APPENDIX H

HIGHWALL MINING ASSESSMENT & DESIGN RESPONSE TO PAC REVIEW REPORT

GEONET *Consulting Group*
124 Ironbark Road
Chapel Hill
QLD 4069
Australia

Tel: (07) 3878 1152
Mob: 0400 939 728
Email: geonetcg@ozemail.com.au

Mining Geomechanics and Materials Engineering

A.B.N. 40 056 752 606

23 January, 2013

Coalpac Pty Ltd
42 Morrow Street
Taringa
QLD 4068

Attention: Ian Follington, Bret Leisemann

Dear Ian & Bret,

RE: REVIEW OF COAL UCS DATA: INVINCIBLE COLLIERY

Thank you for inviting GEONET to review the Invincible Colliery coal strength data measured by Maquarie Geotechnical Laboratory. Your specific request was to review the coal strength data in relation to the material properties input used for the geotechnical modelling of the Coalpac Consolidation Project.

In this letter report the method of estimation of the coal strength used in the original analysis is summarised [1]. Then the updated laboratory testing data will be analysed. Finally a discussion of the new data will be made in relation to the original input parameters.

Original Estimation of Coal Mass Strength

Material properties for the various coal seams are required to analyse stability of coal pillars formed during SHM highwall mining. Since no specific mechanical strength data was available for any of the coal seams an estimate of the typical composite coal seam strength was made based on the strengths of the different coal types and stone bands logged within corresponding seam horizons at Ulan Mine.

Generally the strength of coal in these strata is competent with unconfined compressive strengths in the range 15 MPa to 20 MPa [2]. However, given the shallow cover depths in some areas and the generally deeply incised topography it was estimated that the coal mass strength should be reduced from the intact unconfined compressive strength.

The actual peak strength of the composite coal seam depends on its geometry, particularly the width to height ratio. In a previous report the stress-strain behaviour of Irondale coal was simulated for a pillar with W:H=0.5. The modelled result predicts the limit of elastic behaviour stress at 7.0 MPa and the peak strength at 8.2 MPa. The lower bound value of 7.0 MPa represents the limit beyond which time dependent deformation will occur. For long term stability it is recommended to design pillars which remain within the limit of elastic deformation.

Visual inspection of the Moolarben seam exposures suggests that the coal is similar in its strength attributes as the Irondale seam. The Lithgow seam has a well developed section of bright coal and a substantial section of stone. Based on the geological log, the seam strength was simulated to show the limit of elastic behaviour at 7.2 MPa and the peak strength at 7.5 MPa, Figure 1(a).

Based on the simulated strength of the different coal seams it is concluded that their seam strength properties (as represented by the limit of elastic behaviour) are all similar at about 7 MPa. However, previous experience with a pillar failure in CHM mining panels at Ulan Mine back-analysed the seam strength (i.e. W:H=0.5) to 5.9 MPa [3]. This is in contrast to the original design strength estimate of 8 MPa [4]. Since the Ulan coal is effectively an extension of the Lidsdale/Lithgow seam and the coal seams in the current project area may be affected locally by previous underground mining, it was considered that the SHM design should be based on a lower bound coal mass strength of 6 MPa.

Figure 1(b) shows the simulated strength that was used for coal seams in the Coalpac Consolidation Project mining area. The coal strength (as represented by the limit of elastic behaviour) is 6.0 MPa and the peak strength is 6.2 MPa. The post peak behaviour is notably strain softening down to a residual strength of 2.4 MPa.

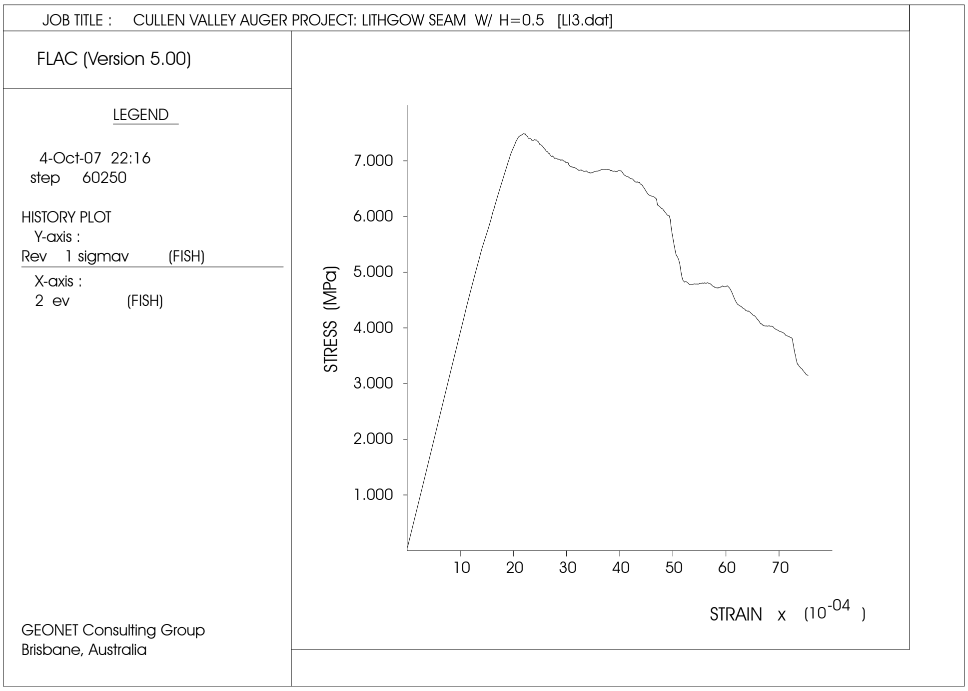

Figure 1(a): Simulated Lithgow coal seam stress-strain behaviour W:H=0.5

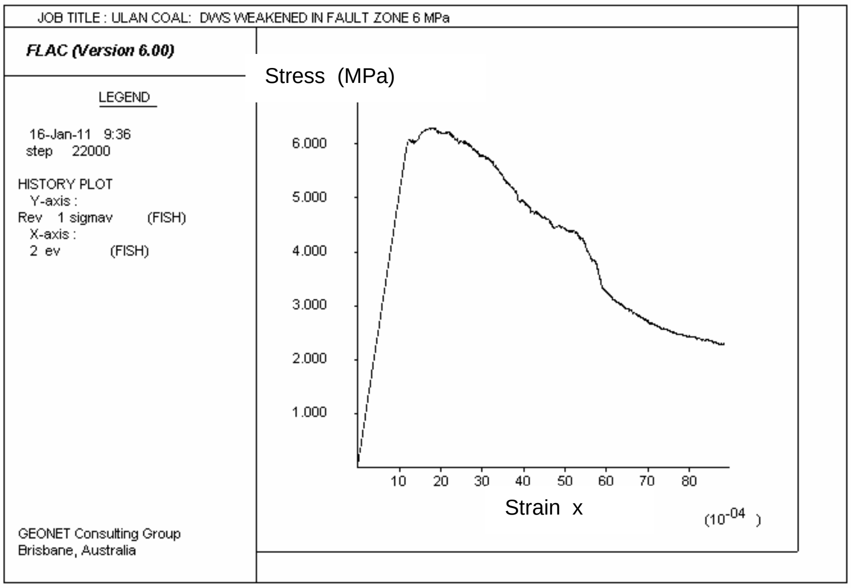

Figure 1(b): Simulated coal seam stress-strain behaviour W:H=0.5

Review of Invincible Coal UCS Data

A total of 37 coal samples were tested by Maquarie Geotech to measure the UCS. Standard testing procedures require that the sample aspect ratio is at least 2.0 and a maximum of 3.0. The ISRM standard testing procedures recommend an aspect ratio of 2.5. The reason for these recommendations is that the measured sample strength will be affected by the sample aspect ratio. Aspect ratios greater than 2.0 ensure that the shear strength of the sample is invoked whereas aspect ratios less than 2.0 induce platen confining effects which effectively increase the strength.

The measured UCS from Invincible coal samples is presented in Figure 2 as a function of the aspect ratio. The results show a wide spread of UCS ranging from 6.8 MPa to 43.6 MPa.

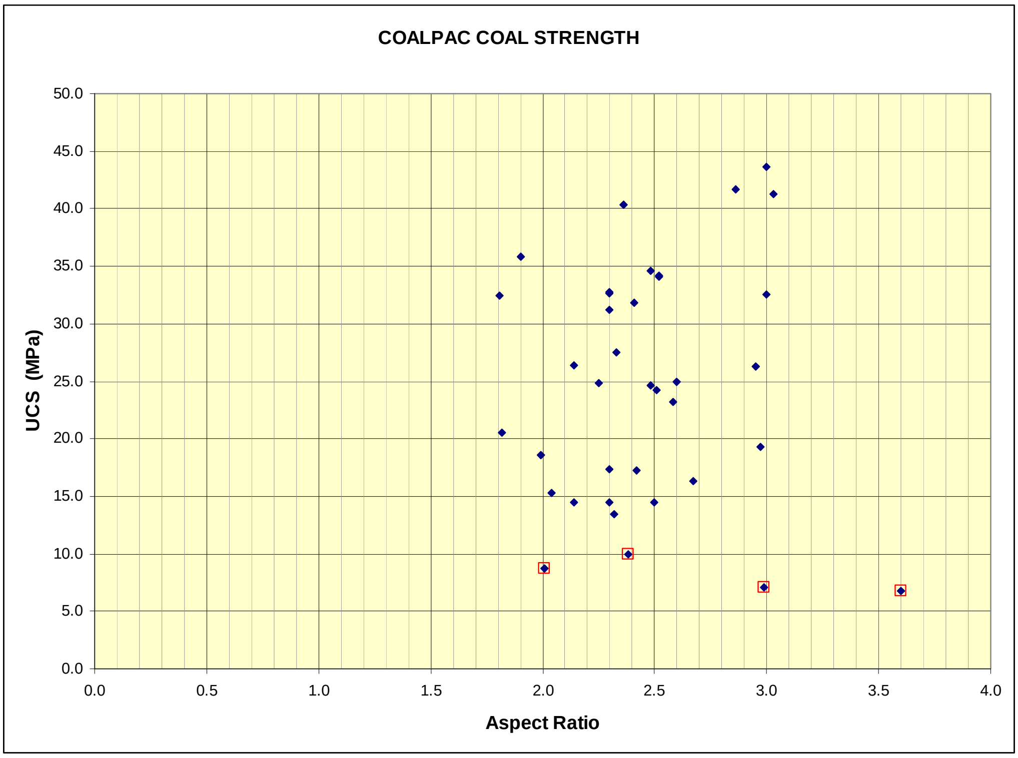

Figure 2: Presentation of coal UCS data as a function of the sample aspect ratio.

I do not believe that there is any relevance to calculate an average strength (and standard deviation) from these data. Rather, the data are used to define the limits, viz:

Intact coal strength: 43.6 MPa

Joint shear strength: 6.8 MPa.

These limits are absolutely relevant to the assigned modelling methodology used for the Coalpac Consolidation Project where a ubiquitous joint constitutive model was used to define the various rockmass units' deformation behaviour.

In Figure 2 the samples which sheared along pre-existing structure within the sample are marked with a red square. Typically these sample results would be discarded as being non-representative. However, it is interesting to note that the lowest value, 6.8 MPa, corresponds directly with the estimated coal seam (rockmass) strength described in the previous section.

It is concluded that the original input parameters used for the Coalpac Consolidation Project provide a conservative, absolutely plausible and defensible estimate of the coal strength. The results presented in the geotechnical stability assessment can therefore be considered to provide an accurate, best estimate of the anticipated deformation behaviour that may accompany highwall mining.

I trust that this brief overview of the recent UCS coal strength data provides you with further confidence that the original geotechnical modelling analysis was based on representative material properties.

Yours faithfully,

GEONET *Consulting Group*

Dr Ian H. Clark

Principal Consultant, Director

REFERENCES

1. GEONET Consulting Group, 2011. Assessment of Stability and Subsidence SHM Highwall Mining, Coalpac Consolidation Project.
2. Highwall Mining Services. 1996. Geotechnical Design Criteria for Proposed Highwall Mining of Opencut Reserves: Ulan Coal Mine.
3. CSIRO, 2000. Review and Back-analysis of Highwall Mining Panel Failure in Pit HW3 Trench, Ulan Mine. Report 722C.
4. The Minserve Group, 2000. HW3 Trench Extension, CHM Design for Ulan Coal Ltd.

REPORT TO: **Coalpac**
Invincible Colliery,
Castlereagh Highway,
CULLEN BULLEN NSW 2790

ATTN: **Hansen Bailey Pty Ltd**
P.O. Box 473
SINGLETON NSW 2330

Review of Highwall Mining Component – Coalpac Consolidation Project (CCP)

REPORT NO: **1301/01.1**

PREPARED BY: **BRUCE K. HEBBLEWHITE**

DATE: **27th February, 2013**

B.K. HEBBLEWHITE B.E.(Min.) PhD
Consultant Mining Engineer

ABN 85 036 121 217

46 Beecroft Road
Beecroft NSW 2119
Ph: (02) 9484 6791
Fax: (02) 9484 6791
Mobile: 04172 67876
Email: hebble@bigpond.com

EXECUTIVE SUMMARY

This report was commissioned by Hansen Bailey to provide a review of the highwall mining component of the Coalpac Consolidation Project (CCP), with emphasis on the mining and geotechnical aspects of the project proposal – in particular with regard to pillar design and stability issues, and surface subsidence effects and impacts. The report provides some background on the project and on highwall mining (HWM); it includes a peer review of the GEONET Consulting Group geotechnical report on aspects of HWM design; discussion of issues raised by the NSW Planning Assessment Commission (PAC) in December, 2012; and recommendations concerning the forward approval and management processes. Some of the key findings of the report are summarised below:

Australian mining practice

- A major area of advance in the Australian underground mining industry has been in mining operating systems and management practices. Mining companies now are far more proactive in identifying inherent risks, be they geotechnical or other, and adopting a proactive risk management approach to the mining operation. Australia leads the world in the adoption of modern risk management approaches to mine management.

- The result of many technical, scientific and management advances across the Australian underground mining industry is that a modern mining operation can be successfully conducted in an environment containing a range of complex hazards; where inter-related performance measures are put in place to ensure that all appropriate stakeholder considerations are linked into the management systems and the mine performs according to agreed compliance measures.

GEONET Report Review

- The report notes that *"only rare isolated faults and fault zones have been encountered in local open cut mining operations".* This is obviously a good sign of what may be expected in new areas, although there should be ongoing forward exploration to maintain good awareness of any potential geologically disturbed regions. Given that open cut mining is conducted in advance of highwall mining, good exposure is provided and should be carefully recorded as operations advance. Further, the extensive existing underground mining within the Project Area, with minimal roof support, provides important information regarding ground conditions and structure beyond the area accessible by open cut mining and should be considered as part of this forward exploration process. This process should be directed by a Management Plan to ensure adequate assessment of ground conditions in advance of operations.

- Coal strength data for pillar design - The principle adopted by GEONET to work with strength limits below the elastic limits of the coal properties is a sound principle and appropriate for pillar design.

- Coal strength database – At the time of the original submission for the project there was only very limited coal strength data available. However additional strength data has now been obtained from within the project area. The conclusion from a January 2013 GEONET review of the new actual site data is that the data used in the original design studies was quite appropriate and represented conservative but appropriate values based on the new information.

- Pillar stability design – based on extensive past experience, a minimum Factor of Safety (FOS) of 1.3 has been applied for web pillars (i.e. no pillars have a FOS below 1.3).

- The report notes that although the minimum 1.3 FOS has been suggested by CSIRO for long term stability, it may not be adequate to ensure long term stability and minimal subsidence in areas of unknown geological variation and other operational variations. (GEONET subsequently applies more conservative pillar designs in such areas. For example Katoomba seam pillar widths have been increased from 2.6m to 3.6m wide (with corresponding FOS increase) to allow for the impact of geological conditions which might result in roof falls).

- Pillar loading has been calculated based on maximum overburden depth in each location even though this will obviously not apply to the entire pillar length, and will in fact be reduced by the protection effect offered by the regularly spaced barrier pillars.

- GEONET has adopted a three stage pillar/mine design approach - empirical, 2D and 3D numerical – this is considered to be a very comprehensive, legitimate and appropriate design methodology.

- The critical span between barrier pillars has been defined as a maximum of twice the overburden (or interburden) thickness, to ensure that the intervening web pillars are not overloaded. This is considered as appropriate and adequate for regional stability. A principle of permanently stable barrier pillars with width:height ratios >5 has been adopted. These design principles are considered to be geotechnically sound.

- As an overall conclusion of the geotechnical design methodology and results of the GEONET design studies, it is considered that the approach that has been adopted is highly appropriate, and is well founded in good geotechnical practice. The use of multiple design methodologies to confirm or refine design parameters is highly commendable. The results of the design work are therefore considered to be suitable for a project study at this stage of an operation. Clearly these results and design parameters should be further refined once actual operating experience is gained and geotechnical performance feedback can be achieved. Such an approach is standard good geotechnical practice.

PAC Responses & Issues

- Final highwall stability – The PAC stated *"more detailed investigation is required at final highwall design stage in order to fully delineate these features and risk assess their stability*". It is considered that this statement is an appropriate requirement to be incorporated into the project approval, as part of the ongoing project management responsibility – in line with good risk management design practice.

- Slope stability - *"The Commission considers that there is insufficient information available on which to judge the risks posed to the pagodas and cliff lines from mining-induced instability in the slopes and also that there is limited information on which to base assessment of the risks to the slopes themselves (as a component of the pagoda landform)…. These information* *deficiencies should be rectified prior to any consideration of approval".* There are some fundamental issues for consideration in response to this statement. **Firstly**, the issue of final highwall slope design has been addressed above and would be considered as part of the ongoing mine design process. **Secondly**, it has already been stated that the geotechnical design approach undertaken in relation to the actual HWM operation has been rigorous and appropriate, using multiple design methodologies to assess the various design parameters of the mining operations to mitigate pillar instability and overlying subsidence risk.

- It would be highly appropriate to incorporate a management technique involving geotechnical monitoring and decision-making based on monitoring data which could provide an appropriate stop point before mining causes any adverse impact on critical surface structures.

- The PAC states *"the risk of subsidence impacts is primarily associated with the proposed use of highwall mining under the pagodas. The risk from subsidence and highwall mining will therefore be dealt with together".* It is appropriate for the applicant (Coalpac) to be required to undertake that the agreed and identified Ben Bullen Significant Pagoda Landforms (SPL) will not incur mining-induced damage critical. But it is clearly not possible for any applicant to categorically demonstrate this in advance. However, it is appropriate for an approval to include sufficient management requirements such that mining will not result in adverse subsidence-induced impacts to the Ben Bullen SPL.

- In the above statement quoted, the PAC makes reference to risks associated with mining beneath SPL. However, since the CCP submission was made to the PAC, the mine plans have been modified such that there is now no planned highwall mining beneath Ben Bullen SPL, Contracted Project.

- In the discussion of pillar stability and subsidence, the PAC quotes lack of actual site-based coal strength data, and also the evidence of a HWM failure at the Ulan Mine due to over-estimation of the coal strength in the HWM pillar design (use of 10MPa instead of a more conservative 5.9MPa figure). In relation to the lack of actual CCP site coal strength data – this is agreed, and, as has already been mentioned, Coalpac has subsequently obtained an additional suite of site strength data for each seam. This new data has been reviewed by GEONET (in January 2013) and has validated the current assumptions in the design studies.

- The Ulan failure implications - In the case of the CCP studies conducted by GEONET, the lower values of coal strength have already been adopted – based on the original Ulan dataset, followed by subsequent additional Invincible coal testing. Values used are much closer to the 5.9MPa figure than the original Ulan 10MPa figure. Furthermore, by adopting numerical modelling studies in addition to empirical designs, the CCP pillar dimensions have already been increased where necessary to take account of potential roof falls (and thereby increasing the effective FOS value above the minimum design standards). It is therefore considered that these issues have been adequately dealt with and do not pose inadequately defined or inappropriate risks.

- Pillar stability and design Factor of Safety (FOS) – The PAC makes the statement that *"an FOS of 1.3 is used throughout the report".* This is simply not correct and may indicate a misunderstanding by the PAC. GEONET have made two key statements; **firstly,** that a <u>minimum</u> value of 1.3 has been adopted for FOS (emphasis added), such that no pillars have an FOS below 1.3, but certainly some are higher. **Secondly,** GEONET has also stated, as quoted by the PAC, that 1.3 may not be adequate in some areas of geological variations, to maintain long term stability and hence minimise subsidence. The PAC also appears to mistakenly believe that barrier pillars have been designed to the minimum 1.3 FOS, whereas in fact the relevant barrier pillar FOS values are well in excess of this value, even under hypothetical, extreme overburden loading conditions.

- Pillar stability due to drivage deviation – a figure of ± 20cm for each pillar has been quoted, based on manufacturer data derived from actual mining trials. It is understood that this amount of potential deviation has been incorporated into the pillar design dimensions.

Overall Conclusions and Recommendations

- It is argued that an approval of the overall proposed mining operation is a suitable and recommended approach. The mining method does not carry any excessively more significant risks than other underground mining methods.

- The issues of protection of the critical surface landforms relates to specific locations within the mining lease, and to specific rock formations within those locations. It is an appropriate strategy to develop further data on the surface impact of the HWM system in this regional geology in areas well away from Significant Pagoda Landforms (SPL) in the early stages of mining.

- Specific final highwalls and HWM layouts can be designed according to the final highwall position (determined via Slope Stability and Blast Management Plans) and the local geology in each location.

- Monitoring of the subsidence effects of the HWM operation ahead and away from the HWM extremities can be implemented as operations approach the SPL. Such monitoring can be incorporated into a Subsidence Management Plan which empowers and in fact binds the mine operator to comply with SPL protection, with mining restrictions applied in response to any "early warning" of subsidence developments. Such an approach will ensure that any impacts of mining are restricted to a safe distance from any SPL, such that even if a HWM pillar failure did occur at some point in the future (deemed as highly unlikely), the impact of such failure would still fall into a region that was outside the zone which might impact the SPL.

1. INTRODUCTION

1.1 Scope of Work

The following is an extract from the scoping document for this report, as provided by Coalpac in the document titled "Scope for Review of Highwall Mining Component of Coalpac Consolidation Project" (CCP), dated 7 January, 2013:

> *"The proposed scope for the review is to critique the approach design and assessment approach taken for the CCP and specifically to provide independent expert opinion on the suitability of the application of the "normal" State regulatory process regarding the generation and approval of Subsidence Management Plans taking into account the relevant geotechnical, geometric and geological factors as they apply across the Project Area over the life of the mine.*
>
> *Specifically we need commentary on what controls and conditions could be applied to allow highwall mining to proceed whilst giving the regulators the appropriate points of measurement for control of the activity (i.e. steps in ongoing planning and approval of a highwall programme through a complex geotechnical and geometrical environment to manage any impact upon the overlying and adjacent rock formations)."*

In addition to the scoping document identified above, the following key documents were provided by Coalpac to aid with this peer review:

- GEONET Consulting Group (December 2011) – *Assessment of stability and subsidence: SHM highwall mining, Coalpac Consolidation Project.* (This report was included in the project Environmental Assessment documentation as Appendix F).
- Coalpac Consolidation Project Environmental Assessment, March 2012.
- NSW Planning Assessment Commission (PAC), (December 2012) – *Coalpac Consolidation Project Review: Main Report.*
- NSW Trade and Investment, Resources and Energy Branch – various letters to the PAC, dated 31/5/12 and 4/10/12, signed by Mr William Hughes, A/Director, Minerals Operations.
- GEONET (23 January, 2013) – letter to Coalpac, headed *"Review of coal UCS data: Invincible Colliery*", signed by Dr Ian Clark, Principal Consultant.
- Caterpillar (31 January, 2013) – *Caterpillar Highwall Mining Systems – Cutter Module Navigation and Steering System.*
- GEONET (18 February, 2013) – letter to Coalpac, headed *"Definition of Barrier Pillar Stability",* signed by Dr Ian Clark, Principal Consultant.
- plus a number of individual plans, diagrams and other data sources.

As indicated above, the peer review is focused on the Highwall Mining (HWM) component of the project and excludes any open-cut related issues. The review is primarily focused on geotechnical issues associated with the proposed HWM aspects of the project, which centre on underground stability considerations, and surface subsidence effects and impacts.

As the author of this peer review, I offer the following comments on the geotechnical aspects of underground stability and subsidence, on the basis of my relevant professional qualifications, experience and background (see Summary CV in Appendix A). A comprehensive CV containing a full list of publications is available on request.

My background relevant to the subsidence aspects of this project includes a close association with a number of different coal mining projects across NSW, Qld and internationally – from various perspectives, including mine design and audit on behalf of coal companies; and consulting/review studies on behalf of government and agencies (eg NSW Dept of Planning and Infrastructure; Dept of Primary Industry; NSW Dams Safety Committee; Qld Government Crown Law; Government of Pennsylvania, USA); a recent such study being as Chair of the Independent Expert Panel of Review into *"Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield"* (jointly for the NSW Dept of Planning & Dept of Primary Industry, 2006-2008).

I will make use of the following subsidence-related terms in this peer review - specifically, subsidence effects, impacts and consequences - and so offer the following definitions which were published in the above Southern Coalfield Report, see extract below.

> *"The Panel has used the term "**subsidence effects**" to describe subsidence itself – ie deformation of the ground mass caused by mining, including all mining-induced ground movements such as vertical and horizontal displacements and curvature as measured by tilts and strains.*
>
> *The term "**subsidence impacts**" is then used to describe the physical changes to the ground and its surface caused by these subsidence effects. These impacts are principally tensile and shear cracking of the rock mass and localised buckling of strata caused by valley closure and upsidence but also include subsidence depressions or troughs.*
>
> *The environmental "**consequences**" of these impacts include loss of surface flows to the subsurface, loss of standing pools, adverse water quality impacts, development of iron bacterial mats, cliff falls and rock falls, damage to Aboriginal heritage sites, impacts on aquatic ecology, ponding, etc."*

1.2 CCP Project Background

The following is a brief overview of the CCP project, to provide some context for the contents of this peer review report. This background information is extracted from the CCP Scope for Review document already referenced above:

> *"Coalpac is seeking Project Approval from the Minister for Planning and Infrastructure under Part 3A of the EP&A Act to consolidate the operations and management of the Cullen Valley Mine and Invincible Colliery under a single, contemporary planning approval. The Project will allow coal mining operations largely within Coalpac's current mining authorities to continue for a further period of 21 years within the Project Boundary, see Figure 2. Opportunistic sand extraction is also proposed within the coal seam stratigraphy.*
>
> *The Project generally comprises the following:*
>
> - *Consolidation and extension of the existing Cullen Valley Mine and Invincible Colliery operations to produce up to a total of 3.5 Mtpa of product coal, including:*
>   - *The continuation of mining operations at Cullen Valley Mine (the area west of the Castlereagh Highway) via both open cut and highwall mining methods to access an additional resource of approximately 40.1 Mt ROM; and*
>   - *The continuation of mining operations at Invincible Colliery (including an extension north into the East Tyldesley area) via open cut and highwall mining methods to access an additional resource of approximately 68.4 Mt ROM;*

- *Mining and coal processing 24 hours per day up to seven days per week with approximately 120 full time personnel plus contractors;*
- *Continuation of coal supply to the local MPPS via a dedicated coal conveyor over the Castlereagh Highway (to be constructed), and emergency supply to MPPS and WPS (via road), with flexibility for supply to additional domestic destinations and Port Kembla (via rail) for export;*
- *Upgrades to existing Invincible Coal Preparation Plant, administration and other infrastructure;*
- *Construction and operation of additional offices at Cullen Valley Mine;*
- *Construction and use of the East Tyldesley Coal Preparation Plant (incorporating the previously approved CDP at Cullen Valley Mine);*
- *Construction and operation of a bridge and haul road across the Wallerawang - Gwabegar Railway Line to permit access to mine the previously approved Hillcroft resource;*
- *The extraction of the Marangaroo Sandstone horizon from immediately below the Lithgow Coal Seam in the northern coal mining area of Cullen Valley Mine. This material will be trucked to an onsite crushing/screening station prior to sale into the Sydney (and surrounds) industrial sand market;*
- *Construction of a rail siding and associated infrastructure to permit transport of coal and sand products;*
- *Integration of water management infrastructure on both sites into a single system; and*
- *Integration of the management of mine rehabilitation and conceptual final landform outcomes for Cullen Valley Mine and Invincible Colliery.*

Pagodas:
'Pagodas' is the common name given to the distinctive sandstone formations found in a limited area on the western escarpment of the Blue Mountains north-west of Sydney. There are two forms: smooth, beehive-like structures (smooth pagodas) and stepped, terraced structures known as platy pagodas. Platy pagodas are the ones potentially impacted by the proposed project. Platy pagodas are massive, intricately patterned Triassic sandstone formations with ironstone banding, see Figures 3, 4 and 5."

The following diagrams and photographs are reproduced from the same "Scope for Review" document, to provide further context for this report. The Figure numbers are those referred to in the above extracted text – Figures 2, 3, 4 and 5 (consequently, there is no Figure 1 in this report).

Figure 2 shows an overall plan of the proposed project location, indicating existing mining operations; proposed open-cut operations; and proposed highwall mining operations, within the CCP lease boundary taken from the CCP Environmental Assessment.

Figure 3 contains photographs of typical pagoda rock formations. Figure 4 is an aerial view of the overall location (dated October 2011), showing mining and town infrastructure plus the natural topography of the area, with the Ben Bullen Significant Pagoda Landform (SPL) in the lower right (south east) of the photograph. Figure 5 is a further photograph looking across some of the existing Invincible Colliery open cut workings and rehabilitation with the Ben Bullen SPL in the background.

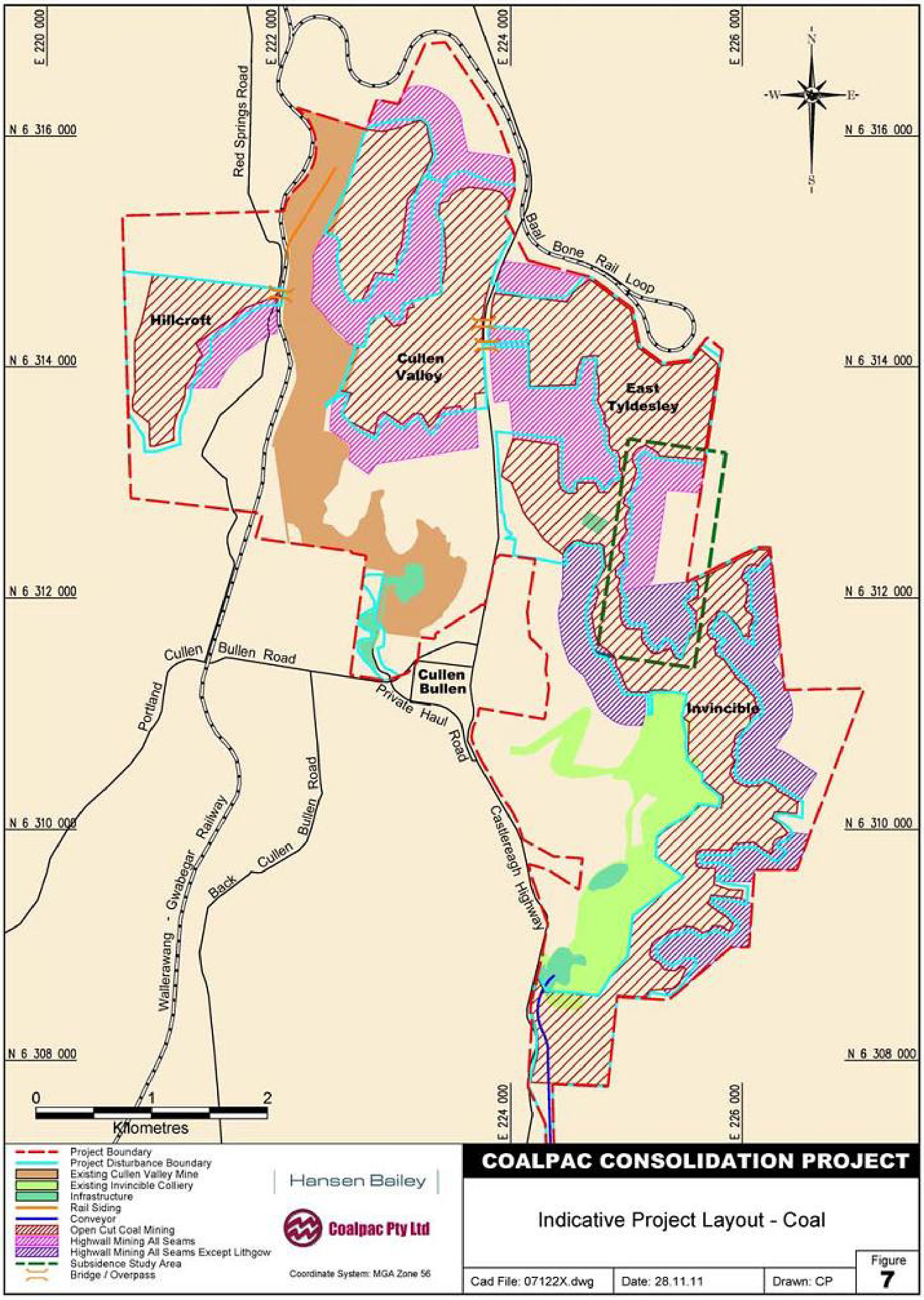

Figure 2. Project Area and Area of Coal Extraction
(source: Coalpac Consolidation Project, Environmental Assessment)

Figure 3. Pagodas (smooth & platy in left picture, platy in the right)
(source: Coalpac Scope for Review document)

Figure 4. Aerial photograph of Cullen Valley Mine and Invincible Colliery showing extent and form of pagodas *(source: Coalpac Scope for Review document)*

Figure 5. Ben Bullen SPL in the background due east of Invincible Colliery (looking Southeast)

(source: Coalpac Scope for Review document)

Figure 6 is a conceptual forward production schedule for the CCP taken from the CCP Environmental Assessment. This indicates the proposed progressive development of the mine – note that all HWM follows open-cut operations in each location – either from existing open-cuts, or from the proposed new open cut areas. On the basis of this schedule, it is clear that there is no planned HWM in areas adjacent to the Ben Bullen SPL in the south-east corner of the lease for at least three or four years.

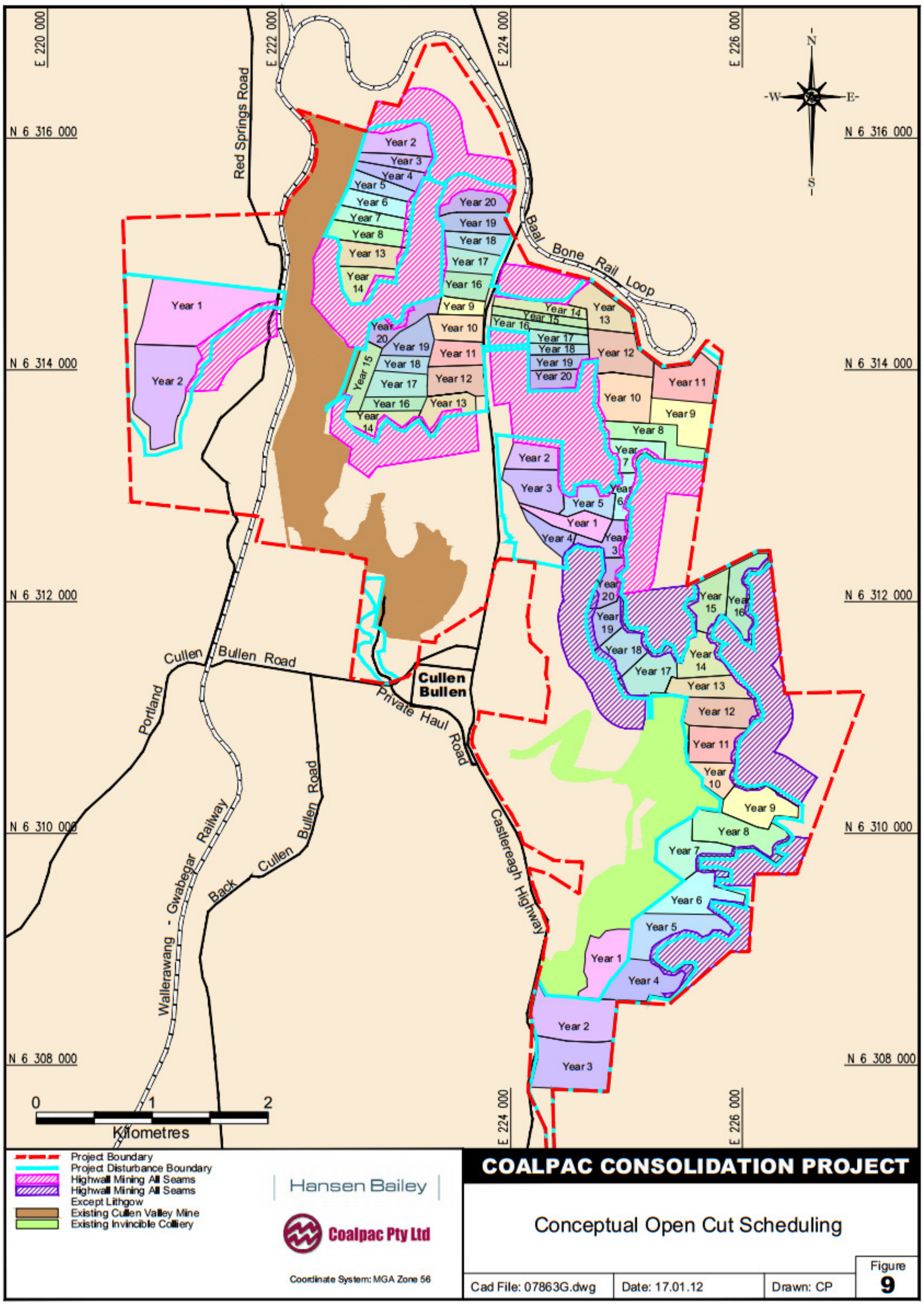

Figure 6. Conceptual open cut production location schedule from Exhibited Project mine plan (*source: Coalpac Consolidation Project, Environmental Assessment)*

1.3 Highwall Mining

This section is a brief discussion of the highwall mining system, and particularly some of the geotechnical factors and considerations considered relevant to this review. The first point to make with respect to HWM is that although it is often classified as a surface mining technique, this is technically incorrect. From a technical perspective, it is an underground mining method, albeit that the mining operation is conducted from a surface location, in terms of all personnel and equipment controls are located on the surface and the underground operation is a totally unmanned mining system – hence the surface mining classification.

Figure 7 is a photograph of a Caterpillar highwall mining system of a kind that is proposed for use by Coalpac in this project. Figure 8 shows the conceptual Coalpac mine layout including the highwall access and the multi-seam HWM operations included as Figure 16 in the CCP Environmental Assessment. Several features of the method seen in this Figure should be noted. Firstly, the HWM equipment punches drives into the coal seam from the highwall, for a proposed distance of up to 305m (for this particular equipment). Secondly, a series of drives are mined from the highwall, in parallel, resulting in long narrow continuous "web pillars" of coal between each punch. Thirdly, after a certain number of such drives, a wider "barrier pillar" is left, before the next group of drives is mined. The role of these barrier pillars is critical in ensuring not only highwall stability, but regional stability for the overburden above the production drives.

Figure 7. Typical HWM equipment and mine cross-section (*source: Coalpac)*

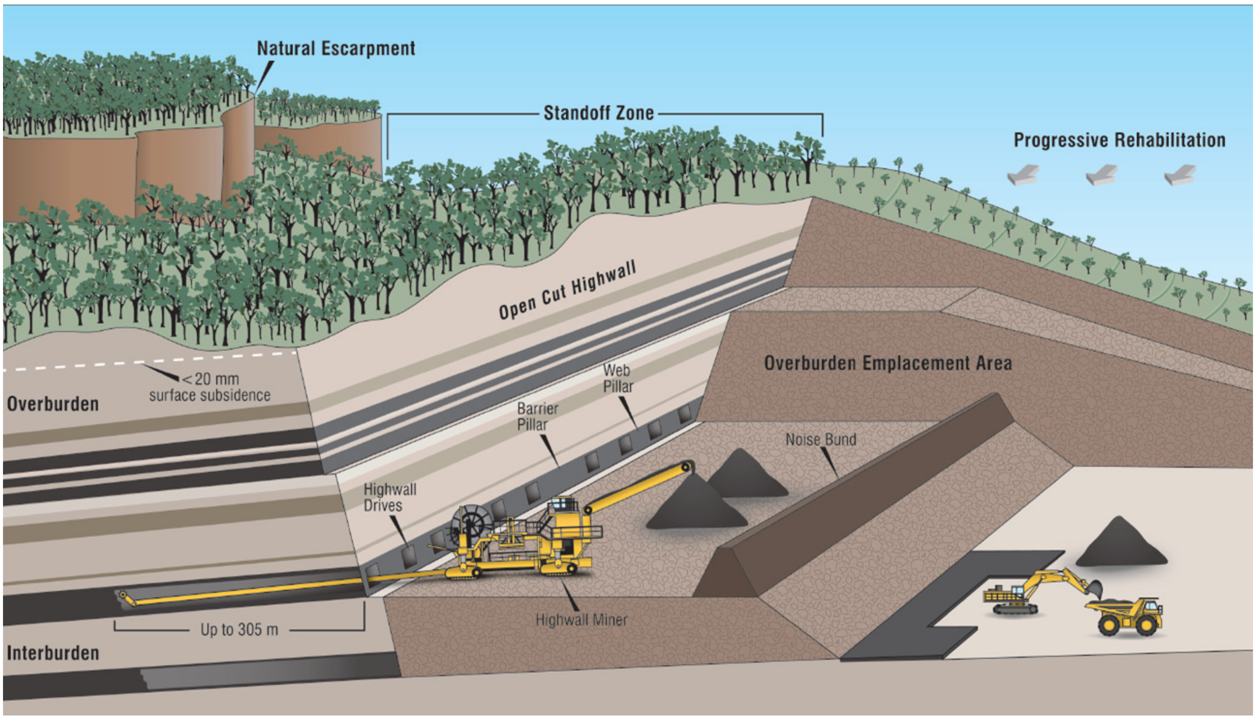

Figure 8. Conceptual multi-seam HWM mine layout *(source: Coalpac Consolidation Project, Environmental Assessment)*

Figure 8 also shows the placement of overburden spoil from the open-cut operations against the highwall. It is understood that this is the intention of the ongoing CCP operation – to place spoil against the highwall on completion of HWM. This practice will clearly eliminate any ongoing concern about time-dependent highwall instability.

In reviewing the design of the highwall mining operation from a geotechnical perspective, it is critical that the performance of both the web pillars and the barrier pillars are considered in combination, and not in isolation. A key element of the geotechnical design is that the barrier pillars carry a proportion of the regional overburden load over the production areas, such that the loading on the intervening web pillars is reduced to a value below the normal overburden "tributary area" loading. The amount of such load reduction is a function of the overall mine and overburden geometry and the coal seam and overburden geology and geotechnical properties.

Another important consideration when discussing highwall mining as an underground mining method is to understand that, as with any underground mining – bord and pillar first workings, pillar extraction or longwall mining – once coal is removed and an underground excavation is created, the surrounding rock mass deforms to a certain extent as the stresses in the rock mass are redistributed to establish a new state of equilibrium in the ground. Any form of underground excavation behaves in this manner – in mining and in civil tunnelling. It is a fundamental aspect of Newtonian physics applied to the behaviour of rock masses subjected to stress fields.

The difference in the response of the ground to different mining methods is one of scale. In the case of pillar extraction, or longwall mining, where excessive underground excavation spans are created, the span exceeds the supporting strength of the overlying rock mass, leading to rock failure, downward deformation of the roof and overlying rock mass and subsequent significant amounts of downward subsidence of the ground surface. The amount of surface subsidence is a function of the span and height of the excavation and the depth of the overburden.

In the case of bord and pillar first workings, or in fact highwall mining (which is just another form of bord and pillar workings from a regional geotechnical perspective), the span of each excavation is greatly reduced (with HWM using even narrower spans (3 to 3.5m) than bord and pillar roadways (5.5 to 6m)). The result is that the response of the rock to the mining process is a very minor amount of relaxation of the immediate rock mass around the drive or heading. This relaxation of the rock mass, combined with a small amount of elastic compression of the intervening pillars due to the increasing load imposed on them by the mining process may cause a very small amount of surface subsidence – a maximum of approximately 10-20mm, for typical pillar heights and layouts. This type of minimal overburden deformation is part of the elastic redistribution in the rock mass and occurs at the time of mining and then stabilises. Consequently, the surface subsidence effects above typical bord and pillar first workings mining or highwall mining are minimal, such that there are no adverse subsidence impacts on any natural or man-made infrastructure.

Highwall mining has been successfully practised around the world for many decades now, having had its origins in the eastern parts of the USA. HWM operations have taken place in Australia since the late 1980s (in NSW, Queensland and WA), using both remote drum-type mining cutter heads resulting in a rectangular excavation profile, or using single or double auger cutter heads producing circular entry profiles. Technology has improved considerably since the early introduction of HWM. In particular, the control of the cutting horizon, and the directional control of the cutter head – linked with accurate sensing/navigation instrumentation – have made great advances in recent decades. Control of the cutting horizon is obviously important to ensure maximum coal recovery and minimal dilution from roof or floor rock. Control of the azimuth or drive direction is critical to ensure straightness of the drives for their full 305m maximum length so that the web pillars between each drive maintain their designed thickness and do not become too narrow and hence potentially unstable.

The navigation system used by Caterpillar in the Coalpac-proposed equipment package is a fibre-optic gyroscopic (FOG) system of inertial navigation. The FOG system provides a continual or incremental three-dimensional sensing of the cutter-head location and can be used to then steer the machine to correct any deviation detected. Actual field tests by Caterpillar using a Joy continuous miner cutter head, in both Australia and the USA, have shown that the system is steerable within a tolerance of ±10cm either side of the target direction or azimuth of the drive direction (ref. Caterpillar Highwall Mining Systems – 31 January, 2013). This means that the actual mined web pillar dimensions should be achievable within ±20cm of design width, allowing for drive deviation on each side of the pillar. This is as good as, if not far better than conventional underground mining directional control, and is considered an acceptable tolerance that has been factored into the design calculations, with a further factor of safety applied if required.

Underground mining methods and systems of all types have improved dramatically over the past thirty to forty years. This has been a combination of major advances in mining technology and equipment – and HWM is no exception in this regard – but also in terms of geotechnical knowledge, from the starting point of exploration and data collection, through to geotechnical design and performance monitoring. A further major area of advance has been in mining operating systems and management practices. Mining companies now are far more proactive in identifying inherent risks, be they geotechnical or other, and adopting a proactive risk management approach to the mining operation. Australia leads the world in the adoption of modern risk management approaches to mine management.

The result of all of these technical, scientific and management advances is that a modern mining operation can be successfully conducted in an environment containing a range of complex hazards; where inter-related performance measures are put in place to ensure that all appropriate stakeholder considerations are linked into the management systems, and the mine performs according to agreed compliance measures.

2 PEER REVIEW OF HIGHWALL MINING COMPONENTS OF PROJECT

This section of the report is focused on the content of the GEONET "Assessment of stability and subsidence" report, which formed Appendix F of the Environmental Assessment. In the form that the report was provided as Appendix F of the EA document, it also contained a separate peer review report by Boyd Mining Pty Ltd, as an Appendix to the GEONET document. The following comments are raised in the order that they appear in the report. Page and section numbers refer to the GEONET report.

- Sections 1 and 2 provide introduction to the project, and describe both the background investigations into HWM technologies, as well as the site geology in the Invincible area. It is noted that HWM is proposed in various locations in the Katoomba, Moolarben, Irondale and Lithgow Seams (in descending order).

- P10, section 2.2 notes that *"only rare isolated faults and fault zones have been encountered in local open cut mining operations".* This is obviously a good sign for what may be expected in new areas, although there should be ongoing forward exploration to maintain good awareness of any potential geologically disturbed regions. Given that open cut mining is conducted in advance of highwall mining, good exposure is provided and should be carefully recorded as operations advance. Further, the existing extensive underground mining within the Project Area, with minimal roof support, provides important information regarding ground conditions and structure beyond the area accessible by open cut mining and should be considered as part of this process. This process should be directed by a Management Plan to ensure adequate assessment of ground conditions in advance of operations.

- It is understood that HWM of the upper seams will take place in some areas above old underground mine workings in the Lithgow seam. On p16 the statement is made *"Recent geotechnical assessment of the pillars [3] confirmed their stability with Factors of Safety in excess of 5".* This statement refers to a report prepared by consulting firm Strata Engineering. This report contains an analysis of pillar dimensions based on mine plan data. It is also understood that Coalpac have already excavated a large number of pillars from old Invincible underground workings and confirmed good correlation between mine plan records and actual dimensions. It is therefore accepted that there is a reasonable and acceptable understanding of the dimensions and hence stability of the old Invincible pillars. Mining above these areas should be able to proceed safely, with normal precautions applied to manage the associated risks.

- Section 2.4 discusses coal strength data, albeit on an initially scarce data availability - essentially sourced from Ulan Mine published data. The principle adopted by GEONET to work with strength limits below the elastic limits of the coal properties is a sound principle and appropriate for pillar design. GEONET acknowledges that there was only a scarce amount of available data to use for design, although it is know that subsequent to this report, additional data has been sourced from the Invincible Colliery area. This new data was reviewed by GEONET and reported to Coalpac on 13 January 2013. The conclusion from the review of the new actual site data is that the data used in the original design studies was quite appropriate and represented conservative but appropriate values based on the new information.

- Section 3 discusses pillar dimension design. Pillar strength is a function of the all-important pillar width:height ratio. Strength is therefore greatly enhanced when pillar widths are increased, or heights decreased. Factor of Safety (FOS) is a function of strength relative to pillar load or applied stress. GEONET have reviewed previous HWM practice and local geological variations to feed into their design approach. Based on past experience, a <u>minimum</u> Factor of Safety (FOS) of 1.3 for web pillars has been adopted (relying on extensive HWM industry research conducted for ACARP by CSIRO). Pillar loading has been calculated using maximum overburden depth (and hence pillar load) in each location even though this will obviously not apply to the entire pillar length, and will in fact be reduced by the protection effect offered by the regularly spaced barrier pillars. It is noted that a maximum cutting width of 3.5m is used, but can be reduced to 3.0m where lower seam sections are recovered and a lower cut height cutterhead is employed. An empirical pillar strength formula has been used for preliminary calculations, based on a power law formula, linking strength to the width:height ratio (note that these formulae do not rely on local site-specific strength data). Pillars have been designed to provide long-term stability based on available database information. It is noted on p23 (section 3.3) that although the minimum 1.3 FOS has been suggested by CSIRO for long term stability, that it may not be adequate to ensure long term stability and minimal subsidence in areas of unknown geological variation and other operational variations.

- Section 4 outlines the further design approach taken to reinforce or refine the empirical design work by undertaking a two dimensional numerical modelling design methodology using the finite difference method (FLAC), incorporating the vertical and horizontal stresses; the actual surface topographic variations; and the surrounding rock mass properties. This work confirmed the empirical pillar design dimensions, and the 1.3 FOS as an appropriate starting point for the design process.

- Section 5 reports on a third design stage adopting a three dimensional modelling study (FLAC3D) used to more fully evaluate the complex geometries of mining sequences and topography. Section 5.3 considers the issue of underlying Lithgow seam workings and their potential impact on reducing overburden rock properties. This work indicates some minor localised effects, although it is not considered to be a HWM limiting factor.

- Section 6 discusses the overall findings of the three design approaches – empirical, 2D and 3D numerical – which is a very comprehensive, legitimate and appropriate design methodology. Arising from this three level study, original pillar dimensions have been modified accordingly. For example, Katoomba seam pillar widths have been increased from 2.6m to 3.6m to allow for roof falls which may cause increased pillar height, hence reduced pillar strength, if not compensated for by increased width.

- Section 7 describes the design approach adopted for barrier pillars. A principle of permanently stable barrier pillars with width:height ratios >5 has been adopted. Pillars exceeding w:h ratios in excess of 5 are known as "squat pillars" and possess significantly greater strength than those with w:h ratios below 5. The critical span between barrier pillars has been defined as a maximum of twice the overburden (or interburden) thickness, to ensure that the intervening web pillars are not overloaded. Both of these design principles are considered to be geotechnically sound.

- The overall report conclusions indicate that maximum subsidence above the multi-seam HWM operations will be less than 20mm, other than one localised region at the southern point of the western highwall which does not impact any surface landscape sensitive areas.

- As an overall conclusion of the geotechnical design methodology and results of the GEONET design studies, it is considered that the approach that has been adopted is highly appropriate, and is well founded in good geotechnical practice. The use of multiple design methodologies to confirm or refine design parameters is highly commendable. The results of the design work are therefore considered to be suitable for a project study at this stage of an operation. Clearly these results and design parameters should be further refined once actual operating experience is gained and geotechnical performance feedback can be achieved. Such an approach is standard good geotechnical practice.

3 DISCUSSION OF PAC RESPONSES AND ISSUES

The PAC report has identified a number of concerns about the project which are currently limiting their consideration of project approval. These include some issues associated with the open-cut operations which are not considered in this review report, such as blasting and open-cut slope stability. It is also worth noting that approval had previously been given for some HWM in sections of the lease, prior to the current request for consolidation under the CCP. The following critical issues raised by the PAC in relation to HWM are now discussed.

- Final highwall stability – *"more detailed investigation is required at final highwall design stage in order to fully delineate these features and risk assess their stability".* This statement is considered appropriate for ongoing mine design, on a site by site basis as the mine progresses. It is not considered appropriate as a blanket design study for the entire project at initial approval stage, as it would not be possible to incorporate all the relevant details of local site geological variations – many of which are not even known at this stage of the project. Therefore it is recommended that this requirement is appropriate to be incorporated into the project approval, as part of the ongoing project management responsibility – in line with good risk management design practice.

- Slope stability - *"The Commission considers that there is insufficient information available on which to judge the risks posed to the pagodas and cliff lines from mining-induced instability in the slopes and also that there is limited information on which to base assessment of the risks to the slopes themselves (as a component of the pagoda landform)…. These information* *deficiencies should be rectified prior to any consideration of approval".* There are some fundamental issues for consideration in response to this statement.

Firstly, the issue of final highwall slope design has been addressed above and would be considered as part of the ongoing mine design process.

Secondly, it has already been stated that the geotechnical design approach undertaken in relation to the actual HWM operation has been rigorous and appropriate, using multiple design methodologies to assess the various design parameters of the mining operations to mitigate pillar instability and overlying subsidence risk.

In relation to the impact of mining slopes and risk to rock formations from mining – it is agreed that there is not a complete set of information available. This is a very complex geotechnical environment that cannot be fully defined by a generic set of designs and risk assessments. Once again, it can only be assessed on a section by section analysis of each mining operation relative to the actual nature of the slopes and rock formations present. This will be done in an ongoing mine design approach.

More importantly, the best control of these "unknown" risks is to implement an appropriate geotechnical monitoring regime on the surface in the regions between mining and various surface landforms, to gather data on the impact of approaching mining on such surface features, and develop a sound knowledge of the ground response to mining – well before mining approaches any critical rock formations.

It would be highly appropriate to incorporate a management technique involving geotechnical monitoring and decision-making based on monitoring data which could provide an appropriate stop point before mining causes any adverse impact on critical surface structures.

- Mine instability and subsidence – *"The risk from subsidence is significant".* The PAC quotes the DRE (Trade and Investment, Resources and Energy) as stating that *"the applicant needs to demonstrate that the rock pagoda features will not incur mining-induced damage and most importantly, pillar stability is such that there is no risk of further subsidence after mining is complete".*

  The PAC goes on to state *"the risk of subsidence impacts is primarily associated with the proposed use of highwall mining under the pagodas. The risk from subsidence and highwall mining will therefore be dealt with together".*

  It is appropriate for the applicant (Coalpac) to be required to undertake that the agreed and identified Ben Bullen SPL will not incur mining-induced damage. However, it is clearly not possible to expect any applicant to categorically demonstrate this in advance.

  However, once again, it is quite achievable and appropriate for an approval to include sufficient management requirements such that mining will not result in adverse subsidence-induced impacts to the SPL.

- A further point of clarification relates to the statement concerning mining beneath the SPL. From the revised Contracted Project plans and information provided to me for this review, there is no indication of any planned HWM activity beneath the SPL. It is understood that

Coalpac has modified the HWM plans, subsequent to the plans that were originally submitted and reviewed by the PAC. Under the Contracted Project mine plans, there is no proposed HWM beneath any significant pagoda landforms (SPL). Figures 9 and 10 indicate the Contracted Project mine plans excluding any mining beneath SPLs. The planned HWM locations are positioned to avoid the Ben Bullen SPL and to incorporate a stand-off distance – again determined on a site by site basis, to ensure no adverse impacts on the Ben Bullen SPL.

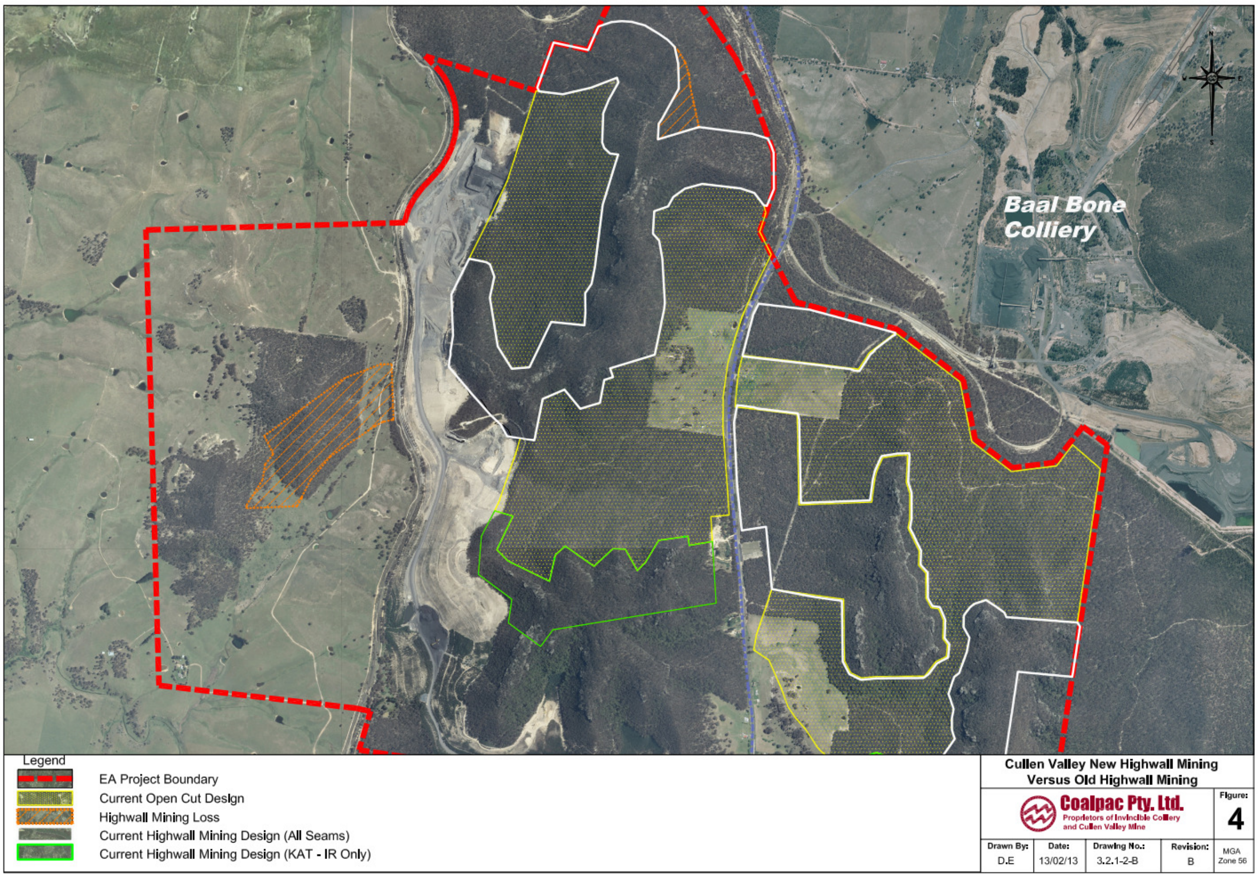

Figure 9. Contracted Project Cullen Valley HWM Layout *(source: Coalpac)*

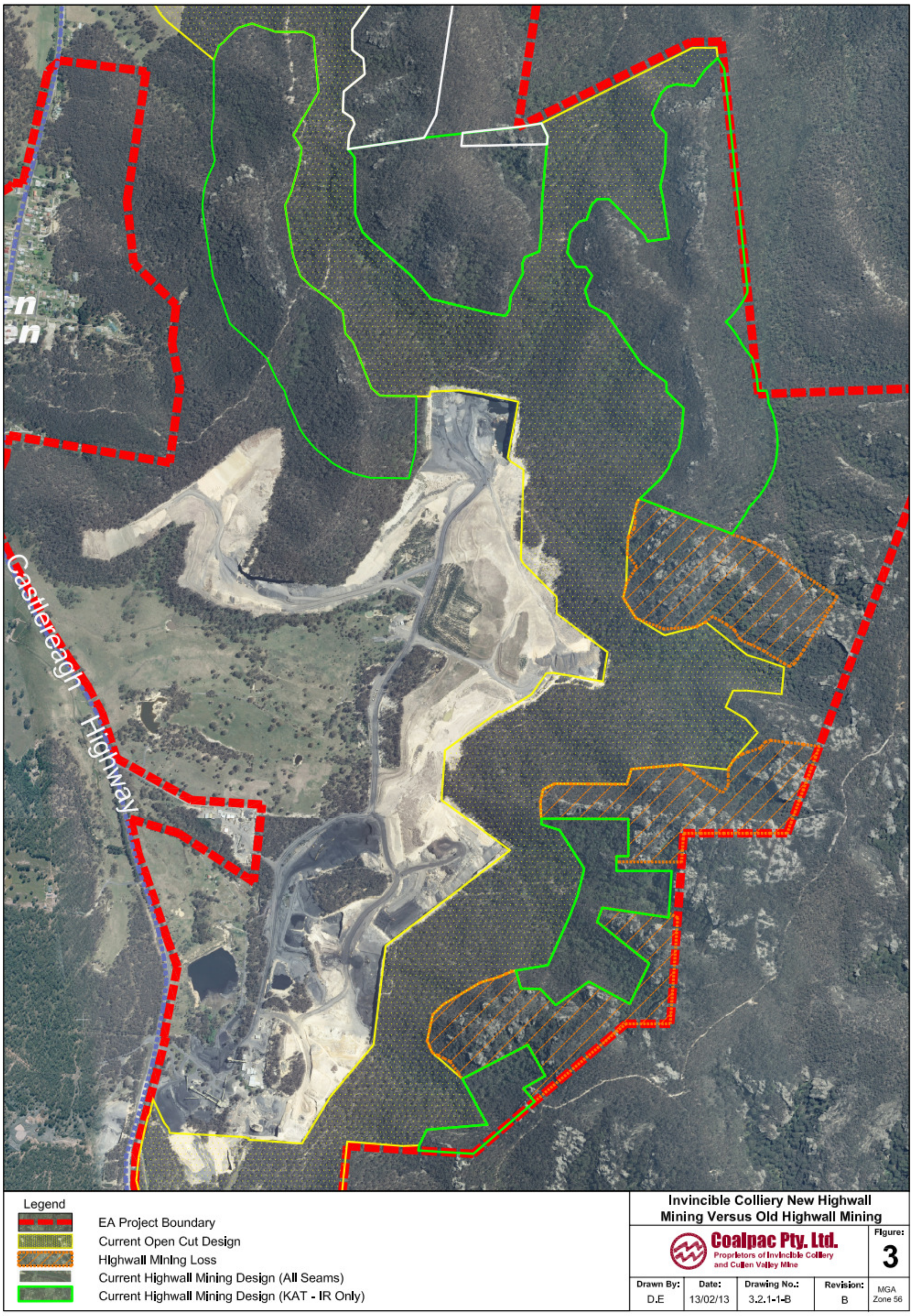

Figure 10. Contracted Project Invincible Colliery HWM Layout *(source: Coalpac)*

- In the same discussion of pillar stability and subsidence, the PAC quotes lack of actual site-based coal strength data, and also the evidence of a HWM failure at the Ulan Mine due to over-estimation of the coal strength.

  In relation to the lack of actual site coal strength data – this is agreed, and as has already been mentioned, Coalpac has subsequently obtained an additional suite of site strength data for each seam. This new data has been reviewed by GEONET (in January 2013) and has validated the current assumptions in the design studies.

  In relation to the Ulan failure, a subsequent investigation by CSIRO revealed that the original design work had used a unit coal strength value of 10MPa, whereas a figure of 5.9MPa should have been adopted in hindsight. It also found that pillar design factors of safety were compromised because of roof falls resulting in higher roadway heights and reducing pillar strengths.

  In the case of the CCP studies by GEONET, the lower, more conservative values of coal strength have already been adopted – based on the original Ulan dataset, followed by subsequent Invincible coal testing. Values used are much closer to the 5.9MPa figure that the original Ulan 10MPa figure.

  Furthermore, by adopting numerical modelling studies in addition to empirical designs, the CCP pillar dimensions have already been increased where necessary to take account of potential roof falls (and thereby increasing the effective FOS value above the minimum design standards).

  It is therefore considered that these issues have been adequately dealt with and do not pose inadequately defined or inappropriate risks.

- The PAC then considered the issue of both pillar stability and barrier pillar stability. They discuss the question of Factor of Safety and make the statement that *"an FOS of 1.3 is used throughout the report".*

  This is simply not correct and may indicate a misunderstanding by the PAC. GEONET have made two key statements:

  Firstly that a <u>minimum</u> value of 1.3 has been adopted for FOS (emphasis added), such that no pillars have an FOS below 1.3, but certainly some are higher.

  Secondly GEONET has also stated, as quoted by the PAC, that 1.3 may not be adequate in some areas of geological variations, to maintain long term stability and hence minimise subsidence.

  GEONET has then applied this principle by significantly increasing some of the pillar dimensions (and hence FOS), which had been originally sized in the first-pass empirical design. Where geological conditions were suspect, such as in poorer roof conditions in the Katoomba seam, numerical modelling was used to determine more appropriate and higher value FOS pillar dimensions. Furthermore, the barrier pillars which are an integral part of the overall design across the mine clearly have an FOS value much greater than 1.3.

In discussion of barrier pillar dimensions, the PAC report states *"the indicative design is built around an FOS of 1.3 (despite the earlier caveats)".* Once again, it appears that the PAC may have misunderstood the GEONET report. Section 7 of the GEONET report discusses the question of barrier pillars and quotes Figure 36 which relates pillar sizes to overburden depths in the Katoomba seam.

However this discussion is referring to web pillars, not barrier pillars (the wording of the report may not be very clear on this point). Evidence of the actual barrier pillar dimensions can be found in section 7.1 where the principle of a minimum W:H pillar ratio of 5 is adopted. This results in barrier widths as follows:

- Katoomba Seam – 10.7m
- Moolarben Seam – 7.2m
- Irondale Seam – 7.8m
- Lithgow Seam – 12.7m

Subsequent advice obtained from GEONET (report to Coalpac dated 18 February, 2013) confirms that the FOS values for the proposed barrier pillars are all in excess of 4, which would indicate that they are virtually indestructible based on known pillar experience (see Table below (*sourced from GEONET Report (18 Feb 2013)*)).

Summary of barrier pillar stress conditions and calculated actual Factor of Safety.

Seam	RL (m)	$Sigma_1$ (MPa)	$Sigma_3$ (MPa)	FoS_{max}	FoS_{min}
Katoomba	960	3.25 - 4.73	1.6 - 1.74	8.34	4.83
Moolarben	940	3.5 - 6.18	2.2 - 2.53	12.80	5.00
Irondale	905	5.1 - 8.20	3.1 - 3.86	10.50	5.69
Lithgow	885	6.1 - 14.0	3.6 - 6.00	9.37	4.38

- Pillar stability due to drivage deviation – the issue of equipment directional monitoring and deviation control has been discussed earlier. A figure of ± 20cm for each pillar has been quoted, based on manufacturer data based on actual mining trials. This amount of potential deviation has been incorporated into the pillar design dimensions.

- The PAC then discusses the age of Lithgow Seam workings as being up to 120 years, and indicates that *"the guarantee of stability needs to extend well beyond the 120 years of current historical experience".* This requirement is an impractical one, from a design perspective. It simply cannot be achieved within the actual workings design. However, in terms of achieving it with respect to avoidance of damage to actual surface structures, the adoption of proactive management controls based on ongoing monitoring and review, to maintain an adequate separation of mining from the significant features is an appropriate means of achieving the desired result.

- Approval process – The PAC states "*The strategy proposed to overcome the defects noted above is to collect the required data as part of the mine planning process and revise the estimates and detailed proposals as part of that process. The problem with this is that the*

Commission is being asked to recommend approval for extensive use of a specific mining technique that carries significant levels of impact risk for natural features of special significance within the project area without the data necessary to properly assess the magnitude of that risk. Deferring a decision of this nature to a subsequent planning process without public scrutiny has been rejected previously by both the Commission and the NSW Land and Environment Court.

In this context the Bulli Seam Operations Report noted at p.370:

- *'It is clear that the Approval must be capable of controlling the nature and magnitude of the risks of impacts, even though subsequent processes (e.g. Extraction Plans) may fill in some detail. However, if 'filling in the detail' extends to obtaining information that was really required to make a sound approval decision in the first place then this could be construed as delegation of the approval function itself.'"*

- On the basis of the above discussion points, it is argued that an approval of the overall proposed mining operation is a suitable and recommended approach. The actual mining system does not carry excessively more significant risks than other underground mining methods. The issues of protection of the critical surface landforms relates to specific locations within the mining lease, and to specific rock formations within those locations.

  It is an appropriate strategy to develop further data on the surface impact of the HWM system in this regional geology in areas well away from Ben Bullen SPL in the early stages of mining.

  Specific final highwalls and HWM layouts can be designed according to local geology in each location. Monitoring of the subsidence effects of the HWM operation ahead and away from the HWM extremities can be implemented as operations approach Ben Bullen SPL.

  Such monitoring can be incorporated into a Subsidence Management Plan which empowers and in fact binds the mine operator to comply with SPL protection, with mining restrictions applied in response to any "early warning" of subsidence developments.

  Such an approach will ensure that any impacts of mining are restricted to a safe distance from SPL, such that even if a HWM pillar failure did occur at some point in the future (deemed as highly unlikely), the impact of such failure would still fall into a region that was outside the zone which might impact the SPL.

4 RECOMMENDED APPROACH – MANAGEMENT CONTROLS

The recommended way forward for this project, and the PAC deliberations, has been indicated in the above discussion. There are a number of stages to this approach.

Firstly, in the light of this report, and any other information obtained by, or submitted to the PAC, hopefully a number of misunderstandings or concerns can be alleviated. This report has attempted to identify a number of these issues in the HWM and geotechnical space.

The critical second step, premised on accepting that the risks posed by the project are not excessive, and are manageable, is to adopt an approval approach that provides overall approval to the project, but with a number of caveats or consent restrictions.

These restrictions can be written into the approval document requiring the mine operator to produce a (Subsidence) Management Plan which incorporates incremental design and further review steps, and specifically some management system guidelines and requirements.

There are a number of precedents for this approach. By way of example, I will briefly describe one such example with which I am familiar and closely involved in, and which I believe is held as an exemplar of "best practice" in terms of subsidence management – at least by the Subsidence Branch of the NSW Dept of Trade and Investment (Resources and Energy), and possibly also by representatives of the Dept of Planning and Infrastructure.

The project is the Dendrobium Mine – Area 3 approval, granted to BHP Billiton, Illawarra Coal. Within the surface above the proposed mining area there is a particularly sensitive feature, known as the Sandy Creek Waterfall. This was identified during the approval process as a significant natural feature that must be protected from any adverse impacts of mining (the identification by the mine and appropriate authorities of significant natural features was consistent with the recommendations from the Southern Coalfield Inquiry). It consisted of a 25m high concave sandstone cliff face with a 20m overhang. Figures 11 and 12 show photographs taken from in front and beneath the waterfall overhang.

The Development Consent provided for the mining area stated:

> *1. The Applicant shall ensure that, as a result of the development:*
> *(a) no rock fall occurs at Sandy Creek Waterfall or from its overhang;*
> *(b) the structural integrity of the waterfall, its overhang and its pool are not impacted;*
> *(c) cracking in Sandy Creek within 30 m of the waterfall is of negligible environmental and hydrological consequence; and*
> *(d) negligible diversion of water occurs from the lip of the waterfall*
> *to the satisfaction of the Director-General.*

It should be noted that the Consent did not provide any prescriptive measures regarding mining set-backs or other measures, but relied on the mine and their resultant Subsidence Management Plan proactively managing the risk. There were at least three separate longwall panels that were proposed to be mined towards the location of the waterfall – Longwalls 6, 7 and 8.

In 2007 Illawarra Coal (IC) applied to modify the Development Consent for Dendrobium Mine. In December 2008 the Development Consent was modified by the Minister for Planning. The amended Statement of Commitments prepared by IC included the following requirements in relation to Sandy Creek Waterfall:

> *6. Sandy Creek Waterfall*
> *Prior to the commencement of mining within Dendrobium Area 3A, Illawarra Coal will:*
> - *establish a "technical committee" that includes BHPB, DPI, MSEC, and independent subsidence and geotechnical experts to advise on Sandy Creek Waterfall,*
> - *develop and implement detailed management outcomes such as a Trigger, Action, Response Plan (TARP), triggers and detailed monitoring where Longwalls 6-8 extract coal within 400 m of the Sandy Creek Waterfall;*
>
> *The detailed management outcomes will be determined in the SMP process.*

Figure 11. View from in front of Sandy Creek Waterfall

The above system has worked effectively and successfully for the period of extraction of all three longwalls. The company has installed a comprehensive surveying and geotechnical monitoring system between the mining location and the waterfall (on the advice of the Technical Committee). The Technical Committee (of which I am an independent geotechnical advisor, and Dr Gang Li, the NSW Principal Subsidence Engineer, is an attendee with observer status) has met regularly over the duration of the three longwall extraction periods. Monitoring data is regularly reviewed against a decision-making matrix. For longwalls 7 and 8, a separate Illawarra Coal management Steering Committee was formed. The Technical Committee provides advice to the Steering Committee who ultimately has the responsibility under the Consent provisions, and the authority to stop or continue mining. Such decisions therefore rest with the Steering Committee.

Figure 12. View from beneath Sandy Creek Waterfall overhang

The process has worked extremely well over this period. Cessation of longwall mining in each panel has been driven by the performance of the "management system" for protection of the waterfall. The management system is embedded in the Subsidence Management Plan. Formal reports on the process have been submitted to both government departments after the completion of each longwall panel.

Whilst there are differences between this and the CCP project (including a different, lower impact type of mining, and the fact that CCP involves multiple natural features, rather than one single one), the model is considered an appropriate one for consideration by the PAC and other relevant authorities.

Bruce Hebblewhite
27th February, 2013

APPENDIX A

Attached is a summary Curriculum Vitae for the author of this report, Bruce Hebblewhite. Bruce Hebblewhite has worked within the Australian mining industry from 1977 to the present time, through several different employment positions. Throughout this period, he has been actively involved in all facets of mining industry operations. In addition, he has visited and undertaken consulting and contract research commissions internationally in such countries as the UK, South Africa, China, New Zealand and Canada. For the majority of his 17 year employment period with ACIRL Ltd he had management responsibility for ACIRL's Mining Division which included specialist groups working within both the underground and surface coal mining sectors, and the coal preparation industry– actively involved in both consulting and research in each of these areas.

In his current employment position with The University of New South Wales, Bruce Hebblewhite is involved in academic management, undergraduate and postgraduate teaching and research, and contract industry consulting and provision of industry training and ongoing professional development programs – for all sectors of the mining industry – coal and metalliferous.

Both past and present employment positions require regular visits, inspections and site investigations throughout the Australian mining industry, together with almost daily contact with mining industry management, operations and production personnel.

SUMMARY CURRICULUM VITAE

Bruce Kenneth Hebblewhite

(Professor, Chair of Mining Engineering)

Head of School and Research Director,
School of Mining Engineering, The University of New South Wales

---

DATE OF BIRTH 1951

NATIONALITY Australian

QUALIFICATIONS

1973: Bachelor of Engineering (Mining) (Hons 1) School of Mining Engineering, University of New South Wales
1977: Doctor of Philosophy, Department of Mining Engineering, University of Newcastle upon Tyne, UK
1991: Diploma AICD, University of New England

PROFESSIONAL MEMBERSHIPS; APPOINTMENTS & SPECIAL RESPONSIBILITIES

Member - Australasian Institute of Mining and Metallurgy
Member - Australian Geomechanics Society
Member – Society of Mining and Exploration (SME), USA
Member - International Society of Rock Mechanics (President – Mining Interest Group (2004 – 2011))
Secretary General (and Council Member) – International Society of Mining Professors (President for 2008/09)
former Executive Director – Mining Education Australia (July 2006 – December 2009)

Expert Witness assisting Coroner: Coronial Inquest (2002-2003): 1999 Northparkes Mine Accident
Member (2005 – 2008): Independent Expert Review Panel (Dendrobium Mine), NSW Dept of Planning
Expert Witness assisting Coroner – Coronial Inquest (2007): 2004 Sydney Cross City Tunnel Fatality
Chair: 2007-2008 Independent Expert Panel of Review into Impact of Mining in the Southern Coalfield of NSW (Dept of Planning & Dept of Primary Industries)
Member, Scientific Advisory Board, Advanced Mining Technology Centre, University of Chile.

PROFESSIONAL EXPERIENCE

2003-present	University of New South Wales, School of Mining Engineering Head of School and Research Director, (Professor, Kenneth Finlay Chair of Rock Mechanics (to 2006);

	Professor of Mining Engineering (from 2006))
2006 – 2009	Mining Education Australia (a national joint venture between UNSW, Curtin University of Technology, The University of Queensland & The University of Adelaide) Executive Director (a concurrent appointment with UNSW above).
1995-2002	University of New South Wales, School of Mining Engineering Professor, Kenneth Finlay Chair of Rock Mechanics and Research Director, UNSW Mining Research Centre (UMRC)
1983-1995	ACIRL Ltd, Divisional Manager, Mining - Overall management of ACIRL's mining activities. Responsible for technical and administrative management of ACIRL's Mining Division covering both research and consulting activities in all aspects of mining and coal preparation.
1981-1983	ACIRL Ltd, Manager, Mining - Responsibility for ACIRL mining research and commissioned contract programs.
1979-1981	ACIRL Ltd, Senior Mining Engineer - Assistant to Manager, Mining Research for administrative and technical responsibilities. Particularly, development of geotechnical activities in relation to mine design by underground, laboratory and numerical methods.
1977-1979	ACIRL Ltd, Mining Engineer Project Engineer for research into mining methods for Greta Seam, Ellalong Colliery, NSW. Also Project Engineer for roof control and numerical modelling stability investigations.
1974-1977	Cleveland Potash Ltd, Mining Engineer and Department of Mining Engineering, University of Newcastle-upon-Tyne, UK - Research Associate. Employed by Cleveland Potash Limited to conduct rock mechanics investigations into mine design for deep (1100m) potash mining, Boulby Mine, N Yorkshire (subject of Ph.D. thesis).

SPECIALIST SKILLS & INTERESTS

- Mining geomechanics
- Mine design and planning
- Mining methods
- Mine safety and training
- Mine system audits and risk assessments
- Education and training