Attachment 6

Peer Review Letters

Narrabri Underground Mine Stage 3 Extension Project

Environmental Impact Statement

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Mr David Ellwood
Director, NCO Stage 3 Project

Cc: Resource Strategies Pty Ltd

My Ref: Report No. 2003/02.2

12th August 2020

Dear Mr Ellwood,

Re: Narrabri Stage 3 Extension Project Subsidence Assessment – Peer Review

I have been asked by Resource Strategies Pty Ltd, who is acting on behalf of Whitehaven Coal Ltd, to provide an independent peer review of the mine subsidence impact assessment carried out by Ditton Geotechnical Services Pty Ltd (DgS) for the Narrabri Underground Mine Stage 3 Extension Project (*"the Project"*).

1. Scope

The particular terms of reference for this peer review were as follows:

1. Review of draft Ditton Geotechnical Services (DgS) Subsidence Assessment with provision of a review report containing commentary.
2. Iterative review of DgS responses to matters identified in (1) above, and subsequent final report.
3. Provision of peer review letter describing the scope of works undertaken and an overall assessment statement.

It should be noted that this subsidence review does not include any detailed level of review with respect to groundwater and related hydrogeology matters.

The documents provided for this peer review were:

- Various components of the NSW Government Gateway Certificate Application submitted by Narrabri Coal, including:
    - Technical Overview of the Narrabri Stage 3 Extension Project.
    - Appendix C: Subsidence Assessment – Parts 1 to 4 (DgS Report No. NAR-005/1, dated 23 January 2019).
    - Appendix D: Preliminary Groundwater Assessment Part 1 (HydroSimulations Report No. HS2018/13d, dated January 2019).
- Dept of Industry advice to Gateway Panel on the Gateway Application, with covering letter from NSW Minister for Planning, dated 26 April 2019.
- Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) advice to Gateway Panel on the Gateway Application, dated 16 April 2019.
- Conditional Gateway Certificate for the Project, issued by the Mining & Petroleum Gateway Panel, dated 4 June 2019.
- Report by the Mining & Petroleum Gateway Panel to accompany issuing of Conditional Gateway Certificate, dated 4 June 2019.
- Plan showing Narrabri Stage 3 Expansion Project – Regional Location (Figure 1).
- Plan showing Approved Narrabri Mine - Indicative Underground Layout (draft) – undated (Figure 2-1).
- Plan showing Approved Narrabri Mine – Project General Arrangement Indicative Underground Layout (draft) – undated (Figure 2-4).
- *"Mine Subsidence Assessment for the Narrabri Underground Mine Stage 3 Extension Project"*; DgS Report No. NAR-005/2, dated 11 May 2020.
- *"Mine Subsidence Assessment for the Narrabri Underground Mine Stage 3 Extension Project"*; updated DgS Report No. NAR-005/2, dated 5 June 2020.
- *"Mine Subsidence Assessment for the Narrabri Underground Mine Stage 3 Extension Project"*; updated DgS Report No. NAR-005/2, dated 5 July 2020.

I have provided comments and opinion in this matter on the basis of my relevant professional qualifications, experience and background (see Summary CV in Appendix A). My background relevant to this project includes a close association with a number of different coal mining projects across NSW and internationally – from various perspectives, including mine design, audit and peer review on behalf of coal companies; and consulting/review studies on behalf of government and agencies (eg NSW Dept of Planning, Dept of Primary Industry and Dams Safety Committee).

2. Background

The following is a brief summary of the project background. This factual information is assumed for the purposes of this review, and has not been independently verified:

The following project background information has been provided by Resource Strategies. This, and all other project-related information is assumed to be correct for the purposes of this review and has not been independently verified.

Figure 1 shows the regional location of the Narrabri Mine. Figure 2 shows a plan of the current approved mine workings and the latest proposed extension layout.

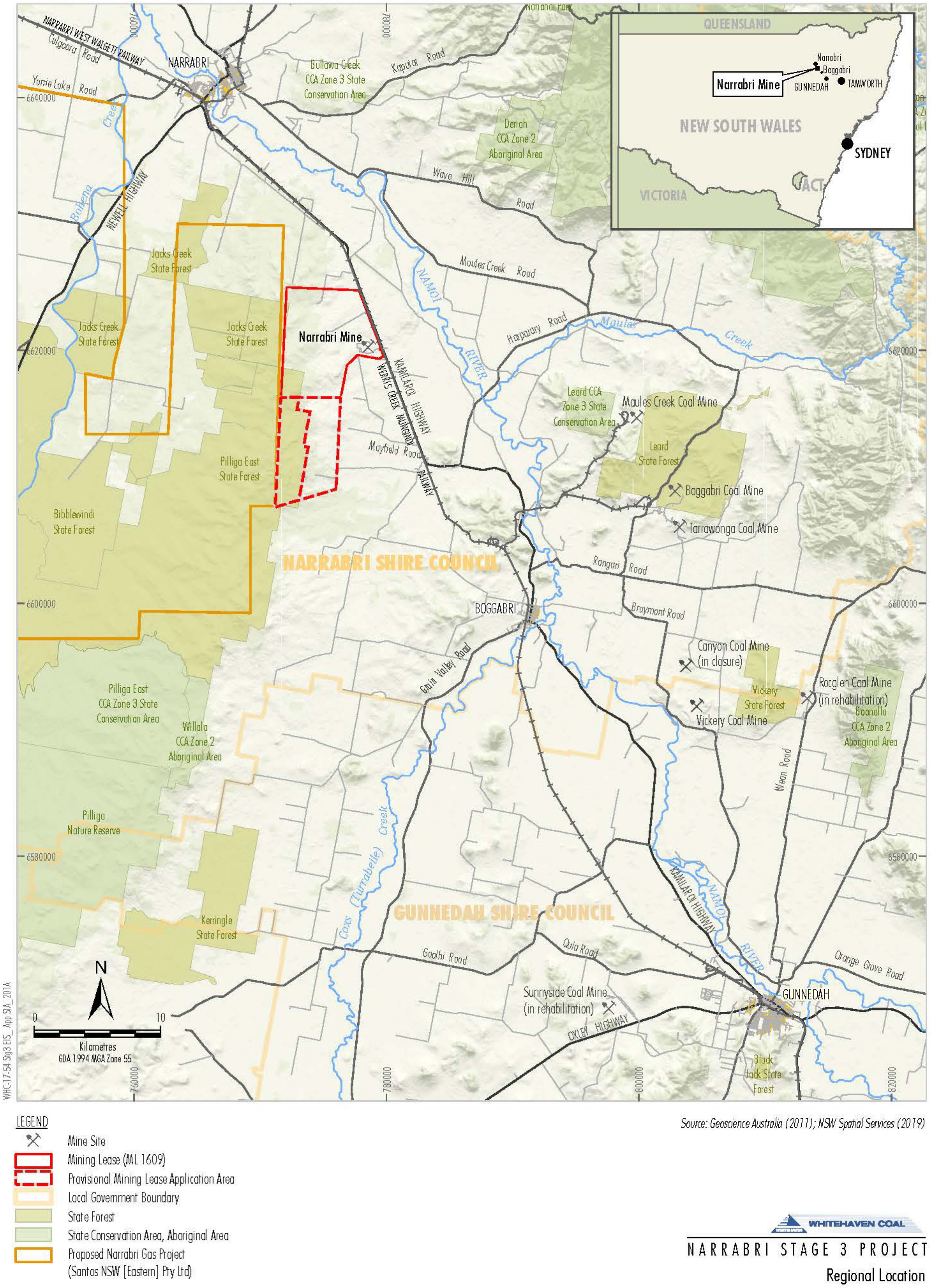

Figure 1. Narrabri Mine and Stage 3 Extension Project – Regional Location
(source: Resource Strategies (June 2020))

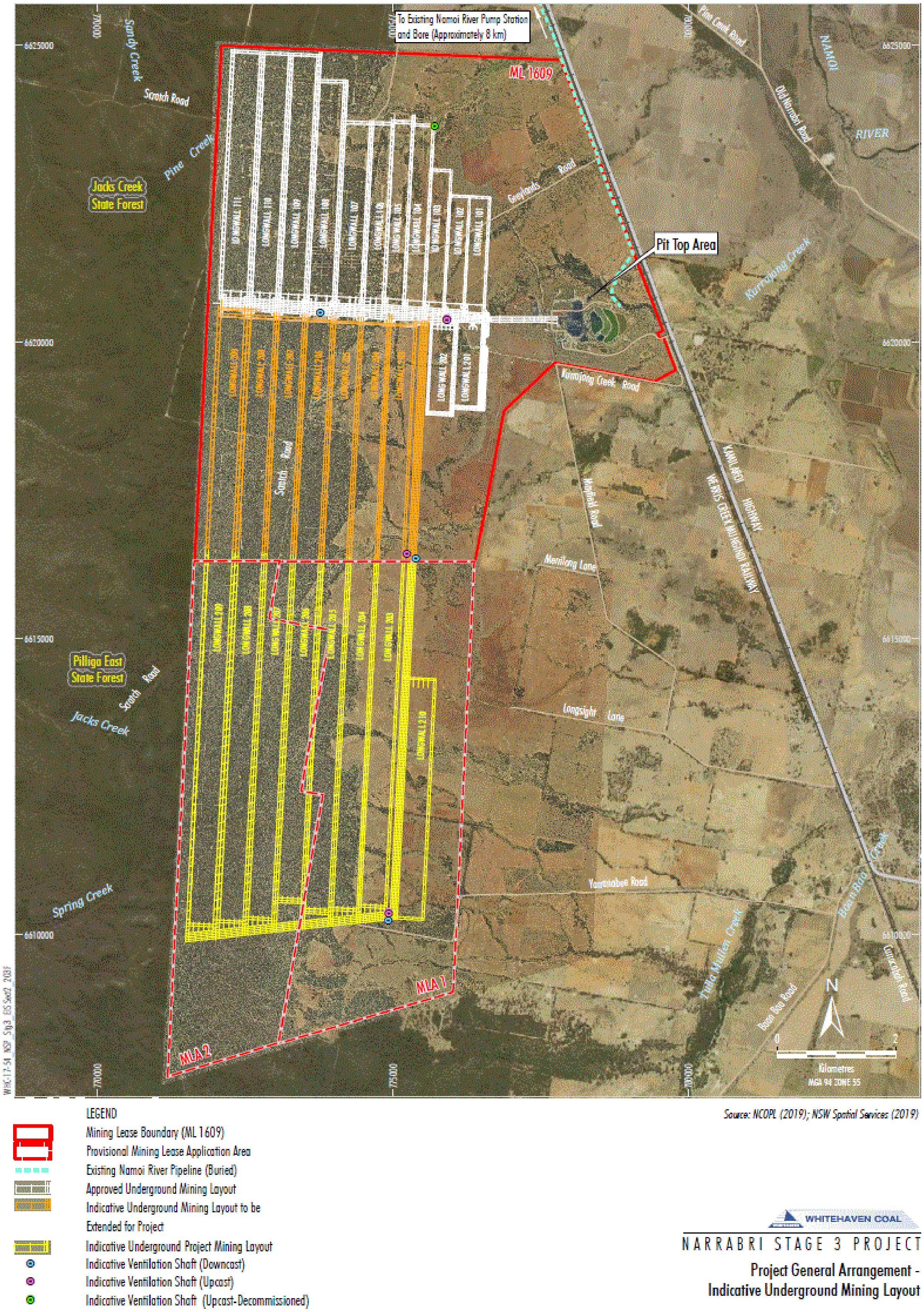

Figure 2. Narrabri Stage 3 Extension Project – Application Area

(source: Resource Strategies (May 2020))

The Project Description provides the following further information regarding the Stage 3 Extension Project:

The Project would include the following activities:

- *continued longwall mining of the Hoskissons Seam involving a southern extension including:*
  - an extension of Longwalls 203 to 209 into MLAs 1 and 2; and
  - an additional longwall (Longwall 210) within MLA 1;
- *continued development of roadways within the Hoskissons Seam and adjacent strata to access mining areas;*
- *continued use of existing roadways and drifts for personnel and materials access, ventilation, dewatering and other ancillary activities;*
- *continued production of up to 11 Mtpa of ROM coal (i.e. no change compared to the approved Narrabri Mine);*
- *continued use of the existing surface facilities (with minor upgrades and extension) and development of additional surface infrastructure associated with roadways, mine ventilation, gas management, exploration, services, water management areas and other ancillary infrastructure above the extended underground mining area;*
- *continued development of mine safety pre-conditioning areas;*
- *continued use of the existing coal reject emplacement area;*
- *disposal of drilling waste products within the rejects emplacement area, including receipt and disposal of similar drilling waste products from off-site;*
- *continued transport of product coal from site by rail;*
- *continued use and progressive development of the sumps, pumps pipelines, water storages and other water management infrastructure and development of additional water management infrastructure associated with the extended underground mining areas;*
- *continued use of the Namoi River pump station, alluvial production bore and pipeline (including potential development of a second approved pipeline);*
- *continued employment of approximately 520 full time equivalent personnel and additional contractors;*
- *continued monitoring, rehabilitation and remediation of subsidence effects and surface disturbance areas; and*
- *other associated minor infrastructure, plant, equipment and activities.*

The approved underground mining area consists of 20 longwall panels. Longwall mining is currently being undertaken in Longwall 109, with extraction of Longwalls 101 to 108a completed.

3. <u>Peer Review Outcome</u>

The procedure outlined above under the Terms of Reference was followed in relation to review of the Mine Subsidence Assessment Report provided. In particular, the initial, peer review was conducted in consideration of the 5 June 2020 DgS NAR-005/2 Mine Subsidence Assessment Report.

This preliminary peer review contained detailed comments and was reported by me in my Report No. 2003/02.1, dated 26 June 2020. The preliminary peer review report should be read for a detailed analysis of the initial DgS subsidence assessment.

In response to this review report, DgS made a number of changes and updates to the Mine Subsidence Assessment Report which have been considered and processed in a rigorous and iterative manner, resulting in the latest version of Report No. NAR-005/2, dated 5 July 2020, which has again been thoroughly peer reviewed.

On the basis of the amended documents, I offer the following summary review conclusions:

- All of the comments, suggestions and requests for further information or clarification made by me in my detailed peer review report have been responded to and addressed, as appropriate.

- I can offer the following summary comments with respect to the DgS Mine Subsidence Assessment, as it is now reflected in the 5 July 2020 version of Report No. NAR-005/2:

    - The subsidence assessment provided, is founded on a monitoring program conducted over the first eight longwall panels at the Narrabri Mine. This has provided a sound baseline of data that is clearly of direct relevance to the mining geometries and geological conditions experienced at Narrabri – in particular, the +4m mining height, the wide longwall panel widths, the moderate depths of cover, the overburden geological units and structural features present, and the relatively flat surface terrain – all of which significantly influence the nature and extent of surface subsidence effects and impacts.

    - This underpinning Narrabri database has been incorporated into a broader Newcastle Coalfield database in order to develop appropriate empirical prediction algorithms, coupled with numerical modelling software (SDPS) to produce three-dimensional subsidence predictions across the proposed mining area.

    - The resultant subsidence predictions, and associated confidence intervals for the Stage 3 project are considered to be appropriate and reliable, within the limits of the prediction methodology.

    - It is noted that the mining conditions fall within the bounds of the empirical subsidence database used for prediction, providing a reasonably good level of confidence in the predictions of both subsidence effects and impacts. Having said this, the database will continue to be expanded through further Narrabri experience (and elsewhere), which will further improve confidence levels in its application.

    - There are some minor surface topographic variations which result in some low level non-conventional subsidence behaviour such as valley closure and uplift, but these are considered to be very minor variations from the otherwise conventional subsidence behaviour predicted over the majority of the lease area.

    - Angles of draw around the perimeter of the subsidence effects indicate quite high values, by comparison with many other mining regions in NSW. The reason for this is not clear but may be associated with the nature of the near-surface geology and weathered surface soil profiles. Further monitoring should continue to assess these high angles, but there are only very low levels of strain associated with these regions such that there are no current adverse impacts detected or predicted.

    - Some regions of quite high surface tensile strains and curvature result in large surface cracking which will require remedial actions. Whilst DgS has made a number of empirically-based predictions of surface cracking, it is considered to be very difficult to accurately predict such impacts either in magnitude or location. A degree of caution must be assigned to this type of impact prediction.

    - The DgS subsidence predictions have included an assessment of the level of connective cracking between the mining horizon and the zones of surface cracking (10 – 20m below surface usually). Based on the predictions made, and the accuracy of the various models used to make such predictions (which are premised on a number of assumptions and estimates), it is expected that mining will result in connective cracking extending through most underground aquifer horizons, and potentially intersecting with surface cracking in some situations. Once again, remedial work should be prepared to deal with any cracking interference to surface water flows, storage and drainage.

- It is considered essential that further monitoring be conducted over the future longwall panels to improve the database and understanding of subsidence effects and impacts. As more data is collected, the prediction model should be periodically reviewed and updated.

- Similarly, further monitoring of potential connective cracking impacts on should be conducted in order to gain an improved understanding of the impacts of mining on the overburden strata units and any groundwater horizons contained within them.

Yours sincerely,

Bruce Hebblewhite

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 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.

Disclaimer

Bruce Hebblewhite is employed as a Professor within the School of Minerals & Energy Resources Engineering, at The University of New South Wales (UNSW). In accordance with policy regulations of UNSW regarding external private consulting, it is recorded that this report has been prepared by the author in his private capacity as an independent consultant, and not as an employee of UNSW. The report does not necessarily reflect the views of UNSW and has not relied upon any resources of UNSW.

SUMMARY CURRICULUM VITAE

Bruce Kenneth Hebblewhite

(Professor, Chair of Mining Engineering),
School of Minerals & Energy Resources Engineering, The University of New South Wales, &

Consultant Mining Engineer

DATE OF BIRTH 1951

NATIONALITY Australian

QUALIFICATIONS

1973: Bachelor of Engineering (Mining) (Hons 1) School of Mining Engineering, Uni. 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; AWARDS & SPECIAL RESPONSIBILITIES

Fellow - Australasian Institute of Mining and Metallurgy
Member - Australian Geomechanics Society
Member – Society of Mining and Exploration Engineering (SME), USA
Member - International Society of Rock Mechanics (President – Mining Interest Group (2004 – 2011))
Emeritus Member - Society of Mining Professors (SOMP) (President (2008/09); Council Member (2006 -2018); Secretary-General (2011-2018))
Executive Director – Mining Education Australia (July 2006 – December 2009)
Chair, Governing Board – Mining Education Australia (2015)
Member, Branch Committee – AusIMM Sydney Branch (2017-2019)

Expert Witness assisting Coroner: Coronial Inquest (2002-2003): 1999 Northparkes Mine Accident
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)
Expert Witness assisting NSW Mines Safety Investigation Unit – Austar Mine double fatality, April, 2014.
Member (2012 – present): Scientific Advisory Board, Advanced Mining Technology Centre, Uni. of Chile.
Trustee (2013 – present): AusIMM Education Endowment Fund
2012 Syd S Peng Ground Control in Mining Award – by SME (USA).
2017 Ludwig Wilke Award for contribution to international mining research and education (Society of Mining Professors).
2017 SME Award for Rock Mechanics (presented at 2018 SME Annual Meeting in Minneapolis, USA in Feb 2018).
2020 AusIMM Institute Medal – for contributions to the mining industry and profession through education, research and training.

PROFESSIONAL EXPERIENCE

2014 – present	University of New South Wales, School of Minerals & Energy Resources Engineering (formerly School of Mining Engineering) Professor of Mining Engineering (p/t)
1995 - present	Principal Consultant - B K Hebblewhite Consulting
2003-2014	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 and practice
- Mine safety and training
- Mine system audits and risk assessments
- Mining education and training

Jacobs

Memorandum

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Subject	**Groundwater Assessment Review**	**Project Name**	Narrabri Underground Mine - Stage 3 Extension Project
Attention	David Ellwood	**Project No.**	IS343800
From	Brian Barnett		
Date	13 October, 2020		
Copies to			

1. Introduction

This document provides final peer review comments on the Narrabri Underground Mine Stage 3 Extension Project – Groundwater Assessment by Australasian Groundwater and Environmental Consultants Pty Ltd., versions 06.01 and 06.02 dated 20 August 2020 and 12 October 2020 respectively (the Report). My review also includes an assessment of the Numerical Modelling Report included as Appendix D of the Report (the Appendix). The Appendix provides a detailed description of the groundwater modelling undertaken to support the impact assessment as presented in the Report.

My review is aimed at assessing the groundwater modelling that has been undertaken to support the environmental impact assessment of the project. Accordingly, I have focussed on those aspects of the conceptualisation and modelling that may influence the simulation of drawdown and flux impacts on the important aquifer systems, and the hydrogeological and environmental assets they support.

As a result of my initial review, there were a number of issues raised as to how the work was reported, and these have been addressed by the authors.

Underground longwall mining at the Narrabri Mine commenced in 2012 with Stages 1 and 2 mining approved. The current work is being undertaken in support of proposed Stage 3 mining and is aimed at investigating groundwater behaviour and quantifying environmental impacts that may arise from Stage 3 mining. The proposed longwall method is expected to alter the local hydrogeological environment as a result of groundwater inflows to the mine workings and from the local disturbance caused by rock deformation and fracturing above completed longwall panels.

Mining is targeted at the Hoskissons Coal Seam which is typically between 7 and 10 m thick, and between 160 and 420 m below surface. It is separated from the Upper Namoi Alluvial and Pilliga Sandstone Aquifers by a number of poorly permeable hydrogeological units that are expected to provide a degree of buffering of drawdown impacts.

2. The Appendix

The Appendix is a comprehensive groundwater modelling report that covers all tasks undertaken in the development and use of the numerical model. It follows the work flow recommended by the

Australian Groundwater Modelling Guidelines (Barnett *et al.,* 2012) except for the hydrogeological conceptualisation which is described in some detail in the Report.

There have been a number of groundwater modelling investigations undertaken within the region of the mine and these have focused on both the water resources of the alluvial aquifer system (McNielage, 2006), and the extraction of water and gas from the underlying coal seams (CDM Smith, 2016). Indeed, there have been a number of modelling investigations aimed at assessing potential impacts from earlier stages of the Narrabri Mine, including;

- An initial model in support of Stage 1 approvals (GHD, 2007).
- Model of longwall mining operation, Stage 2 (Aquaterra, 2009).
- Longwall panel modification (and subsequent model update), Stage 2 MOD 5 (HydroSimulations, 2015 and 2016).
- Stage 3 Gateway Application (HydroSimulations, 2019).

The model has been developed in the MODFLOW USG numerical code using unstructured Voronoi elements to discretize the model domain in a manner that provides refined model cells in the region of the mine and hydrological features of interest. Eleven model layers have been defined on the basis of the principle geological units present, including alluvial sediments and, consolidated sedimentary and volcanic rocks.

Given the location of the mine in relation to the Namoi River and its many tributaries, the assessment of potential impacts of mining on river baseflow is an important consideration for the work. Interaction between groundwater and the network of rivers and streams that drain the region is facilitated through the implementation of both the MODFLOW RIV and STR packages. The STR package has been used to simulate groundwater interactions with the major, gauged rivers and creeks (i.e., the Namoi River and Maules, Cox's and Bohena Creeks). In these features the groundwater model exchange fluxes are constrained by surface flows entering the model domain and by modelled baseflow losses within the model domain. The MODFLOW RIV package has been used to simulate groundwater discharge fluxes to all other water courses that are not gauged and many of which are ephemeral. For these water courses, the RIV package has been parameterised to ensure that they act as drainage features and do not allow groundwater recharge to occur. The approach is appropriate and, in my opinion, provides a reasonable basis for assessing surface water impacts that may arise from mining.

Climate stresses have been simulated through the application of the MODFLOW RCH and EVT packages in appropriate and standard methods. Recharge rates have been constrained through the implementation of a SWAT catchment model with further support from Chloride Mass Balance calculations to provide bounds on model recharge rates.

Calibration has used a range of different types of data including:

- Heads measured in a network of monitoring bores,
- Head differences observed in nested piezometers indicating vertical head gradients,
- Estimated mine inflow rates,
- Estimated baseflow in some of the major rivers and creeks, and
- Presence of springs indicating groundwater levels at ground surface.

By using a range of different types of calibration data, the non-uniqueness in model parameters can be substantially reduced and the resultant model confidence improved. The approach described in the Appendix indicates an excellent use of existing data that maximises the value of historical observations at the site and elsewhere in the model domain.

The calibration method includes a pre-mining steady state, followed by a transient calibration period from 2009 to 2019 covering the historic mining period. The process has been undertaken with a combination of manual testing and automated (PEST) methods. Results are presented in a series of charts and tables showing measured calibration targets and relevant modelled estimates. In general, there is a good correlation between computed and observed behaviour in all calibration data sets (although I note that calibration to groundwater discharge to springs has not been reported). Calibration statistics for groundwater heads are reported for the transient calibration in the form of the Scaled RMS Error as between 3.3%, 7.7% and 9.4 % for alluvial bores, on-site NCOPL bores and other bores, respectively. Calibration matches to all other target data have not been quantified in terms of matching statistics, but a qualitative comparison suggests the model provides a reasonable replication of the observations.

I have concluded that the calibration approach and outcomes meet all reasonable expectations (including guiding principles outlined in Australian Groundwater Modelling Guidelines) and in most regards exceed current industry standards.

The calibrated model transmission and storage parameters are presented in Tables D3.7 and D3.8, respectively. Of particular note with regard to the calibrated hydraulic conductivities included in Table D 3.7 is the extreme levels of anisotropy (ratio of horizontal to vertical hydraulic conductivity) included in Layers 3, 4 and 5 representing the Purlawaugh Formation, Garrawilla Volcanics and the upper part of the Napperby Formation respectively. The table suggests that the average vertical hydraulic conductivity in these layers is typically 3 to 4 orders of magnitude lower than the horizontal hydraulic conductivity. Such high levels of anisotropy appear to be supported by observations that suggest drawdown in and around the mine workings have not propagated towards near surface formations.

Three predictive scenarios have been assessed as follows:

- A Baseline Scenario (null case scenario) that includes neither the Narrabri Mine nor the nearby Narrabri Gas Project.
- A Cumulative Scenario that includes both the Narrabri Mine and the Narrabri Gas Project.
- An Incremental Baseline Scenario that includes the Narrabri Gas Project but does not include the Narrabri Mine.

The cumulative impacts of both the mine and coal seam gas operation have been estimated by comparing the results of the Cumulative Scenario and the Baseline Scenario and the incremental impacts of the mine are calculated by comparing the Cumulative Scenario results with those of the Incremental Baseline Scenario. The approach follows recommendations in the Australian Groundwater Modelling Guidelines in that predictive modelling outcomes are obtained as the difference between two predictive model outcomes.

Maximum predicted incremental (i.e., project only) drawdown estimates are presented in each model layer in Appendix D 4. The results illustrate that for all layers below the Pilliga Sandstone, drawdown is predicted to propagate away from the mine to the west. This is a direct result of the model structure which has most of the deep layers terminating close to the east of the project boundary.

Predicted changes in the model's water budget are illustrated in Table D 4.1 and D 4.2 and in Figure D 4.2. The results indicate that changes in storage dominate all other predicted changes. During mining changes to the Storage In component of the water budget (representing drawdown) match the predicted mine inflow fluxes and in the recovery period the changes in groundwater fluxes are dominated by changes to both the Storage In (on-going drawdown propagation after mining ceases) and Storage Out (rebound in groundwater heads as mine inflows cease) components of the water budget.

Predicted changes in the exchange fluxes with the alluvial aquifers and estimated baseflow are modest and reflect the fact that there is a relatively poor hydraulic connection between the Hoskissons Coal Seam and the shallow alluvial sediments.

The Appendix documents an uncertainty analysis that has involved a Null-Space Monte Carlo approach to explore predictive uncertainty within the bounding constraints of the information contained within the calibration data sets. The approach involves the formulation of multiple model realisations that pass defined calibration criteria and are then used in predictive scenarios. The approach results in a population of predictive outcomes that can then be analysed and reported. The method provides a comprehensive assessment of parameter uncertainty, is consistent with the Australian Groundwater Modelling Guidelines, and is considered to be the current industry benchmark for uncertainty quantification.

3. The Report

The Report provides a thorough and comprehensive description of the hydrogeological environment within which the Project is located. Of particular relevance or concern is the fact that the mine is adjacent to two aquifers of local and regional importance namely:

- The alluvial aquifer system associated with the Namoi River and its tributaries (including Kurrajong Creek and Tulla Mullen Creek) which is relied upon as a water source for a number of irrigators and for stock, domestic and municipal water supplies. It is best described as a high value hydrogeological asset that is already heavily stressed. The environmental assets associated with the aquifer are likely to have already been impacted by historic extraction of groundwater, and
- The Pilliga Sandstone Aquifer which is a regionally significant, highly porous and permeable aquifer that is present within the Mining Lease. It is a GAB aquifer and is part of the Southern Recharge Groundwater Source under the NSW GAB Water Sharing Plan.

The Report provides an excellent summary of the groundwater modelling work described in the Appendix. Important groundwater modelling outcomes are clearly described and illustrated through a series of easily digested maps, charts and tables. The level of reporting is of a high standard and meets all requirements of the Australian Groundwater Modelling Guidelines (Barnett *et al.,* 2012).

4. Conclusion

The groundwater assessment and supporting groundwater modelling work described in the Report and Appendix have been carried out in a professional and rigorous manner and meet or exceed current industry standards. The modelling work has been completed in line with the Guiding Principles included in the Australian Groundwater Modelling Guidelines and I have not identified any fundamental flaws in the work, both in terms of the approaches and assumptions that have been adopted and the interpretation of the outcomes.

5. References

Aquaterra, 2009, Narrabri Coal Mine Stage 2 Longwall Project, Hydrogeological Assessment.

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A., 2012, The Australian Groundwater Modelling Guidelines. Waterlines Report #82, National Water Commission, Canberra.

CDM Smith, 2016, Narrabri Gas Project Groundwater Impact Assessment.

GHD Pty Ltd, 2007, Narrabri Coal Project Groundwater Assessment.

HydroSimulations, 2015, Narrabri Mine Modification, Groundwater Assessment.

HydroSimulations, 2016, Narrabri Mine Groundwater Data Analysis and Re-calibration.

HydroSimulations, 2019, Narrabri Underground Mine Stage 3 Extension Project: Gateway Application Preliminary Groundwater Assessment.

McNeilage, C., 2006, “Upper Namoi groundwater flow model. Groundwater Management Area004; Zones 2,3,4,5,11 and 12. Model development and calibration”, NSW Department of Natural Resources, Parramatta.

Appendix A: Curriculum Vitae

Brian Barnett

Qualifications:

Bachelor of Engineering (Civil), University of Auckland, 1980

Relevant Experience:

Jacobs Group (Australia) Pty Ltd. (Prior to December 2013 SINCLAIR KNIGHT MERZ, AUSTRALIA)

May 2000 to present

Senior Hydrogeologist and Geothermal Reservoir Engineer SKM, Melbourne, Australia.

Responsible for groundwater modelling and geothermal studies. Major projects include:

- ***Australian Groundwater Modelling Guidelines. National Water Commission.*** Project manager and principal contributor to an Australian Groundwater Modelling Guideline that is planned to supersede the current Murray Darling Basin Commission guidelines. The project was completed in March 2012 and the document was published in June 2012.
- ***Frieda River Mine Dewatering Investigations. Xstrata Copper.*** Groundwater modelling of a proposed copper mine in Papua New Guinea. Groundwater models were used to estimate the dewatering pumping requirement for the mine and to provide an assessment of the environmental impacts that may accompany mine dewatering.
- ***New Acland Coal Mine*. *New Hope Group.*** Developed a groundwater model of the New Acland Coal Mine to assist with gaining environmental and industry approvals for expanding coal mining operations. The model was used to predict the likely future inflows to the mining pits and to assess potential impacts that may arise from the inflows and associated drawdown in groundwater

heads. The work has included expert witness appearance in recent Queensland Land Court proceedings.

- ***Wards Well Coal Mine. BMA***. Supervising the modelling of an underground coal mine in Queensland. The model includes time varying material properties that represent deformation of formations above long wall mine panels.
- ***Kulwin Mineral Sands Mine Dewatering Investigations. Iluka Resources Ltd.*** Detailed numerical groundwater models were developed to help design the mine dewatering system. Investigations were aimed at depressuring the local groundwater system to expose the mineral sand deposits to allow dry mining of the resource. The models paid particular attention to vertical flow processes in and around the deposit and hence incorporated multiple (27 layers in total) horizontal layers.
- ***Pardoo Iron Ore Mine Dewatering Investigations. Atlas Iron.*** Groundwater models were developed in the FEFLOW numerical modelling code to estimate the mine dewatering requirements of an iron ore mine in the Pilbara region of Western Australia.
- ***Northern Murray Basin Environmental Effects Statement. Iluka Resources Ltd.*** Preparation of a water management report that formed part of the EES for the Kulwin and WRP deposits in the Northern Murray Basin Project. Work included the development of regional groundwater flow models to assess environmental impacts of dewatering and water disposal.
- ***Mine dewatering for Murray Basin Titanium Ltd for the Wemen Mineral Sand Mine.*** Numerical groundwater models were formulated and calibrated in order to help optimise a dewatering plan for a mineral sand deposit in Northern Victoria. The models were also used to assess the likely impacts of dewatering and associated water disposal on the Murray River.
- ***Mine water management consultant for Murray Basin Titanium Ltd for the Prungle Mineral Sand Mine.*** Responsibilities included the development of numerical groundwater models to assist in designing a groundwater supply scheme to provide water for a dredge mining operation in Northern Victoria. Investigations also included the assessment of groundwater extraction and disposal on local and regional surface water and groundwater resources.
- ***Murray Darling Basin Sustainable Yields Project. CSIRO.*** Groundwater modelling team leader for a major project covering groundwater resources in Queensland, New South Wales, Victoria and South Australia. SKM was contracted by CSIRO in 2007 to undertake the groundwater resource assessment for the entire Murray Darling Basin. The project involved the numerical modelling of all major fresh water aquifers in the basin. Twelve finite difference numerical models were run for the study. Results were used to quantify the available groundwater resources of the basin and to assess the impacts of future climate change and impacts of groundwater development on river flows.
- ***Northern Sewer Project, Groundwater Models.*** Groundwater flow models were developed for the NSP1 and NSP2 sewer tunnels in north Melbourne. The models were used to assess inflows into the tunnels and to determine the likely impacts of groundwater drawdown on the aquifer and on

the associated loss of base flow to local streams and rivers. Models were constructed to assess both the construction and operational phases.

- ***Lindsay River Groundwater Modelling. DNRE Victoria.*** Development of a three dimensional finite element groundwater model of the aquifers within the Lindsay River Anabranch of the Murray River. The model was developed in the FEFLOW modelling code and is being used to design a salt interception scheme.
- ***Numerical Water Trade Models. Mallee CMA Victoria.*** Project manager and leader of modelling team to develop, calibrate and run predictive scenario models for the Nangiloc Colignan and Wemen irrigation areas in northern Victoria. Models were aimed at quantifying the impact on salinity in the River Murray associated with the trading of irrigation water.
- ***South East Queensland Effluent Reuse Study – Darling Downs.*** Brisbane City Council. The impacts associated with future use of treated effluent for irrigation in the Darling Downs was investigated through the development and calibration of large scale three dimensional groundwater flow and solute transport models. Impacts under investigation included changes in groundwater head, changes in the groundwater interaction with rivers and streams and the water quality changes in the aquifer.
- ***Lake Toolibin Groundwater Modelling. CALM WA.*** A three dimensional finite difference groundwater model was formulated to assess the dewatering performance of a network of pumping bores designed to reduce groundwater heads beneath Lake Toolibin. The project is aimed at minimising salinisation of the lake by reducing groundwater discharge through the lake bed.
- ***Barwon Downs Groundwater Modelling. Barwon Water, VIC.*** This project involved the development and calibration of a large three dimensional finite difference groundwater flow model to assess the safe long term yield from the Barwon Downs borefield. Models were calibrated over a thirty year period of observation and were run in predictive mode for 100 years.

KINGSTON MORRISON LIMITED, AUCKLAND

1997 to May 2000

In July 1999, Kingston Morrison Ltd joined the Sinclair Knight Merz Group.

- **Senior Geothermal Reservoir Engineer.** Responsible for all aspects of geothermal reservoir assessment and well testing. Also responsible for all hydrogeological investigations and groundwater modelling.

SUMIKO CONSULTANTS COMPANY LIMITED, TOKYO, JAPAN

1991 to 1997:

Geothermal Reservoir Engineering Manager. Responsible for the enhancement of geothermal reservoir engineering and mineral resource evaluation capabilities in Sumiko Consultants through the acquisition of reservoir and well bore simulation codes and the application of geostatistical methods and software.

GEOTHERMAL ENERGY NEW ZEALAND LIMITED (GENZL), AUCKLAND

1981 to 1991:

Reservoir Engineer. Responsible for all geothermal reservoir engineering studies including extended assignments in Indonesia, Kenya and Japan.

HAWKES BAY REGIONAL WATER BOARD

1979 to 1981:

Groundwater Engineer. Duties included the investigation of hydraulic and chemical characteristics of aquifers in the Hawkes Bay region and the preparation of resource management plans.

T.A. (Tom) McMahon BE, DipEd, PhD, DEng, FTSE
Professor Emeritus

THE UNIVERSITY OF MELBOURNE

David Ellwood
Director NCO Stage 3 Project
Narrabri Coal Operations Pty Ltd
10 Kurrajong Creek Rd
Baan Baa NSW 2390

Dear Mr Ellwood

I have completed my assessment of the Narrabri Underground Mine Stage 3 Extension Project (the Project) Surface Water Assessment prepared for Narrabri Coal Operations Pty Ltd (NCOPL) by WRM Water & Environment Pty Ltd. My comments are set out below. I offer these comments on the basis of my relevant professional qualifications, experience and background (see CV in Appendix A).

My review consisted of reading and commenting on the draft Report revision 3 (0189-13-E2 Draft, 22 May 2020) and subsequent revisions, Report 0189-13-E5, 30 June 2020, Report 0189-13-E6, 9 July 2020, Report 0189-13-E8, 19 August 2020 and Report 0189-13-E9, 6 October 2020. Based on my reading and studying the Reports, I recommended a number of changes, and I can confirm that all these have been appropriately addressed by the Consultant. The Report consists of nine substantive sections; the penultimate section is a summary and conclusions, and the last section is a set of references. There is also an appendix of figures presenting the water balance model calibration results.

Section 1 provides a brief introduction to the Project plus a list of five studies directly relevant to the Surface Water Assessment.

Section 2 includes the Secretary's Environmental Assessment Requirements for the Project. These are listed extensively in Table 2.1 and, as far as I can ascertain in regard to the Report, all these requirements have been dealt with. (I have not checked those listed as being addressed in other reports listed in Section 2.)

The relevant legislation and guidelines relating to the Project are identified and discussed in Section 3 under the headings: Water Management Act 2000 (Section 3.2), Protection of the Environment Operations Act 1997 (Section 3.3), Dams Safety Act 2015 (Section 3.4), NSW Water Quality and River Flow Objectives (Section 3.5), Managing Urban Stormwater: Soils and Construction (Section 3.6), NSW State Rivers and Estuaries Policy (Section 3.7), NSW flood Prone Land Policy (Section 3.8) and Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Developments – Impacts on Water Resources (Section 3.9).

Department of Infrastructure Engineering
The University of Melbourne
Victoria 3010
Australia
email: thomasam@unimelb.edu.au

The existing surface water environment is addressed in Section 4. In Section 4.1, the rainfall data for the mine location (as direct observations, and as data downloaded from the Scientific Information for Land Owners (SILO Data Drill)), and for Boggabri Post Office are consistent and permit a record of daily data for 131 years from 1884 to 2020 to be used in subsequent analysis. The potential evaporation data from SILO Data Drill cover the same period. These long data sets are suitable for the hydrologic analysis described in the Report.

The regional and local drainage within the mine area and associated catchments are described in Sections 4.2 and 4.3. There are two main creeks (Kurrajong and Tulla Mullen Trib 1) and some minor (1st and 2nd order) watercourses that originate or pass through the proposed Mining Lease Applications. Channel descriptions (location, stream width and cross-section, bed material and bed slope) and photographs provide a clear picture of the catchments to be modelled. Existing subsidence in the area is noted. Although there are 176 existing farm dams on contiguous land owned by NCOPL, these are mostly less than 1 ML in capacity. The information in Section 4.2 is in sufficient detail to understand the hydrologic characteristics associated with the Project area.

Surface water quality is discussed in Section 4.5. Both regional water quality, including the Namoi River, and local water quality are measured regularly at many sites within and downstream of the present mine site. The differences in water quality between upstream and downstream of the mine site are small and no trends have been observed in the water quality over the life of the mine. Water quality has also been assessed across the water storages at the Narrabri Mine. I am satisfied Section 4.5 provides an adequate description of the background water quality for the Project.

To complete an understanding of the surface water environment, Section 4.6 deals with flooding. The study concludes that the "…Namoi River would not inundate the Project site under any circumstance." A previous report noted that the Pit Top Area was outside the 100-year average recurrence interval flood extent and as no infrastructure is proposed as part of the Project, no change in flooding impact is anticipated.

In Section 5 there is an extensive discussion (eleven sub-sections) of the existing and approved site water management. The current or approved water management systems include up-catchment diversion structures, raw water storage dams, mine water storage dams, a filtered water storage dam, brine storage dams, sediment dams, water treatment facilities, the Namoi River pump station, alluvial production bore and pipeline, and other water transfer infrastructure (i.e. tanks, pumps and pipelines). The interconnections among these units are shown diagrammatically in Figure 5.3. Six types of water within the current mine modelling are identified including raw water imported for external sources, filtered water from the reverse osmosis and the microfiltration plants, disturbed area runoff, mine runoff, pit-top runoff, and brine. Clean water (surface runoff from the Narrabri Mine site areas unaffected by mining operations) and rehabilitated mine area runoff (runoff from rehabilitated mine areas that have established stable vegetation cover) are considered separately. As far as I'm able to tell without visiting the mine site, Figure 5.3 is an accurate representation of the present water management system.

Water demand and supply are described in Section 5.4. The main water sources include groundwater inflows into the underground workings, captured runoff from disturbed areas, raw water imported to site from the Namoi River pump station and/or alluvial production bore via the pipeline, and potable water trucked to site by a licensed contractor. An important component in the water cycle is mine dewatering which consists of groundwater inflows to the underground workings and mine filtered water. Groundwater inflows cannot be measured directly but are estimated by a simple water balance defined as groundwater inflows = (recorded box cut sump flowmeter volume) – (calculated underground demand return). The groundwater extracted from the mine is then equal to the groundwater inflows plus the gas drainage extraction. I am satisfied with the above estimation procedure.

Sections 5.7 and 5.8 describe respectively controlled releases from the Narrabri Mine site and Brine disposal strategy. Neither of these options have needed to be implemented.

Extensive details of the operation of the current water management system as depicted in Figure 5.3 are discussed in Section 5.9 and the historical behaviour of the system including operational changes are provided in Section 5.10.

The site water management system for the Project is described in Section 6. The objectives and design criteria are set out in Section 6.1. I strongly endorse these design criteria namely:

- to protect the integrity of local and regional water resources;
- to separate runoff from undisturbed and mining-affected areas;
- to design and manage the system to operate reliably throughout the life of the Project in all seasonal conditions, including both extended wet and dry periods;
- to provide water for use in mining and CHPP operations that is of sufficient volume and quality, particularly during periods of extended dry weather;
- to provide sufficient storage capacity in the system to store, treat and discharge runoff as required, particularly during periods of extended wet weather; and
- to maximise the re-use of water on-site.

Sections 6.2 to 6.6. outline the changes in infrastructure required to the service the Project until 2044. It is noted that these changes to the existing/approved Narrabri Mine site water management system schematic are not extensive. They include the construction of the Southern Mine Water Storage and additional sediment dams for the ventilation shaft and service borehole pads.

In order to assess the mine water balance to varying rainfall and catchment conditions during the life of the Project, an internationally developed and well-known computer-based simulation model (known as GoldSim) was used. Details of the modelling are described in Section 7. Inflows to the model, operating at a daily time-step, include direct rainfall on water surface of storages, catchment runoff, groundwater inflows to existing voids and underground, and outflows comprise of evaporation from water surface of storages, CHPP demand, water for dust suppression, wash down, underground water usage, and entrainment of water in co-disposed rejects. For model calibration, rainfall and evaporation data from July 2012 to March 2020 were used and simulations were based on the period January 1889 to January 2020. Although no measured runoff data were available, model calibration was based on recorded water levels and salinity measurements (observed, on average, about every five weeks) in seven dams at the mine site. No validation of the model nor model parameters using independent data was undertaken. Nevertheless, the simulated results suggest the modelling is satisfactory.

The calibrated GoldSim model was used to assess the behaviour of the water management system over the future 24 years of mine operations for a range of climate scenarios, based 131 simulations derived from the 131 years of SILO Data Drill climate data. Model set up and forecasting are described in Section 7.4 and results are presented in Section 7.5. I am satisfied that the above analysis was satisfactory, and the interpretation of results are consistent with model outcomes.

Assessment of potential impacts of the Project on local and regional water sources are addressed in Section 8. In Section 8.1 there is a detailed assessment of the potential impact of subsidence along relevant reaches of Kurrajong Creek, Tulla Mullen Creek Trib 1 and several other minor watercourses. This is a rigorous assessment and, as far as I'm able to judge, addresses the key issues in these ephemeral streams. There is also a discussion in Section 8 regarding potential impacts on local catchment flows, Namoi River flows, potential flooding, surface water quality, and cumulative impacts. From the information provided, I agree there is negligible impact on these. This is summarised in Section 8.8 which addresses Matters of National Environmental Significance. The effect of climate change is addressed in Section 8.9. Based on the projected changes in Table 8.3, I agree with the conclusion that any change on water management due to potential climate change is small compared to climate variability.

In the final substantive section (Section 9), I note that current the Water Management Plan and the Extraction Plan Water Management Plan which include a site water balance, an erosion and sediment control plan, a surface water monitoring plan, and a surface and groundwater response plan in the form of a Trigger Action Response Plan (TARP) would be reviewed and updated. This is appropriate. I concur with the recommendation that the current water monitoring programme be continued and expanded to include two additional background water quality monitoring sites.

In summary, I conclude that, overall, the study detailed in the Project Surface Water Assessment Report was completed in a professional and detailed manner, and the conclusions in the Report are appropriately supplemented by suitable modelling studies carried out by the consultant.

Your sincerely

TA McMahon
9 October 2020

Appendix A Curriculum Vitae

Name: Thomas A McMAHON

Address: Department of Infrastructure Engineering
The University of Melbourne, Victoria, 3010, Australia

Qualifications: BE(Ag) (Melb) 1959, PhD (NSW) 1967, DipEd (Monash) 1972, DEng (Melb) 1980

Academic and Research Positions:

2005 continuing	Professor Emeritus, the University of Melbourne
2005 (December)	Retired from the University of Melbourne
2002-2004	Head, Department of Civil & Environmental Engineering, the University of Melbourne
1993-2004	Professor of Environmental Hydrology, the University of Melbourne
1992-2004	Deputy Director, Co-operative Research Centre for Catchment Hydrology
1987-2004	Co-Director, Centre for Environmental Applied Hydrology.
1980-1992	Professor of Agricultural Engineering, the University of Melbourne
1973/74 & 77/78	Senior Project Engineer, Acres Consulting Services Ltd, Toronto, Canada
1967-1980	Lecturer, Senior Lecturer, Associate Professor, Department of Civil Engineering, Monash University
1960-1967	Research Officer, Hunter Valley Research Foundation, NSW.

- Professor McMahon taught undergraduate and postgraduate courses in hydrology and water resources and in environmental engineering related subjects from 1967 to 2005. He supervised higher degree students (45 PhDs) and Research Masters in most areas of hydrology and water resources, including rainfall-runoff modelling, water resources systems and storage-yield analysis, stochastic hydrology, water demand modeling, global and low flow and flood hydrology, and urban hydrology and related decision support systems.

Consulting and International Activity:

- Consulting work was carried out for many international organisations including Inland Water and Environment (Canada), International Bank for Reconstruction and Development (USA), Institute of Hydrology (UK), Electricity Corporation of New Zealand, Directorate of Water Affairs (South Africa), Porgera Joint Venture (PNG) and Lesotho Highlands Development Authority (Lesotho). From 1976-80, Professor McMahon was Chairman of the UNESCO Working Group (Paris) on low flow hydrology.
- Professor McMahon's international activities included assignments in Canada, Cuba, France, Lesotho, New Zealand, Philippines, South Africa, Soviet Union, UK, USA and Vietnam.
- Recent research includes estimating evaporation, annual runoff from global climate models, discharge rating curves, cost and physical features of dams and reservoirs.
- In Australia, he has consulted to many government agencies on hydrology, water resources and environmental flows including reviews of Canberra, Melbourne and Sydney water supply systems. Over the past 10 years, he has carried out peer reviews of water management systems in open–cut and underground coal and gold mines in NSW, and acted as a reviewer for the Bureau of Meteorology and CSIRO.

Awards:

1978: W.H. Warren Medal by the Institution of Engineers, Australia
1981: Doctor of Engineering by the University of Melbourne
1986: Elected Fellow, Australian Academy of Technological Sciences and Engineering
1994: Guy Parker Award by Australian Water & Wastewater Association Ltd
1997: Guy Parker Award by Australian Water & Wastewater Association Ltd
1997: Crawford H. Munro Orator, Institution of Engineers, Australia
1998: Best paper in Journal of Irrigation and Drainage Engineering, American Society of Civil Engineers
2003: Centenary Medal for services to hydrology and water resources engineering
2005: Awarded Professor Emeritus, the University of Melbourne
2006: Arid Lands Hydraulic Engineering award for 2006, by American Society of Civil Engineers
2014: Inducted into Engineers Australia National Committee of Water Engineering Hall of Fame.

Publications:

Professor McMahon has co-authored 9 books and published over 560 scientific papers, articles, reports and monographs, and presented more than 100 seminars in Australia and overseas on water resources issues. Two important textbooks include:

- Gordon ND, McMahon TA, Finlayson BL, Gippel CJ, Nathan RJ, 2004. *Stream Hydrology: An Introduction for Ecologists. Second Edition*, John Wiley & Sons, Chichester, UK.
- McMahon TA, Adeloye A, 2005. *Water Resources Yield*. Water Resources Publ., Colorado, USA.

Recent papers deal with estimating evaporation for lakes and terrestrial surfaces, uncertainty in annual runoff from global climate models, uncertainty in discharge data, and costs of dams and related infrastructure.

TAM
21 August 2020

Whitehaven Coal Limited
10 Kurrajong Creek Rd
BAAN BAA NSW 2390

Attention: Mark Vile

10 October 2020

Dear Mark

NARRABRI UNDERGROUND MINE STAGE 3 EXTENSION PROJECT
BIODIVERSITY DEVELOPMENT ASSESSMENT REPORT PEER REVIEW

Whitehaven Coal has asked me to review the Biodiversity Development Assessment Report (BDAR) and associated Biodiversity Offset Strategy developed for the Narrabri Underground Mine Stage 3 Extension Project (the Project) by Resource Strategies Pty Ltd.

I hold Biodiversity Assessment Method (BAM) assessor accreditation (BAAS 17004) as provided for under the NSW *Biodiversity Conservation Act 2016* (BC Act). A bi-lateral agreement means that a BAM can also include assessment of impacts on matters of national significance under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

In reviewing the BDAR, I aimed to ensure that it met the BAM and EPBC Act guidelines for assessing the residual impact of the Project on threatened biodiversity. As well as assessing that it accurately reflected the findings of the baseline flora and fauna reports, and provided a feasible and realistic biodiversity offset strategy.

My review comments/corrections have been incorporated to my satisfaction and I consider that the BDAR comprehensively addresses the requirements of the BAM and EPBC Act guidelines.

I have no conflicts of interest in conducting this review.

Yours Sincerely,
HUNTER ECO

Colin Driscoll

Dr Colin Driscoll
Environmental Biologist

Contact Details

PO Box 1047
Toronto NSW 2283

Mobile 0438 773029
Email cd_enviro@bigpond.com

Qualifications

BSc (Lond)
PhD (Newcastle) "*The ecology of reproduction and propagation in a rare plant,* Tetratheca juncea."

Plant Sciences Group
School of Environmental and Life Sciences
University of Newcastle Australia

Employment History

Mar 2007 – current	Independent environmental consultant trading as HUNTER ECO.
Jan 2001 – Mar 2007:	Senior Environmental Biologist with EcoBiological.
1983 – 2000	Part-time environmental consultant.
1977 – 1983	Environmental assessments for the Electricity Commission of NSW through TUNRA along with work towards MSc (Newcastle).
1976 – 1977	Commenced working towards MSc (Biology, Newcastle) Topic: The reproductive biology and ecology of the Sugar Glider (*Petaurus breviceps*).
1967 – 1975	Researcher and Deputy Director Australasian Food Research Laboratories (a division of Sanitarium).

Professional Associations

Australian Network for Plant Conservation
Ecological Society of Australia

Licenses

NPWS Scientific Licence SL101245 valid to October 2020
NSW Biobanking Assessor 0011
NSW BAM Assessor Accreditation BAAS17004 valid to 13/09/2021

Affiliation

The University of Queensland
School of Agriculture and Food Sciences
Adjunct Senior Fellow

ECOLOGY & BIOLOGY

Primary areas of expertise are in the fields of botany and vegetation ecology although I did start my career as a fauna person so have a good knowledge of birds and mammals and a fair knowledge of amphibians and reptiles. Current and past projects and research involve the following:

- Vegetation community classification and mapping
- Threatened flora species monitoring
- Translocation of threatened plant species
- Population density assessment of rare plants
- Rare plant breeding systems
- Pollinator-plant interactions
- Rare plant habitat suitability modelling
- Groundwater Dependent Ecosystems
- Distribution and function of biological soil crusts across Australia's north

TARGETED THREATENED PLANT POPULATION COUNTS

Targeted population counts have been conducted for the following threatened species:

- *Acacia bynoeana*
- *Angophora inopina*
- *Cymbidium canaliculatum*
- *Diuris tricolor*
- *Grevillea parviflora* subsp. *parviflora*
- *Hibbertia procumbens*
- *Melaleuca biconvexa*
- *Ozothamnus tesselatus*
- *Pomaderris queenslandica*
- *Rutidosis heterogama*
- *Senecio spathulata*
- *Tetratheca juncea*
- *Tylophora linearis*

GIS & DATA ANALYSIS

In association with the ecological consultancy and research work, a comprehensive range of skills has been acquired in spatial data management, analysis and presentation using various Geographical Information Systems (GIS), along with other analytical tools. Main programs used are Manifold System GIS, Surfer, SAGA GIS, QGIS, Global Mapper, Primer 7+PERMANOVA, Minitab 19 and several vector and raster handling programs. Capabilities include:

- Georeferencing of aerial images
- Development of digital terrain models
- Visual fields analysis
- Hydrology
- Topography
- Landform analysis
- Lidar data manipulation
- Spatial data management and analysis
- Presentation maps
- Similarity analysis
- Statistical analysis

LEGISLATION

Familiar with the relevant requirements of the following:

Commonwealth
Environment Protection & Biodiversity Conservation Act 1999
Environment Protection and Biodiversity Conservation Regulations 2000
JAMBA, CAMBA & RoKAMBA migratory bird agreements

NSW
Environmental Planning and Assessment Act 1979
Environmental Planning and Assessment Amendment (Biodiversity Conservation) Regulation 2017
National Parks and Wildlife Act 1974
Biodiversity Conservation Act 2016
Biodiversity Conservation Regulation 2017
Biodiversity Assessment Method Order 2017
Water Management Act 2000
Relevant State Environment Planning Policies.
Local Government requirements.

Projects

The following describe the range of work conducted:

- Review of Environmental Factors
- Preparation of Biodiversity Development Assessment Reports and Biodiversity Stewardship Assessment Reports
- Ecological constraints assessment
- Threatened species assessment
- Groundwater Dependent Ecosystems assessment
- Preparation of ecological management and monitoring plans
- Implementation of ecological management and monitoring plans
- Targeted threatened plant surveys, population counts and density assessments
- Threatened plant habitat suitability modelling
- Translocation of threatened plants
- Approved by NSW Department of Planning as an independent specialist auditor of mining ecological management and monitoring programmes

Clients include:

- Extractive industries such as mining and quarrying
- Resource exploration companies
- Local, State (NSW) and Commonwealth Government

Major clients:

- BHP (Mount Arthur and Caroona)
- The Bloomfield Group
- Centennial Coal (Awaba, Cooranbong, Myuna, Mandalong, Newstan)
- Cockatoo Coal (Bylong Valley exploration)
- Peabody Energy (Wilpinjong and Wambo)
- MACH Energy (Mt Pleasant)
- Malabar Coal (Maxwell)
- Whitehaven Coal (Maules Creek, Narrabri, Tarrawonga and Vickery)
- Yancoal (Abel, Donaldson and Tasman)
- Glencore (Mangoola)
- Newcrest Mining
- CleanTEQ
- Newcastle Coal Infrastructure Group
- Lake Macquarie City Council
- NSW Department of Industry Planning and the Environment

Independent Biodiversity Auditor

Biodiversity component within: Independent Environmental Audit – NCIG Export Coal Loader Kooragang Island January 2014 & January 2015 Report prepared by: Trevor Brown & Associates Applied Environmental Management Consultants 3 Forwood Crescent Bundanoon NSW 2578

Peer Reviews

Peer review of annual monitoring reports; Biodiversity Management Plans; Biodiversity Assessment Reports and Biodiversity Offset Strategies; Biodiversity Development Assessment Rorts and Biodiversity Stewardship Site Assessment Reports.

NSW Land & Environment Court (expert witness)

DCR Property Consultants -v- Great Lakes Council Land & Environment Court Proceedings No. 10263 of 2003. Premises: Lot 474, DP95462, Parish of Carrington.

ProTen Karuah Limited ats The Karuah Action Group. Land and Environment Court Proceedings No 10653 of 2004.

Geographic Area

The majority of my work is in Central and Eastern New South Wales with research projects also conducted across Queensland and into the Northern Territory.

Academic

The University of Newcastle, Australia, honours students

A. T. Blundell (2003) *The Powerful Owl* (Ninox strenua) *in Disturbed Environments.*
D. Landenberger (2003) *Defining the Niche of* Tetratheca juncea.
A. Jones (2011) *Conservation genetics and its application to the threatened native shrub* Tetratheca juncea.

The University of Queensland, Gatton, research

Team member (2019 -) *Boosting natural regeneration of nitrogen in grazing lands.*

Reports

Driscoll, C. (2006) Acacia bynoeana: *a review of species information*. Unpublished Report prepared for the Department of Environment and Conservation, Newcastle. EcoBiological. June 2006.

Driscoll, C. (2009) *A review of the ecology and biology of* Tetratheca juncea *Sm. (Elaeocarpaceae*). Prepared for Lake Macquarie City Council. November 2009.

Driscoll C. (2013) *The ecology of* Grevillea Parviflora subsp. parviflora, *a review*. Report prepared for Lake Macquarie City Council March 2013.

Driscoll, C. & Bell, S.A.J. (2008) *The Experimental Translocation of* Tetratheca juncea *Sm. (Elaeocarpaceae) at Gwandalan, Wyong Shire*. Report to Crighton Properties Pty Ltd, Wyong Shire Council, NSW Department of Environment & Climate Change. December 2008.

Peer-reviewed

Bell, S.A.J. & Driscoll, C. (2005) New records for the endangered *Hibbertia procumbens* from the Central Coast of NSW. *Australasian Plant Conservation* 13(4): 24-25.

Bell, S.A.J. & Driscoll, C. (2006) Vegetation of the Tomago and Anna Bay Sandbeds, Port Stephens, New South Wales: Management of Ground Water Dependent Ecosystems. Part 1 – Vegetation Classification. Unpublished Report to Hunter Water. Eastcoast Flora Survey. August 2006.

Bell, S.A.J. & Driscoll, C. (2007) Vegetation of the Cessnock-Kurri Region, Cessnock LGA, New South Wales: Survey, Classification & Mapping. Unpublished Report to Department of Environment & Climate Change. Eastcoast Flora Survey. November 2007.

Bell, S.A.J. & Driscoll, C. (2014) *Acacia pendula* (Weeping Myall) in the Hunter Valley of New South Wales: early explorers' journals, database records and habitat assessments raise doubts over naturally occurring populations. *Cunninghamia* 14: (2014) 179–200

Bell, S.A.J. & Driscoll, C. (2016) Hunter Valley Weeping Myall Woodland – is it really definable and defendable with and without Weeping Myall (*Acacia pendula*)? Cunninghamia 16: 15-30.

Bell, S.A.J. & Driscoll, C. (2017) *Acacia wollarensis* (Fabaceae, Mimosoideae sect. Botrycephalae), a distinctive new species endemic to the Hunter Valley of New South Wales, Australia. Telopea 20:125-136.

Bell, S.A.J. and Driscoll, C. (2020) Data-informed Sampling and Mapping: an approach to ensure plot-based classifications locate, classify and map rare and restricted vegetation types. *Australian Journal of Botany*, in press.

Bell, S., Branwhite, B., & Driscoll, C. (2005) *Thelymitra adorata* Jeanes ms (Orchidaceae): population size and habitat of a highly restricted orchid from the Central Coast of New South Wales. *The Orchadian* 15 (1): 6-10.

Driscoll, C. & Bell, S.A.J. (2006) Vegetation of the Tomago and Anna Bay Sandbeds, Port Stephens, New South Wales: Management of Ground Water Dependent Ecosystems. Part 2 – Groundwater Dependency. Unpublished Report to Hunter Water. Eastcoast Flora Survey. August 2006.

Bell, S., Peake, T., and Driscoll, C. (2007) Dealing with taxonomic uncertainty in Weeping Myall *Acacia pendula* from the Hunter catchment, New South Wales. *Australasian Plant Conservation* 16(1) 14 – 15.

Driscoll, C. (2003) The Pollination Ecology of *Tetratheca juncea* (Tremandraceae): finding the pollinators. *Cunninghamia* 8(1):133-140.

Williams, W.J., Budel, B., & Driscoll, C. (2008) *Biogeography and Biodiversity of Biological Soil Crusts across Queensland*. Australian Rangeland Society. 15th Biennial Conference, Charter's Towers. September 2008.

Williams, W.J., Driscoll, C., Williams, S. & Ezzy, L. (2014) *Ecosystem engineers of the micro-savannah. A study of biological soil and rock crusts with a special focus on cyanobacteria from Pungalina-Seven Emu Nature Reserve, Northern Territory*. Report prepared for Australian Wildlife Conservancy.

Williams, W., Chilton, A., Schneemilch, M., Williams, S., Neilan, B. and Driscoll, C. (2019) Microbial biobanking – cyanobacteria-rich top soil facilitates mine rehabilitation. *Biogeosciences*, 16, 2189–2204.