SARAJI EAST MINING LEASE PROJECT

Environmental Impact Statement

Appendix B-3
Subsidence Modelling Peer Review

BHP Mitsubishi Alliance

Final Report

Indepent Review of the Subsidence Modelling for the Saraji Underground Longwall Mine

Report No.: AEC010001-AA_Rev 0

May 2022

AECOM

FINAL REPORT

INDEPENT REVIEW OF THE SUBSIDENCE MODELLING FOR THE SARAJI UNDERGROUND LONGWALL MINE

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Report No.: AEC010001-AA_Rev 0

Date: May 2022

Revision	Date	Author	RPEQ Number	Reviewer	RPEQ Number	Issued for
0	28/04/2022	G. Boyd	23508	T. Cartledge	16952	Comment

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1 Introduction

Cartledge Mining and Geotechnics (CM&G) has undertaken a peer review on behalf of AECOM Australia Pty Ltd for subsidence modelling for BMA's Saraji East Project in the Bowen Basin, QLD. CM&G understand that as part of the EIS submission, peer review of the subsidence modelling must be undertaken in accordance with the Independent Expert Scientific Committee (IESC) on coal seam gas and large coal mining development guidelines for 'Monitoring and management of subsidence induced by longwall coal mining activity. The scope of work was for a peer review of the subsidence modelling completed for the project.

Subsidence modelling was undertaken by Geonet Consulting Group (Geonet), and results were reported in "Subsidence Over Longwall Panels Revised Longwall Panel Layout Saraji East Underground Mine for AECOM Australia Pty Ltd" dated February 2022.

CM&G engaged Pharos Mining Consultants Pty Ltd and Boyd Mining to provide support on this project. The findings of their reviews are provided herein.

The scope items to be addressed as part of this review were:

1. Subsidence Modelling Inputs:
    - The review process by which subsidence modelling made provision for including rock mass structures in ground impacted by longwall mining.
    - Assess the adequacy of provisions and impact/importance of rock mass structures on the patterns of subsidence predicted.
    - Note where the patterns/mechanisms of subsidence may impact on surface infrastructure/ features during and following longwall panel extraction.
2. Numerical Modelling Veracity
    - Suitability of the modelling and veracity of the techniques adopted
    - Compliance with the IESC guidelines and industry best practices for longwall subsidence modelling
    - Commentary on modelling results
    - Recommendations for additional work, if required

2 Subsidence Modelling and Inputs

2.1 Modelling Software

FLAC 3D (Itasca) discrete element software was adopted by Geonet to complete the subsidence modelling. Features of this software relevant to subsidence prediction include the following capabilities:

- Time stepping process allowing sequential simulation of mining sequence.
- Full deformation analyses under transient stress changes due to the mining process.
- Modelling of defined geological stratification and rock mass defects using ubiquitous joints for which orientation and surface strength was specified.
- Interrogation of deformation states (elastic/elasto-plastic/plastic) as a function of deformation criteria.

- Mapping of yield states as developed for each grid element and predicted displacements associated with determining yield state.

The model was set up to include the major geological strata with properties that reflected the original pre-mining conditions. The modelled section was then stepped through the following stages to simulate the mining operations:

1. Intact geology brought to equilibrium under applied insitu stress field and gravity.
2. Open-cut mining excavations cut into the model.
3. Longwall panels were excavated according to the scheduled sequence (Geonet Figure 12).
4. Longwall coal extraction to a uniform height of 3.6m.
5. After excavation of each stage, stresses and deformation were equilibrated.
6. Roof rock mass allowed to collapse onto floor of longwall panel.
7. Histories of displacement over the longwall panels were monitored.
8. Changes in surface elevation were calculated at each stage of mining to establish the post-mining topography at that period, viz. Years 2025, 2026, 2028, 2032 and 2042.

The peer review has found the model construction, specifications, and management of outputs to be robust, relevant and considerate of significant gaps in the input data.

2.2 Structural Data Inputs

Structural data available as input to subsidence modelling include:

- Geologically modelled coal seams which defined reserves dip and dip direction across the project area.
- The lithological sequence within the geological stratification.
- Stereonet plots of defect orientations were detected in acoustic down-hole surveys of four deep exploration boreholes (see Geonet Figures 4a and 4b).
- Interpreted fault patterns within two-seam horizons (Harrow Creek_H16 and Dysart_D24/25 Seams; see Geonet Figure 4c).

Interpreted faulting in the two horizons was limited to a small area of reserves with the persistence of faults (vertically and horizontally) and geotechnical properties of faulted ground not known. Therefore, no significant database on faulting merited explicit inclusion in the model.

Similarly, no database on joint spacing and surface conditions was available for the variety of strata compositions in the vertical geological sequence. However, defect orientation analysis from downhole acoustic logging had identified two prominent joint orientations (dip and strike). This data, coupled with the dip and dip direction of the geological strata over all the panels, helped define:

- The orientation of prominent joint sets over the project area, and
- Orientation of any bedding plane partings across the reserves.

These are the dominant features controlling the mobilisation of rock mass strength and in some instances, control the patterns of subsidence over long-walled panels.

2.3 Provisions for rock mass structures in modelling

Prominent structural features can be modelled in FLAC 3D either explicitly (location, orientation, extent, and strength properties coded into the model) or implicitly (represented by the functionality of the code). Structures modelled implicitly used the code functionality of ubiquitous joints (uj's), which are planar defects of specified orientation, surface strength and stiffness embedded throughout the model or portions of the model where specified. Therefore, the provisions for modelling structures throughout the model adopted:

- No explicit modelling of structures.
- All structures modelled implicitly using uj's representing bedding plane partings aligned with the dip and dip direction of geologically modelled strata making up the overburden
- Rock mass jointing orientated as per vertical borehole survey results with dips set at 80^o +/- 10^o and trends of 069^{o}T and 169^{o}T for the two joint sets recognised.

Orientated bedding partings (BP) and two joint sets (J1, J2) were randomly distributed through the model zones (grid cells) in the ratio (BP:J1:J2::40%:30%:30%).

Strength parameters assigned to structures were set at 10% of the intact cohesion strength and slightly reduced friction values with a tensile strength on ubiquitous joints set at 10 per cent of the reduced cohesion strength.

The specification of bedding plane partings and ubiquitous joints honoured:

- The geological stratification over the mineable reserves
- The measured orientation of defects from borehole surveys, and
- The known trend of faults intersecting two-seam horizons.

These provisions are considered realistic and in the absence of more detailed information on the rock mass structures prevailing over the project area. It is further considered the provisions represent some conservatism in the results of the modelling.

2.4 Review Queries and Responses

Boyd Mining submitted certain queries relating to the representation of rock mass structures in the FLAC 3D model. These were addressed by Geonet with the following summary responses; the full response By Geonet is appended to this report.

2.4.1 *Re: Tertiary strata deformation and water tightness*

The clay-rich Tertiary strata, some 30m to 65m deep at the surface, were modelled with specified strength and yield parameters consistent with an overconsolidated clay; ubiquitous joints embedded in Tertiary strata provided a proxy for the development of fissures commonly developed in deep Tertiary strata throughout the Bowen Basin (but not verified for the SEML project area).

Full subsidence over the supercritical panels LW101 to LW104 and LW201 to LW202 was predicted with the implication of subsidence cracking significantly increasing the potential for surface water infiltration and for "flooding" the underground workings.

Deformation predicted from FLAC modelling was for widespread shear failure, and the material reduced to a plastic deformation state. However, on the near-surface, the drier, hard to very hard overconsolidated clays could result in deep tension cracks, the extent of which might be discernible from further interrogation of the FLAC 3D results.

On further interrogation of deformation styles in the Tertiary cover, Geonet concluded shear failure throughout the strata with peak vertical shear failure over the abutment edges of each panel is likely to manifest as vertical cracking. However, Geonet also concluded; any moisture ingress would result in "self-sealing" of the clay-rich strata and limit vertical infiltration capacity.

2.4.2 *RE: Emulation of more persistent rock mass structures, i.e. faults*

If shear stresses determined at any point align or co-align with ubiquitous joint orientations, then "failure" along adjacent networks of joints and partings will develop "step-path" mechanisms for failure propagation in a manner commonly observed in mine pit faces, and exposures of underground caved strata.

The "random" generation of uj's (within narrow ranges of dip and dip directions) adopted in the modelling allows combinations of deformation and failure of the intact rock and/or yield along partings and joints to mimic the presence of more persistent features such as faults occurring with similar trends. In this way, the model provides adequate proxies for the presence of faults.

2.4.3 *RE: Variation in ubiquitous joint strengths on rock mass strength*

Given Geonet used rock and soil strength parameters consistent with industry experience, the impact of actual parameter values lying outside this range and the impact on subsidence patterns was raised with the following response.

The constitutive law governing load response on ubiquitous joints is essentially the Mohr-Coulomb criterion which yields an "elastic/perfectly plastic" stress-strain response. Provided the appropriate relative strength on defects to intact strata is set, this response acts to progressively soften the overall material strength so as to yield an "elasto-plastic" stress-strain response for the rock mass. Cumulative vertical components of strain so generated gave estimates of the vertical subsidence. The more competent the rock mass (intact and jointed) the lower the cumulative vertical strain and hence, subsidence.

Boyd Mining concludes the model has adequately recognised these relativities erring, if anything, on the conservative.

2.4.4 *RE: Impact on modelled structures on subsidence patterns*

Measured defect orientations from borehole surveys coupled with fault orientations "mapped" from exploration data co-aligned with planned longwall panels' long axes. This promotes the alignment of any yield in the rock mass to the defect orientation. Hence, the" tight" patterns of subsidence within the panel footprints as expected and the constrained extent of subsidence outside the panel footprints.

It was noted that both northern and southern panels and the modelled joint orientation (J2) align with major (Basin) tectonic faults to the immediate northeast of the project area. Therefore, the pattern and aerial extent of subsidence is consistent with these features.

2.5 Potential impacts of subsidence on surface infrastructure

The brief called for the peer review to raise concerns about damage to surface infrastructure or features because of the predicted subsidence. This review has noted two areas of concern:

1. Damage to the Hughes Creek channel and risk of drainage into underground workings
2. The proximity of current open-cut boundaries to the startup panels impacting underground ventilation circuits.

The Hughes Creek diversion and alignment across most northern panels will result in subsidence along the creek course of between 3.4m and 0.1m. Boyd Mining estimates this will result in subsided creek bed levels lying 1.2m to 1.5m below the level of the downstream non-subsided creek bed (see Figure 3.1).

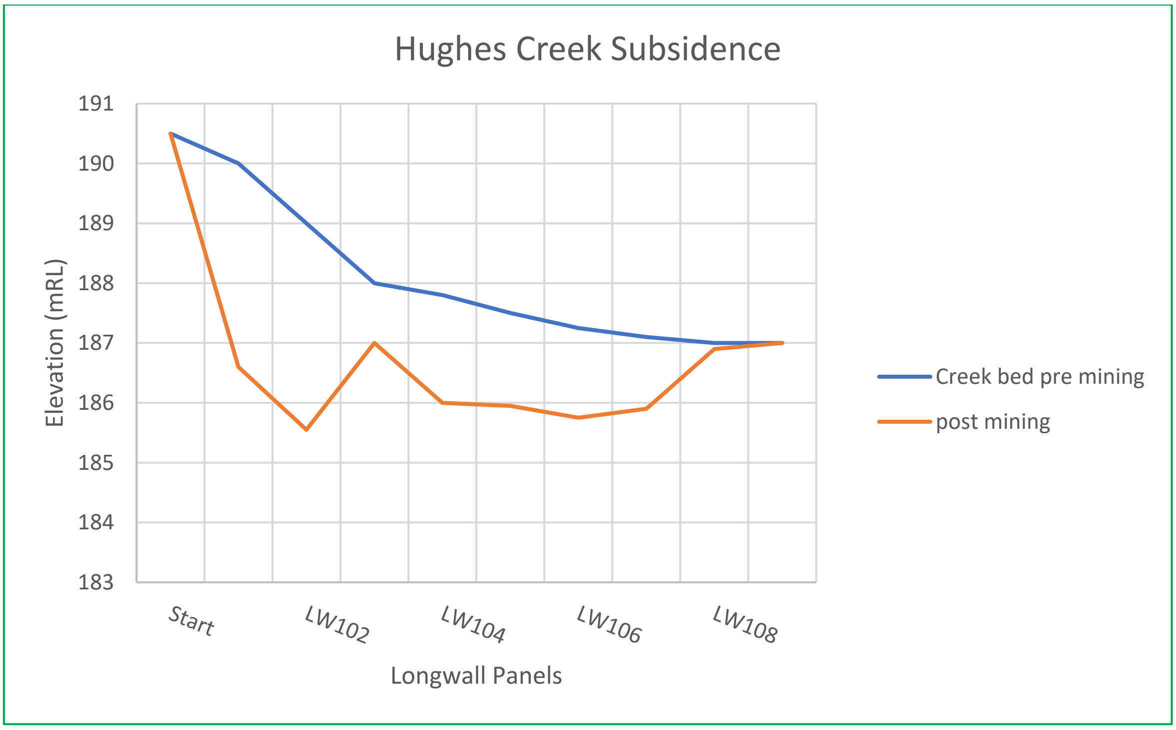

Figure 3-1: Creek bed levels post subsidence

As a result, the concern is for:

- Elevated flow volumes through the enlarged channel dimensions represent the potential for high levels of vertical infiltration into underground workings.
- The risk of flooding of underground workings unless it can be shown the clay-rich composition of Tertiary strata up to 30m thick will soften and self-seal on expansion due to moisture absorption of the clay composition.
- Impounded water over subsided creek beds in early panels is available to drain sequentially into subsequently subsided zones and associated cracking before self-sealing of clay compositions can occur.

The risks for flooding of surface drainage, particularly over the supercritical panels, will depend on the vertical conductivity through Tertiary strata and the degree to which moisture softening and swelling of clay compositions on moisture ingress will reduce vertical conductivity. Current subsidence modelling has defined bulk hydraulic conductivities for all overburden to assess vertical infiltration rates. Equally important is further assessment of Tertiary clay soils' mechanical and physical properties over the range of moisture contents from dry to saturated.

Panels LW101, LW102 and LW201 will be located to adjacent final open-cut pit walls. The rock mass behind the final pit walls will be damaged by blasting and by relaxation toward the open cuts for a distance of at least 1.5 times the final pit wall height. Coupled with cracking and dilation of the rock mass impacted by subsidence, the network of open airways so created may adversely impact ventilation networks in the underground mine and the ready escape of fugitive gasses.

3 Numerical Modelling Veracity

3.1 Suitability of Modelling and Veracity of Techniques Adopted

1 The finite-difference numerical method (FLAC3D) adopted in the analysis is suitable for modelling mine subsidence. Numerical modelling methods are generally accepted in the industry for predicting mine subsidence, particularly in greenfield mine sites where limited site-specific experience (monitoring data) is available. Furthermore, both numerical and empirical methods are acceptable for predicting mine subsidence as per IESC Guideline "Monitoring and Management of Subsidence Induced by Longwall Coal Mining Activity"

2 Model construction and sequencing generally follow best practice numerical modelling procedures. The roller boundary conditions applied to the sides of the model are suitable for simulating deformation in the overburden, and the model is large enough to mitigate any edge effects. Furthermore, the model allows the collapse of the rock mass onto the floor of the longwall, which is desirable to simulate caving and goaf compaction. Excavation in the model is sequenced (staged) with stresses and deformations equilibrated after each excavation stage which is also best practice.

3.2 Compliance with IESC Guidelines and Industry Best Practice for LW Subsidence Modelling

1 As stated above, the finite difference numerical method (FLAC3D) adopted in the analysis is suitable for modelling mine subsidence. Numerical modelling methods are generally accepted in the industry for predicting mine subsidence, particularly in greenfield mine sites where limited site-specific experience (monitoring data) is available. Furthermore, both numerical and empirical methods are acceptable for predicting mine subsidence as per IESC Guideline "Monitoring and management of subsidence induced by longwall coal mining activity."

2 When numerical modelling methods are used, it is engineering best practice to "calibrate" the model or benchmark the modelling results against some available empirical data. While it is accepted that Saraji East is a greenfield mine without any site-specific subsidence monitoring data. It is also noted that the Bowen Basin has a reasonable amount of empirical subsidence data from surrounding mine sites that can and should be used to benchmark/calibrate the numerical modelling results. The data covers a range of mining geometries, geology, and geotechnical conditions in the Bowen Basin.

3.3 Commentary on modelling results

1 At first glance, the subsidence factors seem to be on the high side. Using LW201 and LW101 as an example, the subsidence factors are 0.75 and 0.94, respectively. This means that the resulting subsidence is between 75% and 94% of the extraction height of 3.6m. Both LW panels are supercritical (W/H > 1.4), and therefore, maximum possible subsidence is expected to occur. From empirical (field observations) of supercritical panels, the subsidence factors generally range between 0.55 and 0.65. in other words, the resultant subsidence is typically between 55% and 65% of the extraction height.

2 One possible explanation for the relatively "high" subsidence factors is weak overburden rock mass that caves readily and thereby increasing subsidence magnitude

(subsidence factor). Based on the rock mass derivation, which estimates the strength of the Permian strata to be between 3MPa and 10MPa, then the rock mass would be classed as relatively weak. Due to the low strength of the rock mass, goafing in some areas would be expected to extend further up into overburden (through the Permian strata and up into the Tertiary sediments). Some of the modelling results also indicate this and are therefore consistent with expectations. In the case of LW101 with subsidence of factor of 0.94, the relatively wide panel(320m) at shallow depth(140m) likely contributed to the high subsidence factor as well.

3. Of course, the depth of cover also influences the subsidence magnitude. The modelling indicates that subsidence factors decrease with an increase in depth of cover as the LW panels become critical/subcritical at depths ≥300m. This is consistent with known and observed (field) LW subsidence behaviour.

4 Conclusions and Recommendations

4.1 Subsidence Modelling Inputs

Results of subsidence modelling by Geonet Consulting Group and reported in March 2022 (with addendums) have suitably provided for small and potentially larger-scale geological structures in the features available to the FLAC 3D modelling software. These features have been employed to represent joints, bedding partings and perhaps local (upright) faulting in orientations consistent with limited field data available and with trends of major Basin structures adjacent to the project area.

The degree and patterns of subsidence over the proposed mine area follow expectations given the:

1. Co-alignment of panel orientations with small- and large-scale structural trends.
2. The setting of reasonable relativities between estimated intact rock strength and the strength of modelled rock mass defects.

Subsidence following the mining of each panel will result in the Hughes Creek bed lying at lower elevations than the creek course beyond the mine area. As a result, the creek bed will take increased flows during run-off events and pond water following such events. It is possible the creek bed comprising Tertiary clay soils will swell on wetting and deep moisture ingress to limit vertical infiltration into underground workings. The capacity for this to occur will depend on the degree of vertical cracking of the 30m+ deep Tertiary clay soils particularly over super critical panels where the maximum calculated subsidence is predicted to continue to the ground surface. It is recommended appropriate soils classification testing be completed for Tertiary clay soil samples extracted over the full depth of the strata to define:

- Soil plasticity limits
- Linear shrinkage and
- Swell index tests

More detailed testing might include confined strength testing to test for swell potential under low normal loads.

4.2 Modelling Veracity

1 When numerical modelling methods are used, it is engineering and industry best practice to try to "calibrate" the model or benchmark the modelling results against some available empirical data. While it is accepted that Saraji East is a greenfield mine without any site-specific subsidence monitoring. It is also noted that the Bowen Basin has a reasonable amount of empirical subsidence data from surrounding mine sites that can and should be used to benchmark/calibrate the numerical modelling results. The data covers a range of mining geometries, geology, and geotechnical conditions.

   i **It is therefore recommended that the results of the numerical modelling be benchmarked against available empirical subsidence data from surrounding mines in the Bowen Basin. The benchmarking exercise need not be exhaustive, just needs to include a relevant (some similarities) data sample.**

   ii **Plot numerical results (subsidence, subsidence factors, strain etc.) against empirical data for comparison and provide brief commentary on observations.**

2 It is expected that the rock mass stress strength of the overburden will have a significant influence on subsidence magnitude. All things being equal, a relatively "weak "overburden is likely to result in goafing extending further up into the overburden and therefore increasing subsidence. The opposite is true, a slightly "stronger" overburden is likely to result in reduced subsidence.

   i **It is therefore recommended that a sensitivity analysis using the range of derived rock mass strengths (low, average, and high) be undertaken.**

   ii **Report the subsidence results (range) for the three scenarios (low, average, and high) and provide brief commentary on observations.**

3 The width of LW201 (southern panels) has been reduced to 220m at shallow depths ranging between 120 and 130m. It is assumed that this was done to reduce subsidence (subsidence factors) and minimise subsidence impact on adjacent Hughes Creek. Even with the reduced panel width, modelling indicates a subsidence factor of 0.75, which might be high, considering the adjacent Hughes Creek. Not sure of the exact location or extent of Hughes Creek, it is possible that it is outside of the influence of LW201.

   i **It is therefore recommended that a review of potential subsidence impacts/if any, on Hughes Creek resulting from the extraction of LW201. The aim should be to determine acceptable subsidence thresholds/tolerances minimise the impact on the creek. Should thresholds not be met, consider modifying the mine plan (i.e., further reducing LW201 panel width). Not sure of the exact location or extent of Hughes Creek, it is possible that it is outside of the influence of LW201**

Appendix A: Geonet Response

GEONET *Consulting Group*
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Mining Geomechanics and Materials

A.B.N. 40 056 752 606

27 March, 2022

The Minserve Group Pty Ltd Level 6, 200 Adelaide Street, Brisbane City QLD 4000	AECOM Level 8, 540 Wickham Street, Fortitude Valley QLD 4006

RE: SUBSIDENCE MODELLING: SARAJI EAST COAL MINE PROJECT

In response to your email of 25 March 2022, it was requested to provide a response to the following queries that have arisen with regard to the peer review process:

1. Demonstrate inclusion of tertiary layer in modelling to understand impacts at surface, particularly to Hughes Creek and Boomerang Creek.
2. Further detail on use of ubiquitous joints in the FLAC 3D model to represent small and large (persistent) structures (e.g. bedding planes and joints).
    a. How the model generated UJs and associated strength and orientation as a function of rock type.
    b. Whether the specifications could emulate more persistent rock mass structures.
    c. Observed impact of variations in ubiquitous joint specifications on rock mass strength.
    d. Possible impact on patterns of subsidence as a result.
3. Tilt/slope predictions – to cover all three deformation parameters (subsidence, strain, tilt).

I have addressed each of these queries in the order as presented in your email.

1. Demonstrate inclusion of Tertiary layer in modelling

The Tertiary sediments are included explicitly in the model as is shown in Figure 1. In the original report the stratum was not shown in the geology plots as Tertiary was identified under a different slot name in the model.

I note also that I omitted to include the assigned material properties in Table 3.1 in the report. This will be corrected in the final report. But for the record the updated tabulation of data is shown in Table 1 below. The source of these properties is my personal database.

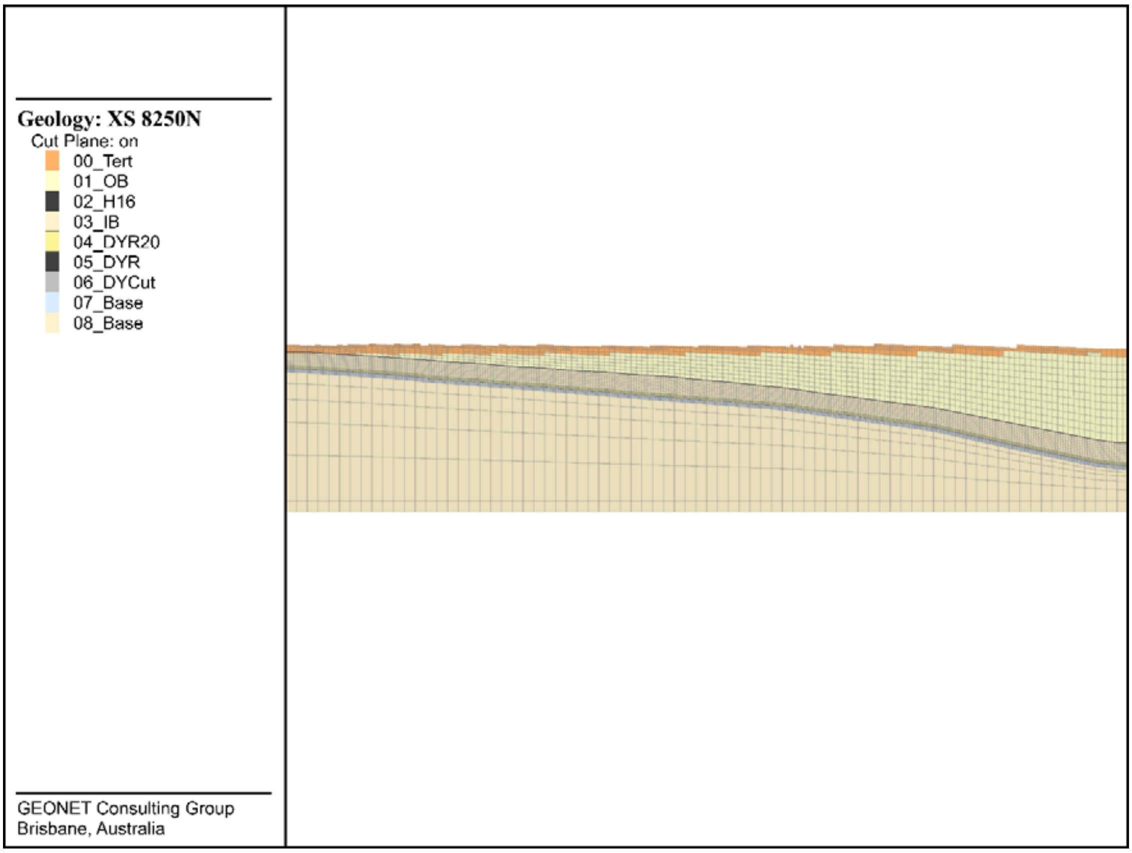

Figure 1: Geological units included in the geotechnical model

Table 1: Material properties for the principal rockmass units

	Input		Intact Properties			Rockmass Properties			
Rock Type	**GSI**	**UCS (MPa)**	**Cohesion (MPa)**	**ϕ (o)**	**s**	**UCS_rm (MPa)**	**coh_rm (MPa)**	**E_rm (GPa)**	***v*_rm**
Tertiary Seds	45	9.39	2.60	32	0.002218	0.44	0.123	2.30	0.253
01_OB	69.4	39.80	11.03	32	0.033373	7.27	2.015	19.273	0.216
02_H16_Coal	65	22.50	5.01	42	0.020468	3.22	0.717	11.248	0.223
03_IB	73	42.00	11.64	32	0.049787	9.37	2.597	24.357	0.211
06_DY_Coal	74	22.50	5.01	42	0.055638	5.31	1.181	18.884	0.209
07_Base	78	43.50	9.46	43	0.086774	12.81	2.786	33.056	0.203

2. Application of ubiquitous joints in FLAC 3D to represent structural elements

2.1 Creation of UJs and associated strength and orientation as a function of rock type

In this project there was limited structural data pertaining to individual rockmass units of the overburden strata and coal seams. I have used the most representative data sets available for cleat measured in the Dysart seam and joints in overburden. I further assumed that the correlation between overburden joint sets and coal cleat indicated a structural imprint associated with a single tectonic event. As such, it is the same joint sets which pervade the Dysart coal seam and Permian overburden strata. The data set was presented in a pole plot diagram in the original report as Figure 4(a), reproduced below as Figure 2.

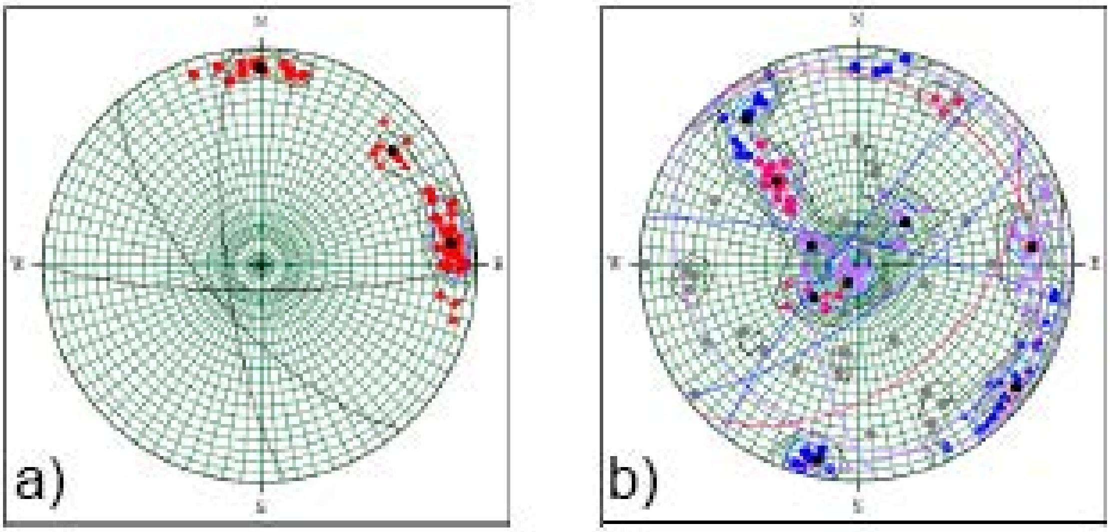

Figure 2(a): Coal cleat and 2(b) Joint set orientations

In the model it was assumed that the two joint sets and bedding planes were distributed randomly throughout the model zones in proportion of 30% allocated to J1 and 30% to J2 with the remaining 40% of zones assigned bedding plane orientations. The orientation of the bedding planes mimicked the dip and dip direction of the coal seam roof at the location of the zone.

The strength properties of cohesion and tensile strength assigned to the ubiquitous joint in each zone is one tenth that of the intact material strength. The assigned friction angle on the ubiquitous joint is typically a couple of degrees less than that of the intact material. Similarly, for the dilation angle.

Ultimately, the rockmass deformation behaviour will be governed principally by the stiffness and shear strength parameters assigned to the intact material and not the ubiquitous joints.

2.2 Whether the specification could emulate more persistent rock mass structures

If fault surfaces had been provided by the client then these could have been included in the model by aligning the ubiquitous joints in the plane of the fault. The fault mapping that was available (Figure 4(c) in the original report) showed that there were no major faults transecting the proposed mining layout.

The ability of the distributed UJs to respond to formation of large scale persistent mining induced fractures is intrinsically embedded in the code. If shear stresses are aligned to form a fracture in (or close to) the plane of UJ then the UJ will shear accordingly. However, if the insipient shear plane is intersected by a UJ which is normal (or at a high angle) to this shear plane then the code will interrogate the magnitude of the shear stresses in relation to the intact material properties. If these stresses are sufficient to fail the intact material in that zone then the condition of that zone will be updated to indicate the failure.

In effect the distribution of randomly orientated UJs in the model grid creates the environment for a step-path mechanism of failure to develop through the rockmass. Note also that application of the ubiquitous joint constitutive model allows for structurally controlled failure to evolve in the rockmass. A mechanism of structurally controlled failure cannot evolve if a continuum Mohr-Coulomb or Hoek-Brown constitutive model is used.

2.3 Impact of variations in ubiquitous joint specifications on rock mass strength

To fully address this question is a PhD thesis and beyond the scope of work for this project.

The ubiquitous joint constitutive law is essentially the Mohr-Coulomb criterion with an embedded criterion to test for resolution of the principal stresses in relation to the orientation of the assigned UJ. If the orientation of the UJ plane is aligned so as to mobilise shear on that plane then this will be recorded. In effect the zone could yield on the UJ prior to the intact strength being exceeded. Alternatively, if the UJ is orientated normal to the principal stress then it will not be mobilised but the criterion will test for the principal stress in relation to the assigned intact shear strength properties.

In a model of the rockmass I assign UJs according to the measured joint set distribution. In sedimentary rocks the bedding planes are typically more abundant than the conjugate joint set; and mudstones are typically more laminated than shales which in turn have a greater proportion of bedding than competent sandstone strata. I assign the proportions of joint sets based on my assessment of the insitu rockmass conditions from borehole logs.

The Mohr-Coulomb criterion yields an "*elastic perfectly plastic*" stress-strain response. Within a zoned rockmass the presence of UJs in proximity to the developing shear localisation will be to gradually soften the overall material response so as to yield an "*elasto-plastic*" stress-strain response.

2.4 Possible impact on patterns of subsidence as a result

The choice of material properties assigned to the intact material and ubiquitous joints has a profound effect on the predicted subsidence. The values specified rely on my experience and engineering judgement with regard to the interpretation of laboratory test results, the geology and the numerical modelling methodology.

For the record, the model for Saraji Mine was run six times with different material properties assigned to the various strata before I was satisfied with the results. I do not consider it prudent to present the results from the various analyses. The results presented in my report stand as testament to my professional judgement.

3 Tilt/slope predictions – to cover all three deformation parameters (subsidence, strain, tilt).

The scope of work for this study explicitly stated the purpose of the report was to predict the subsidence that may develop following longwall mining of the design provided.

In such a greenfield prefeasibility study, subsidence is the key element of interest with respect to the anticipated environmental impact. This refers specifically to the vertical displacement of overburden strata to surface above the mined longwall panels.

Tilt is the first derivative of the subsidence profile, calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is really only reported when assessing the effect of subsidence on structural damage to buildings and infrastructure. It is not of any value for assessment of changes to greenfield topography. Similarly for strain measurements.

Notwithstanding this last statement, what will be of primary interest to this stage of environmental assessment is the effect of subsidence on the overall groundwater characteristics of the overburden. Hence, I have included in the report a thorough presentation of the distribution of volumetric strain induced in the rockmass. This parameter has the most significant influence on rockmass permeability and porosity, properties which are essential for downstream groundwater studies.

Yours faithfully,

GEONET *Consulting Group*

Ian Clark

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Principal Consultant, Director

Appendix B: AECOM Response

1.0 Subsidence Modelling Peer Review Recommendations

Cartledge Mining and Geotechnics (CM&G) has undertaken a peer review on behalf of AECOM Australia Pty Ltd for subsidence modelling for BMA's Saraji East Mining Lease Project in the Bowen Basin of Queensland.

CM&G understand that as part of the EIS submission, peer review of the subsidence modelling must be undertaken in accordance with the Independent Expert Scientific Committee (IESC) on coal seam gas and large coal mining development guidelines for 'Monitoring and management of subsidence induced by longwall coal mining activity. The scope of work was for a peer review of the subsidence modelling completed for the project.

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2. Numerical Modelling Veracity

- Suitability of the modelling and veracity of the techniques adopted
- Compliance with the IESC guidelines and industry best practices for longwall subsidence modelling
- Commentary on modelling results
- Recommendations for additional work, if required

On this basis, the peer review made the following recommendations. A response is provided for each recommendation.

1.1 Peer Review recommendation 1

When numerical modelling methods are used, it is engineering and industry best practice to try to "calibrate" the model or benchmark the modelling results against some available empirical data. While it is accepted that Saraji East is a greenfield mine without any site-specific subsidence monitoring. It is also noted that the Bowen Basin has a reasonable amount of empirical subsidence data from surrounding mine sites that can and should be used to benchmark/calibrate the numerical modelling results. The data covers a range of mining geometries, geology, and geotechnical conditions.

a. It is therefore recommended that the results of the numerical modelling be benchmarked against available empirical subsidence data from surrounding mines in the Bowen Basin. The benchmarking exercise need not be exhaustive, just needs to include a relevant (some similarities) data sample.

b. Plot numerical results (subsidence, subsidence factors, strain etc.) against empirical data for comparison and provide brief commentary on observations.

The underground mine plan modelled reflects a conceptual layout based on currently available exploration data and current progress of open cut mining. During the detailed design process and operational mining, new site-specific geological and geotechnical data, open cut mining progress and/or subsidence monitoring results will inform modifications to the underground mine plan and mining geometries.

Subsidence modelling of the underground mine plan predicted subsidence factors ranging from about 0.75 (LW201) to 0.94 (LW101) in the western panels indicating maximum possible subsidence is expected to occur. These findings are supported by rock mass derivation estimates of strength of the Permian strata between 3-10 MPa, which classify the rock mass as relatively weak with potential to extend goafing higher increasing subsidence magnitude. Depth of cover also influences subsidence magnitude; with shallow depth (140 m) of overburden above these longwall panels consistent with known and observed subsidence behaviour in the region.

The Peer Review states the predicted subsidence factors are higher than the typical range of 0.55 and 0.65. According to the Management and monitoring of subsidence induced by longwall coal mining activity (Commonwealth of Australia, 2015), subsidence factors in the Bowen Basin may approach 0.90.

Subsidence factors derived for measurements in the Bowen Basin were presented in the EIS for Lake Vermont Meadowbrook and Project China Stone (the same dataset in both reports). The figure reproduced as Figure 1 shows the average is around 0.65; however, the observed factors range from below 0.5 to 0.8.

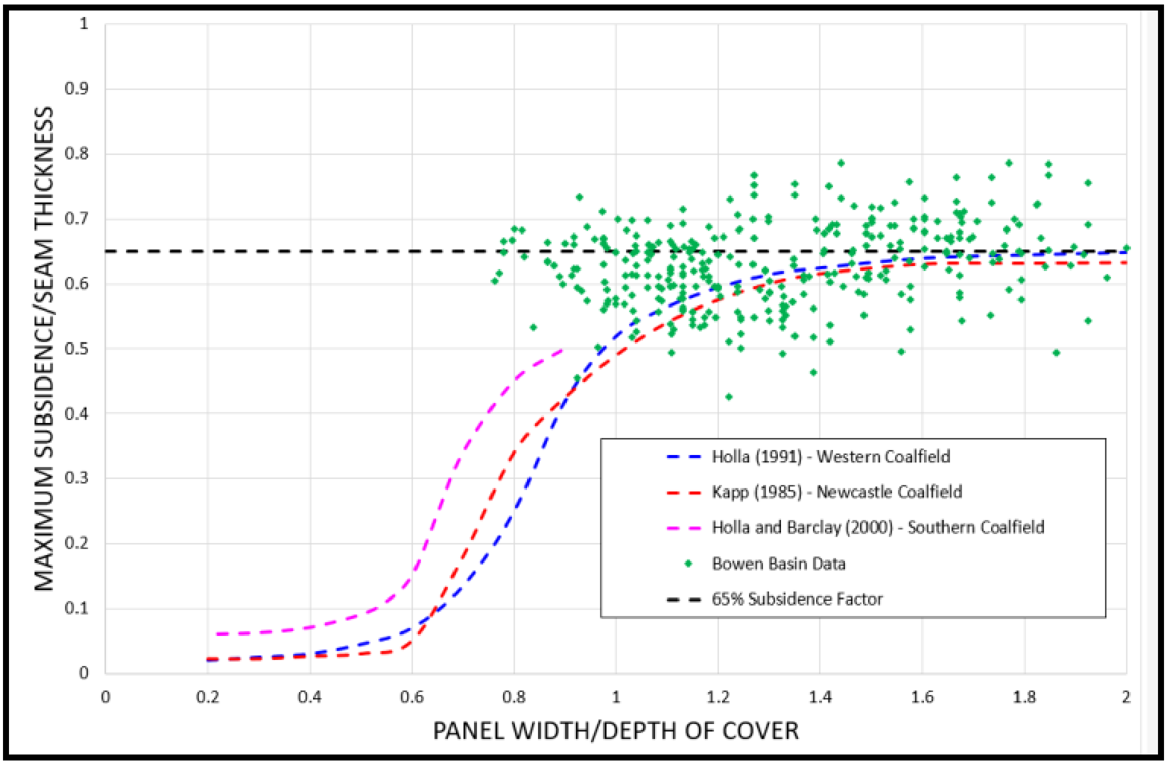

Figure 1 **Sag Subsidence over Single Longwall Panels in Virgin Ground(Gordon Geotechniques, 2022)**

Subsidence predictions depend on the seam height as well as the subsidence factor. As seam height may change between projects, there will be less similarity between similar projects than for subsidence factor. For mining a 3.6 m coal seam, the predicted subsidence of 2 m to 3.5 m for the Project is within the range of values predicted in other EIS for surrounding mines:

- 0.9 m – 1.3 m (sub-critical) for Grasstree Extension (2017)
- 1.5 m – 2.5 m for South Galilee Coal Project (2012)
- 2.9 m – 5 m for Lake Vermont Meadowbrook (2022)
- 3.9 m – 6.4 m for Red Hill (2011).

When benchmarked against empirical subsidence data and results of surrounding mines in the Bowen Basin, the predicted subsidence associated with the Project is representative of underground longwall mining of shallow coal seams.

Based on the findings presented by the subsidence modelling, the EIS proposes an adaptive management strategy responding to routine subsidence monitoring and reporting during operations. The EIS outlines the pre- and post-subsidence monitoring methodologies, parameters and frequencies in Section 6.0 of the Subsidence Management Plan (Appendix K-2). The landform, surface water and ecology monitoring programs include parameters to assist in the early identification of greater than expected rate of change or decline (e.g. waterway channel slope, scouring and erosion on waterway bed/banks, presence of cracks and erosion features, riparian vegetation condition). Aerial LiDAR will be flown annually to validate predictions and help mitigate future impacts.

Changes to the mining schedule or layout during operations (which may mean actual subsidence differs from the predicted subsidence) will also be assessed using the adaptive management approach.

1.2 Peer Review recommendation 2

It is expected that the rock mass stress strength of the overburden will have a significant influence on subsidence magnitude. All things being equal, a relatively "weak "overburden is likely to result in goafing extending further up into the overburden and therefore increasing subsidence. The opposite is true, a slightly "stronger" overburden is likely to result in reduced subsidence.

a. It is therefore recommended that a sensitivity analysis using the range of derived rock mass strengths (low, average, and high) be undertaken.

b. Report the subsidence results (range) for the three scenarios (low, average, and high) and provide brief commentary on observations.

Rock mass stress strength of the overburden has a significant influence on the magnitude of subsidence. However, it is well established that rockmass strength is scale dependent and typically relates towards the weakest measurement in laboratory tests.

The subsidence modelling presents rock mass derivation estimates of strength of the Permian strata between 3-10 MPa, which classify the rock mass as relatively weak with potential to extend goafing higher increasing subsidence magnitude.

Rock mass properties examined and derived in context of measured coal strata rock types in Figure 6 of Section 3.4 (Rockmass Properties) – refer blue highlights on Figure 2 below. Project rock mass properties selected represent worst case conditions for relevant rock types. Accordingly, these property values represent site conditions; a sensitivity analysis is not required.

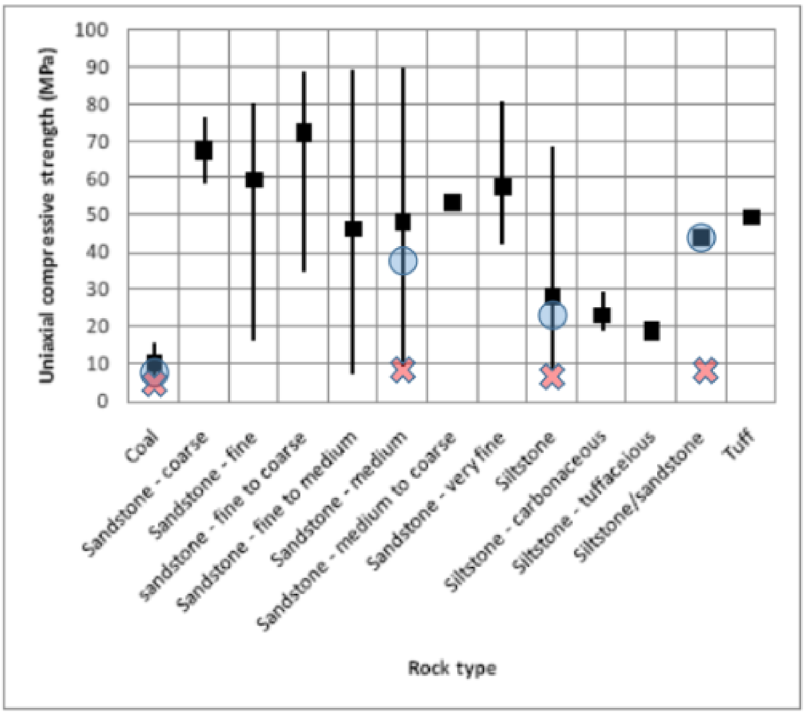

Figure 2 Compressive strength of various rock mass properties

1.3 Peer Review recommendation 3

The width of LW201 (southern panels) has been reduced to 220 m at shallow depths ranging between 120 m and 130 m. It is assumed that this was done to reduce subsidence (subsidence factors) and minimise subsidence impact on adjacent Hughes Creek. Even with the reduced panel width, modelling indicates a subsidence factor of 0.75, which might be high, considering the adjacent Hughes Creek. Not sure of the exact location or extent of Hughes Creek, it is possible that it is outside of the influence of LW201.

a. It is therefore recommended that a review of potential subsidence impacts/if any, on Hughes Creek resulting from the extraction of LW201. The aim should be to determine acceptable subsidence thresholds/tolerances minimise the impact on the creek. Should thresholds not be met, consider modifying the mine plan (i.e., further reducing LW201 panel width). Not sure of the exact location or extent of Hughes Creek, it is possible that it is outside of the influence of LW201

Proposed response:

Panel 201 lies close to the LOX zone and adjacent to disturbance associated with the open cut mining. The underground mine plan modelled assessed in the EIS reflects a conceptual layout based on currently available exploration data and progress of open cut mining in 2016. Accordingly, this was defined as the assessment scenario for purpose of the EIS when commissioned in 2016.

Prior to development of the Project, the underground mine plan will be reviewed and revised to accommodate the progress of open cut mining; where panel 1 is removed, the resulting mine plan has potential to avoid and minimise impacts to Hughes Creek.

During the detailed design process and operational mining, new site-specific geological and geotechnical data, open cut mining progress and/or subsidence monitoring results will inform modifications to the underground mine plan and mining geometries.