INDEPENDENT ADVISORY PANEL FOR UNDERGROUND MINING

ADVICE RE:

NARRABRI COAL OPERATIONS

LONGWALLS 203 - 206

EXTRACTION PLAN

March 2023

EXECUTIVE SUMMARY

Narrabri Mine is an underground coal mine located approximately 25 kilometres (km) south-east of Narrabri and approximately 60 km north-west of Gunnedah. The mine is located within the Narrabri Shire local government area and in the North-West Slopes and Plains region of NSW and is operated by Narrabri Coal Operations Pty Ltd (NCOPL), a wholly owned subsidiary of Whitehaven Coal Limited (Whitehaven), on behalf of the Narrabri Mine Joint Venture.

Stage 1 of the existing mine received project approval in November 2007. Coal production using continuous miner methods commenced in 2010. Stage 2 of the existing mine received development consent on 26 July 2010. The mine has been extracting coal by longwall methods since June 2012. The approved mine comprises 20 longwall panels (being Longwalls 101 to 111 and Longwalls 201 to 209) which extract coal from the Hoskissons Seam within Mining Lease (ML) 1609. The Stage 2 project approval (08_0144) has been modified seven times and allows for the production and processing of up to 11 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal until 26 July 2031.

On 1 April 2022, the NSW Department of Planning and Environment approved the Narrabri Underground Mine Stage 3 Extension Project (SSD-10269). Whilst the Department had issued the development consent for SSD-10269, the EPBC approval (EPBC 2019/8427) for Stage 3 works is still under consideration by the Commonwealth Department of Climate Change, Energy, the Environment and Water.

Condition 4 of Schedule 3 of the Project Approval for Stage 2 requires the preparation and implementation of an Extraction Plan (EP) to the satisfaction of the Secretary for any second workings to be mined. The Extraction Plan must demonstrate that mining operations do not cause exceedances of the performance measures identified in Tables 1 and 2 within Condition 1 and Condition 2 of Schedule 3 of the Project Approval.

On 30 November 2022, the NSW Department of Planning and Environment (DPE) requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Extraction Plan for Longwalls (LW) 203 to 206 at Narrabri Mine.

Specifically, the DPE requested advice on:

1. *The predicted impacts on groundwater, groundwater dependent ecosystems (GDE) and surface water (including impacts on the Namoi alluvium) associated with subsidence effects above the longwall panels, and impacts on Aboriginal heritage with consideration of the Panel's advice to the Department on the Stage 3 development;*
2. *the proposed surface, groundwater and GDE monitoring program and associated performance measures and TARPS, noting that the monitoring is targeted to Stage 2 performance measures and conditions under PA 09_0144.-however the panel should consider the proposed monitoring program in relation to providing monitoring to inform Stage 3 performance measures (for water resources and subsidence); and*
3. *proposed gas drainage and greenhouse gas minimisation management measures.*

The Panel reviewed a range of documents in preparing its advice, met on multiple occasions via videoconference and requested supplementary information from the Applicant. It also undertook a site inspection of relevant surface features at Narrabri Mine. The Panel's key conclusions and recommendations are:

1. <u>Mine Plan and Subsidence Implications</u>

   The Panel concludes that:

   (i) The predictions of subsidence effects and impacts that inform the EP are of a similar order of reliability as those of alternative methods and are fit-for-purpose, recognising that a degree of uncertainty is associated with all subsidence prediction methodologies.

(ii) The Panel has no reason to believe that the EP supported by other statutory workplace health and safety requirements will not achieve the Performance Measures for Built Structures and Public Safety.

(iii) The potential consequences of connective fracturing for fugitive emissions of greenhouse gases from mine workings to the surface through this fracture network needs to be considered in the Greenhouse Gas Minimisation Plan required to be developed under Schedule 4

2. Heritage Management Plan

The Panel concludes that:

(i) There is a credible likelihood that subsidence associated with the proposed mine layout will impact the physical state and heritage values of Aboriginal heritage site Mayfield GG1, which: contains 43 grinding grooves; was not identified at the time of Project Approval; and is more significant than the only grinding groove site identified at the time of the Project Assessment.

(ii) There is a lack of clarity and consistency in the EP regarding the nature, mitigation, remediation and acceptance of key stakeholders of any physical damage and degradation of cultural heritage values caused by subsidence-induced cracking at the Mayfield GG1 site.

(iii) The Subsidence Risk Assessment does not conform to some relevant Australian risk assessment guidelines and does not achieve many of the objectives of undertaking a risk assessment.

(iv) Notwithstanding this and the lack of consideration of political consequences in the risk assessment, the residual risk rating of 'High' for cracking of Mayfield GG1 is credible.

(v) The TARP relating to managing subsidence impacts on Mayfield GG1 serves no purpose in preventing cracking of Mayfield GG1.

(vi) The proposal by NCOPL to develop an action plan for the management of Mayfield GG1 site within 6 months of approval of the EP is applicable only if the EP is approved on the basis that cracking of the site is permissible and that the Secretary will give approval for Aboriginal objects at the site to be damaged or, the action plan includes TARPs that provide confidence that cracking will be prevented at the site.

(vii) If cracking of Mayfield GG1 is unacceptable then:

a. the preventative measures detailed in the Heritage Management Plan are weak by subsidence engineering standards and may have little or no influence on the development of cracking at the site.

b. stronger preventative measures would normally be required, such as revising the location of the longwall panels relative to the site of Mayfield GG1, leaving coal unmined under the site and/or slotting around the site to interrupt the transmission of ground strains.

c. logically and practically, an action plan for the management of Mayfield GG1 should form part of the EP and be based on clearly articulated and measurable performance measures.

d. consideration may need to be given to a staged approval if there is a prospect that the mine layout will need to be changed in order to achieve compliance with performance measures for Mayfield GG1.

The Panel recommends that:

(i) The Department gives careful consideration to:

   a. the acceptability of NCOPL's plans to provide answers within 6 months to the question of connection of the grinding groove rocks to the bedrock and the decisions that derive from that and from discussions with Registered Aboriginal Parties (RAPs).

   b. if the EP can receive a staged approval given the current level of uncertainty around NCOPL's action plan for site Mayfield GG1.

(ii) If it is intended not to prevent cracking of Mayfield GG1, then the assessment of the LW203-LW206 EP should include:

   a. Verification that cracking of Mayfield GG1 is acceptable to all key stakeholders.

   b. Verification that key stakeholders, including government, are involved in assessing and accepting the risks associated with this approach, including reputational and political risk.

   c. Verification that, as per the Consent Conditions, the Secretary will approve damage to this Aboriginal heritage site.

(iii) If cracking of Mayfield GG1 is unacceptable then prior to further assessment, the EP for LW203-LW206 should:

   a. include clear, unambiguous and measurable performance measures for Mayfield GG1.

   b. include all management plans relevant to complying with the performance measures for Mayfield GG1.

3. Surface Water

The Panel concludes that:

(i) A creek water loss estimation method is required to support a water access license application for the Eulah Creek Water Source. Water take from this source is expected to be non-negligible. A water loss estimation method is not proposed in the EP although there is a commitment to consider methods prior to surface cracking being detected. The Panel concludes that this approach is generally acceptable but the commitment to delivering a method is not definite enough.

(ii) Diversion of water from the watercourses (creeks) in the subsidence area to the mine void is expected to be small and may be unobservable. Nevertheless, the likelihood of connective surface-void fracturing is considerable and unexpected inflows of water associated with rainfall may occur. The Surface Water Management plan refers to trigger for determining unexpected inflows but does not include a detailed TARP that specifies responses.

(iii) A predicted surface water impact is subsidence ponding. The proposed approach to managing individual ponds is non-specific. This is appropriate since the suitable method requires expert assessment of the pond and its environment after the pond has formed. However, the Extraction Plan does not provide confidence that suitable remediation or alternative management methods are available and does not provide clear criteria for selecting a method.

(iv) There is a lack of published guidance in Australia regarding management of subsidence ponds including the circumstances in which a pond should be allowed to evolve without active management.

(v) The Erosion and Sediment Control Plan appears to be satisfactory, including the update proposed for Stage 3.

(vi) The Stage 3 Development Consent places new emphasis on protection of riparian and aquatic ecosystems, with the relevant performance measure based on "negligible environmental consequences". Operating under Stage 3 will require explicit performance indicators and TARPs including flow conditions, groundwater levels, water quality, watercourse morphology, and aquatic and riparian ecology at selected sites.

(vii) The TARPs in the EP WMP do not provide confidence that performance measures can be met through escalation of adaptive management.

(viii) The various documents included in the EP and referred to in the EP lack consistency in performance indicators and details of the TARPs, making it challenging to review and interpret parts of the EP.

The Panel recommends that:

(i) A method proposal for estimating surface water losses should be submitted by NCOPL to the Department prior to surface subsidence impacts being observed.

(ii) A detailed TARP for surface water diversions to the mine void should be included in the EP based on measured inflows to the void and their relation to rainfall events.

(iii) More information should be provided in the EP about available subsidence pond remediation options and criteria for determining the best option.

(iv) Water management TARPs at the highest trigger levels should include consideration of interruption to mining to allow corrective management actions to be proposed and approved by the Department.

(v) If operating under the Stage 3 Development Consent, the performance measure "Negligible environmental consequences beyond those predicted in the document/s listed in condition A2(c)" should be addressed by a suite of explicit performance indicators and corresponding TARPs in the EP WMP including for flow conditions, water quality, watercourse morphology, and aquatic and riparian ecology at selected sites.

(vi) Future Annual Review appendices should show water quality time-series plots that include all baseline years to allow inspection of variability and trends.

(vii) The actions associated with the highest level triggers in the TARPs should incorporate definitive actions towards ensuring that performance measures are achieved (in cases where the TARP is associated with a performance indicator and performance measure).

(viii) Greater effort is needed by NCOPL to achieve consistency and effective cross-referencing between the documents relevant to the EP WMP.

4. Groundwater

The Panel concludes that:

(i) While the evidence points to limited impacts to the Pilliga Aquifer, there is a need to increase the monitoring of the Sandstone to provide confidence in the groundwater modelling predictions.

(ii) The planned additional monitoring should be implemented as soon as practicable and prior to completion of LW 203.

(iii) Unexpectedly high inflows to the mine workings should be a trigger for a full reappraisal of the groundwater assessment and an update to the groundwater model. Care should be taken to maintain the monitoring network for mine inflows, including ensuring timely repairs to faulty equipment.

(iv) Impacts to the Namoi aquifer are expected to be small and not discernible in the groundwater monitoring results for the aquifer. As with the Pilliga aquifer, if mine inflows significantly exceed the expected values then the likelihood of impacts to the aquifer should be reviewed.

(v) Performance indicators and a TARP for the Mayfield Spring and high priority GDEs need to be developed. Specific high priority GDEs monitoring sites should be proposed based on ground surveys. Monitoring should include shallow groundwater levels.

(vi) The TARPs for groundwater should be improved. Improvements are required to the operational approaches used for the TARPs as well as to the triggers that are adopted.

The Panel recommends that:

(i) The planned upgrades in the monitoring network for the Pilliga aquifer should be completed as soon as practical and no later than the end of completion of LW 203.

(ii) Mine inflows need to be measured as accurately as practicable and that any failures of monitoring equipment are rectified rapidly to ensure adequate ongoing information to trigger and support reanalysis of groundwater conditions relevant to the Pilliga and Namoi aquifers.

(iii) NCOPL should develop performance indicators for the Mayfield Spring to assist the assessment of impacts and their significance. The proposed monitoring and evaluation appear to be appropriate for this feature.

(iv) The EP WMP should be revised to include a clear statement on how consequences for high priority GDEs will be managed (this applies irrespective of whether operations are under Stage 2 or Stage 3).

(v) The rainfall condition should be removed from the trigger for mine inflows exceedance of a threshold increase.

(vi) A review and update of the TARPs for groundwater level changes should be undertaken to improve the quality and the usefulness of the TARPs (as per advice in Section 5.7).

(vii) NCOPL evaluate whether it has sufficient monitoring data against which to measure the contributions to drawdown in the Pilliga sandstone from all sources and that the methods for assessing the parties responsible for mitigation of impacts are agreed with DPIE Water.

5. Greenhouse Gas Emissions

The Panel concludes that:

(i) *Section 5.3 Greenhouse Gas Emissions Management Measures* of the EP and the associated review comprising Appendix J of the EP are out of context with the required contents of the EP as specified in Schedule 2 of the Project Approval and should not form part of the EP

(ii) Rather, greenhouse gas emissions (GHGE) management measures and the associated Palaris (2023) contribution should be presented separately by NCOPL as an updated Greenhouse Gas Minimisation Plan and reviewed by the Department in the context of Conditions 7, 31 and 32 of Schedule 4 of the Project Approval. This should factor in presenting the Palaris Review (Appendix J) in the form of a formal report rather than as a PowerPoint summary

(iii) The Greenhouse Gas Minimisation Plan does not adequately address all matters required under Schedule 4, particularly in regard to developing a research program to inform the continuous improvement of greenhouse gas minimisation on site

(iv) The following matters in the Palaris (2023) review require clarification and/or further development to aid in achieving compliance with Schedule 4:

a. Quantify rather than estimate outbye emissions

b. Given the increase in CH_4 concentration in the LW203–LW206 area, the study of emissions should be extended to identify the modelled concentration of CH_4 and CO_2 in ventilation emissions. This would provide a clearer basis for the assessment of the use of VAM technology

c. Review and confirmation of gas concentrations in non-coal strata, including further testing of non-coal strata.

d. Updating of the models of emissions, including sensitivity analysis of GHGE to these gas sources and direct measurement of gas retained in the coal as it exits the longwall panel

e. Review and potential uptake of methods for retaining more seam gas in-situ for the same level of production

(v) Other matters that should also be addressed in developing the Greenhouse Gas Minimisation Plan include:

a. The potential for fugitive GHGE through connective fracturing to surface

b. Management of emissions from the above ground coal stockpiles, including a method to determine stockpile emissions

c. Summarising the time-based GHGE reductions achieved to date for the site along with time-based targets for future reduction

d. Periodic review of the progress of commercial and emerging greenhouse gas emission reduction technologies for both CH_4 and CO_2 to assess applicability to and uptake by NCOPL

e. Periodic evaluation of the costs of the most prospective greenhouse gas minimisation technologies in the Narrabri Mine context along with the development of a marginal abatement cost (MAC) curve

f. Development of a research program to inform the continuous improvement of greenhouse gas minimisation on site

The Panel recommends that:

(i) NCOPL develop its Greenhouse Gas Minimisation Plan to be in compliance with Schedule 4 of the Project Approval including addressing matters raised in this advice.

(ii) NCOPL prepare a clearly specified research program to inform the continuous improvement of greenhouse gas minimisation on site. The plan should prioritise actions and present timelines for completion actions. Based on the current advice, the plan should include the following topics:

a. Investigations to better understand the distribution and quantity of CH_4 and CO_2 in non-coal formations

b. Determination of emissions from the above ground coal stockpiles

c. Regular review of the progress of commercial and emerging greenhouse gas emission reduction technologies for both CH_4 and CO_2 to assess applicability to and uptake by NCOPL

d. Options assessment for opportunities to retain gas in the strata through selection of mine design and operational parameters that increase the rate of face retreat and reduce the potential for connective fracturing to surface and through the management of the moisture content of the coal seam.

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1.0 SCOPE OF WORKS

The Narrabri Mine is an underground coal mine located approximately 25 kilometres (km) south-east of Narrabri and approximately 60 km north-west of Gunnedah. The mine is located within the Narrabri Shire local government area and in the North-West Slopes and Plains region of NSW.

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3. proposed gas drainage and greenhouse gas minimisation management measures.

The Chair of the Panel (Em. Professor Jim Galvin) nominated the following members of the Panel to prepare the advice:

- Em. Professor Jim Galvin – Chair – Subsidence and Mining
- Professor Neil McIntyre – Surface Water
- Em. Professor Rae Mackay – Groundwater
- Dr Ray Williams – Greenhouse Gas
- Prof. Dianne Wiley – Greenhouse Gas

2.0 METHOD OF OPERATION

The Panel convened by videoconferences throughout the preparation of its advice and was administratively supported by Secretariat staff provided by the DPE's Major Project and Resource Assessment Teams. All five Panel members also undertook a site inspection on 9 February 2023.

A wide range of documents were reviewed by the Panel in preparing this review. The principal documents are summarised in Table 1.

Table 1: Key documents reviewed by the Panel

Document Reference	Document Name
Extraction Plan	Extraction Plan – Narrabri Underground Coal Mine LW 203-206, including the following addendums/volumes: • Extraction Plan: Main Document • Appendix A - Water Management Plan • Appendix B -Land Management Plan • Appendix C – Biodiversity Management Plan • Appendix D – Heritage Management Plan • Appendix E – Built Features Management Plan • Appendix F – Public Safety Management Plan • Appendix G – Coal Resource Recovery plan • Appendix H – Plans 1-8 • Appendix I – Risk Assessment LW 203-206 – Rev A • Appendix J – Gas Emissions Review for Longwall 203-206 • Appendix K – Subsidence Monitoring Program
The Applicant's Response to Additional Information Requests	• NCO IAPUM RFI Response EP LW 203-206, dated 3 February 2023 • GHG Narrabri project Greenhouse Gas Emission Mitigation Strategy Draft Working Document – Palaris Mining Pty Ltd, March 2009 • Narrabri LW109 Modelling Gas Management, Palaris, October 2019: • WHC_PLN_NAR_Greenhouse Gas Minimisation Plan (2017) • GHG 2b. Predrainage boreholes UIS and SIS LW 101 to LW 206 • GHG 1e. WHC_PLN_NAR_ Greenhouse Gas Minimisation Plan • GHG 2a – Longwall 108 and 109 Gas Make Data dated 17 January 2023 • GHG 3b. Predrainage boreholes (SSIS and UIS) LW203-LW206 • GHG 1d - WHC EERS FY22 Report_NCO • GHG 1d - WHC EERS FY21 Report_NCO • GHG 1d -WHC EERS FY20 Report_NCO • GHG 1d - WHC EERS FY19 Report_NCO • WHC 6420-03 RFI Responses Narrabri Underground Longwalls 203-206 dated 23 January 2023
The Applicants response to questions raised during site visit	• Narrabri Mine Extraction Plan for LW203 to LW206 – IAPUM Briefing, 9 February 2023

Agency Advice	• Advice from Mining Exploration and Geoscience, dated 8 March 2023 • Advice from Heritage NSW, dated 12 March 2023 • Advice from Biodiversity, Conservation and Science Directorate, dated 15 March 2023

2.1. SITE VISIT, SUBSEQUENT INFORMATION AND MEETINGS

Site Visit

The site inspection by the Panel took place on 9 February 2023. It involved a briefing at Narrabri Mine by the Applicant, followed by an inspection of key surface features relevant to the EP.

The Panel was accompanied by the Applicant and its relevant consultants, the DPE's Secretariat for the Panel and a member from the DPE's Resource Assessments team.

Subsequent Information

The Panel sourced additional reports from the Applicant, as outlined in Table 1.

Meetings

The Panel convened several times over the course of preparing its advice. Table 2 summarises the schedule of meetings held in chronological order.

Table 2: Schedule of meetings held

Meeting Date	Meeting Information
30 November 2022	Panel Meeting – Initial Briefing by DPE
30 November 2022	Whitehaven Coal Briefing
13 December 2022	Panel Approach Discussion
9 February 2023	Site Visit
23 February 2023	Panel Meeting Discussion
14 March 2023	Panel Meeting Discussion

3.0 SUBSIDENCE

3.1. SUBSIDENCE DEFINITIONS

This advice is premised on the following definitions as recommended by the 'Southern Coalfield Inquiry' (DoP, 2008) and as adopted in Schedule 1 of the Consent Conditions for the Narrabri Coal Project – Stage 2.

- **Subsidence Effects:** the deformation of the ground mass surrounding a mine due to the mining activity. The term is a broad one and includes all mining-induced movements, including both vertical and horizontal displacement, tilt, strain and curvature.
- **Subsidence Impacts:** the physical changes to the ground and its surface caused by **subsidence effects**.
- **Environmental consequences**: the environmental consequences of **subsidence impacts**, including: damage to built features; loss of surface flows to the subsurface; loss of standing pools; adverse water quality impacts; development of iron bacterial mats; cliff falls; rock falls; damage to Aboriginal heritage sites; impacts to aquatic ecology; ponding

3.2. SUBSIDENCE EFFECTS AND IMPACTS

The prediction of subsidence effects and impacts has been undertaken by Ditton Geotechnical Services Pty Ltd (DGS, 2022) and constitutes Appendix J of the Extraction Plan. The Panel is familiar with the methodologies adopted by Ditton Geotechnical Services (DGS) and their robustness and order of accuracy from the Panel's 2021 review of the Narrabri Coal Stage 3 Extension Project (IAPUM, 2021). At the time, the Panel concluded that the subsidence assessment did not present any particular difficulties or uncertainties.

There is a degree of uncertainty associated with all surface subsidence prediction methodologies. Appendix J provides evidence that the order of accuracy of the methodologies adopted by DGS compare favourably with alternative prediction methodologies and that the methodologies are being regularly refined for the site-specific circumstances at Narrabri Mine by reviewing measured outcomes against predicted outcomes. One opportunity for improvement and for the sake of completeness is to take into account the influence of subsequent mining operations on subsidence predictions for the LW203-LW206 EP. As reflected in Figure 7a of Appendix J (DGS (2022), subsidence over the western flank of LW206 will be subject to modification if and when LW207 is extracted. Nevertheless, the Panel is not aware of any concerns that could arise in this regard on this specific occasion. The Panel is of the view that its conclusions relating to the prediction of subsidence effects and impacts in 2021 have been reinforced by the information contained in Appendix J and that these also apply to the LW203-LW206 EP.

The Panel concludes that:

1. The predictions of subsidence effects and impacts that inform the EP are of a similar order of reliability as those of alternative methods and are fit-for-purpose, recognising that a degree of uncertainty is associated with all subsidence prediction methodologies.

3.3. ENVIRONMENTAL CONSEQUENCES

3.3.1. Explicit Consent Performance Measures

Conditions 1 and 2 of Schedule 3 of the Consent Conditions associated with the Project Approval for Narrabri Coal Project - Stage 2 stipulate subsidence impact performance measures relating to:

- Water Resources (Condition 1)
- Biodiversity (Condition 1)
- Built Features (Condition 2)
- Public Safety (Condition 2)

The Panel's advice in relation to assessing the EP against Condition 1 is contained in later sections of this document. Its advice in respect of Condition 2 has been informed by a site inspection over some areas of the mine which have already experienced surface subsidence due to longwall mining.

Built Features include dwellings, buildings, farm dams, powerlines, roads, fences, contour drains, other rural structures[1]. There is a large experience base in NSW of undermining these types of structures in conformance with the performance measures stipulated in Table 2 of Condition 2 (basically being that built features must remain safe; serviceable where practicable, with loss of serviceability to be fully compensated; repairable and must be fully repaired or else replaced or fully compensated). It is the Panels' understanding that NCOPL own the majority of built features that could be subjected to subsidence effects and impacts associated with extracting LW203 to LW206; that these features will be vacated if required prior to coming under the influence of surface subsidence caused by longwall mining operations; and that many are not required to remain serviceable or repairable.

It is also the Panel's understanding that public access to the surface overlying LW203 to LW206 is restricted. The NSW Work and Safety (Mines and Petroleum Sites) Regulation 2022 requires NCOPL to develop and effectively implement a Mine Safety Management System. and it is reasonable to expect that this management system will contain provisions for managing both safety associated with undermining built features and public safety and to complement the Public Safety Management Plan (Appendix F of the EP for LW203-LW206).

The Panel notes that neither Schedule 3 nor the Subsidence Assessment (Appendix J) have regard to the potential consequences of connective fracturing for fugitive emissions of greenhouse gases from mine workings to the surface through this fracture network. This mechanism has relevance to the development of the Greenhouse Gas Minimisation Plan required under Schedule 4 and is noted in Section 6 as an area that requires further consideration.

The Panel concludes that:

1. The Panel has no reason to believe that the EP supported by other statutory workplace health and safety requirements will not achieve the Performance Measures for Built Structures and Public Safety.
2. The potential consequences of connective fracturing for fugitive emissions of greenhouse gases from mine workings to the surface through this fracture network needs to be considered in the Greenhouse Gas Minimisation Plan required to be developed under Schedule 4

3.3.2. Non-Explicit Consent Performance Measures – Aboriginal Heritage

3.3.2.1. Background Information

The Environmental Impact Statement that supported the Development Application for the NCOPL Stage 2 Project included an Aboriginal Heritage Assessment (AS&R., 2009) that identified only one site where axe-grinding grooves occurred. This was described as:

> *The three axe-grinding grooves occur on two sandstone floaters (Site 10b) and so the only impact to the site from subsidence would be the vertical displacement of the floaters, which would have no impact on the axe-grinding grooves.*[2]

The grinding groove site (Site 10b) was labelled on Figure 7 of the Aboriginal Heritage Assessment (AHA) as *'Site of Higher Scientific Significance'*. The AHA reported that DGS (2009) had advised:

[1] p14 of the Extraction Plan
[2] p 5-46. Aboriginal Heritage Assessment (AS&R., 2009)

....there is the possibility that subsidence could cause fracturing of any sandstone platforms on which grinding grooves occur.[3]

The Consent Conditions for the Stage 2 Project include a requirement under Schedule 3 (h) (bullet 4) that each EP is to include a:

Heritage Management Plan, which has been prepared in consultation with OEH and relevant stakeholders for Aboriginal heritage, to manage the potential environmental consequences of the proposed second workings on heritage sites or values

Condition 22 of Schedule 4 states in respect of a Heritage Management Plan that:

The Proponent shall not destroy damage or deface any known Aboriginal objects (as defined in the National Parks and Wildlife Act 1974) without the written approval of the Secretary.

The National Parks and Wildlife Act 1974 defines an Aboriginal object as:

.....any deposit, object or material evidence (not being a handicraft made for sale) relating to the Aboriginal habitation of the area that comprises New South Wales, being habitation before or concurrent with (or both) the occupation of that area by persons of non-Aboriginal extraction, and includes Aboriginal remains.

3.3.2.2.Identification of Mayfield GG1 and Site Exposure to Damage

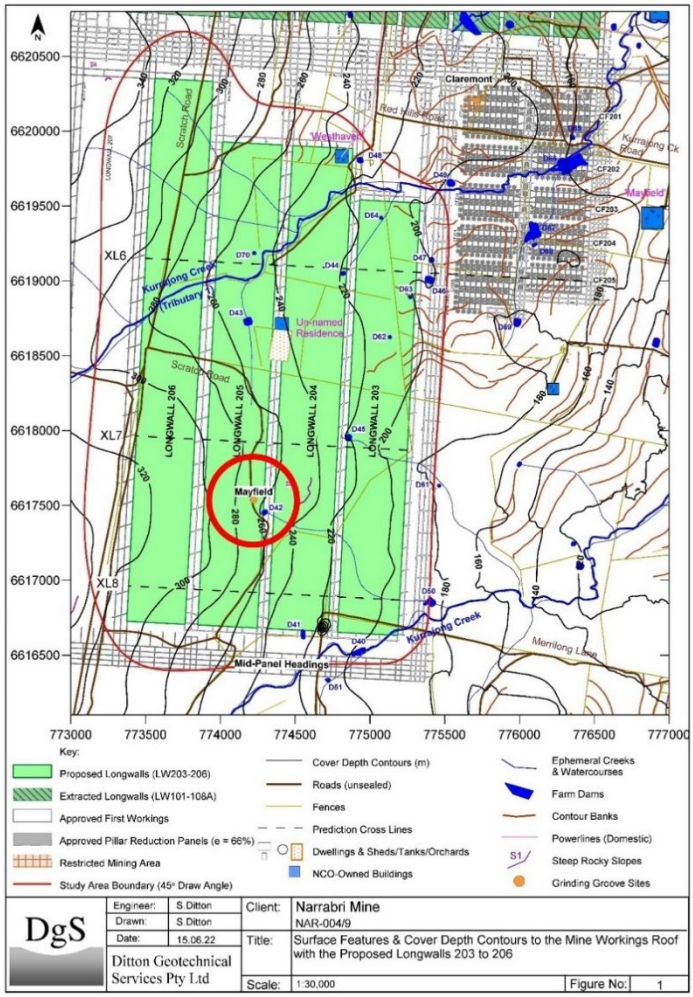
In addition to artifact scatters and isolated artefacts, an axe grinding groove site, referred to as Mayfield GG1 and also as AHIMS 19-6-0192, is located within the EP area over LW205. This Aboriginal heritage site is close to the chain pillars separating this longwall panel from LW204, as shown in Figure 1. Since the site was not identified in the original Environmental Impact Statement (EIS) for Stage 2, the Panel assumes that its existence was unknown at the time of project assessment. The Mine Subsidence Assessment for the LW203-LW206 EP, Appendix J, (DGS, 2022), describes and assesses this site variously as:

- *One Aboriginal cultural heritage site 'Mayfield' (forty-three grinding grooves in six separate sandstone outcrops) is located above the proposed LW205. The site has 'moderate' scientific significance according to Whincop Archaeology, 2020.*[4]
- *There is one grinding groove site (Mayfield GG1) located above proposed LW205. The site is located on sandstone bedrock or possibly 'loose' boulders. The quality of the grinding grooves is considered to be 'excellent' and regionally rare for the size of the groove cluster. (DGS, 2022).*[5]
- *43 grinding grooves on 6 separate large slabs of bedrock in drainage line; the site is considered to most likely be on the bedrock (DGS, 2022)*[6]
- *It is assessed that the Mayfield GG1 grinding grooves are expected to be subject to transient strains of up to 5 mm/m and final compressive strains of 5 mm/m. Based on Table 20* [which records the location of the site as '*Sandstone Bedrock'*] *it is 'possible' to 'likely' that the grooves may be impacted by cracking in their current location. Partial soil excavation around the 'slabs' may further alleviate cracking potential.*[7]

[3] p 5-19. Aboriginal Heritage Assessment (AS&R., 2009)
[4] p ES-2
[5] p ES-7
[6] p 73, Table 2
[7] p 75

The strain values predicted by DGS (2022) are based on the assumption that the strains are associated with conventional subsidence behaviour and are uniformly distributed over the surface. In the case of rock, this is rarely the case once a fracture is induced in the rock mass. Both field and laboratory testing confirm that a tensile strain of around 0.5 mm/m is sufficient to induce cracking of a rock mass, whereafter cracking tends to concentrate at that site. This means, for example, that a tensile strain of, say, 5 mm/m can be expressed in the field as a 50 mm wide crack every 10 m. Similarly, rock can typically only sustain a uniformly distributed compressive strain up to 3 mm/m before failing and concentrating compressive strain at that site. Therefore, the Panel concurs with DGS (2022) that it is 'possible' to 'likely' that the axe grinding grooves could be impacted by cracking in their current location (relative to the layout of the longwall panels). However, the Panel notes that it is rarely feasible to predict the locations of concentrated cracks.

Table 3-3 of DGS (2022) provides indicative probabilities of the occurrence of cracking for various ranges of uniformly predicted tensile and compressive strain. These quantify the descriptions of 'possible' and 'likely' as adopted by DGS. The term 'possible' corresponds to a 10 to 50% probability of crack damage and the term 'likely' to a >50% probability of crack damage to Mayfield GG1.



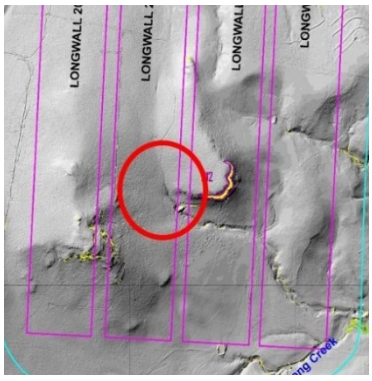


Figure 1: *Plans showing the location of Aboriginal Heritage Site Mayfield GG1 (AHIMS 19-6-0192) within the area covered by the LW203-LW206 EP Application (adapted from Figure 1 and Figure 2c of DGS (2022)).*

The Panel inspected Mayfield GG1 on 9 February 2023. It formed the view that the grinding grooves are located on a ledge of outcropping sandstone in a drainage line. This is not inconsistent with the areal view of the region shown in Figure 1. The nature of the topography in the area raises the question of whether the site could also be impacted by non-conventional subsidence behaviour, specifically valley closure. DGS (2022) makes a general conclusion that *'as the valleys across the longwalls are very broad between crests, the development of 'upsidence' and closure along the creek beds is likely to be negligible'.*[8] That conclusion has regard to survey measurements across Pine Creek which detected a maximum compressive strain of 6.2 mm/m and uplift of 64 mm. In many circumstances, values of this magnitude can result in negligible impacts on surface structures but a compressive strain of 6.2 mm/m is significant if cracking of the Aboriginal heritage site is to be avoided, especially if this strain is to be added to that component of surface strain resulting from conventional subsidence behaviour.

3.3.2.3. Subsidence Risk Assessment

Appendix I of the Extraction Plan comprises a Subsidence Risk Assessment. The combination of likelihood of cracking of Mayfield GG1 and the consequences should the site be cracked resulted in a risk rating of 'High', both with existing controls in place and also with additional controls in place.[9] The risk rating was arrived at based on a likelihood rating of 'likely' and a consequence rating of 'medium'. The Risk Assessment does not provide insight into if or how well the probability of cracking associated with the term 'likely' in the Risk Assessment aligns with that quantified by DGS.

The Subsidence Risk Assessment also does not identify which of the following seven criterion utilised in the risk assessment were instrumental in determining the consequence rating of 'medium' for the cracking of Mayfield GG1.

- Safety
- Health
- Environment
- Reputation
- Community
- Compliance
- Economic

Based on experience in similar situations, it appears to the Panel that the criteria most likely to determine a consequences rating of 'medium' would be:

- *Reputation – adverse impact on operator's reputation. Significant public exposure in regional media*
- *Community – Mistrust/opposition among some stakeholders with moderate influence on public opinion and decision makers.*
- *Compliance – Non-compliance with external, or non conformance with internal requirement with moderate impact and/or issue of a financial penalty.*

Undertaking a risk assessment of the prediction and monitoring of subsidence effects and impacts is important for several reasons, including the objectives of:

[8] p 63 of DGS (2022)

[9] Note. In Rev A of the Extraction Plan, the residual risk of cracking was rated as 'medium' following the application of additional controls. In response to queries from the Panel regarding the effectiveness of the additional controls, the Panel was advised that the residual risk rating has been increased to 'High'.

- Identifying the likelihood that a proposed mine plan will deliver outcomes that do not breach Consent Conditions
- Identifying and informing the type and effectiveness of controls required to remain in compliance with Consent Conditions
- Informing the type, location and frequency of monitoring of subsidence effects and impacts
- Informing the construct of Trigger Action Response Plans (TARP)[10]
- In the case of Mayfield GG1, specifically informing the construct of the Heritage Management Plan for the LW203-LW206 Extraction Plan.

These are not inconsistent with the objectives stated in Section 1.3 of the Subsidence Risk Assessment. However, the Panel considers that the Subsidence Risk Assessment does not achieve many of these objectives and does not fully conform to risk assessment guidelines that it commits to, in particular MDG1010 – Risk Management Handbook for the Mining Industry (MDG-1010, 2011) and MDG1014 – Guide to Reviewing a Risk Assessment of Mine Equipment and Operations (MDG-1014, 1997). The Panel notes that the risk assessment team only comprised three technical staff from NCOPL and three members of the consultancy assisting with preparing the EP. The risk assessment team thus lacked key stakeholders required to meet the guidelines, including the technical experts such as the author of the Mine Subsidence Assessment (Appendix J) and representatives of Heritage (OEH) and Aboriginal heritage stakeholders.

This lack of breadth of contributions raises questions about the adequacy of the assessment. For example, if the risk criteria had also included political considerations as part of reputation or as a standalone criterion and/or the meaning of 'likely' adopted in the risk assessment had been aligned to that quantified in the Subsidence Assessment (DGS, 2022), the risk assessment may have produced significantly different outcomes. A broader risk assessment team would have/should have addressed these types of considerations. The political context is important given the involvement of government in preparing the Aboriginal Heritage Management Plan, in having to approve the possible or likely damaging of Aboriginal objects and in approving the EP.

3.3.2.4. Heritage Management Plan

Appendix D – Heritage Management Plan (HMP) provides evidence of consultation with the Narrabri Local Aboriginal Land Council (NLALC), which has advised NCOPL that:

> *With the grinding grooves they are very significant as it shows where people would use areas of significance, this area should be protected as due to the rarity of the site. Once it is fully assessed a decision will be made by all RAPS*

NCOPL's response includes an assurance that all Registered Aboriginal Parties (RAPs) will be included in investigations and decision-making process.

The HMP reproduces DGS's probability predictions of subsidence induced crack damage to Mayfield GG1. It goes onto state:[11]

> *Mayfield GG1 is subject to indirect impacts associated with the effects of subsidence or, if connected to bedrock, may be subject to potential cracking and/or possible erosion damage. NCOPL will undertake further investigation within 6 months of approval of this EP-HMP (and prior to the commencement of secondary workings) to determine the potential*

[10] A plan designed to prevent a threat from escalating by identifying potential precursors, or triggers, to the threat event, assigning a hierarchy of alarms, or trigger levels, to each potential precursor, and specifying responses for each trigger level (Galvin, 2016).
[11] Section 4.5, p22 of Aboriginal Heritage Management Plan

connection to bedrock with an appropriately qualified specialist (e.g. archaeologist, geologist, geomorphologist) and the RAPs.

If the investigations determine that the site is connected to bedrock, additional management measures will be determined in consultation with the appropriately qualified specialist and the RAPs. These measures may include electronic monitoring equipment, regular inspections by the RAPs, and/or potential relocation of the grinding grooves to a suitable location. The Mine Subsidence Assessment Report suggests that partial soil excavation around each slab with hand tools may reduce strain transfer into the slabs during subsidence and reduce the potential for cracking.

An action plan will be developed for the management of this site within 6 months of approval of this EP-HMP which will include the outcomes of the investigation and will outline the mitigation options determined in consultation with the RAPs.

During active subsidence, NCOPL will monitor Mayfield GG1 on a monthly basis to assess potential cracking and subsidence impacts. Monitoring for cracking will cease once monitoring indicates that subsidence movement has ceased.

It appears to the Panel from the above description that it is accepted that Mayfield GG1 could be impacted by mining-induced cracking. If this is the case then questions that arise include:

1. Can the HMP be finalised at this point in time without further input from OEH and RAPs?
2. Is it feasible to limit the EP approval for the time being to LW203 & LW204 until there is more clarity about the management of Mayfield GG1?
3. If cracking of Mayfield GG1 occurs, does this constitute an exceedance of the Performance Measure recorded in the Table 4-1 of the HMP, being:

   Surface cracking, vertical displacement or erosion does not compromise Aboriginal objects or cultural heritage values.

Based on the Panel's experience in not dissimilar circumstances, cracking can negatively impact on both the integrity of the grinding grooves themselves and on the cultural heritage values of the site in which they are hosted. The Performance Measure is unquantifiable and cannot be managed and audited unless it is supported by a quantitative definition of what constitutes *'compromise'*. This is apparent from the list of *'Key assessment considerations'* recorded against this Performance Measure in Table 4-1. None of the considerations provide a basis for determining if the Performance Measure has been satisfied. The Panel sought clarification from NCOPL on *'What are the criteria for determining that Aboriginal objects or cultural values have not been compromised by mining impacts, especially cracking?'* The Panel was referred to the subsidence monitoring program in Section 5 of the HMP.

Table 5-1 of the HMP is an extract from Table 3-1 of the Subsidence Monitoring Program – Appendix K of the EP and presents the following subsidence monitoring program for Aboriginal cultural heritage sites:

- *Monthly during mining and monthly following mining for a period of 12 months.* (Note: This monitoring frequency is specific to Mayfield GG1.)
- *Prior to, and within six months of the cessation of mining*
- *Annually*

This monitoring program does not provide for the degree of high frequency monitoring of crack development as mining approaches Mayfield GG1 that could be expected if cracking is to be avoided. Monthly monitoring is not of sufficient frequency to inform a TARP for the purpose of avoiding cracking of the Aboriginal heritage site. Effectively, NCO is relying on monitoring after the event to determine areas of surface cracking and to decide on *'any additional mitigation measures that may be required (e.g. monitoring, surface collection, or area salvage)'*. The response suggests that there are no measures planned to prevent cracking of the Aboriginal heritage site.

Table 6-1 of the HMP presents the TARP for managing subsidence impacts on Aboriginal heritage sites. The lowest trigger level (Level 1) is:

> *Surface cracks <50 mm present within 50 m of a cultural heritage site, and no erosion identified.*

The responses to that trigger are:

- *Document occurrence of surface cracks*
- *Continue monitoring*
- *Summarise occurrence in relevant reports*

The Panel concludes from this that there is no restriction on Mayfield GG1 being impacted by cracks up to 50 mm in width and no requirement to remediate these cracks.

The second TARP Level (Level 2) is the highest, being:

- *Surface cracks >50 mm present within 50 m of a cultural site and/or*
- *Erosion as a result of cracking identified.*

The responses to this trigger level are as for Level 1 plus safety fencing and signage, advising relevant stakeholders and implement remediation measures as appropriate, which may include salvage of cultural heritage.

It could be concluded from the TARP that there are no restrictions to the frequency, magnitude and extent of cracking at Mayfield GG1. Hence, the Panel inquired of NCOPL 1)*'why does the TARP have no regard to the consequences of surface cracks less than 50 mm in width?'* and 2) *'What is the point (value) of the TARP when it does not contain any provision for the avoidance of cracking at Mayfield GG1?'* The responses to these questions included:

- *Measures to protect Aboriginal objects or cultural heritage values include salvaging Aboriginal objects prior to impact, and assessing new and existing sites for risk of impact and implementing appropriate measures to reduce the risk. These measures are applicable for all cultural heritage sites regardless of impact risk level (e.g .for surface cracks less than 50 mm in width)*
- *The response for Level 1 trigger is commensurate with the level of risk……The EP-Land Management Plan states that "Minor cracks (i.e. less than 50 mm wide) are not expected to require remediation as geomorphological processes will likely result in these cracks filling naturally over time. Therefore the risk of impact to Aboriginal objects or cultural values is low.*
- *An investigation will be conducted within 6 months of approval of the EP-HMP (prior to secondary workings) to determine the potential connection to bedrock. If the site is connected to bedrock, additional management measures will be put in place in consultation with the RAPs and a suitably qualified specialist. One of the additional measures includes the potential to relocate the site. An Action Plan will be developed following the investigation to manage this site which will outline the most reasonable and feasible mitigation options. Frequent monitoring of the Grinding Grooves will occur if the site is not relocated to assess the potential for cracking*

The responses provide no insight into the type and feasibility of measures that may be applied to reduce the risk of cracking at Mayfield GG1. It is stated that the risk of impact to Aboriginal objects or cultural values is 'low', in contrast to the Subsidence Risk Assessment which rated the residual risk as 'high'. It is difficult to comprehend how the grinding grooves could be relocated and, further, how that activity even if feasible, would not compromise the heritage value of the site.

It appears that the Applicant considers that cracks of up to 50 mm in width (and, in fact greater according to the TARP) do not constitute damage to Aboriginal Heritage objects values associated with Mayfield GG1. The Panel inquired of NCOPL *'Why are Aboriginal objects or cultural heritage values not compromised by any cracking, irrespective of width?'* It was advised by NCOPL that:

NCOPL will implement management measures to protect all Aboriginal objects or cultural heritage values irrespective of the potential for impact (e.g. width of surface cracks). Based on extensive monitoring, NCOPL have adopted the < 50 mm and > 50 mm criteria for surface cracking to provide an indication that remediation will be likely for any crack > 50mm. Minor cracks (i.e. less than 50 mm wide) are not expected to require remediation as geomorphological processes will likely result in these cracks filling naturally over time. If there is a risk of impact to any Aboriginal object or cultural heritage values, mitigation actions will be implemented to mitigate the risk in accordance with the EP-HMP, which may include site salvage by the RAPs

The Panel questions how Mayfield GG1 can be protected from damage by the proposed mine layout. If the site is to be protected from damage, supplementary avoidance measures will most probably be required, the effectiveness of which cannot be assured. Trenching around the site is an example of one of these possible measures. NCOPL's response states that mitigation actions will be implemented if there is a risk of impact. Given that the Subsidence Risk Assessment has already identified that the risk of impact to Mayfield GG1 is 'high', the mitigation measures proposed for this site would normally be detailed in the EP and considered as part of the approval process for the EP (assuming in the first instance that mitigation of impacts rather than prevention of impacts is acceptable to stakeholders).

If no restrictions are to be placed on the frequency, magnitude and extent of cracking at Mayfield GG1, then a number of matters require further consideration and/or clarification, including:

1. How is the (uncontrolled) level of damage permissible under the TARP consistent with the performance measure that surface cracking does not compromise Aboriginal objects or cultural heritage values?
2. Is this potential level of impact (damage) consistent with the commitments and expectations given to RAPs?
3. Has or will the Secretary agree to approve damage to Mayfield GG1?
4. What consideration has been given to the impact of cracking on accelerated weathering of Mayfield GG1, including the impact of the severe variations in seasonal conditions at the site?

3.3.2.5. Conclusions and Recommendations re Mayfield GG1

The Panel concludes that:

1. There is a credible likelihood that subsidence associated with the proposed mine layout will impact the physical state and heritage values of Aboriginal heritage site Mayfield GG1, which: contains 43 grinding grooves; was not identified at the time of Project Approval; and is more significant than the only grinding groove site identified at the time of the Project Assessment.
2. There is a lack of clarity and consistency in the EP regarding the nature, mitigation, remediation and acceptance of key stakeholders of any physical damage and degradation of cultural heritage values at the Mayfield GG1 site caused by subsidence-induced cracking.
3. The Subsidence Risk Assessment does not conform to some relevant Australian risk assessment guidelines and does not achieve many of the objectives of undertaking a risk assessment.
4. Notwithstanding this and the lack of consideration of political consequences in the risk assessment, the residual risk rating of 'High' for cracking of Mayfield GG1 is credible.
5. The TARP relating to managing subsidence impacts on Mayfield GG1 serves no purpose in preventing cracking of Mayfield GG1.
6. The proposal by NCOPL to develop an action plan for the management of Mayfield GG1 site within 6 months of approval of the EP is applicable only if the EP is approved on the basis that cracking of the site is permissible and that the Secretary will give approval for Aboriginal

objects at the site to be damaged or, the action plan includes TARPs that provide confidence that cracking will be prevented at the site.

7. If cracking of Mayfield GG1 is unacceptable then:
    a. the preventative measures detailed in the Heritage Management Plan are weak by subsidence engineering standards and may have little or no influence on the development of cracking at the site.
    b. stronger preventative measures would normally be required, such as revising the location of the longwall panels relative to the site of Mayfield GG1, leaving coal unmined under the site and/or slotting around the site to interrupt the transmission of ground strains.
    c. logically and practically, an action plan for the management of Mayfield GG1 should form part of the EP and be based on clearly articulated and measurable performance measures.
    d. consideration may need to be given to a staged approval if there is a prospect that the mine layout will need to be changed in order to achieve compliance with performance measures for Mayfield GG1.

The Panel recommends that:

1. The Department gives careful consideration to:
    a. the acceptability of NCOPL's plans to provide answers within 6 months to the question of connection of the grinding groove rocks to the bedrock and the decisions that derive from that and from discussions with the RAPs.
    b. if the EP can receive a stage approval given the current level of uncertainty around NCOPL's action plan for site Mayfield GG1.
2. If it is intended not to prevent cracking of Mayfield GG1, then the assessment of the LW203-LW206 EP should include:
    a. Verification that cracking of Mayfield GG1 is acceptable to all key stakeholders
    b. Verification that key stakeholders, including government, are involved in assessing and accepting the risks associated with this approach, including reputational and political risk.
    c. Verification that, as per the Consent Conditions, the Secretary will approve damage to this Aboriginal heritage site.
3. If cracking of Mayfield GG1 is unacceptable then prior to further assessment, the EP for LW203-LW206 should:
    a. include clear, unambiguous and measurable performance measures for Mayfield GG1.
    b. include all management plans relevant to complying with the performance measures for Mayfield GG1.

4.0 SURFACE WATER

4.1. THE ISSUES

- Although surface water losses from creeks due to surface cracking over LWs 203-206 are expected to be low, sufficient surface water take licenses are required (9A of the Stage 2 Approval) for which loss estimates will be needed. The EP does not estimate losses or propose an estimation method although the revised version commits to a method being developed prior to any subsidence-induced surface cracking. The issue is whether it is acceptable to begin secondary extraction without having an agreed or proposed estimation method in place.
- Although surface flow losses are predicted to be low and the potential for losses due to diversions of water to the void will be negligible according to the NCOPL (Section 3.2.1 of the EP Water Management Plan (WPM)), a significant probability of subsurface fracturing connecting with surface cracking at LW203 is recognised. The issue is whether proposed TARPs are sufficient to manage surface water losses.
- Enhanced ponding of water due to surface subsidence is predicted. Potential environmental consequences include loss of water due to enhanced evaporation, impaired water quality, and alteration of the local and near-downstream aquatic and riparian ecosystems. The EP commits to remediation of ponds where vegetation is significantly impacted using an approach to be advised by an expert geomorphologist. The lack of detail may be considered inconsistent with the Stage 2 Development Consent condition that "*a detailed description of the measures that would be implemented to remediate predicted subsidence impacts under individual Extraction Plans*". The issue is whether further detail should be provided prior to approval of the EP.
- The Panel also questions whether leaving subsidence ponds in place instead of remediating them might be appropriate in some circumstances, even if the transition involves localised damage to native vegetation. This is an issue for longer-term consideration.
- In its assessment of the Stage 3 EIS, the Panel concluded that the potential sedimentation and erosion impacts were under-stated, and that careful attention to sediment and erosion management plans should be included in the Extraction Plan. The issue is whether the sediment and erosion control plan satisfies the requirements of the Stage 2 and Stage 3 Development Consents.
- The Stage 3 Development Consent puts new emphasis on protection of aquatic and riparian ecosystems. The issue is whether the proposed WPM can be considered applicable to mining under the Stage 3 Development Consent, in particular with respect to performance indicators and TARPs related to aquatic and riparian ecosystems.
- The proposed surface water TARPs include responses related to investigations, reporting, consulting and corrective actions on the surface. There are none relating to changing the mining plan in cases where severe impacts occur or where corrective surface actions do not succeed.

4.2. ANALYSIS AND ADVICE

Four versions of the WPM were considered in preparing this advice:

- Narrabri Mine Extraction Plan Water Management Plan LW 203 – LW 206, Rev A, 8 November 2022
- Narrabri Mine Extraction Plan Water Management Plan LW 203 – LW 206, Rev 0, 10 February 2023
- Narrabri Mine Water Management Plan, 6 March 2013 (Stage 2)
- Narrabri Mine Water Management Plan, 29 November 2022 (Stage 3 – for approval)

The former two plans were developed as part of the Extraction Plan for LW203-206. The Rev 0 version includes small modifications to Rev A made to address recent comments from DPE-Water (the comments and modifications are listed in Attachment 2 of Rev 0). The analysis and advice here refers only to the Rev 0 version, referred to here as the EP WMP. The other two plans listed above are more generic water management plans that aim to cover the whole of Stage 2 and Stage 3, referred to here as Site WMP (Stage 2) and Site WMP (Stage 3). The relation between the Site WMP and the EP WMP is stated in the EP WMP as

"*It will be noted that a Site Water Management Plan (Site WMP) has been prepared for the Narrabri Mine as required under Project Approval Schedule 3 Condition 13… Due to the association between the documents, this [Extraction Plan] WMP refers to the Site WMP… to avoid duplication and repeat, and to minimise the possibility of inconsistencies between the documents*."

This approach is sensible, however is complicated when assessing the EP WMP under the Stage 2 approval because aspects of the Site WMP (Stage 2) does not cover the LW 203-206 area. Rather, the EP WMP aligns better with the Site WMP (Stage 3).

4.2.1. Estimation of Surface Water Losses from Creeks

The Panel understands that an additional surface water access license may be required for surface water taken from the Eulah Creek Water Source, which is part of the Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources. Estimates of water take from the ephemeral creeks in the mining area will be required to support the license application.

Surface water losses from creeks due to surface cracking over LWs 203-206 are predicted to be negligible by the NCOPL (Section 3.2.1 of the EP WMP). This is due to the predicted low frequency with which surface cracking will intersect subsurface fractures that connect to the mine void, the low frequency of flow events limiting opportunity for diversion of flow into surface cracks, and the proposed remediation of surface cracks. The Panel notes: 1) there is considerable uncertainty regarding the potential for connectivity of surface cracking with subsurface fracturing (up to 25% probability of surface to void connectivity for LWs 203 according to the DGS (2022) Section 9.4.8); 2. Non-negligible losses may also occur due to the subsidence ponding of water and associated increases in evaporation losses.

Regarding the latter mechanism, the subsidence report (DGS, 2022) predicts a net increase in Kurrajong Creek Tributary 1 pond volume of 29.5 ML and net increase in pond area of 4.88 Ha (Table 13 of that report). Translating this net volume increase into a net increase in evaporation is not trivial, but the value of 29.5 ML can be treated as the maximum potential loss after each significant runoff event. Alternatively, an upper bound annual value can be approximated by applying a representative open water evaporation estimate of 1587 mm/year to the net increase in ponded area, which gives an increase in evaporation loss of approximately 77 ML/year. This is an upper bound value because it assumes the increase of 4.88 Ha is present continually and neglects evapotranspiration that would have occurred in any case from the same area irrespective of mining. Runoff from creeks in this region can be as low as 4% of rainfall (an approximate value, based on calculations by the Panel using data from Bohenna Creek Newell gauge). If it is assumed that 4% applies to Kurrajong Creek Tributary 1, its average annual flow volume prior to LWs 203-206 would be approximately 300 ML/year. The upper bound evaporation estimate of 77 ML/year is 26% of that value. This volume is small although not necessarily negligible and demonstrates the need for considering pond evaporation in loss estimates.

The direct approach to estimating surface water losses is to gauge water flows upstream and downstream of the project area and at benchmark sites, and use flow modelling to infer from the measurements how much water is lost due to the mine project. The challenge of flow gauging in the environment surrounding Narrabri Mine and the expected low magnitude of losses from creeks has meant that the NCOPL does not propose to install gauges or conduct surface flow modelling for the creeks. This decision was endorsed by the Panel in its advice on the Stage 3 EIS. In that advice, the

Panel advised that the NCOPL should consider alternative estimation methods to support water take licensing (and this is a condition of Stage 3 Approval, B36 e iii).

In response to the need to consider alternative estimation methods, the EP WMP, following consideration of feedback from DPE-Water, includes "*An assessment will be conducted by a surface water specialist prior to any surface cracking occurring within the Extraction Plan Area to consider alternative methodologies to measure and/or predict creek flows. Following the assessment, the appropriate method (if feasible) for formally recording creek flow conditions, and contingency measures will be incorporated into the Site WMP*". The Panel considers this to be generally satisfactory. The potential advantage of having an agreed method in place earlier than proposed, for example prior to beginning secondary extraction, would be to ensure that the required monitoring including baseline monitoring was in place prior to any subsidence impacts. However, the practicable loss estimation methods do not require such prompt measurements of surface water to be made. Daily recording of mine water inflows beginning prior to secondary workings will be required to support estimation of surface-to-void flow diversions, which is proposed (EP WMP Section 6.2.4). Furthermore, surveys of ponding (including location, width, depth, area), conducted monthly and following a significant rainfall event (EP WMP Table 7.1) are proposed, which will support approximate estimation of water loss due to evaporation. The lack of more frequent measurements of pond area and depth will limit accuracy with which surface water losses due to evaporation can be estimated; however, the use of approximate upper bound estimates based on the proposed survey data is appropriate due to the low volumes involved.

Therefore the Panel does not see any reason to require a surface water loss estimation method proposal at this stage of its advice; however it would be better if a method proposal is required to be submitted for approval prior to surface cracking being detected, rather than a commitment only to conduct an assessment.

4.2.2. TARPs for surface flow losses

There are no TARPs for surface flow losses in the EP WMP. There is a TARP for mine water inflows in Section 6.2.4 of the EP WMP based on measuring departure of 3-week inflow volumes from predictions of the groundwater model following rainfall events. The Panel considers this to be a satisfactory approach to determining unexpected surface flow losses. The triggers and management actions following triggers should be fully specified in Section 7 of the EM WMP. The Site WMP (Stage 3) does not contain a TARP related to void inflow measurements, however includes the statement "*The Surface and Groundwater Response Plan and TARPs (NCOPL, 2017a; 2017c) will be reviewed and updated for Stage 3*".

4.2.3. Subsidence ponding

A potentially significant disturbance to the surface water system is enhanced ponding of water due to surface subsidence. Predicted ponding due to LWs 203-206 is mapped and quantified in DGS (2022)[12]. During its visit to Narrabri Mine, the Panel visited a subsidence pond over a previously mined longwall, where significant impacts to native vegetation had been observed and a plan for remediation was in place.

The most detailed description of a pond remediation plan that the Panel could find in the available documents is in the Land Management Plan, Section 5.6:

[12] Summary in Table 13 and Figure 15a,b

"The standard management measures for the remediation of subsidence induced ponding are:

- *ponding located in areas with no vegetation, or if vegetation is not affected, will be allowed to self correct;*
- *ponding located in areas with affected vegetation, or if ponding significantly alters or affects flows, will be assessed and remedial actions (that present the lowest environmental impact) developed in consultation with a geomorphologist; and*
- *If Threatened Ecological Communities are impacted, or downstream water quality analysis indicates a change in EC trends (refer to the Water Management Plan [Appendix A to EP 203-206]), the ponding will be assessed, and remediation options will be developed to afford the maximum practical protection to the affected feature."*

The Panel considers that detailed descriptions are case dependent and cannot be prescribed for each case in the EP. Nevertheless, given this is a principal remediation and rehabilitation challenge, the representation of standard management measures (e.g. as copied above) is unsatisfactory, and more detail about the available remediation options and criteria for determining the best option should be provided in the EP, or appropriate guidelines or reference studies that provide this information should be referred to, if available. If these references are not available (the Panel is not aware of any) then the lack of guidance is a matter for longer-term consideration by the industry.

The Panel during its field visit noted the potential net ecological benefits of allowing a pond to self-correct irrespective of observed vegetation impact. Table 8.1 in the Site WMP (Stage 2) includes the provision "*Ecological benefits of ponded water should be considered before any of the above action is taken*" when considering remediation actions for subsidence ponds. The Site WMP (Stage 3) does not include the same provision. The issue of whether and where subsidence ponds should be allowed to self-correct and the lack of guidance on this topic is a matter for longer-term consideration by the industry.

4.2.4. Erosion and Sediment Control Plan

Section 5.3 of the EP WMP refers to the Erosion and Sediment Control Plan within the Site WMP. The Site WMP (Stage 2) refers to an Erosion and Sediment Control Plan, Coffey Geotechnics (2008), which "*outlined the hydrological characteristics of the Pit Top Area and how stormwater runoff was to be managed during the construction phase of the Project*." The Site WMP (Stage 2) also commits to applying the requirements of Managing Urban Stormwater: Soils and Construction manual (Landcom, 2004), which is a key requirement of the Stage 2 Development Consent. During its site visit the Panel was shown examples of erosion and sediment controls that have been applied following the Landcom (2004) guidelines. The Panel has no reason to believe the requirements for erosion and sediment control under the Stage 2 Development Consent are not being met, and that they will not continue to be met during mining of LWs 203-206. The proposed Site WMP (Stage 3) includes a substantially updated Erosion and Sediment Control Plan. The Panel has not identified any significant concerns regarding its applicability to LWs 203-206.

4.2.5. Management of Consequences for Aquatic and Riparian Ecosystems under Stage 3 DC

The Stage 2 Development Consent mentions "ecosystems" only in the context of rehabilitation objectives (Table 1): "*Restore ecosystem function, including maintaining or establishing self-sustaining native ecosystems*". An additional requirement for vegetation is "*The Proponent shall ensure that clearing and disturbance of vegetation above the mining area is minimised, to the satisfaction of the Secretary*". The Stage 3 Development Consent puts new emphasis on protecting aquatic and riparian ecosystems, specifically the Performance Measure for Aquatic and Riparian Ecosystems is "*Negligible environmental consequences beyond those predicted in the document/s listed in condition A2(c)*". Condition A2(c) relates to the predictions made in the EIS. This Performance Measure points to a need for performance indicators and TARPs for key ecosystem function indicators including flow conditions, groundwater levels, water quality, watercourse

morphology, and aquatic and riparian ecology in and around the watercourses potentially affected by the project. The Performance Measure suggests that representative high priority GDEs and other significant springs and water dependent ecosystems (including Mayfield Spring) should be monitored and TARPs and performance indicators developed, and adequate baseline data collected.

GDEs are considered further as part of the Panel's groundwater advice.

4.2.6. Other Issues with Surface Water TARPs

The EP WMP includes TARPs for watercourse water quality, vegetation health (ponding), watercourse morphology, and groundwater levels. It includes monitoring of Mayfield Spring but no TARP.

A general issue with all TARPs included in the EP WMP is the reliance on reporting, assessments, application of surface remediation measures, and re-assessments if these measures are unsuccessful, rather than allowing for further escalation that may lead to interruption of mining. Such further escalation may be especially appropriate where performance measures or other statutory requirements were being compromised. For example, for changes in watercourse morphology, the highest level TARP action is "*If implemented erosion control measures are found to be ineffective, identify cause and rectify or replace with effective measures. Continue monitoring*." The Panel considers this to be inconclusive outcome of the TARP process that does not provide confidence that performance measures can be met by adaptive management. As noted above, this issue takes new relevance due to new performance measures for ecosystems under Stage 3.

While two relevant performance measures are listed in Table 1.2 of the EP WMP, related to loss of water flow into the Great Artesian Basin aquifers and disturbance of vegetation, only one performance indicator is identified (Section 4), i.e. "*Groundwater volumes extracted from Great Artesian Basin water source are measured and reported annually against licensed groundwater extraction volume*". No performance indicator related to vegetation disturbance is identified. The EP WMP notes that performance indicators for water quality are implicit in the TARPs "*SSGVs [i.e. the trigger levels used in the watercourse water quality TARP in EP WMP Table 7.1] are proposed as performance indicators*". It would be helpful if all intended performance indicators were explicitly listed and related to the relevant performance measure, as is currently done for the single performance indicator in Section 4. Where applicable the relevant performance indicator should be referred to the in the TARP table.

The EP Biodiversity Management Plan (Appendix C) includes additional TARPs related to watercourse morphology and hydrology (soil moisture), some of which over-lap those in the EP WMP. The EP Biodiversity Management Plan (Table 4.1) also includes a substantial list of "performance measures" and "performance indicators" related to subsidence impacts and consequences. The Panel has not reviewed the EP Biodiversity Management Plan in detail, however brief review of its TARPs and its Table 4.1 shows that it is somewhat inconsistent with the performance indicators and TARPs in the EP WMP.

The level 1 and level 2 watercourse water quality triggers (Table 7.1 of the EP WMP) are based on 90th and 95th percentiles of baseline data collected at sites KC1US and KCUS since 2007. It is unclear how the TARP trigger values relate to elements of the applicable guidelines [(ANZECC & ARMCANZ, 2000) and (ANZG, 2018)] including the choice of the aforementioned percentiles and the use of samples back to 2007 that are not necessarily representative of contemporary water quality. However, the TARPs are generally consistent with standard practice in the NSW coal mining industry and given the low risk to surface water quality during flow events at these sites and the difficulty of collecting baseline water quality data sets due to intermittency of flow, the Panel does not have strong concerns about proceeding using the proposed triggers. It is recommended that future Annual Review appendices show water quality time-series plots that include all baseline years to allow inspection of variability and trends. A potential consideration for the Department is the sufficiency of the industry's response to the revised 2018 guidelines on setting trigger values (ANZG, 2018) and the particular challenge of intermittently flowing watercourses.

4.3. CONCLUSIONS AND RECOMMENDATIONS

4.3.1. Conclusions

1. A creek water loss estimation method is required to support a water access license application for the Eulah Creek Water Source. Water take from this source is expected to be non-negligible. A water loss estimation method is not proposed in the EP although there is a commitment to consider methods prior to surface cracking being detected. The Panel concludes that this approach is generally acceptable but the commitment to delivering a method is not definite enough.
2. Diversion of water from the watercourses (creeks) in the subsidence area to the mine void is expected to be small and may be unobservable. Nevertheless, the likelihood of connective surface-void fracturing is considerable and unexpected inflows of water associated with rainfall may occur. The Surface Water Management plan refers to trigger for determining unexpected inflows but does not include a detailed TARP that specifies responses.
3. A predicted surface water impact is subsidence ponding. The proposed approach to managing individual ponds is non-specific. This is appropriate since the suitable method requires expert assessment of the pond and its environment after the pond has formed. However, the Extraction Plan does not provide confidence that suitable remediation or alternative management methods are available and does not provide clear criteria for selecting a method.
4. There is a lack of published guidance in Australia regarding management of subsidence ponds including the circumstances in which a pond should be allowed to evolve without active management.
5. The Erosion and Sediment Control Plan appears to be satisfactory, including the update proposed for Stage 3.
6. The Stage 3 Development Consent places new emphasis on protection of riparian and aquatic ecosystems, with the relevant performance measure based on "negligible environmental consequences". Operating under Stage 3 will require explicit performance indicators and TARPs including flow conditions, groundwater levels, water quality, watercourse morphology, and aquatic and riparian ecology at selected sites.
7. The TARPs in the EP WMP do not provide confidence that performance measures can be met through escalation of adaptive management.
8. The various documents included in the EP and referred to in the EP lack consistency in performance indicators and details of the TARPs, making it challenging to review and interpret parts of the EP.

4.3.2. Recommendations

1. A method proposal for estimating surface water losses should be submitted by NCOPL to the Department prior to surface subsidence impacts being observed.
2. A detailed TARP for surface water diversions to the mine void should be included in the EP based on measured inflows to the void and their relation to rainfall events.
3. More information should be provided in the EP about available subsidence pond remediation options and criteria for determining the best option.
4. Water management TARPs at the highest trigger levels should include consideration of interruption to mining to allow corrective management actions to be proposed and approved by the Department.
5. If operating under the Stage 3 Development Consent, the performance measure "Negligible environmental consequences beyond those predicted in the document/s listed in condition

A2(c)" should be addressed by a suite of explicit performance indicators and corresponding TARPs in the EP WMP including for flow conditions, water quality, watercourse morphology, and aquatic and riparian ecology at selected sites.

6. Future Annual Review appendices should show water quality time-series plots that include all baseline years to allow inspection of variability and trends.
7. The actions associated with the highest level triggers in the TARPs should incorporate definitive actions towards ensuring that performance measures are achieved (in cases where the TARP is associated with a performance indicator and performance measure).
8. Greater effort is needed by NCOPL to achieve consistency and effective cross-referencing between the documents relevant to the EP WMP.

5.0 GROUNDWATER

5.1. INTRODUCTION

The Department has requested the Panel to consider the following:

- predicted impacts on groundwater, and groundwater dependent ecosystems (GDE) (including impacts on the Namoi alluvium) associated with subsidence effects above the longwall panels
- the proposed groundwater and GDE monitoring program and associated performance measures and TARPS

The Panel's advice is based on the updated extraction plan for Longwalls 203-206 including supporting appendices. The plan was last updated on 10 February 2023. The advice extends the IAPUM advice provided on the Groundwater Impact Assessment (AGE, 2020) prepared for the Stage 3 expansion of Narrabri Mine. The potential impacts of the current extraction plan are based to a significant degree on the groundwater modelling and assessments that were undertaken for the Stage 3 submission.

The predicted impacts and monitoring program are considered in five parts:

1. the Pilliga aquifer
2. the groundwater conditions above the mine workings
3. the Namoi alluvium aquifer
4. the Mayfield spring GDE
5. other GDEs

The final section considers the groundwater performance measures and TARPS.

5.2. THE PILLIGA AQUIFER

The Stage 2 consent conditions state that:

> *The Proponent shall ensure that within 5 years of the date of this approval, any loss of water flow into the Great Artesian Basin aquifers (equal to the maximum predicted impact, or the measured impact of the project, whichever is the greater), is managed, licensed or offset (including the possibility of injection of raffinate) to the satisfaction of DPE Water.*

The Pilliga sandstone forms part of the NSW Great Artesian Basin (GAB) Southern Groundwater Recharge Source. Its eastern limit lies above Narrabri Mine, though it does not appear from the data provided to extend above LWs 203-206. As a part of the GAB the sandstone is subject to groundwater development controls that limit total cumulative impacts to groundwater levels. While enhanced vertical hydraulic connection to the mine is likely, the degree of enhancement is not predicted to lead to significant impacts on the Pilliga Sandstone. The predictions are based on the Stage 3 groundwater model results. Nevertheless, depressurisation of the Pilliga sandstone may be possible through regional depressurisation of the underlying formations if the hydraulic properties of the aquitards are underestimated in the model. The Purlawaugh and Garrawilla formations that lie beneath the Pilliga sandstone are considered a part of the GAB Southern Groundwater Recharge Source by the Water Sharing Plan. However, the Purlawaugh formation largely acts as an aquitard locally and the Garrawilla volcanics have only limited areal extent. For these reasons, the recommendation by DPE Water in its review of the EP to focus on measuring impacts to the Pilliga sandstone and not the other formations of the GAB is considered by the Panel to be appropriate.

Based on the current monitoring data (Narrabri Coal Mine Annual Groundwater Review 2021, 2022), groundwater level declines are not apparent in the Pilliga sandstone away from the 100 series longwall mine workings. Information provided in the Stage 3 submission, including the groundwater modelling results, suggest that if drawdowns in the Pilliga Sandstone away from the mine area do occur, they will be small (<2 m). While the impacts should be small, the available monitoring sites are too few and too spatially limited to confirm this for the Stage 2 expansion, including for LWs 203-

206. The only current monitoring location in the Pilliga Sandstone for performance assessment is P7. It lies more than 2 km to the west of the northern limit of the 100 series LWs. Consequently, P7 is not likely to respond quickly to impacts that may arise from the planned Stage 2 or Stage 3 mining. A new bore, P82, is planned west of LWs203-206 that should provide more responsive data for possible adaptive management, but this has yet to be constructed. The inclusion of this bore in the monitoring network can be expected to assist in delineating impacts to the Pilliga sandstone aquifer. The Panel recommends that construction of P82 is completed as soon as practicable and no later than the completion of LW203. VWP P42-90 in the Pilliga sandstone should also provide additional evidence of possible impacts beyond the mine for the 200 series longwalls and Stage 3. While the data collected can assist with the identification of impacts, it is unlikely that drawdowns at the monitoring sites will occur soon enough to allow for the adaptive management of mine design to mitigate impacts. In this case alternative measures should be considered, notably in relation to mine inflows. If observed mine inflows prove to be significantly greater than predicted then reappraisal of the groundwater conditions would be warranted, including redevelopment of the groundwater model and reanalysis of the impacts.

The Panel recommends that mine inflows are measured as accurately as practicable and that any failures of monitoring equipment are rectified rapidly to ensure adequate ongoing information to support reanalysis of groundwater conditions.

5.3. GROUNDWATER CONDITIONS ABOVE THE MINE WORKINGS

The information provided in the extraction plan provides limited detail on the height of connected fracturing or the predicted impacts on groundwater table levels above the mine workings. Connective cracking between the mine workings and the surface are assessed to have a probability of <25% (DGS, 2022). Whilst this assessment appears reasonable, insufficient data have been presented to confirm impacts on the shallow groundwater conditions. The evidence from the previous groundwater modelling and data from P57 suggests that impacts on shallow groundwater can be anticipated over the mine area. This issue was noted in the previous IAPUM advice for Stage 3 (IAPUM, 2021):

> *The height of Zone A fracturing, as defined by the Ditton and Merrick methodology, of the formations above extracted longwall panels generally intersects the outcrop formations above the mine and the expected zone of surface cracking intersects the top of Zone A over much of the planned mine area. The available data for the nested monitoring facility (P57) that lies over longwall 108 shows the impact of subsidence with depressurisation impacts occurring over all depths below the water table once longwall mining starts and drawdowns are observed at all monitored depths when mining approaches approximately within 200 m of the monitoring facility. The monitoring facility fails once it is undermined. This type of response can be expected across the whole of the mine and would indicate that significant impacts on the upper formations could generally be expected to occur.*

The additional multilevel piezometer array to be installed above LW203 will provide new data to assist with the assessment of vertical flows and the occurrence of enhanced deep drainage from the near surface. Further assessment of the monitoring data from above the Stage 1 area should be undertaken to increase understanding of the potential groundwater drainage from the near surface. All monitoring points that become damaged due to subsidence should be reinstated or replaced to provide the data required for further updates of the groundwater model.

Current observations suggest that mine inflows are presently less than those predicted, though the Panel is unclear whether the lower inflows are simply a consequence of recent changes to the 100 LW series mining program. From the available data, the Panel does not expect increased mine inflows above those predicted but for assurance the Panel recommends, as previously noted, that good mine inflow monitoring is maintained and that TARPs are developed to address changes to inflow patterns. The TARPs are required to address (1) licensed groundwater use and (2) model assumptions about hydraulic connectivity to the near surface aquifers, particularly the Pilliga sandstone.

5.4. THE NAMOI ALLUVIUM AQUIFER

The Panel's previous advice for the Stage 3 expansion of Narrabri Mine that reductions in groundwater flow to the Namoi aquifer are small and are unlikely to be observable in the Namoi aquifer monitoring remains valid for the current mine extraction plan. Only if significant increases in mine inflows above those predicted are observed should further investigations and updated modelling be undertaken to assess groundwater flow impacts to the Namoi aquifer as noted in the previous section.

5.5. THE MAYFIELD SPRING GDE

No GDEs are located above the mine footprint and the Mayfield Spring is the only GDE in proximity to the extraction plan long walls. The spring's outflow has previously been used for stock watering. The spring lies approximately one kilometre south of the current extraction plan footprint. Evidence of mining impacts on the Spring to date is not available. The distance from Longwall 203 to the spring would indicate that mining impacts under the current extraction plan should be small. Greater impacts are likely if Stage 3 development takes place.

Section 6.2.9 identifies the records required to assess the condition of the Spring. In the responses to DPE water recommendations in Table A2-1, NCOPL states that this section establishes performance criteria, monitoring and evaluation of Mayfield Spring. While the section addresses monitoring and evaluation procedures, performance indicators and TARPs are not included. The panel recommends that NCOPL develop performance indicators and a TARP for the Spring to assist the assessment of impacts and their management. The proposed monitoring appears to be appropriate for this feature.

5.6. OTHER GDES

Responding to a recommendation by DPE-Water that the water management plan should "*establish performance targets to monitor, evaluate and report on high priority GDEs*", Table A2.1 of the EP WMP reports "*Impacts on GDEs and other receptors outside of the mine footprint and Extraction Plan Area will be monitored and managed in accordance with the revised Stage 2 WMP (not yet approved*)" making reference to Section 6.2.9 of the EP WMP. Section 6.2.9 of the EP WMP describes monitoring of only Mayfield Spring (not itself a high priority GDE). Hence the proposal in the EP WMP to monitor and report impacts on high priority GDEs remains unclear.

The proposed Site WMP (Stage 3) (Section 4.2.3, Table 4.1) identifies the high priority GDEs and outlines a monitoring program, although is not specific about the high priority GDE monitoring sites and omits groundwater monitoring at these sites. There is no proposal in the Site WMP (Stage 3) for high priority GDE performance indicators and TARPs.

5.7. PERFORMANCE MEASURES AND TARPS

The performance measure for groundwater is from Table 4.1 of the WMP (Extraction Plan Appendix A):

> *The Proponent shall ensure that, within 5 years of the date of this approval, any loss of water flow into the Great Artesian Basin aquifers (equal to the maximum predicted impact, or the measured impact of the project, whichever is the greater), is managed, licensed or offset (including the possibility of injection of raffinate) to the satisfaction of DPE Water.*

The proposed performance indicator is:

> *Groundwater volumes extracted from Great Artesian Basin water source are measured and reported annually against licensed groundwater extraction volume.*

The performance measures is reasonable but the performance indicator as expressed in Table 4.1 is restricted to groundwater water flow and does not address groundwater level change within the GAB.

However, the management approaches cover both water flow and groundwater level and the impacts arising from changes to both.

The trigger for investigations to occur if mine inflow rates are higher than predicted is specified in Section 6.2.4 of the WMP:

> *In consideration of the sensitivity analysis conducted on the groundwater model (HydroSimulations, 2015) and the potential variability of mine inflows (on a daily basis compared to the weighted average annual inflow of the model), an observed inflow rate 100% in excess of the predicted base case mean monthly inflow rate at any stage during the EP 203-206 operational period sustained for three consecutive weeks where a significant rainfall event has occurred during this period, will trigger an investigation and preparation of a response plan…*

The magnitude of the change in inflow rate appears to be reasonable as a trigger. The restriction to a change in inflow rate that is associated with a significant rainfall event is not reasonable. The link between higher inflow rates and rainfall constrains the trigger to consider only one type of concern, namely, high vertical hydraulic connection between the shallow surface and the mine. This is not the only concern. Of greater concern is the potential impact on the aquifers of the GAB. In this case, any large exceedance of the predicted inflows to the mine should trigger an investigation and update of the groundwater assessment. The Panel recommends removing the rainfall condition from the trigger.

The Trigger Action Response Plans itemised in Table 7.2 for groundwater levels for the Piezometer have some practical implications and limitations and should be upgraded considering the following:

- It is not appropriate to check data quality only when an exceedance of a trigger is observed. Data quality assessment should be the normal operating regime and be met under Trigger level 0. The 2021 Annual groundwater report highlights that data errors have been missed that should probably have been picked up as part of routine quality checks. Additionally, VWP failures have been observed and used to explain unusual observations. The unusual data are being reported and the inconsistencies noted but plans for correction or repair of the VWPs are not routinely addressed. Potentially valuable observations are being lost because of the current approach.
- Trigger level 1 is effectively redundant if data quality checks are observed routinely. As written, the trigger becomes a wait and see measure to see if Trigger level 2 arises
- Trigger level 1 could be better targeted not at looking at an exceedance but at the trend in groundwater level change. The progression of water levels towards an exceedance would potentially be a better measure if early warning of a level two Trigger is desirable and early decisions around applicable approaches to mitigation are appropriate. Given the timeline for changes in mining practice or offsetting etc, using advance warning measures would be better than waiting for an exceedance to occur.
- Trigger level 2 which tends to be the primary trigger for action after persistent exceedance of a measure occurs tends to progress to hydrogeological review and recommendations. This is appropriate but greater emphasis needs to be on the specification of the applicable timeline for completing the review.

Triggers for water quality seem to be appropriate.

5.8. OTHER MATTERS

As the performance measures for assessing impacts on the GAB involve cumulative impacts from all extraction sources, there is a requirement to assess the drawdown interference from other extractions and in particular the gas project to the west of Narrabri Mine. The Panel recommends that NCOPL evaluate whether they have sufficient monitoring data against which to measure the contributions to drawdown in the Pilliga sandstone from all sources and that the methods for assessing the parties responsible for mitigation of impacts are agreed with DPE Water.

5.9. CONCLUSIONS AND RECOMMENDATIONS

The Panel concludes that:

1. While the evidence points to limited impacts to the Pilliga Aquifer, there is a need to increase the monitoring of the Sandstone to provide confidence in the groundwater modelling predictions.
2. The planned additional monitoring should be implemented as soon as practicable and prior to completion of LW 203.
3. Unexpectedly high inflows to the mine workings should be a trigger for a full reappraisal of the groundwater assessment and an update to the groundwater model. Care should be taken to maintain the monitoring network for mine inflows, including ensuring timely repairs to faulty equipment.
4. Impacts to the Namoi aquifer are expected to be small and not discernible in the groundwater monitoring results for the aquifer. As with the Pilliga aquifer, if mine inflows significantly exceed the expected values then the likelihood of impacts to the aquifer should be reviewed.
5. Performance indicators and a TARP for the Mayfield Spring and high priority GDEs need to be developed. Specific high priority GDEs monitoring sites should be proposed based on ground surveys. Monitoring should include shallow groundwater levels.
6. The TARPs for groundwater should be improved. Improvements are required to the operational approaches used for the TARPs as well as to the triggers that are adopted.

The Panel recommends that:

1. The planned upgrades in the monitoring network for the Pilliga aquifer are completed as soon as practical and no later than the end of completion of LW 203.
2. Mine inflows are measured as accurately as practicable and that any failures of monitoring equipment are rectified rapidly to ensure adequate ongoing information to trigger and support reanalysis of groundwater conditions relevant to the Pilliga and Namoi aquifers.
3. NCOPL develop performance indicators for the Mayfield Spring to assist the assessment of impacts and their significance. The proposed monitoring and evaluation appear to be appropriate for this feature.
4. The EP WMP should be revised to include a clear statement on how consequences for high priority GDEs will be managed.
5. The rainfall condition should be removed from the trigger for mine inflows.
6. A review and update of the TARPs for groundwater level changes is undertaken to improve the quality and the usefulness of the TARPs (as per advice in Section 5.7).
7. NCOPL evaluate whether they have sufficient monitoring data against which to measure the contributions to drawdown in the Pilliga sandstone from all sources and that the methods for assessing the parties responsible for mitigation of impacts are agreed with DPE Water.

6.0 GREENHOUSE GAS EMISSIONS

6.1. THE ISSUES

The Department has advised the Panel that:

> *To inform the Extraction Plan, NCOPL has engaged a suitably qualified specialist to conduct a gas emissions review for the extraction of coal from LW 203 to LW 206. The predicted greenhouse gas emissions were calculated over an approximate five-year mining period. The total gas volumes and calculated emissions arising from the extraction of LW 203 to LW 206 are presented in Appendix J.*

It has requested the Panel:

> *to review relevant information relating to the Extraction Plan, including the gas emissions report and provide its consideration and any advice or recommendations with a focus on:*
>
> - ..
> - ..
> - *proposed gas drainage and greenhouse gas minimisation management measures.*

Appendix J is titled *Gas Emission Review for Longwall 203 to Longwall 206* and comprises 12 PowerPoint slides prepared by a consultant (Palaris, 2023) that present predicted gas emissions for LW203–LW206 and summarise the approach being adopted by NCOPL and Palaris to develop a Decarbonisation Pathway. The Palaris review does not provide the assumptions and analysis that inform the gas predictions. The Panel gained a better, but still incomplete, insight into these important aspects through sourcing a range of additional information from NCOPL (identified in Table 1, Section 2 of this advice).

The extraction of LW203-LW206 at Narrabri Mine constitutes part of the Narrabri Coal Project – Stage 2 and, therefore, is required to be undertaken in compliance with the Consent Conditions for Project Approval 08_0144 issued in 2010 and with subsequent approved modifications.

Schedule 2 requires that:

> *The Proponent shall implement all practical measures to prevent and/or minimise any harm to the environment that may result from the construction, operation, or rehabilitation of the project.*

Condition 4 of Schedule 3 requires the Proponent to prepare and implement an Extraction Plan for any second workings and lists a range of matters that this plan must address. Greenhouse gas is not one of these matters and there appears to be no reason for the gas emission review to be included in the Extraction Plan.

However, Schedule 4 lists requirements in relation to greenhouse gas emissions and the Panel has had regard to these, including:

Condition 7

> *The Proponent shall:*
>
> *(a) Implement all reasonable and feasible measures to minimise the……release of greenhouse gas emissions from the project.*

Condition 31

The Proponent shall implement all reasonable and feasible measures to minimise the greenhouse gas emissions from the underground mining operations to the satisfaction of the Secretary.

Condition 32

Prior to carrying out longwall coal mining operations, the Proponent shall submit a Greenhouse Gas Minimisation Plan for the approval of the Secretary. The Plan must be:

a) Prepared in consultation with BCS

b) Identify options for minimising greenhouse gas emissions from underground mining operations, with a particular focus on capturing and/or using these emissions;

c) Investigate the feasibility of implementing each option;

d) Propose the measures that would be implemented in the short to medium term on site; and

e) Include a research program to inform the continuous improvement of greenhouse gas minimisation on site.

6.2. GREENHOUSE GAS EMISSIONS

6.2.1. Definitions

In Australian coal mining, the term 'gas' applies generically to all types of gas which pollute air as it is being pumped through the ventilation circuit of a mine. There are a number of sources of gas, the principal two being gas desorbed (released) from strata and gas that is a product of combustion (e.g. diesel engines, coal oxidation).

The term 'gas' in the Panel's advice refers specifically to methane (CH_4) and carbon dioxide (CO_2), both of which are strata gases within Narrabri Mine and the principal sources of greenhouse gas emissions (GHGE) from the underground coal mine workings. CH_4 is a product of coal maturation while CO_2 has been emplaced during later geological igneous events.

The advice is premised on the following definitions:

- **Global Warming Potential (GWP) for methane**: 28 t of CO_2-e per t of CH_4 (NGERR, 2008).[13]
- **Greenhouse gas emissions (GHGE):** emissions of CO_2 and CH_4 to atmosphere (expressed as t of CO_2-e), following the guideline for estimating emissions from coal mines (CER, 2022).
- **Non-gassy mine:** an underground mine that has less than 0.1% methane in its return ventilation[14] (NGERMD, 2022).
- **Scope 1 emissions:** *in relation to a facility, means the release of greenhouse gas into the atmosphere as a direct result of an activity or series of activities (including ancillary activities) that constitute the facility* (NGERR, 2008) [15].
- **Scope 2 emissions:** *in relation to a facility, means the release of greenhouse gas into the atmosphere as a direct result of one or more activities that generate electricity, heating,*

[13] *NGER Regulation 2.02*
[14] Air exhausted to atmosphere after having travelled through the mine workings.
[15] *NGER Regulation 2.23*

cooling or steam that is consumed by the facility but that do not form part of the facility (NGERR, 2008)[16].

6.2.2. Basic Longwall Mining Principles

Underground coal seams are accessed from surface via tunnels and/or shafts. The area where access is gained to a targeted coal seam is usually referred to as the 'pit bottom'. From here, sets of roadways are driven in the coal seam in various directions to access the coal in the mining lease. The 'inbye' direction in a mine is the direction of the mining face when approached from the pit bottom (i.e. going in the mine). The *"outbye'* direction is the direction of the pit bottom when approaching from the working face (i.e. going out of the mine). The process of roadway drivage is referred to as *'development',* with those roadways that are required to remain in service for an extended period of time being referred to as '*main development roadways*'.

In the case of longwall mining, large blocks of coal referred to as *'longwall panels'* are delineated by driving one, two or three roadways down each longitudinal boundary of each block and connecting them at the inbye extremity of the block. The process of driving the roadways is known as *'longwall development'.* The longwall mining equipment is installed in the connecting roadway at the inbye end of the longwall panel, from where it proceeds to extract coal by progressively cutting slices of coal about 1 m in width off the face as it retreats outbye. As each slice is extracted, the longwall face equipment is moved forward, allowing the undermined superincumbent strata to collapse behind the longwall face (or inbye of the longwall face). The collapsed area is referred to as the *'goaf'* and can act as a gas reservoir due to its porosity (void content). However, as the longwall face progressively retreats outbye from a point in the goaf, the goaf at that point is subjected to higher loads from the overlying strata, resulting in compaction of the collapsed rock material and reduction in porosity. The zone between the operating longwall face and the point where the goaf compacts to its maximum extent is referred to as the *'Active Goaf Zone',* Figure 2.

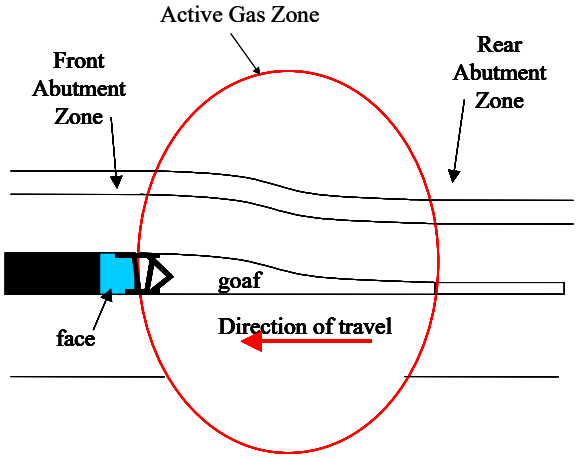


Figure 2: *Schematic showing the active gas zone in relation to the front and rear abutments zones of a longwall panel*

[16] *NGER Regulation 2.24*

Underground coal mines in Australia are ventilated by utilising one or more exhausting fans (vacuum cleaners) located on the surface over a mine shaft or tunnel entry to the mine workings. The low pressure created by the fans draws air down from the surface through the other mine entries and causes it to flow through one or more separate circuits of underground roadways known as 'intake airways' until the air reaches the working places in each ventilation circuit. The air is then returned to the surface along roadways referred to as 'return airways'. In the process of circulating through the mine workings, the air becomes contaminated, primarily by emissions of strata gas and dust.

6.2.3. Significance of Methane and Carbon Dioxide

CH_4 will not sustain life, is flammable and is explosive when it constitutes between 5 and 15% of an air mixture. Because CH_4 is lighter than air, it can collect in high spots in the mine workings that may be difficult to access and monitor. CH_4 emissions can also give rise to a thin layer of explosive gas mixture at roof level[17] that can extend for long distances, especially if the mine workings are dipping. In the case of longwall mining, CH_4 can be released in the goaf from remnant coal and from surrounding fractured strata (including other coal seams). It is not uncommon for methane to constitute more than 15% of the atmosphere in the goaf, in which case the mixture is outside of the explosive range (due to lack of sufficient oxygen to sustain an ignition). However, in these circumstances, because the atmosphere at the working face has to be maintained well below the explosive range[18], there is an area within the goaf where the methane/air mixture passes through its explosive range. For these and other reasons, methane is one of the greatest hazards in underground coal mining.

The density of CO_2 is 1.53 times that of air, making it more resistant to dilution by mixing with the air in the mine ventilation circuit. Given the right conditions, it can desorb from coal so rapidly that it results in an instantaneous *outburst* (or violent ejection) of coal and CO_2. Outbursts are initiated by a sudden, localised pressure drop at a site in a coal seam where there is a high propensity for fast desorption – such as on a fault zone containing pulverised coal (mylonite). The violent ejection of material and the generation of an irrespirable atmosphere either separately or in combination can have fatal consequences. Narrabri Mine is one of a number of Australian coal mines that are potentially prone to outbursts. This requires it to routinely test coal samples before the start of mining in an area to verify that gas has been predrained to below the designated gas content threshold for outbursts at the mine.

6.2.4. Storage and Release of Seam Gas

It is convenient to express the gas composition of a coal seam as either the ratio CH_4/CH_4+CO_2 or CO_2/CH_4+CO_2. The ratio CH_4/CH_4+CO_2 is adopted in this advice.[19]

Gas is adsorbed under increasing pressure and desorbed when pressure reduces sufficiently. The amount of desorbed gas in coal determined by laboratory testing is referred to as *Measured Gas Content, Qm*. Not all gas is accounted for in Qm. The *Total Gas Content, Qt* = Qm + Q3'[20] the latter term being the gas remaining in the coal at the completion of a laboratory gas content test.

With increasing fluid pressure, an increasing amount of gas can be adsorbed within the coal. Adsorption isotherms are determined in the laboratory and describe the relationship between fluid pressure and the corresponding equilibrium sorption capacity. Figure 3 has been prepared by the Panel

[17] Referred to as '*methane layering*'

[18] Legislation typically requires power to be turned off at a concentration of 1.25% CH_4 and the working place to be evacuated once the concentration of methane in the general air body exceeds 2%

[19] If, for example, the gas composition is 5% CH_4 and 95% CO_2, the ratio CH_4/CH_4+CO_2 is 0.05

[20] Terminology and notation is consistent with Australian Standard AS3980-1999 for gas content testing

for illustrative purposes only but is typical of figures derived from laboratory determined isotherms. It shows that for any given pressure, the sorption capacity of CO_2 is much greater than that of CH_4.

If the Total Gas Content, Qt, of the coal is equal to the gas sorption capacity of the coal, the coal is said to be fully saturated. For Narrabri Mine, the coal is highly undersaturated with gas. To illustrate the impact of gas saturation, the connected horizontal and vertical orange lines in Figure 3 correspond to a gas content of ~5 m^3/t at a reservoir (pore or fluid) pressure of ~2250 kPa[21]. If the gas is 85% CO_2 and 15% CH_4 then to get this gas mixture to desorb, the pore pressure must be reduced to below ~265 kPa, being the pressure at which this gas content reaches gas sorption capacity (i.e. the intersection of the horizontal orange line with the bold red saturation curve).

CO_2 is more difficult to predrain from coal than CH_4 in the case of Narrabri Mine because of the degree of undersaturation and the corresponding low desorption pressure of CO_2. These factors require pore pressure (which primarily consists of water pressure) to be reduced from the in-situ values in the coal by a large amount for pre-drainage to be effective. By contrast, if the gas is 100% CH_4, it can be seen that a CH_4 gas content of 5 m^3/t would begin to desorb at a pore pressure of around 1,510 kPa (i.e. the intersection of the horizontal orange line with the dashed blue saturation curve). Desorption pressure is one of the main factors driving gas drainage and is the main reason why CH_4 is more easily drained than CO_2 when the coal is in-situ.

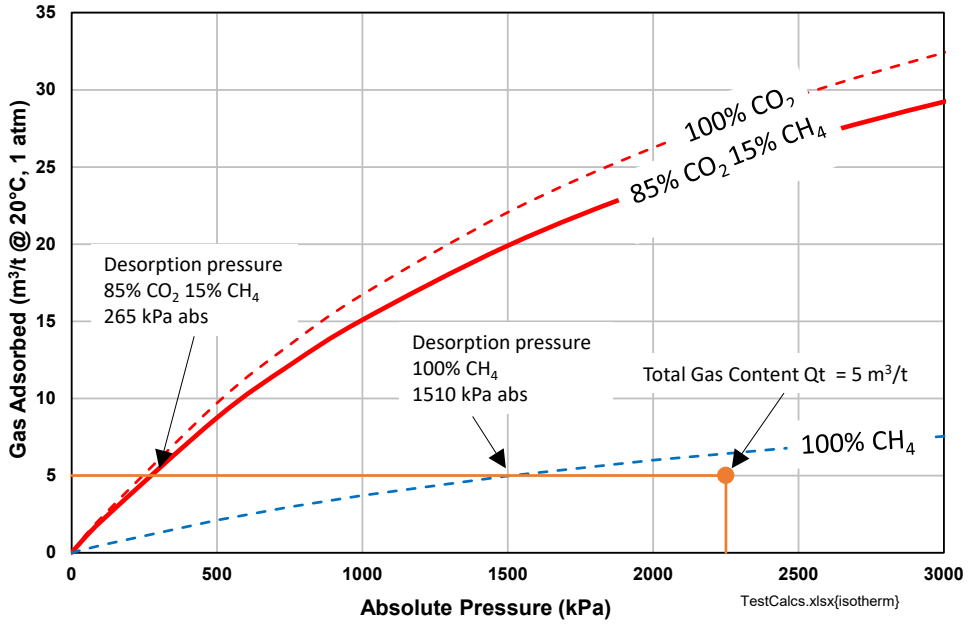


Figure 3: *Gas sorption capacity versus pore water pressure for varying gas proportions of CH_4 and CO_2 (prepared for illustrative purposes only)*

Once the pore pressure has been relieved (as occurs, for example, when coal is cut, is in a fractured or caved state in the goaf, or crushed for processing), desorption rate is a key parameter with CO_2 exhibiting a faster rate of gas desorption than CH_4. Moisture levels in the coal have an important bearing on desorption rate, with dry coal desorbing its gas much faster than wet coal. The impact of moisture on desorption rate is greater for CO_2 than for CH_4.

[21] The approximate virgin pore pressure and gas content for the LW203 – LW206 area

In high CH_4 content mines, it is common for gas to be at saturation in the coal. In such a situation, CH_4 can "spill over" and be present as free gas in surrounding porous rocks, such as coarse-grained sandstones. However, CO_2 generally never experiences fully saturated conditions and so is unlikely to be present as free gas within the porous rocks. CO_2 is highly soluble in water, so it is possible for it to be present because it is dissolved in water in both the pores of non-coal rocks and in the cleat system of the coal.

Primary (or principal) controls for managing the hazards presented by CH_4 and CO_2 include inseam drainage of gas before mining commences in an area (*'predrainage'*), dilution of CH_4 and CO_2 with mine ventilation air during mining (*'ventilation'*), and drainage of gas directly from the goaf to the surface via boreholes as mining progresses (*'postdrainage')*.

6.3. GREENHOUSE GAS EMISSIONS ASSESSMENT

Although there is no consent requirement to specifically assess greenhouse gas emissions in the Extraction Plan, *Section 2.2 Special Assessments* of the Extraction Plan presents a summary of total gas emissions (tonnes of CO_2-e) over 5 years for the extraction of LW203-LW206. This is supported by *Appendix J* to the Extraction Plan which provides a review in PowerPoint format of the outcomes of a full gas emissions assessment completed by Palaris (2023). This review, together with historical emissions, provides the basis for the Panel's assessment of how well the Consent Conditions relating to minimisation of greenhouse gas emission (GHGE) are being satisfied by NCOPL.

6.3.1. Total GHGE Assessment

The Palaris (2023) review indicates an annual GHGE of about 1.1 Mt CO_2-e. This represents an approximate 100% increase on emissions data contained in National Greenhouse and Energy reports by Whitehaven Coal Limited (financial years 2019, 2020, 2021, 2022). No explanation for the increase is given, although it is likely that the increase in CH_4 concentration in the seam gas is the major contributor, since for LW203-LW206 the ratio of CH_4/CH_4+CO_2 is about 0.15 to 0.2 on average compared to about 0.05 to 0.1 for the 100 series longwalls mined to date (see Figure 4). For the same volume of gas, this change in ratio would result in around a doubling of GHGE.

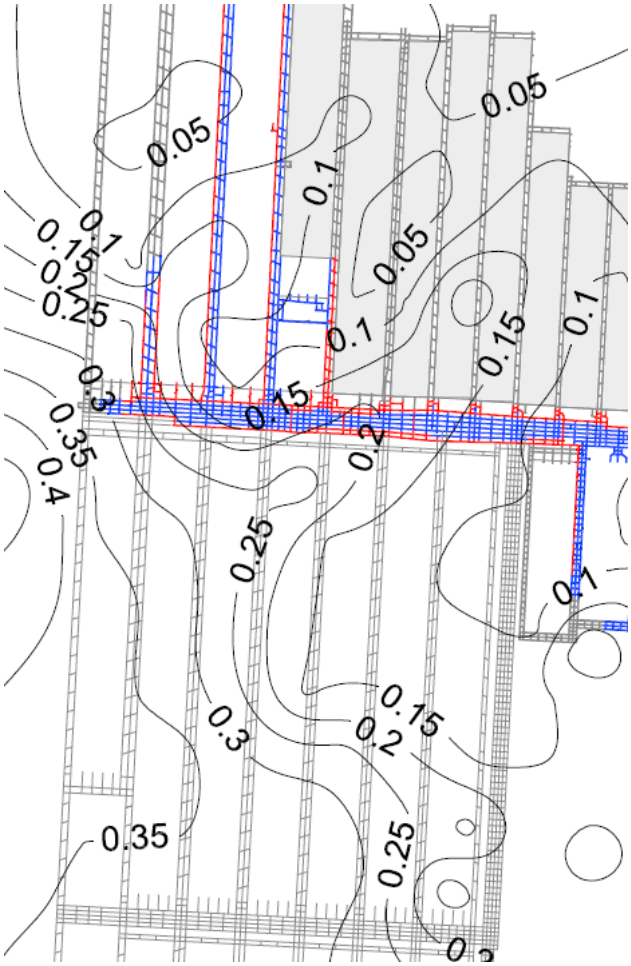


Figure 5: *Hoskissons seam gas composition – ratio CH_4/CH_4+CO_2 (WHC, 2020)*[22]

For LW203-LW206, Palaris (2023) attributes a much higher percentage (~81%) of the total emissions to the ventilation stream than has been the case historically. This corresponds to the summation of the development and longwall sources shown in Figure 5. The ventilation stream figure in the 2017 Greenhouse Gas Management plan is 32%. Figure 5 shows only 6.1% of the total gas emissions are expected to be derived from predrainage. This compares with a figure of 33% given in the 2017 Greenhouse Gas Management plan. The apparently lower requirement for predrainage is primarily because the gas content is assessed to be below the threshold required to initiate outbursts in the working face.

[22] p 19

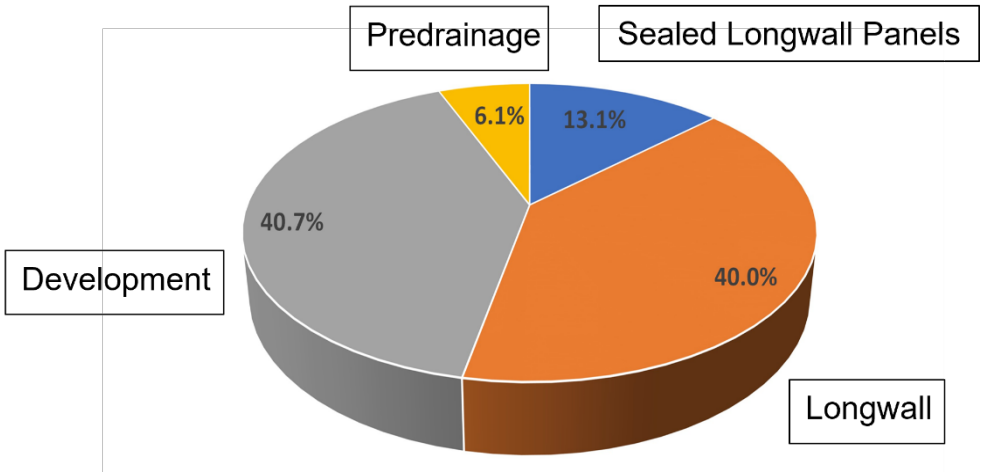


Figure 5: *Make up of gas sources tonnes CO2e LW203-LW206 based on data in Palaris (2023)*

Figure 6 shows the CH_4/CH_4+CO_2 ratio for different mining stages. The figure of 0.42 for development mining appears quite high given that the predicted in-situ gas ratio is around 0.2 but could be plausible, depending on modelling assumptions. The values are produced with the SIMEDWin gas reservoir simulator using a coal permeability of 10 mD.

While the methodology used to inform the Palaris (2023) review appears to be industry 'state-of-art', there are two main features at Narrabri Mine that warrant a review of the underpinning modelling, namely:

- The dominant CO_2 environment
- The low and changing CH_4/CH_4+CO_2 ratio.

For the modelling, a significant source of gas (~35%)[23] has been assigned to the non-coal formations (Digby Conglomerate RDC, Arkaroola Formation ARK) as apparently model results based only on gas in the coal are insufficient to explain the GHGE to date. Further, the modelling appears to assume the same CH_4 concentration in the non-coal strata as in the coal.

[23] *WHC6420-03 RFI Responses Narrabri Underground Longwalls 203-206 23Jan23.pdf* slide 14

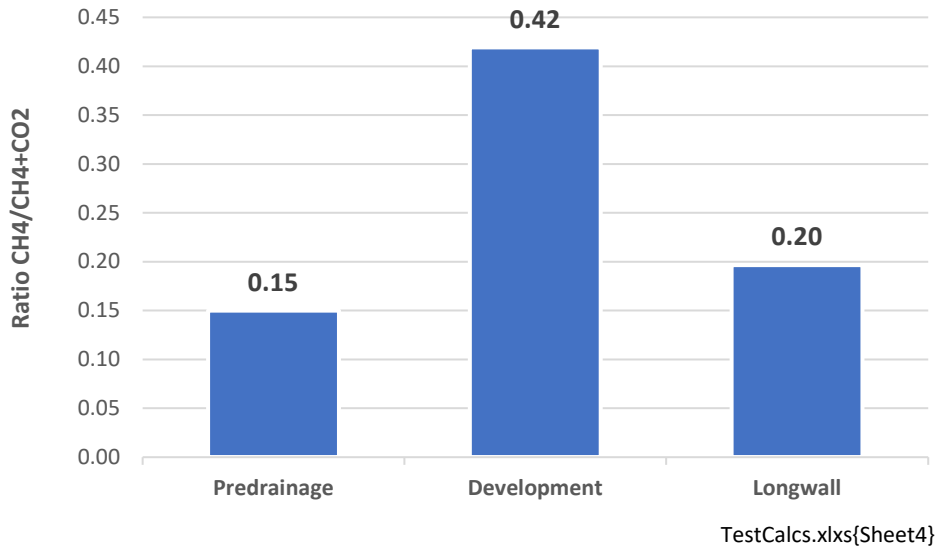


Figure 6: *Ratio CH_4/CH_4+CO_2 for LW203-LW206 derived from Palaris (2023)*

The validity of the assumed non-coal gas quantity and composition should be reassessed. The Panel considers it more likely that only CO_2 is present in the non-coal formations. If this consideration is correct it may explain why the CH_4/CH_4+CO_2 ratio for the ventilation exhaust gas is historically lower (0.04) than for the predrainage gas (0.06) in the 2017 Greenhouse Gas Minimisation Plan (WHC, 2017). Typically, predrainage gas would be confined to the Hoskissons seam (containing CH_4) while ventilation gas would be released from all sources. Moreover, it would indicate that the total CH_4 estimated in the Palaris review could be an over-estimate and this, in turn, would affect the GHG forecasts and proposed mitigation strategies.

The Panel considers that additional investigations are warranted to better understand the distribution and quantity of CH_4 and CO_2 in the non-coal formations. As a preliminary step, the emission model should be re-run assigning only CO_2 to the non-coal units to assess the influence of this assumption on their GHGE results. The outcome is likely to provide impetus to future work directed at assessment of the gas contained in the non-coal horizons.

6.3.2. Greenhouse Gas Minimisation Plan

6.3.2.1. Decarbonisation Pathway

In accordance with Condition 32, the *Greenhouse Gas Minimisation Plan* was first prepared in 2012 by SLR Consulting Australia Pty Ltd (WHC, 2012), updated in 2017 by Advitech (WHC, 2017) and is presently being further updated for the Stage 2 approval. *Appendix J* of the Extraction Plan includes a summary of the three-phase decarbonisation pathway that Palaris is developing in conjunction with NCOPL. These phases are:

- Phase 1: Map the Carbon Footprint
  Obtain a comprehensive GHGE profile for the operations categorised by fugitive, mobile combustion, stationary combustion, and process emissions.
- Phase 2: Identify Abatement Opportunities
  Review all significant abatement opportunities for Scope 1 and Scope 2 emissions and identify viable options.
- Phase 3: Pathway Prioritisation
  Prioritise options using a Marginal Abatement Cost (MAC) Curve that includes estimates of associated CAPEX and OPEX costs.

Each of these phases is discussed in turn in the following sections.

6.3.2.2. Phase 1: Map the Carbon Footprint

While *Appendix J* states that Phase 1 of the decarbonisation pathway is complete, two areas that do not appear to have been addressed are:

1. Determination of emissions from above ground coal stockpiles for the period between the time the coal exits the mine and when it is shipped off-site. While NGE reporting does not require this if a mine (such as Narrabri Mine) is classified 'non-gassy'[24], consideration of the contribution to overall site GHGE is warranted, including a scheme of measurement.
2. Investigation of gas quantity and composition in the non-coal strata.

The Panel recommends that these areas are addressed to complete the carbon footprint map.

6.3.2.3. Phase 2: Identify Abatement Opportunities

Clauses 31 and 32 of the Consent Conditions stipulate that greenhouse gas emissions (GHGE) must be minimised from underground mining operations. While there could be conjecture as to the meaning of the phrase 'underground mining operations', it is clear from the *Greenhouse Gas Minimisation Plan* that NCOPL considers this to include a wide range of Scope 1 and Scope 2 emissions across the different activities and emission points on site, including emissions from the coal itself. This approach is in line with international best practice.

<u>*Site GHGE*</u>

The current reasonable and feasible measures that NCOPL is undertaking to minimise the release of GHGE from the site, excluding from the underground coal, involve regular plant and equipment maintenance, selection of energy efficient plant and equipment, staff training so that continuous improvement can be achieved, and sourcing electricity from renewable or carbon neutral energy sources.

Specific GHGE minimisation measures reported in the *Greenhouse Gas Minimisation Plan* include replacing use of diesel with energy supply from the grid and establishing KPIs for energy usage for each operational area over time covering areas such as air compressors, lighting, water pumping, ventilation, water treatment, the drift conveyer, CSG generation and repairing leaks. The KPIs are presented in the *Energy Saving Action Plan* prepared in 2014 by Advitech (NAR, 2014) proceeding from a Level 3 Energy Audit. The 2014 *ESAP* is an update of the 2011 *ESAP* which is an update of the original 2008 *ESAP*.

The Panel considers that all of the above aspects of minimisation of site GHGE are adequately addressed.

As noted under Phase 1, the management of emissions from above ground coal stockpiles warrants further consideration.

<u>*Underground coal GHGE*</u>

Only commercial or near commercial technologies have been considered by NCOPL for CH_4 minimisation, these being combustion, flaring, oxidation, upgrading/enrichment, and injection to a natural gas pipeline. The Panel notes that the purpose of combustion, flaring or oxidation is to convert CH_4 to CO_2, thereby reducing the global warming potential (GWP) of CH_4 from 28 to 1. Upgrading, enrichment or injection of the CH_4 into a pipeline only reduces the GWP when the gas is subsequently

[24] *NCOPL Response to RFI - Greenhouse Gas Emissions - 17 Dec 21.pdf*

combusted, flared or oxidised. Using pre-drainage gas to enrich ventilation gas prior to oxidation (see below for further details) is the most prospective option for NCOPL. While other mines have successfully implemented flaring, this is currently considered problematic at Narrabri Mine due to high CO_2 concentrations in the seams being mined. An evaluation of the suitability of flaring at Narrabri Mine was undertaken by WHC (2021). Flaring may become viable for future longwalls as higher CH_4 concentration seams are mined.

Goaf gas has represented 2% of the total site GHGE (WHC, 2017), contributing the lowest quantity at the highest CH_4 concentration (27%). However, even this concentration is considered too low to reliably sustain either flaring or combustion. While upgrading using pressure swing adsorption (PSA), molecular sieve adsorption (MSA), amine gas sweetening, membrane separation or cryogenic separation is viable in some circumstances, the CH_4 concentration in goaf gas at NCOPL is considered to be below the limits of such current commercial (or near commercial) technologies. As for pre-drainage gas, enrichment of ventilation gas prior to oxidation probably represents the most prospective option for minimisation of CH_4 in goaf gas. Upgrading using an optimal mix of pre-drainage and goaf gas may also be worthy of consideration as a future research program. The Panel notes that for LW203-LW206 the drainage of gas from the goaf using wells is deemed unlikely, depending on whether the ventilation can handle the goaf gas.

Ventilation exhaust gas represented 47% (the largest component) of the total site GHGE in the 2017 version of the Greenhouse Gas Minimisation Plan (WHC, 2017), contributing the highest quantity at the lowest CH_4 concentration (~0.03%). For LW203–LW206, this proportion has been modelled by Palaris (2023) as being much greater (81%) excluding outbye sources but there is no indication how this translates to CH_4 concentration in the ventilation exhaust. Quantifying the CH_4 concentration in the ventilation exhaust would be helpful for assessing mitigation strategies.

There are currently two types of commercial ventilation air methane (VAM) technologies available based on the process of oxidation that are suitable for minimising CH_4 in ventilation gas. These technologies have already been used commercially for control of atmospheric pollutants such as odours and volatile organics. They have been installed (with suitable safety measures) at mines in China, USA and Australia where CH_4 concentrations are above 0.2%. The Panel is aware of R&D trials in a number of locations that are seeking to reduce the concentration of gas that can be oxidised. However, the ventilation exhaust gas at Narrabri Mine is below the apparent commercial technology limit of 0.2%. Further, at Narrabri Mine, VAM would currently incur high capital and operating costs while achieving relatively low total abatement, unless enrichment with pre-drainage or goaf gas could reliably achieve much higher abatement. Consequently, VAM is not identified in the Extraction Plan as a technology under further consideration for GHGE minimisation. Nevertheless, NCOPL should maintain a watching brief on developments in VAM technologies.

A feature of NCOPL's GHGE minimisation considerations to date is that only current commercial or near commercial options for minimisation of CH_4 have been considered. No consideration appears to have been given to the use of technologies at a lower level of technology readiness but with good technical potential in the Narrabri Mine context or in undertaking R&D trials to determine the potential suitability of these technologies. The Panel considers that these opportunities should be recognised in NCOPL's research plan.

One other potential avenue for minimisation of GHGE from coal production that has not been considered by NCOPL is to exploit the relationship between production of seam gas in the strata versus rate of longwall face retreat. There is a zone of active gas emission extending from the longwall face to the rear abutment in the goaf (see Figure 2) but behind the rear abutment the emissions are much reduced. The faster the face retreats, the quicker gas emissions become constrained to the reduced values behind the rear abutment. A fast rate of mining produces more gas per unit of time, but less gas per tonne of coal mined due to this process, as shown by CO_2 gas makes in Figure 7 for LW109 at Narrabri Mine.

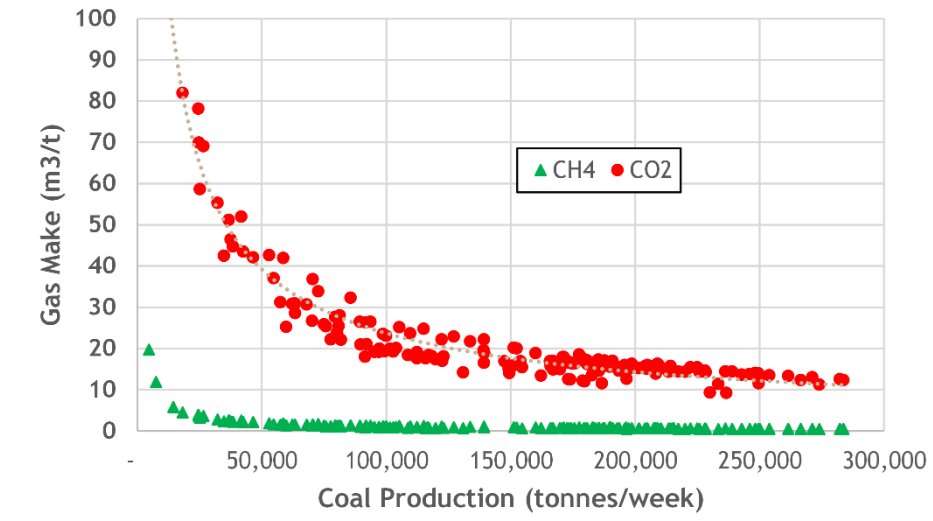


Figure 7: *Gas make curves for CO_2 and CH_4, LW109, Narrabri Mine (derived from data supplied by NCOPL file GHG 2a – Longwall 108 and 109 Gas Make Data 17Jan23.xlsx)*

A fast rate of retreat is favoured by:

- A shorter longwall face (narrower longwall panel width)
- Mining a thinner coal horizon
- A faster rate of coal cutting (albeit producing more gas per unit of time, but less gas per tonne mined)

A narrower longwall panel width also has the potential to reduce fugitive gas emissions through connective fracturing to surface. This potential environmental impact of connective fracturing was not identified in the subsidence assessment.

Additionally, the rate of gas desorption is affected by the level of moisture saturation. Low moisture saturation favours a faster rate of gas desorption. Predrainage dries out the coal such that the remaining gas is prone to a faster rate of desorption. Laboratory testing (unpublished internal tests by GeoGAS, circa 1996) on CO_2 rich coal of similar rank to that at Narrabri Mine shows the rate and extent of gas desorption of CO_2 is especially sensitive to moisture levels. An avenue of research thus presents itself whereby the coal is water infused (via predrainage boreholes) prior to mining, potentially resulting in:

- A lower rate of gas emission reporting to the longwall return (i.e. lower GHGE for a given level of production)
- Reduced dust issues and spontaneous combustion risk.

6.3.2.4. Phase 3: Pathway prioritisation

While the 2012 version of the *Greenhouse Gas Minimisation Plan* presented a high level costing for VAM, neither the current version of this Plan nor the Extraction Plan provide any further cost details and a MAC has not been prepared.

6.3.2.5. Research Program for Continuous Improvement of Site GHGE Minimisation

The Consent Conditions include a requirement for the *Greenhouse Gas Minimisation Plan* to include '*a research program to inform the continuous improvement of green house gas minimisation on site*'. The current Plan contains one brief section titled '*RESEARCH PROGRAM*'. It contains a commitment to continuing to review mine gas concentrations and to investigate methods of reuse if CH_4

concentrations increase. Further, it commits to updating management plans and reporting on GHG abatement measures in the Annual Report. However, these activities appear to be a continuation of business as usual (BAU) activities. It does not appear that NCOPL has a current documented research program that provides an outline of experimental activities that demonstrate a systematic, scientific progression of work leading to logical conclusions and the generation of new knowledge (as defined in a known framework such as core R&D activities of the Commonwealth Government's R&D Tax incentive or a coal industry ACARP research proposal). A number of initiatives that could form the basis of a research program have been identified in the previous sections. These include:

1. Investigations to better understand the distribution and quantity of CH_4 and CO_2 in non-coal formations
2. Determination of emissions from the above ground coal stockpile
3. Review of national and international R&D trials that are seeking to reduce the concentration of ventilation gas that can be oxidised
4. Options assessment for opportunities to retain more gas in the strata through selection of mine design and operational parameters that increase the rate of face retreat and through the management of the moisture content of the coal

6.4. CONCLUSIONS AND RECOMMENDATIONS

The Panel concludes that:

1. *Section 5.3 Greenhouse Gas Emissions Management Measures* of the Extraction Plan and the associated Palaris (2023) review comprising Appendix J of the Extraction Plan are out of context with the required contents of the Extraction Plan as specified in Schedule 2 of the Project Approval and should not form part of the Extraction Plan
2. Rather, greenhouse gas emissions management measures and the associated Palaris (2023) contribution should be presented separately by NCOPL as an updated Greenhouse Gas Minimisation Plan and reviewed by the Department in the context of Conditions 7, 31 and 32 of Schedule 4 of the Project Approval. This should factor in presenting the Palaris Review (Appendix J) in the form of a formal report rather than as a PowerPoint summary
3. The Greenhouse Gas Minimisation Plan does not adequately address all matters required under Schedule 4, particularly in regard to developing a research program to inform the continuous improvement of greenhouse gas minimisation on site
4. The following matters in the Palaris (2023) review require clarification and/or further development to aid in achieving compliance with Schedule 4:
    i. Quantify rather than estimate outbye emissions
    ii. Given the increase in CH_4 concentration in the LW203-LW206 area, the study of emissions should be extended to identify the modelled concentration of CH_4 and CO_2 in ventilation emissions. This would provide a clearer basis for the assessment of the use of VAM technology
    iii. Review and confirmation of gas concentrations in non-coal strata, including further testing of non-coal strata.
    iv. Updating of the models of emissions, including sensitivity analysis of GHGE to these gas sources and direct measurement of gas retained in the coal as it exits the longwall panel.
    v. Review and potential uptake of methods for retaining more seam gas in-situ for the same level of production
5. Other matters that should also be addressed in developing the Greenhouse Gas Minimisation Plan include:
    i. The potential for fugitive GHG emissions through connective fracturing to surface
    ii. Management of emissions from the above ground coal stockpiles, including a method to determine stockpile emissions
    iii. Summarising the time-based GHGE reductions achieved to date for the site along with time-based targets for future reduction

iv. Periodic review of the progress of commercial and emerging greenhouse gas emission reduction technologies for both CH_4 and CO_2 to assess applicability to and uptake by NCOPL
v. Periodic evaluation of the costs of the most prospective greenhouse gas minimisation technologies in the Narrabri Mine context along with the development of a marginal abatement coast (MAC) curve
vi. Development of a research program to inform the continuous improvement of greenhouse gas minimisation on site

The Panel recommends that:

1. NCOPL develop its Greenhouse Gas Minimisation Plan to be in compliance with Schedule 4 of the Project Approval including addressing matters raised in this advice.
2. NCOPL prepare a clearly specified research program to inform the continuous improvement of greenhouse gas minimisation on site. The plan should prioritise actions and present timelines for completion actions. Based on the current advice, the plan should include the following topics:
    i. Investigations to better understand the distribution and quantity of CH_4 and CO_2 in non-coal formations
    ii. Determination of emissions from the above ground coal stockpiles
    iii. Regular review of the progress of commercial and emerging greenhouse gas emission reduction technologies for both CH_4 and CO_2 to assess applicability to and uptake by NCOPL
    iv. Options assessment for opportunities to retain gas in the strata through selection of mine design and operational parameters that increase the rate of face retreat and reduce the potential for connective fracturing to surface and through the management of the moisture content of the coal seam.

7.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

The Panel has reviewed the Extraction Plan submitted by the Applicant, including the addendum material. As a result of this review, the Panel offers the following summary conclusions and recommendations:

1. Mine Plan and Subsidence Implications

   The Panel concludes that:

   (i) The predictions of subsidence effects and impacts that inform the EP are of a similar order of reliability as those of alternative methods and are fit-for-purpose, recognising that a degree of uncertainty is associated with all subsidence prediction methodologies.

   (ii) The Panel has no reason to believe that the EP supported by other statutory workplace health and safety requirements will not achieve the Performance Measures for Built Structures and Public Safety.

   (iii) The potential consequences of connective fracturing for fugitive emissions of greenhouse gases from mine workings to the surface through this fracture network needs to be considered in the Greenhouse Gas Minimisation Plan required to be developed under Schedule 4

2. Heritage Management Plan

   The Panel concludes that:

   (i) There is a credible likelihood that subsidence associated with the proposed mine layout will impact the physical state and heritage values of Aboriginal heritage site Mayfield GG1, which: contains 43 grinding grooves; was not identified at the time of Project Approval; and is more significant than the only grinding groove site identified at the time of the Project Assessment.

   (ii) There is a lack of clarity and consistency in the EP regarding the nature, mitigation, remediation and acceptance of key stakeholders of any physical damage and degradation of cultural heritage values caused by subsidence-induced cracking at the Mayfield GG1 site.

   (iii) The Subsidence Risk Assessment does not conform to some relevant Australian risk assessment guidelines and does not achieve many of the objectives of undertaking a risk assessment.

   (iv) Notwithstanding this and the lack of consideration of political consequences in the risk assessment, the residual risk rating of 'High' for cracking of Mayfield GG1 is credible.

   (v) The TARP relating to managing subsidence impacts on Mayfield GG1 serves no purpose in preventing cracking of Mayfield GG1.

   (vi) The proposal by NCOPL to develop an action plan for the management of Mayfield GG1 site within 6 months of approval of the EP is applicable only if the EP is approved on the basis that cracking of the site is permissible and that the Secretary will give approval for Aboriginal objects at the site to be damaged or, the action plan includes TARPs that provide confidence that cracking will be prevented at the site.

   (vii) If cracking of Mayfield GG1 is unacceptable then:

      a. the preventative measures detailed in the Heritage Management Plan are weak by subsidence engineering standards and may have little or no influence on the development of cracking at the site.

b. stronger preventative measures would normally be required, such as revising the location of the longwall panels relative to the site of Mayfield GG1, leaving coal unmined under the site and/or slotting around the site to interrupt the transmission of ground strains.

c. logically and practically, an action plan for the management of Mayfield GG1 should form part of the EP and be based on clearly articulated and measurable performance measures.

d. consideration may need to be given to a staged approval if there is a prospect that the mine layout will need to be changed in order to achieve compliance with performance measures for Mayfield GG1.

The Panel recommends that:

(i) The Department gives careful consideration to:

a. the acceptability of NCOPL's plans to provide answers within 6 months to the question of connection of the grinding groove rocks to the bedrock and the decisions that derive from that and from discussions with Registered Aboriginal Parties (RAPs).

b. if the EP can receive a staged approval given the current level of uncertainty around NCOPL's action plan for site Mayfield GG1.

(ii) If it is intended not to prevent cracking of Mayfield GG1, then the assessment of the LW203-LW206 EP should include:

a. Verification that cracking of Mayfield GG1 is acceptable to all key stakeholders.

b. Verification that key stakeholders, including government, are involved in assessing and accepting the risks associated with this approach, including reputational and political risk.

c. Verification that, as per the Consent Conditions, the Secretary will approve damage to this Aboriginal heritage site.

(iii) If cracking of Mayfield GG1 is unacceptable then prior to further assessment, the EP for LW203-LW206 should:

a. include clear, unambiguous and measurable performance measures for Mayfield GG1.

b. include all management plans relevant to complying with the performance measures for Mayfield GG1.

3. Surface Water

The Panel concludes that:

(i) A creek water loss estimation method is required to support a water access license application for the Eulah Creek Water Source. Water take from this source is expected to be non-negligible. A water loss estimation method is not proposed in the EP although there is a commitment to consider methods prior to surface cracking being detected. The Panel concludes that this approach is generally acceptable but the commitment to delivering a method is not definite enough.

(ii) Diversion of water from the watercourses (creeks) in the subsidence area to the mine void is expected to be small and may be unobservable. Nevertheless, the likelihood of connective surface-void fracturing is considerable and unexpected inflows of water associated with rainfall may occur. The Surface Water Management plan refers to trigger for determining unexpected inflows but does not include a detailed TARP that specifies responses.

(iii) A predicted surface water impact is subsidence ponding. The proposed approach to managing individual ponds is non-specific. This is appropriate since the suitable method requires expert assessment of the pond and its environment after the pond has formed. However, the Extraction Plan does not provide confidence that suitable remediation or alternative management methods are available and does not provide clear criteria for selecting a method.

(iv) There is a lack of published guidance in Australia regarding management of subsidence ponds including the circumstances in which a pond should be allowed to evolve without active management.

(v) The Erosion and Sediment Control Plan appears to be satisfactory, including the update proposed for Stage 3.

(vi) The Stage 3 Development Consent places new emphasis on protection of riparian and aquatic ecosystems, with the relevant performance measure based on "negligible environmental consequences". Operating under Stage 3 will require explicit performance indicators and TARPs including flow conditions, groundwater levels, water quality, watercourse morphology, and aquatic and riparian ecology at selected sites.

(vii) The TARPs in the EP WMP do not provide confidence that performance measures can be met through escalation of adaptive management.

(viii) The various documents included in the EP and referred to in the EP lack consistency in performance indicators and details of the TARPs, making it challenging to review and interpret parts of the EP.

The Panel recommends that:

(i) A method proposal for estimating surface water losses should be submitted by NCOPL to the Department prior to surface subsidence impacts being observed.

(ii) A detailed TARP for surface water diversions to the mine void should be included in the EP based on measured inflows to the void and their relation to rainfall events.

(iii) More information should be provided in the EP about available subsidence pond remediation options and criteria for determining the best option.

(iv) Water management TARPs at the highest trigger levels should include consideration of interruption to mining to allow corrective management actions to be proposed and approved by the Department.

(v) If operating under the Stage 3 Development Consent, the performance measure "Negligible environmental consequences beyond those predicted in the document/s listed in condition A2(c)" should be addressed by a suite of explicit performance indicators and corresponding TARPs in the EP WMP including for flow conditions, water quality, watercourse morphology, and aquatic and riparian ecology at selected sites.

(vi) Future Annual Review appendices should show water quality time-series plots that include all baseline years to allow inspection of variability and trends.

(vii) The actions associated with the highest level triggers in the TARPs should incorporate definitive actions towards ensuring that performance measures are achieved (in cases where the TARP is associated with a performance indicator and performance measure).

(viii) Greater effort is needed by NCOPL to achieve consistency and effective cross-referencing between the documents relevant to the EP WMP.

6. Groundwater

The Panel concludes that:

(i) While the evidence points to limited impacts to the Pilliga Aquifer, there is a need to increase the monitoring of the Sandstone to provide confidence in the groundwater modelling predictions.

(ii) The planned additional monitoring should be implemented as soon as practicable and prior to completion of LW 203.

(iii) Unexpectedly high inflows to the mine workings should be a trigger for a full reappraisal of the groundwater assessment and an update to the groundwater model. Care should be taken to maintain the monitoring network for mine inflows, including ensuring timely repairs to faulty equipment.

(iv) Impacts to the Namoi aquifer are expected to be small and not discernible in the groundwater monitoring results for the aquifer. As with the Pilliga aquifer, if mine inflows significantly exceed the expected values then the likelihood of impacts to the aquifer should be reviewed.

(v) Performance indicators and a TARP for the Mayfield Spring and high priority GDEs need to be developed. Specific high priority GDEs monitoring sites should be proposed based on ground surveys. Monitoring should include shallow groundwater levels.

(vi) The TARPs for groundwater should be improved. Improvements are required to the operational approaches used for the TARPs as well as to the triggers that are adopted.

The Panel recommends that:

(i) The planned upgrades in the monitoring network for the Pilliga aquifer should be completed as soon as practical and no later than the end of completion of LW 203.

(ii) Mine inflows need to be measured as accurately as practicable and that any failures of monitoring equipment are rectified rapidly to ensure adequate ongoing information to trigger and support reanalysis of groundwater conditions relevant to the Pilliga and Namoi aquifers.

(iii) NCOPL should develop performance indicators for the Mayfield Spring to assist the assessment of impacts and their significance. The proposed monitoring and evaluation appear to be appropriate for this feature.

(iv) The EP WMP should be revised to include a clear statement on how consequences for high priority GDEs will be managed.

(v) The rainfall condition should be removed from the trigger for mine inflows.

(vi) A review and update of the TARPs for groundwater level changes should be undertaken to improve the quality and the usefulness of the TARPs (as per advice in Section 5.7).

(vii) NCOPL evaluate whether it has sufficient monitoring data against which to measure the contributions to drawdown in the Pilliga sandstone from all sources and that the methods for assessing the parties responsible for mitigation of impacts are agreed with DPE Water.

7. Greenhouse Gas Emissions

The Panel concludes that:

(i) *Section 5.3 Greenhouse Gas Emissions Management Measures* of the EP and the associated review comprising Appendix J of the EP are out of context with the required contents of the EP as specified in Schedule 2 of the Project Approval and should not form part of the EP

(ii) Rather, greenhouse gas emissions (GHGE) management measures and the associated Palaris (2023) contribution should be presented separately by NCOPL as an updated Greenhouse Gas Minimisation Plan and reviewed by the Department in the context of Conditions 7, 31 and 32 of Schedule 4 of the Project Approval. This should factor in presenting the Palaris Review (Appendix J) in the form of a formal report rather than as a PowerPoint summary

(iii) The Greenhouse Gas Minimisation Plan does not adequately address all matters required under Schedule 4, particularly in regard to developing a research program to inform the continuous improvement of greenhouse gas minimisation on site

(iv) The following matters in the Palaris (2023) review require clarification and/or further development to aid in achieving compliance with Schedule 4:

a. Quantify rather than estimate outbye emissions

b. Given the increase in CH_4 concentration in the LW203–LW206 area, the study of emissions should be extended to identify the modelled concentration of CH_4 and CO_2 in ventilation emissions. This would provide a clearer basis for the assessment of the use of VAM technology

c. Review and confirmation of gas concentrations in non-coal strata, including further testing of non-coal strata.

d. Updating of the models of emissions, including sensitivity analysis of GHGE to these gas sources and direct measurement of gas retained in the coal as it exits the longwall panel

e. Review and potential uptake of methods for retaining more seam gas in-situ for the same level of production

(vi) Other matters that should also be addressed in developing the Greenhouse Gas Minimisation Plan include:

a. The potential for fugitive GHGE through connective fracturing to surface

b. Management of emissions from the above ground coal stockpiles, including a method to determine stockpile emissions

c. Summarising the time-based GHGE reductions achieved to date for the site along with time-based targets for future reduction

d. Periodic review of the progress of commercial and emerging greenhouse gas emission reduction technologies for both CH_4 and CO_2 to assess applicability to and uptake by NCOPL

e. Periodic evaluation of the costs of the most prospective greenhouse gas minimisation technologies in the Narrabri Mine context along with the development of a marginal abatement cost (MAC) curve

f. Development of a research program to inform the continuous improvement of greenhouse gas minimisation on site

The Panel recommends that:

(i) NCOPL develop its Greenhouse Gas Minimisation Plan to be in compliance with Schedule 4 of the Project Approval including addressing matters raised in this advice.

(ii) NCOPL prepare a clearly specified research program to inform the continuous improvement of greenhouse gas minimisation on site. The plan should prioritise actions and present timelines for completion actions. Based on the current advice, the plan should include the following topics:

a. Investigations to better understand the distribution and quantity of CH_4 and CO_2 in non-coal formations

b. Determination of emissions from the above ground coal stockpiles

c. Regular review of the progress of commercial and emerging greenhouse gas emission reduction technologies for both CH_4 and CO_2 to assess applicability to and uptake by NCOPL

d. Options assessment for opportunities to retain gas in the strata through selection of mine design and operational parameters that increase the rate of face retreat and reduce the potential for connective fracturing to surface and through the management of the moisture content of the coal seam.

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