INDEPENDENT ADVISORY PANEL FOR UNDERGROUND MINING

ADVICE RE:

DENDROBIUM EXTENSION PROJECT

SSD-8194

October 2020

EXECUTIVE SUMMARY

OVERVIEW

NSW Department of Planning, Industry and Environment: Energy Resources and Compliance requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Dendrobium Extension Project - SSD-8194. The initial Scope of Works stated:

> *The Department is primarily seeking advice on longwall void widths for the two proposed mining domains (Area 5 and 6), and the relative environmental costs and benefits associated with different longwall widths, including whether a reduction in the void widths would materially reduce the environmental impacts of the project.*

Subsequently, the Scope of Works was broadened to include a focus on subsidence impacts associated with the specific mine layout on which the EIS is based.

Dendrobium Mine operates within the Greater Sydney Catchment Special Areas in the Southern Coalfield of NSW. The mine owner, South32, is seeking approval for an extension to the mining operation in order to extract Area 5 in the Bulli Seam and Area 6 in the Wongawilli Seam. The Dendrobium Extension Project (DEP) is the first major mining project in the catchment to be assessed in the last decade, with the current mine being based on an approval that is nearly two decades old.

It is well established that mining panel width, height of extraction and depth of mining are important factors in determining the environmental impacts of mining-induced subsurface and surface ground subsidence. The EIS does not include any substantive sensitivity analysis of the influence of longwall panel width or mining height on subsidence effects, impacts and consequences. Nearly all longwall panel widths continue to be 305 m. The surface and groundwater assessments in the EIS are based on assuming a worst case outcome, being that the deep subsurface connective fracture zone will overlap with the shallow near-surface connective fracture zone to result in connective fracturing from the mine workings through to the surface over the mine workings in Areas 5 and 6. No justification on technical or environmental grounds has been provided for panel widths of 305 m, with the Panel being advised by the Proponent that it is based on experience with this width at Dendrobium Mine and economic returns.

The Proponent proposes to offset the environmental consequences associated with connective fracturing during the operational life of the mine by paying government for surface water taken from the catchment, funding or implementing works that reduce existing losses (e.g. pipe losses or evaporation) and offsetting impacts to swamps and some other aspects of biodiversity. The EIS appears to assume that the mine can be sealed successfully after the cessation of mining and so negate ongoing water loss from the catchment. It neither provides an explanation of how connections to the mine (including through neighbouring mines) can be sealed successfully nor an assessment of the long term effects, impacts and consequences of mine sealing on neighbouring mines, the environment, water quantity and quality in the catchment and public safety. If the mine cannot be sealed, then consideration has to be given to how to manage and offset groundwater and surface water inflow to the mine workings in perpetuity.

Against this background, this advice has been structured around reviewing the sections of the EIS relating primarily to subsidence, groundwater and surface water, having regard to the findings of the Southern Coalfield Inquiry (2008), the Planning Assessment Commission’s reports for the Metropolitan Coal Project (2009) and the Bulli Seam Operations Project (2010) and the Independent Expert Panel for Mining in the Catchment (2019) and to supplementary information including key stakeholder submissions and responses to questions put to the Proponent by the Panel. It then considers the DEP impact on some aspects of mine closure planning, the adequacy of mine closure planning as reported in the EIS and the implications of the DEP for the management of water take from the catchment after mine closure. The advice has a limited focus on swamps given that impacts on them are to be offset.

CONCLUSIONS

Overview

Non-conventional subsidence

1. At Dendrobium Mine, longwall panel width is not the key control when considering environmental impacts on natural surface features due to mining-induced non-conventional subsidence, in particular, valley closure. This is because environmental impacts due to non-conventional surface subsidence start to plateau at longwall panel widths that are reported to be too narrow to be economic at Dendrobium Mine.
2. Rather, the key control for limiting environmental impacts on natural surface features due to non-conventional subsidence is, as reflected in the mine layout proposed for Areas 5 and 6, the setback distance of longwall panels from natural surface features.
3. Therefore, in respect of non-conventional subsidence, project assessment needs to have a focus on the rigour in identifying the nature and scale of environmental impacts, the appropriateness of the limits selected for environmental impacts, the reliability of setback distances of longwall panels proposed for preventing these limits being exceeded, and the suitability of the mine layout to adaptive management as a control for preventing exceedances of predicted impacts.

Conventional subsidence

4. Environmental impacts associated with conventional subsidence are of both a surface and subsurface nature and include the height of connective fracturing. Environmental impacts due to conventional subsidence are particularly sensitive to changes in longwall panel width and extraction height, as well as some parameters over which there is limited control, such as depth of mining.
5. There continues to be much conjecture and uncertainty as to both how to predict the height of connective fracturing and how to confirm this height in the field.
6. The conservative approach by the Proponent to assume connective fracturing to surface and to utilise offsets and compensatory provisions for impacts in the Sydney Water Catchment is a pragmatic means of setting performance measures that are consistent with the recommendation of the IEPMC (OCSE, 2019b) that *"Government should seek opportunities to improve the effectiveness of performance measures, especially for watercourses and swamps, by specifying them in unambiguous, quantifiable and measurable terms."*
7. Should this approach for dealing with connective fracturing due to conventional subsidence not be assessed as appropriate or adequate, changes in longwall panel widths and/or extraction height may be required, rather than (as in the case of non-conventional subsidence impacts) changes in the offset distances to longwall panels.

Proponent's approach

8. The Proponent's approach, effectively, appears to be: 1) deciding which natural surface features warrant a level of protection from mining-induced impacts; 2) nominating the tolerable levels of impacts for these features; 3) avoiding exceedance of these levels through a combination of setback distances and remediation; and, 4) maximising economic returns by offsetting and compensating for environmental impacts to a range of other surface features and all subsurface features, notwithstanding that these impacts may not fully materialise, if at all, in Areas 5 and/or 6.

Panel's Scope of Works

9. In respect of the Department's initial request for the Panel to provide advice on *the relative environmental costs and benefits associated with different longwall widths, including whether a reduction in the void widths would materially reduce the environmental impacts of the project*, the Panel cannot provide this advice. This is because the EIS and supporting documentation, including the Proponent's responses to some of the Panel's questions, do not provide the necessary

information and analysis to enable the impact of different longwall panel widths to be fully and adequately assessed.

Subsidence Assessment

Prediction of Subsidence Effects

10. EIS Appendix A, Subsidence Assessment, constitutes an assessment of surface subsidence and not of subsurface subsidence, notwithstanding that it does touch on some limited aspects of mining-induced subsurface ground movements.

11. The methodologies for predicting mining-induced subsidence effects (movements) on the surface are adequately described in the EIS, are appropriate to the DEP and have been diligently applied in the defined Study Area, with deviations from predicted subsidence effects capable of being adequately managed through established approval conditions.

12. Mining-induced subsidence effects due to mining in Area 5 are predicted to extend beyond the Study Area and into Area 3B and their impact on features in Area 3B needs to be assessed.

Mine Layout

13. The Panel has serious reservations as to whether the mine layout put forward as the Maximum Case constitutes a realistic point of reference for a contemporary mining approval. If it does not, then much of the coal that the Proponent claims to be forgoing in adopting the Base Case may not have been available for extraction in the first instance.

14. The Base Case may be more realistic of the upper bound today for a mine layout in the Sydney Water Catchment than of an economically viable layout that takes ecological and mine closure implications into account.

15. The Minimum Case is not particularly helpful as it is not based on objective or agreed environmental targets and is not related to an economic appraisal.

16. The subsidence assessment of mining layout options does not provide a basis for assessing the sensitivity of environmental impacts and consequences to setback distances from natural features; longwall panel width; longwall extraction height; and longwall panel orientation.

Surface Fracturing

17. While the same type of impact (cracking) due to conventional subsidence may occur as longwall panel widths become narrower, the intensity of the impacts (fracturing width, frequency and depth) can be expected to reduce. This may have important implications for the volume of surface water that can be diverted into the subsurface, and into the mine through connected fractures.

Impact Assessment for Watercourses

18. The Subsidence Impact Assessment includes an environmental impact assessment of valley closure for Avon River, Cordeaux River and Donalds Castle Creek based on an impact model developed by the expert subsidence consultant.

19. Environmental impact assessment for all other significant watercourses has not been undertaken in either the Subsidence Impact Assessment or the Surface Water Assessment. Rather, both reports defer to the Proponent's identification of which key stream features are significant and the nomination of setback distances to support the Proponent's stated purpose of reducing the potential impacts of subsidence. The setback distances are not based on the level of risk of impact (where risk is a combined measure of likelihood of an impact and the consequences of the impact) but are fixed and intended to reduce potential subsidence impacts rather than to prevent environmental impacts.

Impact Management

20. EIS Appendix A concludes that '*The assessments…..indicate that the levels of impact on the natural and built features can be managed by the preparation and implementation of the appropriate management strategies*'. The Panel does not concur that this can be achieved for all impacts, such as groundwater head declines and subterranean flow changes.

Groundwater

Assessment of Regional Groundwater Impacts

21. The groundwater modelling provides satisfactory evidence that the consequences on regional groundwater users will be small and are unlikely to be of concern.

Assessment of Mine Inflows

22. During mining, inflows have been estimated to be a peak of 18 ML/day reducing to 8 ML/day by the end of mining for Area 5 and a peak of 3.5 ML/day shortly before the end of mining for Area 6. The estimated rates of inflow are stated to be conservative (i.e. at the high end of the possible range). The level of conservatism cannot be determined from the available modelling but the inflows appear to be an acceptable first estimate of the likely impacts. Therefore, the figures provided should be adopted in determining any approval for the mine. In the long term the mine inflows will be fully derived from surface recharge. At this stage, because there is a lack of clarity as to if and how Dendrobium Mine can be sealed, it should be assumed that surface losses from the catchment will occur over the long term and potentially in perpetuity.

Assessment of Groundwater Recovery and Mine Discharges

23. The groundwater modelling of the post mining period is not based on a clear, technically feasible description of mine sealing. As a consequence, it is not possible to assess the risks and impacts of groundwater recovery on the surface water environment or on the pattern of discharges of mine water and potential contamination from the mine at this time.

24. There are uncertainties associated with groundwater pressure recovery and mine outflow volumes and quality following mine closure, which are not addressed in the EIS and which require considerable investigation and planning, including analysis of the feasibility of sealing Dendrobium Mine, whether or not the Dendrobium Extension Project is approved.

Surface Water

Assessment of Impacts and Consequences on Rivers and Named Creeks

25. The assessment of environmental impacts on the three watercourses identified in the EIS as being the most significant, namely, Avon River, Cordeaux River and Donalds Castle Creek, is based on a single impact type (Type 3) and a valley closure threshold value nominated by the Proponent. There are inconsistent and, sometimes, incorrect interpretations of the rock bar model on which the impact assessments are based. This is a matter for consideration during project assessment.

26. Although the EIS is supported by a document titled *Stream Risk Assessment* it does not constitute a risk assessment that is consistent with the intent of recommendations over the past decade of a number of Panels concerned with mining in the Southern Coalfield or with Australian and international standards and guidelines for risk assessment (such as MDG-1010 (2011) and ISO 31000 (2009)). This is because it does not objectively identify the likelihood of the hazards materialising, the consequences should they materialise, and the residual risk after implementing the controls. Rather, the Stream Risk Assessment is a useful tabulation of information on stream

features, the threshold values used by South32 to determine key stream features, debateable likelihood predictions confined to only rivers and named creeks, and the remediation and offset provisions for features deemed to be at risk.

27. A risk assessment approach provides an objective basis for assessing the scale and acceptability of environmental impacts on watercourses. The Panel has tested the concept of a risk management approach along the lines recommended by Southern Coalfield Inquiry (DoP, 2008) and developed in the PAC report for the Metropolitan Coal Project (DoP, 2009) and considers that its application would provide considerable assistance in this matter in assessing the likelihood and consequences of environmental impacts and deciding on acceptable threshold values that then inform mine design.

28. Notwithstanding the above qualifications and reservations, the Panel is of the view that any sound risk assessment process is likely to rank the setback distance to Donalds Castle Creek and to LA13 drainage line as principal risk factors associated with the proposed mine plan.

29. The assessment of surface flow losses is based on the groundwater model. Due to the low resolution and accuracy of the groundwater model in the vicinity of watercourses, and the limited sensitivity analysis undertaken, the Panel does not consider the predicted losses from rivers and named creeks to be necessarily conservative. Nevertheless, they are likely to be very low relative to water supply yields from the catchment.

30. Baseline and control site flow gauging, subject to accuracy requirements recommended in the EIS, should be established promptly to maximise baseline data collection, aiming to achieve four years of baseline data at performance measure (or compensation loss accounting) sites and control sites where practicable, and at least two years at all gauged sites.

31. The assessment of potential for adverse consequences on stream and reservoir water quality lacks consideration of long term cumulative contaminant loads, including emergence of contaminated shallow and deep groundwater post-closure. It is not sufficient to assume, as the EIS does, that the current lack of evidence of water quality consequences will continue long term.

32. The hydrological modelling of swamps is a welcome addition to the assessment process. This and the surface flow modelling should be updated during the mine planning process as new data become available.

Assessment of Impacts on Drainage Lines (2nd to 3rd order streams)

33. The assessment of environmental impacts on streams identified as significant in the Surface Water Assessment is based on stream features, threshold values for these features, and fixed standoff distances all of which appear to have been nominated by the Proponent. The approach contrasts with that used to assess environmental impacts on the Avon River, Cordeaux River and Donalds Castle Creek. The Panel has not had the benefit of a field visit to form a view on the Proponent's impact assessment criteria for the specific streams.[1] The merits and acceptability of the Proponent's impact assessment approach to watercourses and standoff distances need careful consideration during the assessment process.

34. The impact assessments do not recognize that watercourses constitute systems that can rely on all stream features for their function and ecological integrity. The identification of the select stream features does not assure the full protection of streams from mining impacts. There is doubt about the biodiversity benefits of protecting localised stream features when cease-to-flow conditions in the associated sub-catchments are predicted to occur more than 70% more frequently in some streams under median climatic regimes. The PAC for Bulli Seam Operations concluded that it was not satisfied that stream values were protected by a focus on limiting fracturing only at rockbars but allowing for fracturing elsewhere in the valley floor.

[1] Due to COVID 19 restrictions

35. It appears that setback distances for key stream features have been based on Type 3 impacts having been observed in the pools along Drainage Line WC21 prior to the longwalls in Area 3B approaching within 50 m.[2] The proposed setback distances are 50 m when mining is only undertaken on one side of the stream and 100 m when it is undertaken on both sides. These setback distances contrast with Type 3 impacts having occurred in Area 3B at Dendrobium Mine at distances of 115 m to 290 m from longwall panels.[3] The setback distances for the select stream features are based on reducing the potential for environmental impacts, rather than total avoidance, and on facilitating their remediation should impacts occur. Remediation is confined to partially re-establishing the site-specific functionality of individual features. It is not intended to and will not restore the function and values of a stream system.

Swamps

36. The principal areas of concern regarding consequences for the ecological integrity of those parts of the Special Areas that are expected to be affected by the DEP are the loss of stream habitat in low order streams, the potential impacts of widespread reduction in near-surface groundwater levels and the direct impacts on upland swamps.

37. Approval of any viable mine plan in Area 5 or 6 will require some proportion of the upland swamps to be undermined.

38. The swamps are predicted to experience impacts and consequences due to the cracking of the underlying sandstone and subsequent increased drainage of the swamp. The DEP envisages undermining within 60 m of 25 swamps (19 in Area 5, 6 in Area 6), deeming this necessary to achieve an economically viable mine. The Proponent has provided for offsets to compensate for the consequences of mining over the full area of the Coastal Upland Swamp EEC.

39. The risks of permanent loss of swamps due to the combination of mining impacts and severe bushfire need to be further considered in the context of the impacts of the 2019-2020 bushfires observed at other locations.

40. The EIS envisages impacts along most of the 1st and 2nd order streams and sections of some higher order streams. The ecosystem values of these streams are unlikely to be protected by the setbacks around 'key stream features'.

Mine Closure Planning

41. The consideration given to mine closure planning in the EIS is simplistic and lacks engineering design and risk assessment.

42. Some important aspects of the EIS have a reliance on being able to effectively seal the mine at the completion of mining so that it floods, groundwater levels and pressures recover, and water is not diverted from the catchment in perpetuity.

43. The EIS does not question whether it is physically feasible to seal the mine. This needs careful consideration as a basis for assessing the feasibility of some important controls associated with managing mine water inflow after mine closure, including the type, magnitude, longevity and cost of offsets and compensatory provisions for impacts on water quantity and water quality in the catchment in perpetuity.

44. Offset and compensatory provisions should have regard to the consequences of not being able to seal the mine effectively, should that possibility materialise.

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[2] EIS Appendix A, p29.
[3] EIS Appendix A, p47.

45. The extraction of Areas 5 and/or 6 is unlikely to change the existing legacy of past mining operations at Dendrobium Mine and in surrounding mines in respect of sealing Dendrobium Mine at the end of mining operations and how this impacts on managing mine water inflow in perpetuity. It could increase the scale of the legacy impacts that will need to be managed after mine closure.

RECOMMENDATIONS

Project Assessment

It is recommended that the assessment of the DEP give consideration to the following:

1. As a matter of due diligence, the consent authority should confirm the scope and appropriateness of the selected key stream features.
2. In respect of stream classification, whether any of the streams impacted by the proposed mining warrant classification as being of special significance.
3. The adoption of a risk assessment approach for evaluating the nature and scale of environmental impacts, the appropriateness of the limits selected for environmental impacts, the reliability of setback distances of longwall panels proposed for preventing these limits being exceeded, and the suitability of the mine layout to adaptive management as a control for preventing exceedances of predicted impacts.
4. In respect of surface water losses in the context of mine closure, whether the approach to assessment of compensation is appropriate or warrants future review.

Project Approval Conditions

Should the DEP be approved in its current form, it is recommended that the approval conditions make provision for:

5. A suite of Management Plans to support Extraction Plans as per contemporary practice but taking into account the recommendations of the IEPMC that:
   i. consent conditions that make provision for meeting the requirements of performance measures by avoidance, mitigation or remediation need to be quite specific about the scope of attributes that have to be avoided, mitigated or remediated and the verification standards that avoidance, mitigation and remediation measures have to satisfy.
   ii. TARP triggers for surface and groundwater should be based on meaningful indicators developed in consultation with relevant agencies and authorities with oversight and regulatory responsibilities for mining.
6. The development of a Mine Rehabilitation and Closure Plan (MRCP) within a stipulated period to support the Extraction Plan.
   i. The stipulated period could be of the order of 3 to 5 years.
   ii. The MRCP should be based on a robust risk assessment that includes input from key stakeholders and independent third party specialists in mine closure in order to fully and objectively identify the potential hazards associated with mine closure, the likelihood and consequences associated with these hazards materialising, the extent to which consequences can be controlled should the hazards materialise, and the residual risks after control measures have been put in place.
   iii. The MRCP should be peer reviewed by mine closure specialists on an annual basis during its development and every three years after development

iv. Consideration should be given to making continuing approval of the Extraction Plan during development of the MRCP conditional on demonstration on an annual basis of satisfactory progress in developing this management plan.

7. The MRCP to include provision for:

   i. Establishing the practicality of effectively and safely sealing Dendrobium Mine and those other mines that may directly or indirectly be connected hydraulically to Dendrobium Mine.

   ii. Improved modelling of points of groundwater outflow and water quality, and identification of potential needs for treatment

   iii. Options for managing residual risks, such as mine water discharge in perpetuity, should Dendrobium Mine not be able to be effectively sealed and, conversely, contaminated leakages should it be effectively sealed.

8. Government ensuring the provisioning and guaranteeing of adequate funding to cover both mine closure and all potential residual risks after mine closure.

Project Residual Risks

Ground engineering is characterised by gaps in knowledge bases and pervasive uncertainty and so there is always a degree of residual risk and opportunities for improvement in time to come that require any project approval to be underpinned by a suite of robust risk management plans. Should the project be approved, the Extraction Plans should be supported by management plans that make provision for the following:

<u>Surface water assessment</u>

9. The impacts and consequences predictions presented by the Proponent are not necessarily worst-case despite the use of a range of conservative assumptions. This is due to limitations of the predictive models employed. It seems unlikely that these limitations can be resolved in the short term. So, in addition to developing applicable TARPs for surface water, progressive model updating and refinement of surface water monitoring should be required.

10. The methods, criteria and thresholds used by the Proponent to determine key stream features, the absence of features of special significance, and the likelihood of impacts to rivers and named creeks should be regularly reviewed and the outcomes should be used to update the assessment of mining impacts to inform Extraction Plans.

11. Work should continue to be undertaken on water loss accounting methods and monitoring to more reliably inform surface water loss compensation.

<u>Groundwater assessment</u>

12. Groundwater modelling should continue to be reviewed and updated and further reports on the model outputs prepared in relation to the following matters:

    a. Re-evaluation of the spatial distribution of hydraulic properties of the geological formations to ensure that the property distributions represent the best conceptual understanding of the geological and hydrogeological setting and are not numerical artefacts of the chosen methods of property assignment and data averaging.

    b. Extension of the sensitivity analysis to ensure that the calibration of the model is adequately examined as part of the analysis and that uncertainties in the key outputs of the modelling, such as mine inflows and surface losses are appropriately assessed and kept up to date.

    c. Incorporating mine closure planning properly into the modelling of groundwater impacts after the end of mining.

13. The model should be updated regularly considering both new information from ongoing monitoring and considering further development of the subsurface mine closure plans. Updates should occur at intervals no longer than every three years. The modelling updates should undergo peer review.

14. In preparing reports on the groundwater modelling, effort should be made to improve the presentation of the modelling results by adopting mapping scales that allow detailed interrogation of spatial outputs by a reviewer. A5 scale maps are inadequate. As the majority of impacts are at the mine area scale, it would be beneficial for a greater focus on the mining areas when reporting outputs such as local water balances and for increased use of temporal plots to present information for the mine areas.

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1. INTRODUCTION AND SCOPE OF WORKS

On 26 August 2020, the Executive Director of Energy Resources and Compliance, NSW Department of Planning, Industry and Environment (Mr Mike Young) requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Dendrobium Extension Project (SSD-8194). Specifically:

> *The Department is primarily seeking advice on longwall void widths for the two proposed mining domains (Area 5 and 6), and the relative environmental costs and benefits associated with different longwall widths, including whether a reduction in the void widths would materially reduce the environmental impacts of the project.*

Subsequently, the Scope of Works was broadened to include a focus on subsidence impacts associated with the specific mine layout on which the EIS is based.

The Chair of the Panel (Em. Professor Jim Galvin) nominated the following members of the Panel to prepare the advice, recognising that Panel membership was constrained to some extent by conflict of interest considerations:

- Em. Professor Jim Galvin – Chair – Subsidence and Mining
- Em. Professor Rae Mackay – Groundwater
- Professor Neil McIntyre – Surface Water
- Dr Ann Young – Swamps and Ecology

2. METHOD OF OPERATION

COVID19 constraints prevented the Panel from meeting in person and from undertaking a site inspection. Throughout the course of preparing this review, the Panel convened several times a week by videoconference. Two sets of questions were submitted to the Proponent and these were addressed by way of two video conferences supported by written responses and additional reports. A video conference was also convened with WaterNSW.

The Dendrobium Extension Project (DEP) is the first major mining project in the catchment to be assessed in the last decade, with the current mine being based on an approval that is nearly two decades old. The Panel has had regard to a number of public inquiries and approval assessments in the interim that set benchmarks for informing contemporary assessment of mining approvals in the Sydney Water Catchment. These are:

- 2008 - *Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield - Strategic Review* (DoP, 2008). This is often referred to as the Southern Coalfield Inquiry.
- 2009 - *The Metropolitan Coal Project Review Report*. NSW Planning Assessment Commission (DoP, 2009).
- 2010 - *Bulli Seam Operations PAC Report.* NSW Planning Assessment Commission.(DoP, 2010).
- 2019 - *Independent Expert Panel for Mining in the Catchment (IEPMC) Report: Review of Specific Mining Activities at the Metropolitan and Dendrobium Coal Mines.* (OCSE, 2019a, 2019b).

A wide range of documents was reviewed by the Panel, the principal ones being:

- Relevant sections of the EIS for the Dendrobium Extension Project, with a particular focus on:
    - EIS Appendix A (Subsidence Assessment)

- EIS Appendix B (Groundwater Assessment)
    - EIS Appendix C (Surface Water Assessment)
    - EIS Appendix D (Biodiversity Assessment Report)
    - EIS Appendix E (Aquatic Ecology Assessment)
    - EIS Appendix P (Geological Structures Report)
    - Attachment 5 (Peer Review Letters)

- Relevant sections of Responses to Submissions.
- Key Agency advices to DPIE (primarily from DPIE – BCD, DPIE – Water and WaterNSW).
- South32 Responses to advices of Key Agencies, including a memo advice relating to water discharge into the catchment after mine closure that was prepared on 7/9/2020 and received by the Panel on 8/9/2020.
- Final advices of Key Agencies to South32 Responses, including that of WaterNSW dated 17/9/2020 and received by the Panel on 22/9/2020.
- Responses to Panel questions directed to South32 through DPIE on 8/9/2020 and 21/9/2020.
- The advice of Mine Subsidence Engineering Consultants (MSEC) to South32, dated 30/09/19, on Subsidence Impacts of Reduced Longwall Widths.
- Revised version of EIS Figure 6-5 and Response to Submission Figure 6-3B showing relationship between height of complete groundwater drainage based on the Tammetta equation (Tammetta, 2013) and the surface cracking zone assumed by the Proponent for the purpose of the EIS.
- Dendrobium Amendment Report, August 2020
- *Review of Dendrobium Extension Project's Proposed Mine Plan*. Prepared by MineCraft. July 2020.
- *Review of the Key Economic Interactions between the Dendrobium Mine and Related Entities in the Wollongong Region*. Prepared by BAEconomics. June 2020.

3. FOCUS OF THIS ADVICE

Dendrobium Mine operates within the Greater Sydney Catchment Special Areas in the Southern Coalfield of NSW. The mine owner, South32, is seeking approval for an extension to the mining operation in order to extract Area 5 in the Bulli Seam and Area 6 in the Wongawilli Seam utilising longwall mining and maintaining, with some minor exceptions, the current longwall panel width of 305 m.

The Department's requests of the IAPUM did not identify specific environmental aspects on which it is seeking advice. However, it is clear from stakeholder submissions and discussions with government that the potential impacts of longwall panel width on water quantity, water quality and swamps are of particular concern. These have been contentious issues in the Southern Coalfield for many years as evidenced by the benchmark reports noted in Section 2 of this review, in reports commissioned by DPIE[4], reports and submissions of other stakeholders[5], and in submissions relating to the EIS for the DEP.

[4] For example, PSM Height of Fracturing report - Sullivan & Swarbrick (2017)
[5] For example, Turner (2016), Chivas et al (2020)

It is well established that mining panel width, height of extraction and depth of mining are important factors in determining the environmental impacts of mining-induced subsurface and surface ground subsidence. In general terms, the magnitude of subsurface subsidence determines the impact of mining-induced fracturing on groundwater hydraulic heads, pressures and recharge and the stability and performance of subterranean structures (such as tunnels). The magnitude of surface subsidence determines the impact of vertical and horizontal displacement and ground curvature on the structural integrity and function of natural and built surface structures. This includes the impact of mining-induced fracturing on the redirection of surface water into subterranean flow networks, the extent to which this redirected water reports back to the surface and the change in quality of that water.

The EIS does not include any substantive sensitivity analysis of the influence of longwall panel width or mining height on subsidence effects, impacts and consequences. Nearly all longwall panel widths continue to be 305 m. No justification on technical or environmental grounds has been provided for panel widths of 305 m, with the Panel being advised by the Proponent that it is based on experience with this width at Dendrobium Mine[6] and economic returns. Rather, the surface and groundwater assessments in the EIS are based on assuming a conservative water loss, being that the deep subsurface connective fracture zone will overlap with the shallow near-surface connective fracture zone. That is, connective fracturing from the mine workings through to the surface has been assumed over the mine workings in Areas 5 and 6 even though this is not necessarily the case[7]. This conservative approach (i.e. assuming maximum likely impact) removes the need to precisely define parameters such as the height of fracturing, height of free drainage etc., which have been the subject of much dispute.

Further to the conservatism of the groundwater and surface water assessment, the Proponent proposes to offset the environmental consequences associated with connective fracturing during the operational life of the mine by paying government for surface water taken, funding or implementing works that reduce existing losses (e.g. pipe losses or evaporation) and offsetting impacts to swamps and some other aspects of biodiversity.

The conservative approach by the Proponent to assume connective fracturing to surface and to utilise offsets and compensatory provisions for impacts in the Sydney Water Catchment is a pragmatic means of setting performance measures that are consistent with the recommendation of the IEPMC (OCSE, 2019b) that *"Government should seek opportunities to improve the effectiveness of performance measures, especially for watercourses and swamps, by specifying them in unambiguous, quantifiable and measurable terms."*

It is technically feasible to reduce short term and long term environmental impacts by avoiding seam-to-surface connective fracturing by modifying panel width and, where practical, mining height. This is reflected in the Panel's initial Scope of Works which sought advice on the relative environmental costs and benefits associated with different longwall widths, including whether a reduction in the void widths would materially reduce the environmental impacts of the project. The Panel cannot provide this advice. This is because the EIS and supporting documentation, including the Proponent's responses to some of the Panel's questions, do not provide the necessary information and analysis to enable the impact of different longwall panel widths to be fully and adequately assessed.

Notwithstanding this, in response to its inquires of the Proponent, the Panel was provided on 29 September 2020 with a 15 page letter report, dated 2 January 2018, prepared by SCT Operations Pty

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[6] Longwall panel width was increased from 250 m to 305 m at the start of Longwall 8.

[7] The use of the Tammetta equation, as recommended by the IEPMC (OCSE, 2019a) is not because it is necessarily a technically sound technique or the most accurate but because of all the predictive techniques, it generally produces the highest estimates of the height of connective fracturing for Dendrobium Mine and, therefore, predicts worst-case outcomes. The Tammetta equation predicts that over a large proportion of Area 5 the deep subsurface connective fracture zone will not overlap with the shallow near-surface connective fracture zone. (Figure 3B of the Submissions Report).

Ltd for South32 and titled *"Investigation of Influence of Panel Width on Inflows from Surface at Dendrobium Mine."*. The reports of the IEPMC and the DEP EIS do not have regard to this letter report. It contains data and raises concepts that warrant consideration in regard to the influence of panel width on water inflow at Dendrobium Mine. Unfortunately, as this document only came to the Panel's attention late in its review, the Panel has not been able to fully critique it. Suffice to state that while some concepts appear to have merit, the issues are more complex than presented in the report and there are other factors that also need to be considered.

A second major issue that has directed the focus of the Panel's advice is mine closure. The EIS lacks clarity about how mine water inflow is to be managed after the cessation of mining[8]. The Panel sought clarification from the Proponent and was advised that *"studies would be finalised as part of the closure planning process required under the existing Development Consent."* It appears to the Panel that mine closure planning is yet to be undertaken and that, in the interim, the EIS is based on an assumption that the mine can be sealed successfully from a hydraulic perspective after the cessation of mining. The EIS neither provides an explanation of how all connections to the mine (including through neighbouring mines) can be sealed successfully nor an assessment of the long term effects, impacts and consequences of mine sealing on the environment, water quantity and quality in the catchment and public safety.

If the mine cannot be sealed, then consideration has to be given to how to manage and offset groundwater and surface water inflow to the mine workings in perpetuity. That situation has implications for mine design and offset provisions relied upon in the EIS and, therefore, is also a focal point of this advice.

Against this background, the Panel's advice has been structured around reviewing the sections of the EIS relating to Subsidence, Groundwater, and Surface Water, having regard to the findings of the IEPMC and to supplementary information including key stakeholder submissions and responses to questions put to the Proponent by the Panel. It then considers the DEP impact on some aspects of mine closure planning, the adequacy of mine closure planning as reported in the EIS and the implication of the DEP for the management of water take from the catchment after mine closure. This approach forms the foundations for formulating the Panel's advice to the Department. The advice has a limited focus on swamps given that impacts on them are to be offset.

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[8] For example:

1. EIS Appendix B Groundwater, p66 states *"There are no areas in the Dendrobium Mine where inflow has ceased, however it is expected that drawdown would persist until inflow ceases, and the mine re-fills after the sealing of the adit entrance, and an equilibrium is finally re-established"*
2. Ltr_DND_WaterNSW Supplementary Information (September 2020) advises *"The proposed mining in Areas 5 and 6 would not affect the requirement to seal mine portals following closure of the Dendrobium surface facilities"*
3. P2 Response to DPIE Request for Information 2 June 2020 advises *Post-mining, the $34M infrastructure would be gifted to the NSW Government, enabling ongoing access to the reservoir of water that would be stored in the historic mine workings for treatment and beneficial use."*

4. SUBSIDENCE

This review has regard to the following documents:

- EIS Appendix A: Subsidence Assessment, comprising MSEC Report MSEC856 (Rev B), dated 9/7/19 (MSEC, 2019).
- MSEC letter report to South32 Illawarra Coal, dated 30 September 2019, re: Dendrobium Mine - Plan for the Future: Coal for Steelmaking. Influence of longwall void width on the predicted subsidence effects.
- South32 Response of 14//9/20 to Panel's questions of 9/9/20, which included reliance by South32 on the following report.
- MSEC letter report to South32 Illawarra Coal, 18 February 2016, re: Dendrobium Area 3B – Review of Subsidence Predictions and Impact Assessments. Addendum Report for MSEC792 (Rev C).
- South32 Response of 28/9/20 to the Panel's supplementary questions of 21/9/20.

MSEC (2019), which comprises EIS Appendix A, deals with the prediction of subsidence effects and the potential impacts of these on natural and built structures. The EIS does not include a peer-review of the report. The MSEC report was finalised prior to the release of the final report of the IEPMC and, hence, it does not reflect some aspects raised by the IEPMC.

4.1. DEFINITIONS

Ground subsidence is an expression of ground deformation. The term 'subsidence' has two meanings in underground coal mining. It is used generally to refer to all mining-induced movements of the overburden and the surface. It is also used specifically to refer to the vertical component of ground movement. The IEPMC adopted the general meaning (OCSE, 2019a) and that has been carried through to this report. Similarly, so have the following definitions of subsidence effects, subsidence impacts and subsidence consequences that evolved out of the Southern Coalfield Inquiry (DoP, 2008) and which were subsequently adopted by the Planning Assessment Commission (PAC) and the IEPMC.

- *Effect* - the nature of mining-induced deformation of the ground mass. This includes all mining-induced ground movements such as vertical and horizontal displacements and their expression as ground curvatures, strains and tilts.
- *Impact* - any physical change caused by subsidence effects to the fabric of the ground, the ground surface, or a structure. In the natural environment these impacts are principally tensile and shear cracking of the rock mass, localised buckling of the strata and changes in ground profile.
- *Consequence* - any change caused by a subsidence impact to the amenity, function or risk profile of a natural or constructed feature. Some consequences may give rise to secondary consequences. For example, the redirection of surface water to the subsurface through mining-induced fractures may be a primary consequence for water inflow to a reservoir and result in secondary consequences for surface ecology.

4.2. PREDICTION METHODOLOGY FOR SURFACE SUBSIDENCE EFFECTS

The conventional components of surface subsidence have been predicted using the empirical incremental profile method (IPM), which was developed by MSEC more than 20 years ago. The method was peer reviewed as part of the Metropolitan Coal Project PAC (DoP, 2009) and the Bulli Seam Operations PAC (DoP, 2010) and found to be appropriate and as reliable as alternative subsidence prediction techniques.

This remains the case, with a number of improvements and refinements having been made to the prediction tool in the intervening period. These include adopting a statistical approach to predicting the reliability of strain predictions (being that component of conventional subsidence that displays the highest deviation from prediction) and numerical modelling which complements the empirically based predictions and extends predictive capability to aspects of subsurface ground response to mining. These advances have been applied in (MSEC, 2019) to review and recalibrate the IPM to Areas 5 and 6.

Predictions of non-conventional components of surface subsidence in the EIS have also been based on empirical techniques developed by MSEC that utilize large databases of field measurements. The techniques dominate in the NSW coal industry. Valley closure is a particularly important component of non-conventional subsidence and the correlation between predicted and measured valley closure using the MSEC technique is considerably poorer than that for conventional subsidence parameters. This has resulted in an unusual practice of not basing the assessment of impacts and consequences on measured valley closure but, rather, on predicted valley closure, irrespective of how well predicted valley closure movements may agree with measured valley closure movements. Nevertheless, this approach generally produces conservative (over-estimated) predictions of valley closure and prevails. The concept is explained in more detail in OCSE (2019b).

Because of the site-specific nature of subsidence, the prediction of subsidence effects is not a precise science and a degree of uncertainty is associated with the outcomes of any prediction technique. Experience at Dendrobium Mine and Metropolitan Mine have demonstrated that variability associated with the IPM and the prediction of valley closure using the MSEC model, with few exceptions, can be managed through approval conditions that require the Proponent to monitor predicted versus measured subsidence, regularly update subsidence predictions, employ adaptive management, and undertake mitigation and remediation.

Importantly, the prediction of subsidence effects for the DEP and, therefore, the impact assessments for natural and built features, have regard to the cumulative movements from all current and future mining areas. MSEC (2019) and supporting references describe in greater detail the methodologies for predicting conventional and non-conventional subsidence effects and the reliability of these predictions.

The Panel concludes that the methodologies are adequately described in Appendix A of the EIS, are appropriate to the DEP and have been diligently applied in the defined Study Area, with deviations from predicted subsidence effects capable of being adequately managed through established approval conditions. It notes, in passing, that mining-induced subsidence effects due to mining in Area 5 are predicted to extend beyond the Study Area and into Area 3B and, therefore, their impact on features in Area 3B may also need to be assessed.

4.3. MINE LAYOUT OPTIONS

Subsidence assessment is specific to a mine layout. In this proposal, most longwalls are 305 m wide and mining height up to 3.2 m in Area 5 and up to 3.9 m in Area 6. Some longwall panels have been shortened, narrowed or divided to allow setbacks from stored waters, major streams and key stream features. The EIS reports that several alternative longwall layouts to the Base Case were considered. Two are presented in EIS Appendix A, being the:

- *Maximum Case – where the longwalls mine directly beneath the streams, the setbacks from the Full Supply Levels (FSLs) for the Reservoirs have been reduced from 300 m to 150 m and the Dam Walls have been reduced from 1000 m to 500 m; and*
- *Minimum Case – where the longwalls have been set back from the swamps by minimum distances of 50 m from the ends and 100 m for the sides. The setbacks from the streams and the FSLs of the Reservoirs are the same as the Base Case.*[9]

[9] EIS Appendix A, p29.

In respect of the criteria that define the Maximum case, the Panel notes that the assumed setback distance from the dam walls is generally consistent with the 1976 recommendations of the Reynolds Inquiry into Coal Mining under Stored Waters in the Southern Coalfield of NSW (Reynolds, 1976). However, in light of the findings and recommendations of the Planning Assessment Commission (e.g. DoP (2010)[10]) and conditions associated with existing mining approvals (e.g. Subsidence Management Plan for Dendrobium Longwall 16, October 2017[11]), the Panel considers that the criteria nominated for the maximum case of 1) mining directly under streams and 2) reducing setback distance from FSL to 150 m are dated and are very unlikely to be endorsed in a contemporary approval for mining in the catchment.

Thus, the Panel has serious reservations as to whether the Maximum Case constitutes a realistic point of reference for a contemporary mine approval in the catchment. If it does not, then much of the coal that South32 claims to be forgoing in adopting the Base Case may not have been available for extraction in the first instance.

In respect of the criteria for swamps and streams that define the Minimum Case, it appears from the documentation and discussions with the Proponent that these reflect the Proponent's judgements of what constitutes tolerable and acceptable level of impacts and consequences for swamps and streams when economic implications are taken into account. The setback distances chosen to represent the Minimum Case do not assure that swamps are protected from surface cracking. The Minimum Case does not incorporate a reduction in longwall panel width. Without the benefit of an economic appraisal of the mine layout, the lower bound for a Minimum Case is undefined. It is possible that more conservative layouts are still economic and better represent the lower bound for environmental impacts and consequences.

The mine layout for the Base Case is premised on a comparative assessment of the magnitude of subsidence effects associated with the Maximum, Base and Minimum Case mine layouts. Overall, the Panel considers the subsidence assessment that supports the Base Case to be sound subject to providing a correct and consistent interpretation of the frequency of Type 3 subsidence impacts (discussed in more detail in Section 4.3.3 of this review).

The subsidence assessment of mining layout options does not provide a basis for assessing the sensitivity of environmental impacts and consequences to setback distances from natural features; longwall panel width; longwall extraction height; and longwall panel orientation. In the case of unnamed streams, it simply states that '*It is not possible to develop an economically viable longwall layout to avoid all these tributaries*'.[12] The Panel accepts this could be the case, but no evidence is presented to support this position or to rebut the proposition that there are less economic, but nevertheless economic, alternative mine layouts that deliver better environmental outcomes.

4.4. SUBSURFACE AND SURFACE FRACTURING

EIS Appendix A includes an assessment of impacts on a wide range of natural and built features. The Panel has confined its written review of this section of the EIS to impacts and consequences associated with surface water and groundwater. It notes, however, that MSEC is very experienced in impact prediction and its predictions for other natural features are consistent with the Panel's knowledge of past field performance. The stability of dam walls has implications for environmental impacts and

[10] Executive Summary, p iv. "*The Panel is of the view that it is no longer a viable proposition for mining to cause more than negligible damage to pristine or near-pristine waterways in drinking water catchments or where these waterways are elements of significant conservation areas or significant river systems. As noted in the Metropolitan PAC Report, this level of damage would not be acceptable in any other assessment of water resource use.*"
[11] Longwalls were set back a minimum of 300 m from Lake Avon
[12] EIS Appendix A, p28.

consequences and for public health and safety but has been excluded from the Panel's review as it falls outside its expertise.

The Secretary's Environmental Assessment Requirements (SEARs) for the DEP were produced before the publication of the IEPMC reports (OCSE, 2019a, 2019b). The SEARs include a requirement for the EIS to address impacts and environmental consequences of the development on the natural and built environment, taking into consideration connective fracturing above longwall panels.

MSEC (2019) reports that *the assessment of height of connective fracturing has been undertaken by the specialist geotechnical consultant on the Project*. Consequently, EIS Appendix A only constitutes an assessment of surface subsidence and not of subsurface subsidence, notwithstanding that it does touch on some limited aspects of mining-induced subsurface ground movements.

The influence of longwall panel width on predicted surface subsidence effects is the subject of a letter report from MSEC to South32 Illawarra Coal on 30 September 2019. It states that *"South32 has engaged MSEC to review the predicted subsidence effects and the potential for physical impacts (i.e. surface cracking and rock fracturing) based on narrower longwall void widths".* As such, the advice of MSEC is confined to the influence of longwall panel width on subsidence of the surface.

MSEC advised that the potential for physical impacts is not dependent on absolute vertical subsidence and that physical impacts develop due to differential movements, which are described by curvature and strain. The advice goes on to assess conventional and non-conventional surface responses to variation in longwall panel width, noting that surface cracking and rock fracturing are generally not observed in the Southern Coalfield where the predicted tensile strains are less than 0.5 mm/m and the predicted compressive strains are less than 2 mm/m. On this basis, MSEC concludes that both conventional and non-conventional subsidence will result in surface cracking for longwall panel widths ranging from 150 m to 305 m, with *predicted valley related effects for 150 m to 305 m wide longwalls considered to be sufficient to result in fracturing, shear, dilation and buckling of the strata in the bases of valleys".*

In response to questions from the Panel, South32 has referred the Panel to another MSEC letter report dated 18 February 2016 and titled: *"Review of Subsidence Predictions and Impact Assessments. Addendum Letter Report for MSEC792 (Rev C)".* That letter basically advises that wide rock fractures can occur across the full range of predicted vertical subsidence and predicted curvatures and that once vertical subsidence reaches a threshold value, only small additional valley related movements occur with increasing vertical subsidence. South32 has also advised[13] that this advice *supports "that there is not a strong correlation between the predicted vertical subsidence and the types of impacts, indicating that impacts will occur at lower levels of subsidence and therefore narrower panels".* The Panel notes, however, that the MSEC letter report of 18 February 2016 on which South32 relies is not confined to mining-induced cracking of valley floors. Rather, the letter report specifically notes that there was a series of cracks up to 1.5 m wide located above the commencing end of Longwall 3 that developed as a result of downslope movement and that, for reasons of clarity, those cracks have not been shown on the plot of maximum soil and rock fracture width versus curvature that constitutes Figure 2 of MSEC's advice.

It is the Panel's understanding that as the surface curves more in tensile zones in response to increasing subsidence, either rock fractures have to become wider or additional fractures have to be initiated to dissipate the additional stretch of the ground surface. That is, while the same type of impact may occur as longwall panel widths become narrower, the intensity of the impacts (fracturing width, frequency and depth) can be expected to reduce. This may have important implications for the volume of surface water that can be diverted into the subsurface, and into the mine through connected fractures. It can also impact on the potential to successfully remediate fracture networks beneath watercourses and swamps.

[13] Email 14 Sept 2020 from Gary Brassington, South 32 to Matt Riley, DPIE

4.5. SUBSIDENCE IMPACTS ON WATERCOURSES

4.5.1.Base Information

The term *'Rivers and Named Creeks'* refers in this review to the Avon River, the Cordeaux River, Donalds Castle Creek and Wongawilli Creek. The Subsidence Assessment (EIS Appendix A) singles out Avon River, Cordeaux River, Donalds Castle Creek and Wongawilli Creek for standalone impact assessment. It refers to the tributaries of these four watercourses as *'drainage lines'*. The drainage lines are generally first and second order streams but do include sections of third order streams.

The Stream Risk Assessment, which comprises Appendix B of EIS Appendix C, Surface Water Assessment, identifies the most significant streams as the Avon River and the Cordeaux River, followed by Donalds Castle Creek. It does not mention Wongawilli Creek and classifies all other watercourses as *'unnamed streams'*. The Avon River and the Cordeaux River are classified as perennial, Donalds Castle Creek as not perennial, and all unnamed streams as ephemeral.

Both the Subsidence Assessment and the Stream Risk Assessment report that South32 identified that the following stream features, referred to as *'key stream features'*, were more significant than other stream features:

- Pools with volume > 100 m^3 and holding water.
- Steps > 5 m height with a permanent pool at the base.

The mine layout is based on variable setback distances of longwall panels from the Avon River, the Cordeaux River, and Donalds Castle Creek and fixed setback distances from key stream features located on drainage lines. The variable setback distances have been determined on the basis of limiting predicted valley closure to < 210 mm. The fixed setback distances have no regard to valley closure but are based on the following criteria identified on the basis of experience in mining in the vicinity of drainage line WC21 in Area 3B at Dendrobium Mine[14].

- 50 m horizontal setback from the key stream feature to the longwall (where there is no longwall mining on any other side of the stream feature).
- 100 m horizontal setback from the key stream feature to the longwall (where longwall mining is to occur on two or more sides of the key stream feature).

South32 proposes to remediate key stream features, where subsidence has resulted in physical damage (e.g. significant fracturing of rockbars that results in surface flow diversion and draining of pools)[15]. Examples of the three types of setback distances for future reference are shown in Figure 1 for the north-east section of Area 5 and in Figure 2 for the southern section of Area 5[16].

[14] EIS Appendix A, p29.
[15] Appendix B of EIS Appendix C, p19.
[16] .While this and similar Figures in the Stream Risk Assessment are presented on MSEC letterhead and have a reference number corresponding to the MSEC report that constitutes EIS Appendix A, Subsidence Assessment, they do not appear in the Subsidence Assessment Report.

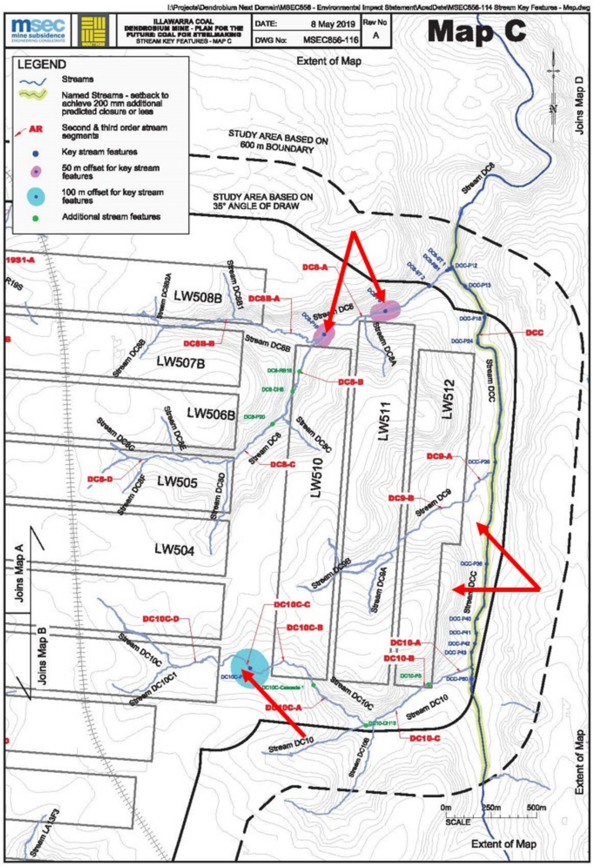

Figure 1: A section of the proposed mine layout for Area 5 showing the three different types of setbacks on which the mine plan is based.

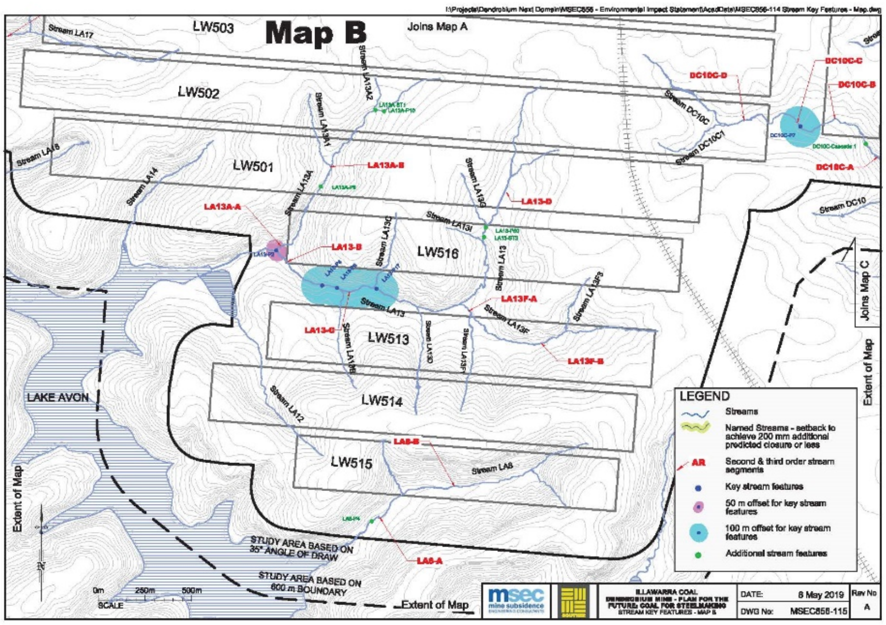

Figure 2: A section of the proposed mine layout in the southern area of Area 5

Risk is a combined measure of the likelihood of a hazard materialising and the consequences should it arise. Although Appendix B of EIS Appendix C (Surface Water Assessment) is titled Stream Risk Assessment and has regard to the recommendations of the Southern Coalfield Inquiry (DoP, 2008) and the PAC report for the Metropolitan Coal Project (DoP, 2009), it does not constitute a risk assessment that is consistent with the intent of these recommendations and with Australian and international standards and guidelines for risk assessment (such as MDG-1010 (2011) and ISO 31000 (2009)). This is because it does not objectively identify the likelihood of the hazards materialising, the consequences should they materialise, and the residual risk after implementing the controls. Rather, the Stream Risk Assessment is a useful tabulation of information on stream features, the threshold values used by South32 to determine key stream features, debateable likelihood predictions confined to only rivers and named creeks, and the remediation and offset provisions for features deemed to be at risk.

4.5.2. Assessment of Environmental Impacts on Rivers and Named Creeks

The assessment of environmental impacts in the Subsidence Assessment (EIS Appendix A) defines a Type 3 impact on a watercourse as *'fracturing which has resulted in pool water levels dropping more than expected after considering the rainfall and groundwater flow conditions'*. At the time of the PAC assessments for the Metropolitan Coal Project (2009) and the Bulli Seam Operations Project (2010), a Type 3 impact had not been recorded at any site that had a predicted valley closure of less than 200 mm. However, it was recognized at the time that this could change in the future[17]. Figure 3 shows the relationship between predicted valley closure and the proportion of Type 3 impacts recorded across the Southern Coalfield as at 2009 and as at 2019. The 2019 graph constitutes the rock bar impact model relied upon in the Subsidence Assessment (EIS Appendix A).

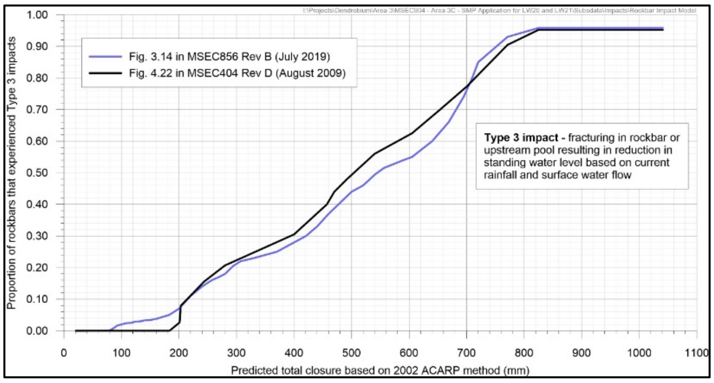

Figure 3: Relationship between predicted total valley closure and proportion of rockbar controlled pools that have experienced Type 3 impacts as at 2009 and also as at 2019.

The Avon River, Cordeaux River, Donalds Castle Creek and Wongawilli Creek are located outside of the longwall mining footprint but within the zone of influence of valley closure. Longwall panels have been set back from these watercourses on the basis of restricting valley closure to 200 mm for the Avon River, 80 mm for the Cordeaux River, 210 mm for Donalds Castle Creek, and less than 20 mm for Wongawilli Creek. The potential for these amounts of predicted valley closure to result in a Type 3

[17] The concept came in for particular scrutiny in the PAC assessments of the Metropolitan Coal Project (DoP, 2009) and the Bulli Seam Operations Project (DoP, 2010), and is discussed in the report of the IEPMC (OCSE, 2019b). The practice of correlating impacts with predicted movements rather than measured movements is unusual and is discussed further in (OCSE, 2019b).

impact has been described in a number of different ways in the EIS and in responses to the Panel's questions. These include:

- The potential for Type 3 impacts is *'considered low, with the affected pools and channel within the Study Area being approximately 7 % for the Avon River, less than 5 % for the Cordeaux River and 9 % for Donalds Castle Creek.'*[18]
- *'The predicted rate of impact of [Type 3] for the pools and channels along this river [Avon] due to the extraction of the proposed longwalls, therefore, is in the order of 7%.*[19]
- *It has been assessed that the likelihood of significant fracturing resulting in surface water flow diversions along the Avon River is very low, i.e. affecting approximately 7 % of the pools and channels along the 0.4 km section of river located within approximately 400 m of the proposed longwalls.*[20]
- *The probability of Type 3 impacts is deemed a suitable assessment criterion based on historical feedback and the SEARs.*[21]

The responses reflect an inconsistent and inaccurate interpretation of the relationship plotted between predicted valley closure and the proportion of Type 3 impacts recorded in the Southern Coalfield. The relationship shown in Figure 3 constitutes a frequency diagram of outcomes recorded across the Southern Coalfield. It neither represents the probability of a Type 3 impact occurring at a specific site nor the proportion of pools along a specific section of a stream that may experience Type 3 impacts.

Site-specific characteristics, such as laminated strata and cross bedding, are important in determining the impact of a given amount of valley closure on a watercourse. The EIS does not describe or assess the site-specific features of those sections of the rivers and named creeks that fall within the zone of influence of valley closure and, thus gives no insight into whether the conclusions based on the regional data set may be inflating or deflating the potential for Type 3 impacts.

The locations of the key stream features identified by South32 on Donalds Castle Creek are shown in Figure 1. Predicted valley closure for each of these features is plotted in Figure C.07 of the Subsidence Assessment and reproduced in Figure 4 of this review. The Figure illustrates the variability in valley closure along the length of the stream and therefore, the variability in the risk of fracturing rock bars. The use of a fixed threshold value of predicted valley closure (e.g. 200 mm) to assess the risk of fracturing may overestimate the risk for those rock bars associated with low values of predicted valley closure well below threshold (e.g. ≤. 100 mm). On the other hand, it could underestimate the risk for those rock bars with predicted valley closure values that are close to threshold (~200 mm) if they have site-specific physical attributes conductive to fracturing. In that circumstance, it is possible that all of these rock bars in the affected area rather than just a percentage of them, could experience Type 3 impacts.

[18] EIS Appendix A, p28.
[19] EIS Appendix A, p47.
[20] EIS Appendix A, p47.
[21] South32 Response of 14/9/20 to Panel's question 1.

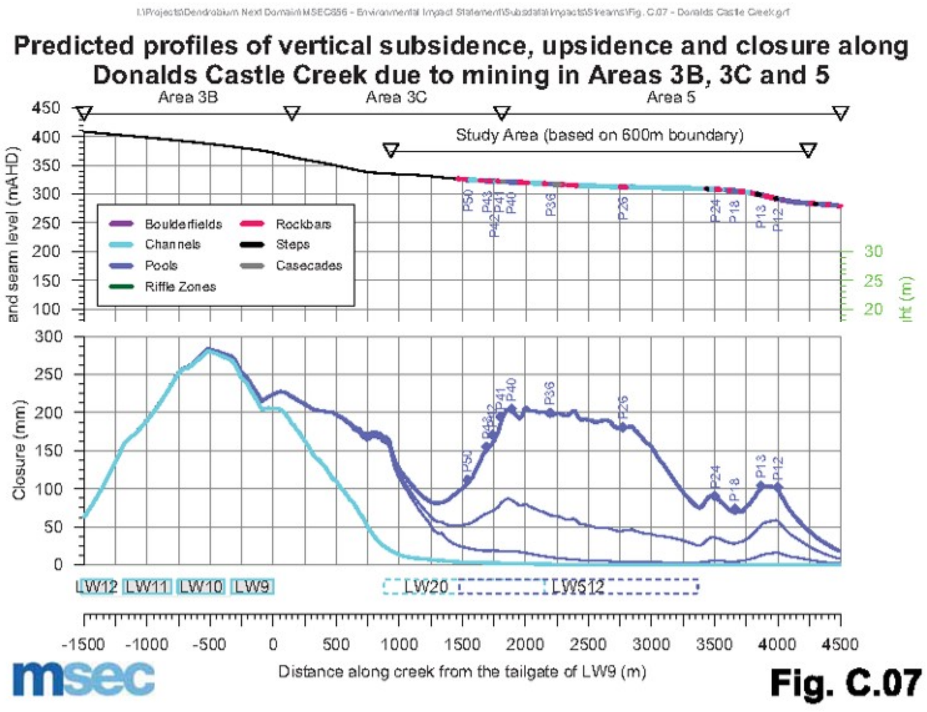

Figure 4: Extract showing predicted valley closure for pools along Donalds Castle Creek.

Without the benefit of a site inspection[22] and site specific geotechnical assessments, the Panel cannot form a view at this point in time on the likelihood and consequences associated with Type 3 impacts in Areas 5 and 6. Likelihood may or may not be greater than predicted in the EIS.

The Panel has tested the concept of a risk management approach along the lines recommended by Southern Coalfield Inquiry (DoP, 2008) and developed in the PAC report for the Metropolitan Coal Project (DoP, 2009) and considers that its application would provide considerable assistance in this matter in assessing the likelihood and consequences of environmental impacts and deciding on acceptable threshold values that then inform mine design. The concept is demonstrated in Table 1 for key stream features identified by South32 on Donalds Castle Creek.

[22] Constrained by COVIDa19 travel restrictions

Table 1: Simple risk assessment of key stream pools on Donalds Castle Creek.

Feature	Consequence Measure		Likelihood Measure
Pool No	**Length (m) Threshold: ≥30m**	**Volume (ML) Threshold: ≥0.3 ML (300m^3)**	**Approximate Predicted Valley Closure (mm) Threshold: ≥150 mm**
DCC_P12	30	0.9	100
DCC_P13	25	0.18	100
DCC_P18	94	1.16	70
DCC_P24	17	0.23	90
DCC_P26	30	0.68	180
DCC_P36	65	0.32	200
DCC_P40	127	1.84	205
DCC_P41	30	0.19	195
DCC_P42	45	0.18	170
DCC_P43	32	0.43	155
DCC_P50	32	1.44	110

The Panel has recognised pool length and pool volume as measures of consequence should the functionality of the pool's controlling rock bar be lost, and valley closure as a measure of likelihood of this occurring. By way of example, it has then identified the threshold levels of acceptable consequential risk based on its choice of threshold values of 30 m for impacted stream length and 0.3 ML (or 300 m^3) of water loss from a pool. A threshold value of 150 mm of predicted valley closure was selected as an acceptable likelihood (less than 4% likelihood of Type 3 impacts if the rock bar model applies) for avoiding these consequences from materialising. On those bases, the risk analysis identifies four pools as requiring a higher level of protection than currently proposed, these being DCC_P26, DCC_P36, DCC_P40 and DCC_P43. That protection is provided by increasing setback distance so as to achieve less than 150 mm of predicted valley closure.

4.5.3.Assessment of Impacts on Drainage Lines

The assessment by MSEC of impacts on drainage lines, which includes sections of third order streams, is based on the identification and mapping by Illawarra Coal of the key stream features noted earlier. The justification for selecting only these features and their threshold values is not presented in the EIS. As identified by the PACs for the Metropolitan Coal Project and the Bulli Seam Operations Project, other controlling stream features can include boulder fields, riffle zones and debris accumulations. The EIS reports that surface water flow diversions are likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls.

The identification of the selected key stream features and the setback of longwall panels by either 50 m or 100 m from these features is not intended to assure the full protection of the key features from subsidence impacts. Rather, as stated in the EIS, the purpose of the setbacks is to reduce potential subsidence impacts on the key stream features. It is the Panel's understanding that remediation is confined to re-establishing the site-specific functionality of these features, where practicable. Remediation is not intended to and will not restore the function and values of the stream system and the loss of baseflow due to groundwater depressurisation.

The Panel has referred to graphs of predicted valley closure in Figures C.05 to C.17 of EIS Appendix A to estimate closure values at key stream features on drainage lines. The predicted valley closures for these pools have been plotted on the rock bar model in increments of 100 mm of closure, as shown in Figure 5. Notwithstanding the potential limitations previously noted with predicting site specific likelihoods of Type 3 Impacts from this model, it can be concluded by weighting the number of pools by the likelihood of Type 3 impacts that around 10 of the 37 controlling rock bars are expected to experience Type 3 impacts resulting in loss of pool water.

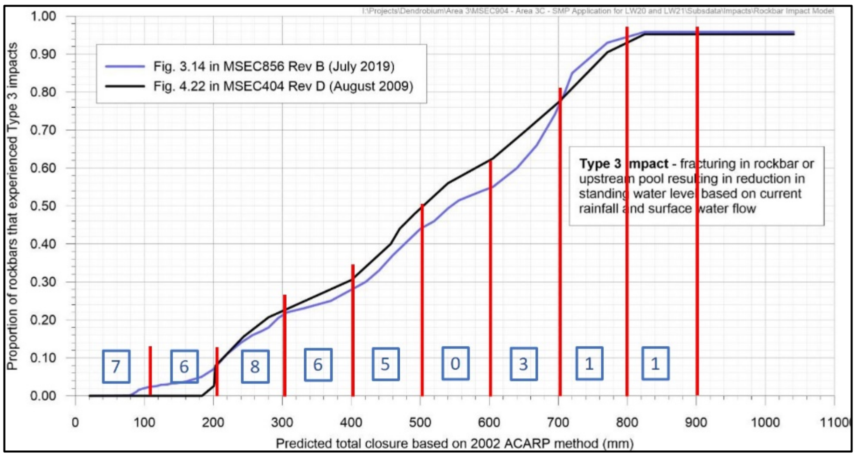

Figure 5: Ranges in predictions of valley closure for key stream pools on drainage lines plotted on MSEC rock bar model.

While this analysis is helpful, it does not provide insight into the consequences associated with the impacted pools. Hence, the Panel repeated the risk assessment process that was applied to pools on Donalds Castle Creek (Table 1), using the same consequence threshold values. The outcomes are shown in Table 2 and flag that the exceedance of the threshold risk levels assumed by the Panel are confined to pools on drainage line LA13 (for pools P4 and P17), in the region where the 100 m diameter setback distance for pools has already resulted in a disruption in the continuity of longwall panels, as shown in Figure 2. Thus, the process gives direction to and aids in objectively assessing environmental impacts and identifying controls and residual risks to inform decision making.

[23] EIS Appendix A, p29.
[24] EIS Appendix A, p47.

Table 2: Simple risk assessment of key stream pools on drainage lines

Feature	Consequence Measure		Likelihood Measure
Pool No	Length (m) Threshold: ≥30m	Volume (ML) Threshold: ≥0.3 ML ($300m^3$)	Approximate Predicted Valley Closure (mm) Threshold: ≥150 mm
AR19_P4	47	0.25	20
AR19_P6	20	0.22	50
AR19_P7	33	0.2	50
AR19_P8	34	0.12	60
AR19_P9	31	0.17	60
AR19_P13	20	0.11	90
AR19_P21	20	0.48	200
AR19_P25	14	0.12	190
AR19_P26	31	0.16	190
AR19_P31	31	0.15	280
AR19_P32	25	0.11	280
AR19_P33	14	0.7	280
AR31_P45	25	0.26	900
AR31_P55	12	0.14	650
AR31_P63	30	0.14	300
AR32_P17	15	0.25	400
AR32_P22	23	0.15	260
AR32_P31	8	0.05	300
CR29_P4	31	0.17	40
CR29_P9	21	0.15	270
CR29_P35	12	0.17	300
CR29_P37	19	0.72	280
CR31_P6	28	0.25	150
CR31_P10	34	0.12	150
CR31_P13	14	0.34	150
CR31_P18	24	1.65	200
CR31_P26	55	0.2	300
CR31_P30	25	0.12	380
CR31_P32	50	0.27	400
CR31_P33	25	0.16	400
DC8_P9	68	0.26	300
DC8_P10	34	0.17	440

DC10_P7	21	0.16	130
LA13_P2	16	0.18	420
LA13_P4	30	1.2	600
LA13_P9	13	0.17	630
LA13_P17	48	0.35	700

4.5.4. Concluding Remarks

The Panel is not necessarily advocating the adoption of the threshold values it chose to illustrate a risk management approach to assessing environmental impacts. But, it is advocating the concept of risk management zones and risk assessment for objectively assessing environmental impacts on watercourses, as have other Panels over the past decade.

Similarly, the Panel is neither endorsing the Proponent's selection of the two key stream feature types nor the threshold values for them. It is mindful of the Bulli Seam Operations Project where the PAC concluded that it was not satisfied that stream values were protected by a focus on limiting fracturing only at rockbars but allowing for fracturing elsewhere in the valley floor. This may or may not be relevant to the DEP. It is difficult to determine without the benefit of a site visit and/or more in-depth discussion on the topic by the Proponent.

Notwithstanding the above qualifications and reservations, the Panel is of the view that any sound risk assessment process is likely to rank the setback distance to Donalds Castle Creek and to LA13 drainage line as principal risk factors associated with the proposed mine plan.

4.6. Assessment of Impacts on Swamps

25[25] upland swamps are located within 60m of the proposed longwalls and these are expected to experience the full range of predicted subsidence movements. EIS Appendix A predicts that mining-induced tilt or vertical subsidence will not cause significant changes in the distribution of the stored surface waters within the swamps. However, it does predict that fracturing of the bedrock is expected to occur beneath the swamps that are located directly above the proposed longwalls.

[25] EIS Appendix A cites 26 swamps as located under longwalls (p iii) but in the detailed assessment in EIS Appendix D Biodiversity Assessment, 25 swamps within 60m of longwalls are listed.

5. GROUNDWATER

This section reviews EIS Appendix B , Groundwater Assessment. The Groundwater Assessment report was prepared by HydroSimulations, with peer review by Kalf and Associates Pty Ltd. The report underwent three updates between December 2018 and May 2019. Two updates were made in response to the reports of the IEPMC and its recommendations. Additional information has been provided in response to questions raised by the Panel that provide further details of the conceptualisations and parameterisation of the groundwater model.

The groundwater assessment report details the development and application of a single regional groundwater model to address the impacts of mining on the groundwater and surface water system around Dendrobium Mine both during mining and for a period of 150 years after the end of mining in 2049. The model is based on the MODFLOW-USG software. This software allows spatial refinement of the model in critical areas and makes it easier to use the model for a range of purposes without the need for the creation of sub-models.

The main purposes of the groundwater modelling have been to investigate the magnitude of water inflows to Areas 5 and 6, stream flow and swamp losses above the mine, impacts on the two major reservoirs (Lake Avon and Lake Cordeaux) and the mining-induced drawdowns for groundwater users regionally.

Recommendations have been made about future hydrogeological investigations and surface and groundwater monitoring.

5.1. SUMMARY

The development of the groundwater model presented in the report from conception through calibration to implementation is generally of a high standard. The selection of the MODFLOW-USG software for development of the model provides a high degree of functionality for representing complex geological settings for conditions where continuous porous media assumptions can be assumed and where the impacts of under-saturation on flow and storage can be simplified to equivalent saturated flow approximations. The software allows hydraulic properties to be varied in time as well as in space. In general, the approach to modelling is well suited to the assessment of regional impacts of longwall mining while dewatering of the mine voids continues.

The approach to development and calibration of the model is generally good but there are limitations to the modelling that make it generally difficult to assess the reliability of the model outputs and also difficult to assess whether further model development in the short term and sensitivity testing of alternative mine plans would provide greater confidence in the model outputs for the purposes of reducing groundwater controlled impacts.

The groundwater model adopts seventeen layers based on the identified geological formations with some formations subdivided to increase vertical resolution of the model and to match modelled layers to zones impacted by mining. Hydraulic parameterisation of the layers is unusual and leads to potential artefacts in the distribution of horizontal hydraulic conductivity whereby the hydraulic conductivities of the formations below an incised valley are higher than below the adjacent high ground irrespective of the formation depth. The validity of this conceptualisation is hard to assess from the data presented. It may not matter for the stated purposes of the modelling but should be reviewed for applicability as part of any further development of the model.

The zones of disturbance above the longwall panels are based on assuming a surface fracturing depth of 10 times the extracted seam thickness and that the connected fractured zone will intersect the surface fracturing zone above each longwall panel, thus enhancing vertical flows to the mine and impacts on the water table. The assumption of full connection of fractures to surface above the mine is stated to be conservative both for groundwater and surface water impacts. It represents, in principle, a worst case for surface and groundwater inflows to the mine workings. The severity of the impact though is dependent on the recharge above the mine and surface water/groundwater interactions. It is not simple to extract information from the EIS to confirm the validity of the recharge/evapotranspiration model or to establish the appropriateness of the modelled groundwater/surface water coupling. The recharge magnitudes adopted over the model area appear to be reasonable. The magnitude of the maximum groundwater-fed potential evapotranspiration also appears to be applicable but, within the EIS, data on observed depths to water table are not given across the model area to substantiate the high values of groundwater fed actual evapotranspiration implied by the modelled water balance data. The specifics of the stream modelled parameters are also not described in sufficient detail to appreciate how the stream aquifer interactions are actually performing.

Using conservative assumptions about mining impacts complicates the assessment of mine inflows for alternative mine designs (i.e. longwall panel width and extraction height). By assuming that strong hydraulic connections between the near surface and the mining depth will occur for all mining widths and heights, the impact of design changes on mine inflows and surface water depletion cannot be characterised. It is an open question whether it would have been better to make 'best' case estimates of the mine inflow and then apply a factor of safety to account for uncertainties impacting this quantity, or whether to apply 'worst' case determinations of mine inflows, as has been undertaken with the current groundwater model. The best-case approach potentially permits greater understanding of the likely impacts of mine design changes to be developed, as well as giving greater clarity on possible sources of uncertainty in the estimation of mine inflows and surface impacts.

The parameterisation of the surface/subsurface flow exchanges is important for estimating the surface water losses in the catchment. In order to gain better appreciation of these exchanges, a more complete understanding of the model representations of the near surface interactions and an assessment of the sensitivity of these to the model's parameterisation are required. The necessary information is not presented in the report and sensitivity analysis of the surface components of the model has not been performed. It is not possible, at this stage, to be comfortable that the worst-case losses from the surface water regime have been identified. Stream depletion can arise from combinations of reductions in overland and groundwater flow to the streams and increases in stream losses to the groundwater. The changes in losses will be a function of changes in the groundwater heads around and along the stream profiles. These will depend on enhancements in the hydraulic properties of the geological formations and the depth of the enhancements as well as the depletion of the shallow groundwater by deep percolation to the mine. Further investigation of these features of the groundwater model is desirable to gain greater insight into the uncertainties in the estimation of loss of stream flows.

The parameterisation of the model for the period after the end of mining is not satisfactory. The transmissivities of the roadways have not been adequately justified. The representation of the roadways could have potentially substantial impacts on the groundwater pressures and groundwater flows across the mining area. The assumption that the roadways have a relatively low transmissivity is not based on a conceptual model for mine closure but on an assessment of the need to prevent numerical instability in the model during the simulated period of mining. This means that the interpretations of groundwater movements for the period following mine closure cannot be relied on. This has implications for the interpretations of long term recovery of stream flows and groundwater discharges along the escarpment. This aspect of the modelling should be reviewed and an improved model developed. Improvement of this part of the model is particularly important for the assessment of the long term mine closure liabilities.

An area explored by the modelling is the potential for significant flows from the reservoirs to the mine. The modelling suggests that there is a low potential of such flows based on averaged behaviour. This is a reasonable statement, but ignores that there might be localised conduits for flow that are not yet identified but would be unlikely to be found prior to mining. While it is agreed that the impact on the reservoir yields can be expected to be small, the requirements for increased dewatering of the areas of the mine closest to the reservoirs cannot yet be discounted. Neither can the longer term release of poor quality water into the reservoirs be discounted following mine closure.

The approach to modelling groundwater recharge includes the rejection of recharge by evapotranspiration from the groundwater table. This increases the stability of the model but has the potential to desensitise the model calibration, which is largely based on the modelled head distribution. Changes in hydraulic properties (particularly for low hydraulic conductivity values) may be varied over quite a wide range without the modelled head distribution being significantly altered because changes in the groundwater flows will only induce small changes in head at the recharge and discharge zones, if compensatory changes to evapotranspiration/recharge are present as is the case here. The level of insensitivity can be determined by a sensitivity analysis that modifies globally all hydraulic conductivity values (both Kv and Kh) together. The sensitivity analyses presented in the Groundwater Assessment Report do not include this type of sensitivity analysis. There is a need to review and update the sensitivity analysis for this reason as well as to investigate the significance of other parameter variations.

The modelling indicates that there is not likely to be a significant impact on other groundwater users regionally as a result of the groundwater impacts of mining Areas 5 and 6. Even considering possible improvements in calibration of the model, this output of the model appears to be reliable.

Overall, the modelling appears to provide a good basis for assessing the key features of the regional groundwater system. However, there is a need for further model development to address the issues that have been summarised here. If mining is approved, the model should go through a series of careful updates as mining develops in order to refine the model's component descriptions and model outputs as well as to improve model calibration against future observations. Model updates should be undertaken in parallel with investigations of options for closing the mine. This should include investigation of internal sealing of the mining roadways. A three-yearly update cycle is warranted given the increases in available data. The modelling updates should undergo peer review at the end of each cycle. This recommendation accords with the Peer Reviewer's recommendations.

5.2. SPECIFIC COMMENTS

5.2.1. Baseline Hydrogeology

The groundwater model adopts seventeen layers based on the identified geological formations with some formations subdivided to increase vertical resolution of the model and to match modelled layers to zones impacted by mining. The model allows for upflow from layers beneath the Wongawilli Seam as well as flows at or above the mined seams.

The identification of hydraulic conductivities for the different layers is unusual in so far as hydraulic conductivity has been first characterised using a depth function that ignores the geology and then a multiplication factor is used to adjust the depth-determined value to give a formation specific value at any location. This two-step procedure introduces an artefact into the modelled hydraulic conductivity distribution for each geological layer by increasing the hydraulic conductivity of the layer beneath deeply incised valleys relative to the hydraulic conductivity of the adjacent areas beneath upland topography. The validity of this spatial pattern of hydraulic conductivity cannot be assessed based on the information provided in the Groundwater Assessment Report but it is not intuitively clear why such a relationship should exist as generally the topography has been created by surface erosion processes. Given the directional/linear nature of the valley forms it would be appropriate to review this model of hydraulic conductivity variation and the impacts that it may be having on the interpretation of the groundwater flows and drawdown patterns around the mining areas.

Vertical hydraulic data appear to be limited to core scale permeability values. The harmonic mean of the data values has been used to calculate initial values for each formation. Using the harmonic mean of the core scale values to estimate vertical conductivity implies assumptions of laterally extensive layering within the formations and no conductive vertical discontinuities. Little evidence is provided to justify these assumptions. From experience, the harmonic mean represents an extreme lower bound estimate in most cases and higher values would be expected in practice. Calibration of the model is used to justify the estimated values for the vertical conductivity. The vertical hydraulic conductivity should be treated cautiously and generally as uncertain based on the limited field-scale data available to quantify the model values. The low values adopted in the model for vertical hydraulic conductivity have a bearing on the interpretations of regional groundwater flows, mine inflows without enhanced vertical connectivity and stream groundwater exchanges.

5.2.2. Regional impacts

No significant impacts on other groundwater users are predicted by the groundwater assessment. Only small changes in groundwater heads are predicted. Even though there are some reservations about the adequacy of the model calibrated hydraulic parameters and the long term predictions of the model, the evidence that impacts on other groundwater users will be small appears unlikely to change even following further model development.

5.2.3. Groundwater Recharge

Diffuse recharge over the modelled area is based on a combination of recharge and extraction of groundwater from the water table by evapotranspiration (<4.5m depth). Shallow groundwater tables over much of the area mean that a high percentage of the available recharge is discharged at the point of recharge as groundwater-fed evapotranspiration. The water balance presented in Table 7.2 of the Groundwater Assessment Report suggests that more than 80% of the recharge over the model domain is returned to the atmosphere as evapotranspiration. This is an important element of the model but has received little attention in considering flows to streams, impacts of mining on surface flow processes, inflows to the mine and model sensitivity. There is a need for a better understanding of the impact of this choice for recharge modelling on each of the major flow terms. The risk is that the model is underestimating the total groundwater flows by underestimating the hydraulic properties of the formations and that the calibration approach, which has been largely based on head calibration and mine inflow calibrations, is desensitised by this selection of a self-balancing recharge model across the majority of the modelled area. A suggestion for an update to the sensitivity analysis is described below.

5.2.4. Stream-aquifer exchanges

Streams have been represented by river boundary conditions. Information provided in a supplementary report in response to questions by the IAPUM explains the approach that has been used to model the streams in greater detail than in the main assessment report. There are apparent features in the information provided that need to be reviewed. The chosen approach is likely to underestimate groundwater contributions to streamflow given the range of stream stage and bed elevations that have apparently been used. The parameterisation may also impact stream contributions to groundwater. It is unclear if the bed conductances of the streams have been modified to reflect enhanced fracturing over the mining areas. This would be expected but whether it is a significant issue for the model estimates of stream flow losses is difficult to assess. At this stage it would be difficult to rely on the model estimates of stream-aquifer exchanges. Sensitivity studies are needed of the stream parameterisation to examine the range of stream flow losses that could be encountered.

5.2.5. Mining Disturbance

The zones of disturbance above the longwall panels have been based on assuming that a surface fracturing depth of 10 times the extracted seam thickness will occur above the longwall panels and that the connected fractured zone above each longwall panel will intersect the surface fracturing zone, leading to enhanced vertical flows to the mine from the water table. No technical basis has been presented for selecting this depth for the surface fracturing zone, but the depth appears to be greater than depths of surface fracturing common to valley closure.[26] The assumption of full connection of fractures to surface above the mine over all panels is stated to be conservative for both groundwater and

[26] See, for example, Mills (2007), MSEC (2019)

surface water impacts. It represents, in principle, a worst case for groundwater inflows to the mine workings. This may be true but it doesn't allow for sensitivity of mine inflows to mine geometry (longwall width and extraction height) to be explored. Mine inflows are modelled using 'stacked drains' with parameter values that have been calibrated against observed head and inflow data for the completed parts of Dendrobium Mine with starting values estimated from the FLAC2D modelling. While the fit of the modelled mine inflows to the existing areas is generally good, the validity of the 'stacked drain' model parameter values for the new mine areas cannot be determined at this stage. This may not matter if the estimated impacts using conservative assumptions are permitted.

The data provided suggest that the predicted zones of complete drainage above the long walls will intersect the Hawkesbury Sandstone over much of Area 5 and all of Area 6. This implies that even with no enhancement of connected fracturing the inflows to the mines could be significant and, with only a modest increase in background vertical conductivity, the inflows could be of the same order as the recharge over the mining area. It is possible that for areas where the zone of complete drainage lies within or below the Bald Hill Claystone that there might be lower inflow magnitudes. However, the uncertainty in the model results precludes any definitive statements being made about the risks of mine inflows. Overall, the magnitudes of predicted mine inflows appear acceptable as a first estimate based on the model calibration. The approach to model parameterisation provides little ability to explore the impacts of alternative mine designs or to be confident that surface impacts could be significantly reduced using narrower longwalls or smaller longwall extraction heights.

5.2.6.Post Closure Model

The modelling from the end of mining in 2049 assumes that the conductivity parameters used for the roadways connecting the mining areas remains the same as the values used during mining. The selection of the conductivities for the roadways for mining does not reflect their real transmissivity, but is a value that is greater than that of the host rock that does not cause numerical convergence problems and allows the low seepages into the roadways to be modelled approximately, and for these flows to be transmitted to the mining areas where the stacked drains remove the mine inflows. The hydraulic conductivities are not applicable for flows between the mining areas if the roadways remain open when mine inflows are no longer extracted by pumping.

No information is provided about the mine roadways post-mining. If they are left open then they represent very high transmission pathways for flow that would prevent significant differences in hydraulic heads occurring between the mining areas in perpetuity. If the exits to the mine are sealed then the groundwater heads would rise uniformly over the mining area. This could lead to high pressures on the exit seals that could affect stability of the ground around the exits. If the mine roadways are sealed between each mine area as well as the mine exits then the individual mining areas would re-pressurise, more or less independently. The hydraulic differences between these concepts are very likely to be substantial and neither are represented by the available model results.

The post-closure period model results do not appear to be applicable for the assessment of the long term behaviour of the mining areas or the recovery of surface water flows above the mining areas in response to the recovery of the groundwater system.

It would be essential for a full assessment of the mining impacts on groundwater and surface water post-2049 to be carried out taking full account of mine closure planning. At this stage, there does not appear to be a defined closure plan for the underground workings on which to base a model of the groundwater impacts. There would be value in commencing mine closure planning for the underground workings as early as practicable to permit a more complete understanding of the closure risks, benefits and costs applicable to both the existing mine area and the planned new mining areas.

5.2.7. Sensitivity Analysis

The sensitivity analysis looks at perturbations of individual variables but this is probably not sufficient for this model. The discussion above on the sensitivity of the model calibration given the particular choice of surface boundary conditions (recharge and groundwater fed evapotranspiration) suggests that a sensitivity analysis is required to investigate the sensitivity of the modelled heads used for calibration to global changes in hydraulic properties. . This would require assessing combinations of variables, including the simultaneous adjustment of horizontal and vertical hydraulic conductivities, as well as mining-induced surface conductivities and recharge rates. As the recharge discharge regime of the model is self-balancing, underestimates of the magnitude of the conductivities could be missed that would be highlighted by a fuller exploration of model sensitivity.

There would also be value in looking more closely at the sensitivity of the finer scale features of the model, particularly the conceptualisation and parameterisation of the surface stream network on surface water losses above the mining areas.

6. SURFACE WATER

This section reviews EIS Appendix C, Surface Water Assessment, Parts 1 to 3. Part 1 is the main report; Part 2 supplementary figures and a Stream Risk Assessment; and Part 3 contains photographs. The report was prepared by Hydro Engineering, with peer viewed by Professor Tom McMahon. The first draft of the report was produced in December 2018 and the final version in May 2019.

The Part 1 report includes: an overview of the surface water catchments and baseline hydrology; description of the surface water management facilities and its predicted water balance; assessment of potential impacts of mining in Areas 5 and 6 including hydrological modelling of catchments and swamps; commentaries on proposals for neutral or beneficial effects on surface water, and stream and swamp remediation options; and recommendations for monitoring.

6.1. SUMMARY

The technical quality of the surface water assessment is good overall, and the report is generally clear regarding the data and methods used and their limitations. Some of the outcomes of the IEPMC reports (OCSE, 2019a, 2019b) have been addressed, including those relating to: independent peer review; baseline monitoring; co-location of flow and quality monitoring; and swamp water balance analysis.

Much of the surface water assessment is preliminary due to the limited data sets available for Areas 5 and 6 at the time of the analysis. The impacts of water take on the flow regime are modelled using catchment models (Australian Water Balance Model - AWBM) that are not yet calibrated using locally obtained data, the baseline flow data not being sufficient at that time. The swamp infiltration and soil moisture modelling is a welcome contribution to impacts assessment and has provided provisional estimates of infiltration rates and loss of baseflow from swamps. As further data become available the models should be refined.

The surface water loss analysis relies on the results of the groundwater modelling, and is therefore affected by the same limitations and uncertainties. In particular, the limitations of the groundwater model identified in Section 5.2.3 will affect accuracy of modelled losses and diversions of surface water.

The surface water impacts modelling covers 14 small catchments across Areas 5 and 6, showing large predicted impacts on flow regimes in undermined areas. The flow regime impacts on Avon River, Cordeaux River and Donalds Castle Creek, have not been modelled except for the annual losses predicted by the groundwater model.

The estimated flow losses are small in proportion to catchment water balance under median conditions. For example, losses are predicted to be 0.55% of the Lake Avon total yield under median annual rainfall and approximately 3.9% under a once-every-ten years low rainfall[27]. The method of calculation is reasonable given current model and data limitations. The Panel questions the conclusion "*This represents a likely indiscernible impact to Lake Avon inflow*", since 3.9% may well be discernible under dry conditions. The significance of losses in extreme drought conditions that are relevant to security yield is not considered in this report. The EIS states[28] that the impact on Wongawilli Creek flow due to the Dendrobium mine is predicted to rise to peak of 2.01 ML/day in 2046. The loss of surface water in the Cordeaux River and Avon catchment (including the reservoir) is predicted to rise to a peak of 3.56-3.84 ML/day in 2046. These are based on conservative assumptions in relation to seam to surface fracturing.

A satisfactory water quality baseline analysis and review of potential short-term consequences have been conducted. Consideration of long-term surface water quality risks is unsatisfactory, being based

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[27] Table 35, EIS Appendix C.
[28] Table 8-5, EIS Appendix B, losses up to sites A and B in Figure 4-9 of Appendix B.

on the existing lack of evidence of consequences with no regard for potential long-term cumulative consequences for water resources or localised consequences due to emergence of contaminated groundwater.

The assessment of risks of fracturing of rivers and named creeks refers to the subsidence assessment (Appendix A of the EIS), in particular the valley closure predictions and predictions of Type 3 impacts using the Southern Coalfield rock bar model. As discussed in Section 4.3.3 of this report, the Panel considers that the rock bar model predictions over-generalise the likelihood of Type 3 impacts and more attention should be given to relevant specific features of the rivers and named creeks: at present there is a risk of underestimating the frequency of Type 3 impacts. Further, relying on Type 3 impacts as a performance measure would neglect the potential for cumulative effects of other impacts (Type 1, Type 2 and baseflow reductions) as is an existing issue at Wongawilli Creek (Section 3.2.1 of OCSE (2019b)).

6.2. SPECIFIC COMMENTS

6.2.1. Baseline hydrology

The report provides a good description of the hydrological context of Areas 5 and 6. The Panel welcomes the early establishment of baseline flow and water quality monitoring. The Panel agrees with the recommendations to establish flow gauges with accuracy and ongoing validation requirements[29], in order to provide at least two years of accurate baseline flow data, and the recommendations for new pluviometers and weather stations. This will be essential for reliable determination of surface flow losses and ecological impacts. Additional gauges would be required to measure total surface flow losses from Areas 5 and 6, and accurate measurement of outflows from the reservoirs. Following OCSE (2018, 2019)[30], four years of baseline data are recommended for these priority sites. The practicality of installing and maintaining additional sites should be considered by the Proponent and WaterNSW. The specific proposals for hydrology monitoring need to be clarified in subsequent water management plans and subject to peer review and approval.

The baseline water quality data presented in summary[31] provides a good basis for water quality impacts assessment. The Panel notes the exceedance of applicable targets for some parameters both in mine-affected and unaffected catchments. It is noted that the established water quality and flow monitoring are reasonably well co-located[32], which provides a basis for understanding water quality spikes and variations in contaminant loads. This will be valuable for ongoing assessment of cumulative impacts to water resources.

Regarding the swamps, good use has been made of available data to comment on swamp lithology, moisture dynamics and their relation to groundwater conditions, which is a significant contribution to baseline knowledge. This will need to be supplemented by measurement of relevant soil physical properties for use in updated modelling.

6.2.2. Water management system – water balance modelling

Sampling from 129 years of historical climate data has been used to represent a range of possible surface water management conditions, to inform development of water management plans[33]. The water balance

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[29] As recommended in Table 45, EIS Appendix C Part 1
[30] The IEPMC recommended "At least two years of baseline (pre-mining impacts) data are required, and ideally at least four years at sites that are strategically important in terms of monitoring water supply, and at control and performance measure sites" (OCSE 2019, 3.3.2)
[31] Tables 17-19, EIS Appendix C Part 1
[32] Figure 6 in EIS Appendix C Part 1
[33] Section 3.3.1 EIS Appendix C Part 1

summary[34] shows the dominance of the groundwater inflow. These inflows are not varied despite carrying high uncertainty and being related to future rainfall. This limitation in the method should be reconsidered, although it is possible that the conservatively high groundwater inflow estimates justify using a fixed value. The reported site water balance should include change of storage even if it is zero.

6.2.3.Effects of longwall mining on surface water resources.

The stream risk assessment framework and assessment approach to streams has been conducted consistent with the steps in Section 6.2 of the Metropolitan Coal Project PAC Report. The assessment should also have regard to the presence downstream of the Upper Nepean Conservation Area and its management objectives.

The definition by the Proponent of key stream features to be protected[35] has no clear justification as discussed in Section 4.3.4.

Experience of cumulative impacts of previous mining areas on Wongawilli Creek means that the emphasis on managing Type 3 impacts is questionable. The IEPMC (OCSE 2019b) noted that there is debate over whether performance measure of no more than minor impacts has been met at Wongawilli Creek due to cumulative impacts of Type 1 impacts, Type 2 impacts and loss of flow due to groundwater depressurisation. Further, while the EIS describes the role of remediation as *"It is proposed that similar remediation methods would be implemented for the Project where subsidence-related physical damage occurs at named watercourses and key stream features"*, the IEPMC report recommended *"Remediation should not be relied upon for features, including watercourses and swamps, that are highly significant or of special significance (as per the guidance provided by the Planning Assessment Commission Panels for the Metropolitan Coal Project and the Bulli Seam Operations Project)"*. The Stream Risk Assessment does not identify any features of special significance and does not explicitly identify any highly significant features, while all stream reaches were assessed as being pristine. Avon River and Cordeaux River are identified as the most significant, for which remediation is expected to be relied upon for small lengths.

The PAC for the Bulli Seam Operations Project was critical of that Project Proponent's assessment of features of special significance. As a matter of due process, the assessment of the DEP should make provision for confirming that none of the streams impacted by the proposed mining warrant classification as being of special significance.

6.2.4.Acceptability of Environmental Consequences

The EIS states *"Any localised water quality impacts are predicted to be insignificant at the catchment scale, based on observations to date"* and *"there have been no reports of any measurable effect on water quality in downstream reservoirs in the Southern Coalfield. Water quality as a result of the Project is therefore not expected to impact on the performance of Avon Dam, Cordeaux Dam or Pheasants Nest Weir"*[36]. The Panel agrees that there is no evidence to date of deterioration of water quality due to the Dendrobium Mine that is significant at catchment scale or detected in reservoirs, except visual impacts due to staining that are expected to reduce over time. However, the Panel is concerned by the absence of analysis of long-term risks to water quality, including:

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34 Table 26 of EIS Appendix C Part 1

35 Section 5.0, EIS Appendix C Part 2 "…stream features meeting the following definition have been classified by South32 as 'key stream features': Pools with > 100 m^3 and holding water; Steps with > 5 m height with a permanent pool at the base."

36 Section 5.4, EIS Appendix C Part 1

- Cumulative effects on reservoir water quality (which, due to large volume in the reservoir and limited monitoring that can be undertaken, are not yet expected to be detected, but may be in the future).

- Potential for increased loads to reservoirs and Pheasants Nest Weir following re-pressurisation should the mine be sealed, including contaminant loads emanating from deep and shallow groundwater.

- Potential for significant localised ecological and visual impacts at points of groundwater emergence following re-pressurisation, should the mine be sealed.

6.2.5. Swamp seepage modelling

Swamp seepage modelling is a positive development, improving on previous impacts assessments, as it begins to address swamp water balances including potential leakage rates from the swamp base, loss of baseflow and changed plant water availability. The modelling should be regarded as preliminary due to the limitations of input data, including the need for approximate (uncalibrated and unmeasured) hydraulic properties (Table 28 of EIS Appendix C), and the reliance on water levels for calibration rather than also soil moisture contents. Modelled unsaturated soil water suctions may also need to be considered for understanding potential impacts on plant water availability and consequence for species diversity. The calibration results are limited in terms of accuracy (e.g. Figure 24 of EIS Appendix C) and refined modelling is required when suitable input and calibration data become available. Reported results should include vertical pressure gradients through the swamp and underlying sandstone to the lower model boundary.

6.2.6. Catchment hydrological modelling

The AWBM modelling is an appropriate way of translating predicted groundwater losses into approximate changes in surface flow regimes. Accuracy is limited primarily by the accuracy of the estimated groundwater losses and by the absence of suitable calibration flow data at time of modelling. Accuracy may also be improved by using longer sequences of input rainfall and analysis of inter-annual variability of the outputs. It is unclear why losses from the base of swamps have been considered as losses from the catchment rather than returning to the streams. This may be conservative if the modelled swamp drainage does not all report to the mine void from these areas.

The modelling serves the purpose of illustrating the potentially large changes to flow regime in some streams due to undermining. The calculated losses in yield reflect the assumptions used in the groundwater modelling to obtain the deep drainage estimates. The losses in yield are reported to be low (0.55% for Lake Avon) for a median climatic condition year and higher for a low (once every ten years) rainfall year (3.9% for Lake Avon). The Panel agrees that a 0.55% loss in a median climatic condition year is likely indiscernible, although the dry-year loss of 3.9% may well be discernible. As noted by the Proponent, a consultation draft report from WaterNSW[37] supports the view that the predicted loss would not significantly hamper water supply. Continuing advice from WaterNSW regarding the significance of project and cumulative losses to water supply may confirm this. It is not a central issue if the proposal for compensation for water loss is accepted.

[37] WaterNSW (2018a). Draft Standardised Assessment Framework for Mining in the Special Areas – Risk Tool Manual April 2018 (Version vC.2) [Consultation Draft]. Referred to on p42 of the South32 Submissions report

6.2.8 Compensation for water losses

The Proponent has proposed to compensate for surface water losses by paying for water that is diverted out of the catchment. Following the IEPMC conclusions (OCSE, 2019b)[38], the Panel supports the principle of compensation and beneficial use as methods of offsetting for water supply losses. The proposed compensation for surface water losses does not account for aquatic ecology impacts of flow loss. There is also potential for disagreement in quantifying the separation of groundwater and surface water losses[39], since ultimately all groundwater losses may be assumed to be recharged from the surface water system. A clear method of loss accounting would need to be agreed.

[38] The IEPMC concluded: *"More appropriate offsets for the situation today for all mining operations may include:*
i. 'purchasing' the water lost from the catchment that can be attributed to mining operations. This includes that component of water take used to fill mining voids created in the overburden as a result of mining. The loss in water quantity could then be compensated for by WaterNSW allocating the financial offset to fund make-up water sources, such as through the operation of desalination plants.
ii. treating the water pumped from the mine to a standard that enables it to supplement water that would otherwise be drawn from the Greater Sydney Water Catchment."

[39] The proposed method of calculation is described in P3 of Enclosure 1, South 32 Response to DPIE Request for Information, 2 June 2020.

7. SWAMPS

This section has regard to Sections 6 and 7 of the EIS Appendices C Surface Water, D Biodiversity Assessment and E Aquatic Ecology Assessment with respect to the ecological consequences of subsidence-related impacts in relation to upland swamps and to watercourses within the mining domains.

7.1. SUMMARY

The degree of protection given to the ecology and biodiversity values associated with the Sydney Water Catchment Special Areas is a major concern for some stakeholders. Biodiversity values relate mainly to streams and swamps, including the valley forms and flow regimes of streams and habitat for flora and fauna. Potential impacts and consequences of mining include fracturing of rock, flow diversions, discolouration of water and stream beds, swamp soil moisture changes, soil erosion and associated consequences for flora and fauna. These potential impacts and consequences are recognised in the project EIS and investigations have been undertaken; the EIS reports a large volume of work to determine the biodiversity status of the mining areas and associated swamp and stream baselines, and the potential impacts of the proposed mining plan. Elements of these investigations and associated management proposals are discussed in this chapter.

The Panel recognises that not all streams, swamps or other ecological assets can be protected while still having a viable mining plan. Decisions are required regarding the degree of protection given to each type of asset. The Panel also recognises that there is uncertainty in predictions of locations and degree of impacts and consequences due to limitations of knowledge and models that cannot be resolved in the near future. Therefore, it is appropriate to accept there will be a requirement for suitable impact management plans, which may include monitoring, prediction updating, mine plan adaptation, remediation and/or offsets/compensation.

Provision has been made for the offsetting of swamps in anticipation of effects on water tables due to cracking of the upper Hawksbury Sandstone. The Panel notes that rehabilitation and remediation strategies for upland swamps, generally recognised as unproven or of limited practicality, are not proposed within the biodiversity offset strategy.

The risks of permanent loss of swamps, due to the combination of mining impacts and severe bushfire, need to be further considered in the context of the impacts of the 2019-2020 bushfires observed at other locations.

The EIS envisages impacts along most of the 1st and 2nd order streams and sections of some higher order streams. The ecosystem values of these streams are unlikely to be protected by the setbacks around 'key stream features'.

7.2. SPECIFIC COMMENTS

7.2.1. Upland Swamps and other ecological communities

<u>Upland Swamps</u>

The IEPMC 2019 Pt2 Report (OCSE, 2019b) noted that *"It is now established that longwall mining directly under swamps in the Southern Coalfield can result in significant changes to swamp hydrology and redirection of surface runoff, which the Panel considers are very likely irreversible"*. Steep declines in swamp groundwater levels after high rainfalls and reduced swamp soil moisture levels post-mining are well documented. The IEPMC noted an example from a longwall operation in the Southern Coalfield of *"significant falls in the water pressures not only near the swamp surface (1m deep* *piezometer) but also in the underlying bedrock (4m and 10m deep piezometers)"*. The DEP EIS notes[40] that upland swamps overlying longwall mining at the Dendrobium Mine have experienced *"changes in hydrology, such as increased rates of water recession following rainfall events and increased duration of dry periods between rainfall events*". There has also been evidence of mining-induced reductions in swamp size, relative loss of 'groundwater dependant sub-communities' and decline of Total Species Richness in some of the previously undermined swamps[41]. A significant ecological outcome of the post-mining hydrological changes is the highly likely reduction in habitat for the endangered Giant Dragonfly, which was observed in 3 swamps in Area 6 and for which 3 swamps in Area 5 and 10 in Area 6 were deemed potential breeding habitat. The setbacks designed to reduce impacts on 'key stream features' will not reduce impacts at any of the upland swamps apart from Den 104, a small (0.5ha) swamp.

In recognition of this understanding, the Project plan provides for the offsetting of the 25 upland swamps within 60 m of proposed longwalls; most of these are small swamps with the largest being 2.4 ha in area[42]. The report by Watershed 2019[43] concluded that swamps more than 60 m from longwalls have not been demonstrated to show greater-than-negligible environmental consequences. While the Panel noted the concern of WaterNSW[44] '*that the predicted ecological impacts of the project, particularly impacts on endangered upland swamps, are inconsistent with one of the key purposes for declaring the Metropolitan Special Area, which is to maintain the ecological integrity of the land*', it has been made aware that offset provisions have been made, including those for habitat impacts and clearing of native vegetation.

Other vegetation communities

Predicted falls in near-surface groundwater levels across the plateau may lower moisture availability to vegetation over the long-term; in other words, have potential consequences similar to, albeit less marked than, those predicted for upland swamps. The 'depth to water' mapping presented to the Panel[45] showed that significantly greater depth to water than pre-mining may persist well beyond the end of mining.

Specifically, the possibility of detrimental changes to the Shale Sandstone Transition Forest (a Threatened Ecological Community) and Koala habitat within it was raised by the Panel with South32. The Panel was advised that *Some mapped areas of Transitional Shale Stringybark Forest are classified as having a moderate potential for groundwater dependence, although depth to water is inferred to typically be 9 m or more (range 5 to >10 m)* but that there are *no 'high priority' GDEs* within the Project Area[46]. The Panel agrees with the likely low or moderate groundwater dependence of non-swamp, non-riparian vegetation in the catchment, but notes that localised moderate consequences may be expected to the Shale Sandstone Transition Forest.

The Panel notes that the NSW Bushfire Inquiry (2020) identified soil dryness as a significant factor in fire severity and the severe impacts of the Gospers Mountain fire on undermined swamps on the Newnes Plateau. It suggests that both the ecological and community-related risks of potentially enhanced fire severity across the mining domains should be considered.

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[40] EIS Section 6.8
[41] EIS Appendix E Section 3.10.3
[42] EIS Appendix D Table 10
[43] Watershed Hydrogeo 2019 Geographic review of mining effects on Upland Swamps at Dendrobium Mine (Appendix 12 of EIS Appendix D Biodiversity Assessment Report - DPIE Doc 27B)
[44] WaterNSW response to Amendment and Supplementary Information – Dendrobium Mine Extension Project (SSD 8194), dated 17 September 2020
[45] South32 Presentation 25 September 2020; Response 28 September 2020
[46] South32 11 September 2020 Independent Panel Presentation

7.2.2. **Offset provisions**

Offsets are required under Commonwealth and/or NSW legislation for five vegetation communities (including Upland Swamps) and six faunal species. Offsets for the DEP were calculated for 'partial impact' on upland swamp vegetation communities HN560 and HN556 but for 'total' impact on threatened species with swamp habitat (Giant Burrowing Frog, Littlejohn's Tree Frog, Giant Dragonfly)[47]. No offsets are required for threatened aquatic species[48]. Offsets related to the Upland Swamps and associated threatened species are provided. '*Rehabilitation as an offset is not proposed and other direct or indirect measures (e.g. remediation of swamps) are unlikely to be required.*'[49]

The Addendum to the NSW Biodiversity Offsets Policy for Major Projects 2016 sits within the Framework for Biodiversity Assessment (FBA): Biodiversity Offsets Policy (BOP); the Framework applies to the clearing of native vegetation. The Addendum requires proponents to '*seek to avoid longwall mining underneath upland swamps'* and to identify '*reasonable measures and strategies to minimise subsidence impacts*' before using offsets. Intended as an approach of last resort, offsets entail identifying and securing sites of equivalent environmental value. For the Upland Swamps, selecting to mine Areas 5 and 6 rather than Area 4[50] was considered by South32 as an avoidance measure. An alternative longwall geometry to minimise impacts was considered (the 'Minimum Case' – see Section 4.2.2 of this report); the current proposed mining layout will avoid undermining several swamps; and direct surface disturbance of the swamps (e.g. for infrastructure installation and operation) will be avoided.

7.2.3. Watercourse ecology

<u>Protection of watercourses and key stream features</u>

The unnamed creeks flowing to Avon River and Donalds Castle Creek from Area 5 may not be of significance for catchment yield; but their lower reaches are 3rd order streams and these streams will '*experience the full range of subsidence impacts*'. Of particular concern is the stream AR19 exiting Area 5 via the Upper Nepean Conservation Area (UNCA) to Avon River, which is important ecologically in supplying flow to the southeastern section of UNCA. This sub-catchment also includes three of the largest upland swamps in Area 5.

While the '*largely ephemeral drainage lines*' across Areas 5 and 6 do not contain key fish habitat and '*consist largely of disconnected pools*', they do '*provide habitat for some native species*' such as macroinvertebrates including crayfish, galaxiids and frogs[51]. Changes in the abundance of macroinvertebrates have been linked to lower pool levels elsewhere above Dendrobium Mine, albeit only in areas of direct undermining and loss of water flow. Macroinvertebrate sampling for the DEP focussed on 3rd order stream sites. The potential cumulative impact of previous mining in the upper Avon River and Cordeaux River and the DEP on such habitat would be approximately 73 km (10%); or if previous bord and pillar mining and other planned longwalls within Dendrobium Mine are included, 147 km (20.6%). However, within the scale of the wider catchment, loss of biota is likely to be minor to negligible. It is noted that the '*shallow perched swamp and Hawkesbury Sandstone aquifers'* are likely to be more suitable habitat for stygofauna than aquifers in deeper strata but no detailed consideration of the importance or distribution of stygofauna is provided[52].

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[47] South32 3 July 2020 Response to DPIE - BCD
[48] South 32 EIS Appendix E Aquatic ecology assessment section 6.5
[49] South32 Letter to DPIE titled Dendrobium Mine _ Response to Further Biodiversity Queries, dated 2 October 2020
[50] EIS Section 6.8.5; South32 Presentation to Panel 11 September 2020. Area 4 lies northeast of Areas 1,2,3A,3C and east of Area 6 between Lakes Cordeaux and Cataract.
[51] South32 EIS Appendix E section 5.2.1.1
[52] South32 EIS Appendix E section 5.2.2

Remediation of streams

The Panel was not able to review detail about the current strategies and progress in remediation of watercourse WC21 and upland swamp Swamp1B in Dendrobium Area 3B. It recognises the difficulties of remediation. It is reported that South32 considered that remediation grouting of WC21[53] was unlikely to lead to recovery of natural flows but was *"limited to targeted pools draining more slowly following rainfall, which may allow these pools to provide some refuge for riparian fauna"*. For grouting cracked bedrock either in a stream or below a swamp, site access may be difficult or impractical or may lead to considerable associated environmental damage; remediation may need to wait until subsidence has plateaued following extraction of adjacent longwalls; the appropriateness of materials (e.g. lime to correct acidity) may be questionable; and grouting is not always able to restore any baseflow to streams. The Panel advises that these difficulties need to be taken into account in assessing any reliance placed on remediation as a management strategy.

[53] Watercourse Wongawilli Creek tributary 21 at Dendrobium Mine

8. MINE CLOSURE PLANNING

8.1. CONTEXT

Some important aspects of the EIS rely on being able to effectively seal the mine at the completion of mining so that it floods, groundwater levels and pressures recover, and water is not diverted from the catchment in perpetuity. The EIS does not question whether it is physically feasible to seal the mine. This needs careful consideration now as a basis for assessing the feasibility of some important controls associated with managing mine water inflow, including the type, magnitude and longevity of offsets for impacts on water quantity and water quality in the catchment.

8.2. CONTEMPORARY MINE DESIGN CONSIDERATIONS

Mine rehabilitation and closure is the process whereby an operational mine is transformed to a completed state that permits the mining lease ownership to be relinquished and responsibility for the site to be accepted by the next land user. The overall objective of mine completion is to prevent or minimise adverse long term environmental, physical, social and economic impacts, and to create a stable landform suitable for agreed subsequent land use (DITR, 2006).

Since 2000, stakeholders have increasingly recognised the need for mine design to include consideration of the implications of design for achieving closed mining sites that are safe, stable, non-polluting and in a community acceptable state. Examples include the 2008 mine closure toolkit produced by the International Council for Mining and Metals (ICMM, 2008), the 2016 mine closure guidelines published by the Australia Government (Australian Government, 2016) and the 2019 report of the Independent Expert Panel for Mining in the Catchment (OCSE, 2019b).

Contemporary approval processes recognise mine closure planning as a life of mine process, commencing with exploration and concluding when the mining site has been rehabilitated and relinquished.

The EIS for the DEP commits to sealing the mine entries as part of existing overall rehabilitation objectives *'that the final rehabilitated landform must be safe, stable, non-polluting and consistent with key stakeholder expectations (where practical) and surrounding lands'*.[54] However, it does not include any consideration of the issues that determine if and how this is practical to achieve.

Design Assumptions

The EIS is based on what the Proponent considers to be a highly conservative case, being that a considerable proportion of surface water over the area of influence of mining reports to the mine workings. The groundwater modelling has simulated this situation by assuming the FLAC2D prediction of seam to surface fracturing applies over all 305 m wide longwall panels, and assuming that conductive surface cracking extends to a depth of 10 times the mining height.

The Proponent proposes to pay for surface water taken from the catchment. No provision has been made for paying for the groundwater component of mine inflow beyond the groundwater licenses already held under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. This is notwithstanding that it may be assumed that ultimately (during and post-mining) the full groundwater take will be recharged from surface water.

No sensitivity analysis has been undertaken of the effect of mining panel width and extraction height on environmental impacts and consequences, even though these parameters have a significant influence

[54] EIS, Section 7.1.1

on the extent of disruption to aquifers and, therefore, on the quantity of groundwater flowing into the mine workings.

8.3. FEASIBILITY OF SEALING DENDROBIUM MINE AND IMPLICATIONS FOR PREDICTING POST-CLOSURE DISCHARGES

The DEP EIS was prepared before the publication of the IEPMC report (OCSE, 2019b)[55]. That report notes a range of issues in assessing long term cumulative impacts of mining on water quality and quantity[56]. The IEPMC identified two fundamental aspects associated with connective fracturing to surface, namely water inflow to the mine from the catchment when the mine is operating and contaminated water outflow from the mine into the catchment after the mine has been sealed and flooded. On the latter aspect, the IEPMC noted that much depends on whether it is physically possible to confine water in the mine and the extent to which the water table can be re-established in order to reverse depressurisation. Thus, the importance of assessing whether it is physically and technically feasible to seal Dendrobium Mine, such that there are no ongoing (in perpetuity) cumulative impacts of its mining operations on water quality and quantity.

The Panel has serious reservations on the issue of outflow from the mine post-closure based on its review of mine plans and inquiries on whether the mine can be effectively sealed by simply sealing its portals and shafts. This is based on factors such as the longwalls in Area 1 having undermined and subsided old workings in Mt Kembla Colliery, unknowns concerning hydraulic connections to the surface in Mt Kembla Colliery and to adjacent mines, and the magnitude of hydraulic pressures that may act on seals and rock strata in both mines in the long term. However, it may be possible to seal Dendrobium Mine using a system of seals installed deeper into the mine. Other issues are the quantity and quality of seepage from the escarpment potentially induced by groundwater recovery and the potential for flushing of contaminants from shallow groundwater during groundwater recovery. Based on the Panel's review of the EIS and discussions with the Proponent, these types of issues are yet to be fully investigated and assessed. Therefore, the Panel cannot form a view on the impacts and consequences associated with both the option to seal and flood Dendrobium Mine and the option to allow water to continue to discharge freely from the mine at seam level.

Implications of Mining Areas 5 and 6

In the course of undertaking this review, a memo (dated 7 September 2020) was prepared for the Proponent summarising the outcomes of numerical modelling that is concerned with the potential for upflow of contaminated water from the mining horizon to the surface. The groundwater modelling and its outcomes for the period post mining does not appear to be appropriate for assessing the likelihood

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[55] The Department has advised that it requested South32 to consider all IEPMC recommendations in an attachment to its RTS.

[56] The IEPMC concluded (OCSE, 2019b) that:

- *"In order to assess long term cumulative impacts of mining on water quantity and quality in the Greater Sydney Water Catchment, there is a need to establish the state of rehabilitation and closure of mines in and adjacent to the catchment. The issue is complicated by factors such as:*
    - *the lack of historical records and monitoring*
    - *the variety of mining systems and the interaction and overlap of mine workings within and between mines*
    - *the lack of detailed mine closure planning in the past*
    - *topographical influences.*
- *As the groundwater table recovers following the cessation of mining, the rising groundwater will inundate subsurface voids and fracture networks and leach metals. The potential for these storages to overflow in the long term to the surface via fractures needs increased attention in mining proposals, especially in the Special Areas where the cumulative impacts could have serious negative consequences for reservoir water quality.*
- *Where mine entrances (or other natural or mining-induced flow conduits) emerge outside the Special Areas at an elevation below the groundwater table and cannot be effectively and safely sealed, a perpetual water loss is likely. Potentially, water flowing from these conduits will require treatment in perpetuity before discharge to waterways or being put to beneficial use."*

of upflow of contaminated water. The hydraulic connections through and between the mines and presumably also at the mine outlets have not apparently been modelled to reflect a prescribed closure plan. It still needs to be demonstrated to a standard commensurate with the potential risks that the extraction of Areas 5 and 6 as designed will not result in unacceptable post-closure discharge of mine water into the catchment.

The DEP proposal provides for holing into Cordeaux Colliery. This in turn requires consideration of what impacts and consequences this might have for water quality and quantity in the catchment due to leakage paths in Cordeaux Colliery. The EIS and supporting information do not acknowledge this risk and how it might be controlled.

If, as a result of mining operations to date, Dendrobium Mine already can no longer be effectively sealed, then the issue becomes one of the contribution of Areas 5 and 6 to leakage through existing and historical mine outlets and the quality of this leakage. The extraction of Areas 5 and 6 will increase the volume of groundwater that will discharge at the mine outlets approximately in proportion to the increase in total recharge (including surface water losses) above the mined areas. Based on the recharge values provided by the Proponent this increase would be 5 ML/day for Area 5 and 2 ML/day for Area 6. This compares to the Proponent's estimated end of mining values for Areas 3A, B, & C of 2, 4 and 2.5 ML/day respectively (Figure 8.1, EIS Appendix B - Groundwater Assessment). However, the Panel cannot form a view on realistic inflow volumes for Areas 5 and 6 and consequent potential discharge volumes because the groundwater model has been set up to conservatively simulate connective fracturing extending from the seam to the surface. There are also significant approximations used in the recharge calculations and model calibration that may lead to over or under-estimation of inflows.

<u>Implications for Offsets</u>

The IEPMC (OCSE 2019b) identified that further investigation is required into how the treatment in perpetuity of mine water discharges can be funded. As far as the Panel knows, the proposed offset for surface water inflow makes no provision for managing impacts and consequences that may only materialise many decades after mine closure as water levels and pressures recover or for the situation where it is not feasible to seal the mine. If it proves impossible or impractical to satisfactorily seal Dendrobium Mine, important questions arise in relation to matters such as 1) ongoing (in perpetuity) payment for surface water taken from the catchment, and 2) ongoing management and funding (in perpetuity) for treating mine water discharge. The latter may apply even if the mine is effectively sealed should significant upward leakage and contaminant flux occur.

The Panel notes that the closure requirements for the Dendrobium Mine are regulated by the existing Development Consent (DA 60-03-2001), which requires the preparation of a Closure Plan at least 2 years prior to the cessation of mining at the site. Against the preceding background, this is considered grossly inadequate in the case of Dendrobium Mine.

The Panel recommends, therefore, that should the project be approved, consideration be given to approval conditions that address:

- As a priority, establishing the practicality of effectively and safely sealing Dendrobium Mine and those other mines that may directly or indirectly be connected hydraulically to it.
- Improved modelling of points of groundwater outflow and water quality, and identification of potential needs for treatment
- Options for managing mine water discharge in perpetuity should it be found that Dendrobium Mine cannot be effectively sealed
- Providing for adequate funding of mine closure planning.

9. CONCLUSIONS

Overview

Non-conventional subsidence

1. At Dendrobium Mine, longwall panel width is not the key control when considering environmental impacts on natural surface features due to mining-induced non-conventional subsidence, in particular, valley closure. This is because environmental impacts due to non-conventional surface subsidence start to plateau at longwall panel widths that are reported to be too narrow to be economic at Dendrobium Mine.
2. Rather, the key control for limiting environmental impacts on natural surface features due to non-conventional subsidence is, as reflected in the mine layout proposed for Areas 5 and 6, the setback distance of longwall panels from natural surface features.
3. Therefore, in respect of non-conventional subsidence, project assessment needs to have a focus on the rigour in identifying the nature and scale of environmental impacts, the appropriateness of the limits selected for environmental impacts, the reliability of setback distances of longwall panels proposed for preventing these limits being exceeded, and the suitability of the mine layout to adaptive management as a control for preventing exceedances of predicted impacts.

Conventional subsidence

4. Environmental impacts associated with conventional subsidence are of both a surface and subsurface nature and include the height of connective fracturing. Environmental impacts due to conventional subsidence are particularly sensitive to changes in longwall panel width and extraction height, as well as some parameters over which there is limited control, such as depth of mining.
5. There continues to be much conjecture and uncertainty as to both how to predict the height of connective fracturing and how to confirm this height in the field.
6. The conservative approach by the Proponent to assume connective fracturing to surface and to utilise offsets and compensatory provisions for impacts in the Sydney Water Catchment is a pragmatic means of setting performance measures that are consistent with the recommendation of the IEPMC (OCSE, 2019b) that "*Government should seek opportunities to improve the effectiveness of performance measures, especially for watercourses and swamps, by specifying them in unambiguous, quantifiable and measurable terms.*"
7. Should this approach for dealing with connective fracturing due to conventional subsidence not be assessed as appropriate or adequate, changes in longwall panel widths and/or extraction height may be required, rather than (as in the case of non-conventional subsidence impacts) changes in the offset distances to longwall panels.

Proponent's approach

8. The Proponent's approach, effectively, appears to be: 1) deciding which natural surface features warrant a level of protection from mining-induced impacts; 2) nominating the tolerable levels of impacts for these features; 3) avoiding exceedance of these levels through a combination of setback distances and remediation; and, 4) maximising economic returns by offsetting and compensating for environmental impacts to a range of other surface features and all subsurface features, notwithstanding that these impacts may not fully materialise, if at all, in Areas 5 and/or 6.

Panel's Scope of Works

9. In respect of the Department's initial request for the Panel to provide advice on *the relative environmental costs and benefits associated with different longwall widths, including whether a reduction in the void widths would materially reduce the environmental impacts of the project*, the Panel cannot provide this advice. This is because the EIS and supporting documentation, including

the Proponent’s responses to some of the Panel’s questions, do not provide the necessary information and analysis to enable the impact of different longwall panel widths to be fully and adequately assessed.

Subsidence Assessment

Prediction of Subsidence Effects

10. EIS Appendix A, Subsidence Assessment, constitutes an assessment of surface subsidence and not of subsurface subsidence, notwithstanding that it does touch on some limited aspects of mining-induced subsurface ground movements.
11. The methodologies for predicting mining-induced subsidence effects (movements) on the surface are adequately described in the EIS, are appropriate to the DEP and have been diligently applied in the defined Study Area, with deviations from predicted subsidence effects capable of being adequately managed through established approval conditions.
12. Mining-induced subsidence effects due to mining in Area 5 are predicted to extend beyond the Study Area and into Area 3B and their impact on features in Area 3B needs to be assessed.

Mine Layout

13. The Panel has serious reservations as to whether the mine layout put forward as the Maximum Case constitutes a realistic point of reference for a contemporary mining approval. If it does not, then much of the coal that the Proponent claims to be forgoing in adopting the Base Case may not have been available for extraction in the first instance.
14. The Base Case may be more realistic of the upper bound today for a mine layout in the Sydney Water Catchment than of an economically viable layout that takes ecological and mine closure implications into account.
15. The Minimum Case is not particularly helpful as it is not based on objective or agreed environmental targets and is not related to an economic appraisal.
16. The subsidence assessment of mining layout options does not provide a basis for assessing the sensitivity of environmental impacts and consequences to setback distances from natural features; longwall panel width; longwall extraction height; and longwall panel orientation.

Surface Fracturing

17. While the same type of impact (cracking) due to conventional subsidence may occur as longwall panel widths become narrower, the intensity of the impacts (fracturing width, frequency and depth) can be expected to reduce. This may have important implications for the volume of surface water that can be diverted into the subsurface, and into the mine through connected fractures.

Impact Assessment for Watercourses

18. The Subsidence Impact Assessment includes an environmental impact assessment of valley closure for Avon River, Cordeaux River and Donalds Castle Creek based on an impact model developed by the expert subsidence consultant.
19. Environmental impact assessment for all other significant watercourses has not been undertaken in either the Subsidence Impact Assessment or the Surface Water Assessment. Rather, both reports defer to the Proponent’s identification of which key stream features are significant and the nomination of setback distances to support the Proponent’s stated purpose of reducing the potential impacts of subsidence. The setback distances are not based on the level of risk of impact (where risk is a combined measure of likelihood of an impact and the consequences of the impact) but are fixed and intended to reduce potential subsidence impacts rather than to prevent environmental impacts.

Impact Management

20. EIS Appendix A concludes that '*The assessments…..indicate that the levels of impact on the natural and built features can be managed by the preparation and implementation of the appropriate management strategies*'. The Panel does not concur that this can be achieved for all impacts, such as groundwater head declines and subterranean flow changes.

Groundwater

Assessment of Regional Groundwater Impacts

21. The groundwater modelling provides satisfactory evidence that the consequences on regional groundwater users will be small and are unlikely to be of concern.

Assessment of Mine Inflows

22. During mining, inflows have been estimated to be a peak of 18 ML/day reducing to 8 ML/day by the end of mining for Area 5 and a peak of 3.5 ML/day shortly before the end of mining for Area 6. The estimated rates of inflow are stated to be conservative (i.e. at the high end of the possible range). The level of conservatism cannot be determined from the available modelling but the inflows appear to be an acceptable first estimate of the likely impacts. Therefore, the figures provided should be adopted in determining any approval for the mine. In the long term the mine inflows will be fully derived from surface recharge. At this stage, because there is a lack of clarity as to if and how Dendrobium Mine can be sealed, it should be assumed that surface losses from the catchment will occur over the long term and potentially in perpetuity.

Assessment of Groundwater Recovery and Mine Discharges

23. The groundwater modelling of the post mining period is not based on a clear, technically feasible description of mine sealing. As a consequence, it is not possible to assess the risks and impacts of groundwater recovery on the surface water environment or on the pattern of discharges of mine water and potential contamination from the mine at this time.

24. There are uncertainties associated with groundwater pressure recovery and mine outflow volumes and quality following mine closure, which are not addressed in the EIS and which require considerable investigation and planning, including analysis of the feasibility of sealing Dendrobium Mine, whether or not the Dendrobium Extension Project is approved.

Surface Water

Assessment of Impacts and Consequences on Rivers and Named Creeks

25. The assessment of environmental impacts on the three watercourses identified in the EIS as being the most significant, namely, Avon River, Cordeaux River and Donalds Castle Creek, is based on a single impact type (Type 3) and a valley closure threshold value nominated by the Proponent. There are inconsistent and, sometimes, incorrect interpretations of the rock bar model on which the impact assessments are based. This is a matter for consideration during project assessment.

26. Although the EIS is supported by a document titled *Stream Risk Assessment* it does not constitute a risk assessment that is consistent with the intent of recommendations over the past decade of a number of Panels concerned with mining in the Southern Coalfield or with Australian and international standards and guidelines for risk assessment (such as MDG-1010 (2011) and ISO 31000 (2009)). This is because it does not objectively identify the likelihood of the hazards materialising, the consequences should they materialise, and the residual risk after implementing the controls. Rather, the Stream Risk Assessment is a useful tabulation of information on stream

features, the threshold values used by South32 to determine key stream features, debateable likelihood predictions confined to only rivers and named creeks, and the remediation and offset provisions for features deemed to be at risk.

27. A risk assessment approach provides an objective basis for assessing the scale and acceptability of environmental impacts on watercourses. The Panel has tested the concept of a risk management approach along the lines recommended by Southern Coalfield Inquiry (DoP, 2008) and developed in the PAC report for the Metropolitan Coal Project (DoP, 2009) and considers that its application would provide considerable assistance in this matter in assessing the likelihood and consequences of environmental impacts and deciding on acceptable threshold values that then inform mine design.

28. Notwithstanding the above qualifications and reservations, the Panel is of the view that any sound risk assessment process is likely to rank the setback distance to Donalds Castle Creek and to LA13 drainage line as principal risk factors associated with the proposed mine plan.

29. The assessment of surface flow losses is based on the groundwater model. Due to the low resolution and accuracy of the groundwater model in the vicinity of watercourses, and the limited sensitivity analysis undertaken, the Panel does not consider the predicted losses from rivers and named creeks to be necessarily conservative. Nevertheless, they are likely to be very low relative to water supply yields from the catchment.

30. Baseline and control site flow gauging, subject to accuracy requirements recommended in the EIS, should be established promptly to maximise baseline data collection, aiming to achieve four years of baseline data at performance measure (or compensation loss accounting) sites and control sites where practicable, and at least two years at all gauged sites.

31. The assessment of potential for adverse consequences on stream and reservoir water quality lacks consideration of long term cumulative contaminant loads, including emergence of contaminated shallow and deep groundwater post-closure. It is not sufficient to assume, as the EIS does, that the current lack of evidence of water quality consequences will continue long term.

32. The hydrological modelling of swamps is a welcome addition to the assessment process. This and the surface flow modelling should be updated during the mine planning process as new data become available.

<u>Assessment of Impacts on Drainage Lines (2nd to 3rd order streams)</u>

33. The assessment of environmental impacts on streams identified as significant in the Surface Water Assessment is based on stream features, threshold values for these features, and fixed standoff distances all of which appear to have been nominated by the Proponent. The approach contrasts with that used to assess environmental impacts on the Avon River, Cordeaux River and Donalds Castle Creek. The Panel has not had the benefit of a field visit to form a view on the Proponent's impact assessment criteria for the specific streams.[57] The merits and acceptability of the Proponent's impact assessment approach to watercourses and standoff distances need careful consideration during the assessment process.

34. The impact assessments do not recognize that watercourses constitute systems that can rely on all stream features for their function and ecological integrity. The identification of the select stream features does not assure the full protection of streams from mining impacts. There is doubt about the biodiversity benefits of protecting localised stream features when cease-to-flow conditions in the associated sub-catchments are predicted to occur more than 70% more frequently in some streams under median climatic regimes. The PAC for Bulli Seam Operations concluded that it was not satisfied that stream values were protected by a focus on limiting fracturing only at rockbars but allowing for fracturing elsewhere in the valley floor.

[57] Due to COVID 19 restrictions

35. It appears that setback distances for key stream features have been based on Type 3 impacts having been observed in the pools along Drainage Line WC21 prior to the longwalls in Area 3B approaching within 50 m.[58] The proposed setback distances are 50 m when mining is only undertaken on one side of the stream and 100 m when it is undertaken on both sides. These setback distances contrast with Type 3 impacts having occurred in Area 3B at Dendrobium Mine at distances of 115 m to 290 m from longwall panels.[59] The setback distances for the select stream features are based on reducing the potential for environmental impacts, rather than total avoidance, and on facilitating their remediation should impacts occur. Remediation is confined to partially re-establishing the site-specific functionality of individual features. It is not intended to and will not restore the function and values of a stream system.

Swamps

36. The principal areas of concern regarding consequences for the ecological integrity of those parts of the Special Areas that are expected to be affected by the DEP are the loss of stream habitat in low order streams, the potential impacts of widespread reduction in near-surface groundwater levels and the direct impacts on upland swamps.

37. Approval of any viable mine plan in Area 5 or 6 will require some proportion of the upland swamps to be undermined.

38. The swamps are predicted to experience impacts and consequences due to the cracking of the underlying sandstone and subsequent increased drainage of the swamp. The DEP envisages undermining within 60 m of 25 swamps (19 in Area 5, 6 in Area 6), deeming this necessary to achieve an economically viable mine. The Proponent has provided for offsets to compensate for the consequences of mining over the full area of the Coastal Upland Swamp EEC.

39. The risks of permanent loss of swamps due to the combination of mining impacts and severe bushfire need to be further considered in the context of the impacts of the 2019-2020 bushfires observed at other locations.

40. The EIS envisages impacts along most of the 1st and 2nd order streams and sections of some higher order streams. The ecosystem values of these streams are unlikely to be protected by the setbacks around 'key stream features'.

Mine Closure Planning

41. The consideration given to mine closure planning in the EIS is simplistic and lacks engineering design and risk assessment.

42. Some important aspects of the EIS have a reliance on being able to effectively seal the mine at the completion of mining so that it floods, groundwater levels and pressures recover, and water is not diverted from the catchment in perpetuity.

43. The EIS does not question whether it is physically feasible to seal the mine. This needs careful consideration as a basis for assessing the feasibility of some important controls associated with managing mine water inflow after mine closure, including the type, magnitude, longevity and cost of offsets and compensatory provisions for impacts on water quantity and water quality in the catchment in perpetuity.

44. Offset and compensatory provisions should have regard to the consequences of not being able to seal the mine effectively, should that possibility materialise.

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[58] EIS Appendix A, p29.
[59] EIS Appendix A, p47.

45. The extraction of Areas 5 and/or 6 is unlikely to change the existing legacy of past mining operations at Dendrobium Mine and in surrounding mines in respect of sealing Dendrobium Mine at the end of mining operations and how this impacts on managing mine water inflow in perpetuity. It could increase the scale of the legacy impacts that will need to be managed after mine closure.

10. RECOMMENDATIONS

Project Assessment

It is recommended that the assessment of the DEP give consideration to the following:

1. As a matter of due diligence, the consent authority should confirm the scope and appropriateness of the selected key stream features.
2. In respect of stream classification, whether any of the streams impacted by the proposed mining warrant classification as being of special significance.
3. The adoption of a risk assessment approach for evaluating the nature and scale of environmental impacts, the appropriateness of the limits selected for environmental impacts, the reliability of setback distances of longwall panels proposed for preventing these limits being exceeded, and the suitability of the mine layout to adaptive management as a control for preventing exceedances of predicted impacts.
4. In respect of surface water losses in the context of mine closure, whether the approach to assessment of compensation is appropriate or warrants future review.

Project Approval Conditions

Should the DEP be approved in its current form, it is recommended that the approval conditions make provision for:

5. A suite of Management Plans to support Extraction Plans as per contemporary practice but taking into account the recommendations of the IEPMC that:
    - iii. consent conditions that make provision for meeting the requirements of performance measures by avoidance, mitigation or remediation need to be quite specific about the scope of attributes that have to be avoided, mitigated or remediated and the verification standards that avoidance, mitigation and remediation measures have to satisfy.
    - iv. TARP triggers for surface and groundwater should be based on meaningful indicators developed in consultation with relevant agencies and authorities with oversight and regulatory responsibilities for mining.
6. The development of a Mine Rehabilitation and Closure Plan (MRCP) within a stipulated period to support the Extraction Plan.
    - i. The stipulated period could be of the order of 3 to 5 years.
    - ii. The MRCP should be based on a robust risk assessment that includes input from key stakeholders and independent third party specialists in mine closure in order to fully and objectively identify the potential hazards associated with mine closure, the likelihood and consequences associated with these hazards materialising, the extent to which consequences can be controlled should the hazards materialise, and the residual risks after control measures have been put in place.
    - iii. The MRCP should be peer reviewed by mine closure specialists on an annual basis during its development and every three years after development
    - iv. Consideration should be given to making continuing approval of the Extraction Plan during development of the MRCP conditional on demonstration on an annual basis of satisfactory progress in developing this management plan.

7. The MRCP to include provision for:
    i. Establishing the practicality of effectively and safely sealing Dendrobium Mine and those other mines that may directly or indirectly be connected hydraulically to Dendrobium Mine.
    ii. Improved modelling of points of groundwater outflow and water quality, and identification of potential needs for treatment
    iii. Options for managing residual risks, such as mine water discharge in perpetuity, should Dendrobium Mine not be able to be effectively sealed and, conversely, contaminated leakages should it be effectively sealed.
8. Government ensuring the provisioning and guaranteeing of adequate funding to cover both mine closure and all potential residual risks after mine closure.

Project Residual Risks

Ground Engineering is characterised by gaps in knowledge bases and pervasive uncertainty and so there is always a degree of residual risk and opportunities for improvement in time to come that require any project approval to be underpinned by a suite of robust risk management plans. Should the project be approved, the Extraction Plans should be supported by management plans that make provision for the following:

Surface water assessment

9. The impacts and consequences predictions presented by the Proponent are not necessarily worst-case despite the use of a range of conservative assumptions. This is due to limitations of the predictive models employed. It seems unlikely that these limitations can be resolved in the short term. So, in addition to developing applicable TARPs for surface water, progressive model updating and refinement of surface water monitoring should be required.
10. The methods, criteria and thresholds used by the Proponent to determine key stream features, the absence of features of special significance, and the likelihood of impacts to rivers and named creeks should be regularly reviewed and the outcomes should be used to update the assessment of mining impacts to inform Extraction Plans.
11. Work should continue to be undertaken on water loss accounting methods and monitoring to more reliably inform surface water compensation.

Groundwater assessment

12. Groundwater modelling should continue to be reviewed and updated and further reports on the model outputs prepared in relation to the following matters:
    a. Re-evaluation of the spatial distribution of hydraulic properties of the geological formations to ensure that the property distributions represent the best conceptual understanding of the geological and hydrogeological setting and are not numerical artefacts of the chosen methods of property assignment and data averaging.
    b. Extension of the sensitivity analysis to ensure that the calibration of the model is adequately examined as part of the analysis and that uncertainties in the key outputs of the modelling, such as mine inflows and surface losses are appropriately assessed and kept up to date.
    c. Incorporating mine closure planning properly into the modelling of groundwater impacts after the end of mining.

13. The model should be updated regularly considering both new information from ongoing monitoring and considering further development of the subsurface mine closure plans. Updates should occur at intervals no longer than every three years. The modelling updates should undergo peer review.

14. In preparing reports on the groundwater modelling, effort should be made to improve the presentation of the modelling results by adopting mapping scales that allow detailed interrogation of spatial outputs by a reviewer. A5 scale maps are inadequate. As the majority of impacts are at the mine area scale, it would be beneficial for a greater focus on the mining areas when reporting outputs such as local water balances and for increased use of temporal plots to present information for the mine areas.

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