above 18 m x 18 m (solid) Pillars (mm)	Strata Compression above 18 m (solid) Bell Out Pillars (mm)
106	145	4.5	4.5	36	22	44.7	24.7
107	150	4.5	4.5	36	22	46.2	25.6
108	115	4.6	4.6	30	18	41.8	23.1
109	115	4.7	4.7	30	18	42	23.1
100 Mains	135	4.5	4.5	34	20	44.6	24.6

Table 1. 18 m x 18 m Solid Pillars – Mavis Downs South.