Mr Mike Young
A/Executive Director
Energy and Resource Assessments
Department of Planning, Industry and Environment
320 Pitt Street
SYDNEY NSW 2000

Dear Mr Young

Re: Advice to Energy and Resource Assessments
IEPMC 2019-04: Dendrobium Coal Mine Longwall 21 Subsidence Management Plan

On 8 November 2019, you requested that the Independent Expert Panel for Mining in the Catchment to review, under Term of Reference 3, the Dendrobium Mine Longwall 20 and 21 Subsidence Management Plan and provide any advice or recommendations in relation to Longwall 21. In particular, the Department requested advice on the appropriateness of the revised panel width and the proposed setback from Wongawilli Creek.

The following review was undertaken by a subcommittee of the Panel, comprised of Emeritus Professor Jim Galvin (Chair), Professor Neil McIntyre, Dr Ann Young and Dr Chris Armstrong, supported with input from Dr Colin Mackie.

Should you have any questions on the attached advice, please do not hesitate to refer them through Dr Jaclyn Aldenhoven, who can be reached on 9338 6838 or email jaclyn.aldenhoven@chiefscientist.nsw.gov.au.

Yours sincerely

Emeritus Professor Jim Galvin
Chair, Independent Expert Panel for Mining in the Catchment
13 December 2019

Cc: Mr Paul Freeman
Mr Howard Reed

Advice to Energy and Resource Assessments, Department of Planning, Industry and Environment
From the Independent Expert Panel for Mining in the Catchment subcommittee
IEPMC 2019-04: Dendrobium Coal Mine Longwall 21 Subsidence Management Plan
Dated: 13 December 2019

1. Overarching Issues

In addition to the SMP for Longwalls 20 and 21 (LW 20 and LW 21) and associated documents, this review has been informed by responses to the Panel's requests to the Department of 8, 21, 27 and 28 November 2019 for additional information and clarification.

The Panel notes that the SMP was prepared following the publication of its Initial Report[1] dated 12 November 2018 but prior to the publication of its Part 2 Report dated 14 October 2019. It acknowledges that it is not feasible for the SMP for LW 20 and LW 21 to take into account the findings of the Part 2 Report, albeit that South32 has endeavoured to do so in some aspects of its responses to the Panel's requests.

The panel widths for LW 20 and LW 21 (being 256 m) have been determined primarily on the basis of mining and economic constraints, with the dominant constraint being geological structures. The analysis and documentation that supports the SMP is based on the assumption that there will be connective fracturing through to the surface. South32 considers this to be overly conservative but has adopted this approach in light of a 'prevailing view' by some stakeholders, of seam-to-surface connection in Area 3B.[2]

Based on allowing for a 50 m buffer zone to safeguard against weathering and surface fracturing and applying the Tammetta equation, the Panel concludes that a panel width of 256 m is sufficient to prevent seam to surface connective fracturing over the deeper areas of LW 21. However, longwall panel width may need to be restricted to the order of 200 m to prevent seam-to-surface connective fracturing over the full footprint of LW 21. The topography of the site and seam dip would have to be assessed in more detail, particularly in regard to whether the shallowest areas fall under the centreline of the longwall panel, where the height of deep fracturing is greatest, or near the flanks of the longwall panel, where the height of deep fracturing is significantly reduced.

Longwall panel width also influences valley closure which, in turn, can significantly impact watercourses. LW 21 is orientated in a near east-west direction and normal to Wongawilli Creek. It retreats towards the creek and is planned to stop some 240 m short of it. This layout is amenable to adaptive management, provided that this approach is underpinned by a robust Trigger Action Response Plan (TARP) to stop the longwall earlier if impacts on Wongawilli Creek are trending towards an exceedance of performance measures.

This is a very different situation to that of LW 20 where, because the panel orientation is both parallel to and closer to Wongawilli Creek and mining is planned to commence at its closest point to the creek, there are fewer adaptive management options. In the case of LW 20, restricting longwall panel width is a critical control for managing impacts on Wongawilli Creek, irrespective of seam-to-surface fracturing considerations. This factor and significant differences in the nature and orientation of geological structures warrant separate SMPs for LW 20 and LW 21 (as experience is now confirming).

[1] The Initial Report was updated and released as the Part 1 Report, 14 October 2019
[2] South32 (4 December 2019) 'Response to the Department of Planning, Industry and Environment', Question 4

2. Prediction of Subsidence Effects

The prediction of conventional subsidence effects has been based on an empirical approach (the Incremental Profile Method – IPM) complemented with a numerical approach (Universal Distinct Element Code - UDEC). Both approaches find extensive application in subsidence engineering and are endorsed by the Panel. The Panel concludes that the Department is entitled to rely upon the predictions, noting that subsidence prediction is not a precise science.

The prediction of non-conventional subsidence effects has been based primarily on observations and measurements of ground responses over previous mining operations, with a focus on those in the Southern Coalfield. There is little alternative and the manner in which this approach has been applied is generally conservative. The logic of using predicted rather than measured total valley closure as a design tool and the likely site-specific representativeness of a rock bar impact prediction model that is based on accumulated performance over the entire coalfield have been discussed in the Panel's Part 2 report. In the case of LW 21, the Panel concludes that the predicted non-conventional subsidence effects and impacts are not inconsistent with experience to date at Dendrobium Mine.

3. Groundwater Impacts

Groundwater related impacts have been assessed by numerical model simulations of the proposed mine plan and mining schedule. This type of model utilises a rectangular grid or mesh to discretise the region into individual cells within which material properties are assigned. A single node is located at the centre of the cell where groundwater elevations and pressure heads are calculated. The updated model has been developed to be appropriately conservative insofar as the (subsidence) crack regime is assumed to extend from seam to surface. Strata material properties including porous storage and permeabilities also appear to be generally conservative.

However the Panel notes that a very coarse grid underpins the model in the areas of LW 20 and LW 21.[3] Cell dimensions of 100 x 200 m have been used to represent these longwalls and adjacent areas where steep hydraulic gradients are likely to be induced as mining progresses. The coarse grid means that nominated panel areas can only be roughly approximated; model cells used to represent a panel width of 256 m in this model would be generally identical to cells used to represent 300 m or wider panels at the same locations. In order to improve the representation of 250 m wide longwalls a cell size of 50 x 50 m would have been more appropriate. The Panel therefore considers the reported (simulated) impacts to be somewhat non unique. The proponent could be requested to assess the implications of cell size on pore pressures and predicted mine inflows prior to completing the assessment of the SMP for LW 20.

The Panel further notes that the mine plan has been represented by assigning so called 'drain' cells to coal extraction areas. Cells above the coal seam that represent a fractured subsidence zone have also been represented by drain cells. This type of boundary condition facilitates the removal of water at a rate which is proportional to the (pressure) head difference between the aquifer and an assigned head (typically near the base of the drain cell). A proportionality constant is prescribed as the 'conductance' which accounts for a number of head losses relating to flow towards a drain cell. Care must be exercised in determining a value for the conductance that reflects the drainage of a variably connected fracture system, including the change in flow direction from vertical to horizontal within the coal seam and other processes.

This method of representing longwalls was largely superseded with the introduction of material property changes invoked in the Surfact code a number of years ago whereby drains were only employed at seam level while vertical and horizontal permeabilities were

[3] See Figure 6, HydroSimulations (2019) Dendrobium Mine, Longwalls 20 and 21 Groundwater Assessment (HS2019-19, May 2019). For Illawarra Coal Pty Ltd

enhanced at a designated time during the model simulation. The current model discards this approach in favour of stacked drains on the basis that model simulation times are shorter and stability is greater.[4] The Panel notes that a desire for shorter model simulation times is irrelevant if the representation of the drainage of longwalls is compromised. Prior to completing the assessment of the SMP for LW 20, the Department could consider asking the proponent to address this issue and provide a measure of assurance that the conceptual drainage model is accurately reflected in the flow model using stacked drains.

Taking a more regional perspective, it is noted that:

1. many observation boreholes exhibit poor correlation between modelled and measured piezometric heads; and
2. mine inflows generated by the model are poorly correlated to measured inflows.

Both of these features are expected to influence the uncertainty associated with calibration, but it is noted that results appear to favour a conservative outcome where predicted impacts are likely to be greater than (future) measured impacts.

In summary, while there is scope for a number of refinements to the groundwater model, it is generally considered conservative and adequate for the purpose of assessing LW 21. There may be opportunities for improvements prior to the assessment of LW 20.

4. Surface Water Impacts

Although the Department requested the Panel to focus its advice only on LW 21, most of the surface water considerations relate both to LW 20 and LW 21 and the available groundwater model predictions integrate the effects of both longwalls. Therefore, both longwalls are referred to in this section.

The SMP predicts that following completion of LW 20 and LW 21 there will be a maximum total rate of loss of surface water due to the Dendrobium mine (including Areas 1, 2, 3A, 3B and LW 20 and LW 21) from Lake Cordeaux of 0.08 ML/day, from Lake Avon of 0.26 ML/day and from the Upper Nepean River Tributaries Headwaters Management Zone (which covers all the creeks affected by Dendrobium) of approximately 4 ML/day (time-averaged over a 5-year period, 2021-2025). This equates to a total maximum predicted time-averaged loss rate due to the Dendrobium mine of less than 4.4 ML/day. This is somewhat lower than the observation in the Panel's recent report that losses over recent years up to the end of LW 13 have been less than 5 ML/day.

Regarding the accuracy of predicted losses, the errors in modelled pressure heads and inconsistencies between predictions and observations continue to lead to little confidence in the groundwater model's ability to predict surface water flow losses. This concern is irrespective of possible additional flow loss due to geological faults and other structural discontinuities. Recommendations relating to managing uncertainty in model predictions are covered in the Panel's Part 2 Report.

Regarding provisions for monitoring surface water losses, the WaterNSW submission notes that the WWL flow gauge is proposed to be replaced to improve accuracy and its conceptual design has been approved by WaterNSW. This is a positive step that can address some concerns raised in previous Panel reports relating to Dendrobium Mine. The Panel agrees with the submission by WaterNSW regarding the need for prompt installation of the new flow gauge and inclusion in the Watercourse Impact, Monitoring, Management and Contingency Plan (WIMMPC) of a methodology for developing the rating curve and developing a relationship between flow measurements at the existing and new gauges, which will help interpret whether any future apparent changes in flows are due to changes in measurement errors.

[4] See Table 4-3, HydroSimulations (2019)

The SMP concludes "*Water quality effects on stored waters of the reservoirs are expected to be negligible and undetectable*". [5] Based on previous commentaries (see Panel's Part 2 report) and the location of LW 20 and LW 21 with respect to any reservoir, this is an appropriate view. However, any pulses of contaminants into Wongawilli Creek due to surface fracturing will be transmitted to Pheasants Nest Weir; this is a water diversion structure and not a reservoir. It is unclear from the SMP if this has been considered and if it has, whether it represents an increased risk of impacts.

The WaterNSW submission introduces the proposed Lower Cordeaux Reservoir, the boundary of which is near to the proposed LW 20 and LW 21. This is a major consideration for potential surface water impacts and how they should be assessed, but the Panel has no information on the likelihood or potential timing of the proposed reservoir, so it is not further addressed here.

The water table is predicted to recover close to pre-mining conditions by 2200. Close to full water table recovery would mean that near-surface fractures that arise may become inundated, potentially leading to increased leaching of contaminants in the long-term. This risk is discussed in the Panel's Part 2 Report. Although that report was not available at the time of the SMP development, this risk should not be overlooked in the SMP.

The SMP states "*The rate of impacts along Wongawilli Creek due to the previous mining [at Area 3B and Area 3A] is considered to be very low*". [6] As raised in the Panel's Part 2 Report, this is not a generally accepted position. In particular, WaterNSW has questioned whether the performance measure relating to minor impacts to Wongawilli Creek has already been breached. This is a fundamental problem of the suitability of the performance measures, as discussed in the Part 2 Report, and not easily resolved within the current approval consent.[7]

5. Swamp Impacts

Only Swamp 144, a small (0.54 ha) banksia thicket swamp, is considered likely to be impacted adversely by upsidence and/or valley closure. Impacts on this and other swamps are covered by the Biodiversity Offset arrangements for Area 3.

In respect of monitoring as specified in the Swamp Impact, Monitoring, Management and Contingency Plan (SIMMCP), several points may be noted:

- Variations in monitoring frequency before, during and after mining may preclude assessment of mining-related impacts, especially in swamps where the piezometers are not logged.
- To assess possible mining-related impacts, the proposed monitoring points in Swamps 144, 145 and 09 should be installed as soon as possible.
- Use of vegetation change to monitor ecosystem functionality is of continuing concern, despite recognition of the less resilient sub-communities identified in the Panel's Part 2 Report (teatree thicket, cyperoid heath), because of the inability so far to distinguish possible mining-related changes from past monitoring data. While the implication may be that no mining-related change has occurred, it is equally possible that the techniques and data have been inadequate to discern the differing extents or causes of change.
- The shallow groundwater impacts are assessed by 'fall below baseline' or change in the recession rate. However, it is unclear in the analysis by Watershed HydroGeo whether a change to more frequent falls to baseline (analogous to a stream no-flow

[5] Page vi, HGEO (2019) Dendrobium Mine, Assessment of surface water flow and quality effects of proposed Dendrobium Longwalls 20 and 21 (D18301)
[6] Page 20, HGEO (2019)
[7] Regarding page 34, HGEO (2019), the Panel notes for the attention of South32 that the observed flows used for WC21-S1 are different to the flow data previously provided to the Panel by South32

condition) and brief spiking only after rainfall is counted as an impact. Swamps 01b_01 and 05_08 are examples.[8]

The mitigation and rehabilitation techniques listed of grouting for bedrock cracking and coir log placement for surface erosion are of limited application and not to date proven in Area 3. Details of the Swamp Rehabilitation and Research Plan have not been made available in the documentation.

The Panel notes Watershed HydroGeo's analysis of potential mining effects on upland swamps and its conclusion that no role for lineaments was found.[9] However, of the 15 swamps close to lineaments, only one (Swamp 01b) was at a lineament that trended towards a longwall panel. Recent information from the Western Coalfield indicates that it is not proximity to a longwall which initiates transmissivity but intersection of a lineament by a longwall. To date, no mining in the Dendrobium areas has taken place where a cluster of faults, dykes and lineaments is mapped near or at longwalls.

6. Risk Assessment

South32 has responded to a recommendation in the Panel's Part 1 Report that all future applications to extract coal within Special Areas should be supported by independently facilitated and robust risk assessments that conform to ISO 31000. The risk assessment submitted adds value to the SMP process.

The following opportunities for improvement are noted for future reference:

- The risk assessment would benefit from an introduction that includes plans of the mining layouts and associated features that are being risk assessed and a description of the mining proposal, such that, that document is stand alone to those not familiar with the project.
- The different circumstances between LW 20 and LW 21 are significant to the extent that each panel should be risk assessed in its own right.
- Although the risk assessment team included appropriately qualified team members, it did not include any external members. Effectively, the team were risk assessing their own work. The inclusion of external expertise can assist in avoiding the common faults in risk assessment discussed in MDG-1014.[10]
- Given the critical nature of the risks and the time span over which they must be managed, a more detailed form of risk assessment based on fault tree and event tree analysis is warranted.[11]
- An explanation of the reasoning that supports consequence ratings. In particular, the Panel questions how it can/has been determined that impacts of faults, dykes and lineaments that are in excess of development consent conditions have duration lifetimes of 3, 10 or 30 years. The Panel wonders why some of these impacts may not be permanent.
- The inclusion of longwall panel width as a control.
- Consideration of cumulative impacts, including the impacts of cracking of first and second order watercourses, on water quality.

[8] Watershed HydroGeo (2019) Geographic Review of Mining Effects on Upland Swamps at Dendrobium Mine. Prepared for South32 Illawarra Coal. March 2019
[9] Watershed HydroGeo (2019)
[10] MDG-1014 (1997) Guide to Reviewing a Risk Assessment of Mine Equipment and Operations. NSW State Government.
[11] The risk assessment undertaken to support the undermining of the Upper Canal and Simpsons Creek aqueduct by LW 409 at Appin Colliery (now operated by South32) provides a point of reference.

- Assessment of the risk presented by the mining proposal to achieving mine rehabilitation and closure in the long term.

7. Performance Measures

The Panel notes that the SMP associates a performance measure of 'minor' with less than 10% of pools experiencing Type 3 impacts - being fracturing that results in pool water levels dropping more than expected after considering the rainfall and surface and groundwater flow conditions. For the record and as discussed in its Part 2 Report, the Panel notes that this does not appear to be consistent with the definition of 'minor environmental impacts' adopted in determinations by the Planning Assessment Commission.

8. Summary Conclusions

It is possible that LW 21 will result in seam-to-surface connective fracturing over some areas, albeit less extensive than over previous 305 m wide longwalls. In the given site-specific conditions, panel width may need to be reduced to the order of 200 m if seam-to-surface connective fracturing is to be totally avoided.

The SMP is premised on seam-to-surface connective fracturing. On that basis, the Panel considers that in general the supporting analysis is conservative; that is, it errs on the safe side. It concludes that provided the TARPs are effective in giving early indication of an exceedance of performance measures, sufficient to stop longwall mining short of its planned finishing line, LW 21 is amenable to adaptive management.

The Panel concludes from its cursory examination of the documentation relevant to LW 20 that the extraction of this Panel could present significantly greater challenges, sufficient to warrant it being assessed in its own right.