INDEPENDENT EXPERT ADVISORY PANEL FOR MINING

ADVICE RE:

DENDROBIUM COAL MINE

LONGWALL 19A

SUBSIDENCE MANAGEMENT PLAN

1 August 2023

EXECUTIVE SUMMARY

Scope of Works

On 16 June 2023, the Director Resource Assessments, NSW Department of Planning and Environment (Jessie Evans) requested the Independent Expert Advisory Panel for Mining (IEAPM – "the Panel") to provide advice in relation to the proposed Subsidence Management Plan (SMP) for secondary coal extraction from Longwall 19A (LW19A) in Area 3A at the Dendrobium Coal Mine. Specifically, the focus is on maintaining the ecosystem functionality of Swamp 15a located immediately east of proposed LW19A which is in the headwaters of SC10, a major tributary of Sandy Creek. The significance of Swamp 15a is recognised in a specific condition of the development consent (Condition 5 of Schedule 3), which states:

> ***Swamp Impact Management***
>
> *5. The Applicant must ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Secretary.*

The primary catalyst for requesting the Panel's advice is concerns raised by the Biodiversity and Conservation Division (BCD) of the Department of Planning and Environment (DPE – "the Department") in early June 2023 that based on historical and, in particular, recent monitoring results, the proposed layout for LW19A will not provide adequate protection to the ecosystem functionality of Swamp 15a.

The Department requested the Panel to provide advice on the appropriateness of the proposed 61 m setback distance of LW19A from Swamp 15a and to consider the likely impacts of the currently proposed mine design in relation to the:

- performance measures required under Schedule 3 Condition 5, including in relation to erosion of the surface or changes in the ecosystem functionality of the swamp, and the structural integrity of its controlling rockbar; and
- performance indicators outlined in the LW19 and 19A Swamp Impact Monitoring, Management and Contingency Plan (SIMMCP – Appendix 3 of the SMP).

The Department also advised that the Panel should feel free to provide any other advice it considers would assist the Department in reviewing the SMP.

Background, Process and Timing

LW19A is adjacent to LW19, which has already been extracted, and is planned to be mined after the extraction of LW21 in another part of the mine. Swamp 15a runs past the eastern ends of both LW19 and LW19A. LW21 is nearing completion and some urgency has been associated with the Panel providing this advice as it could have implications for the Department approving the start of production in LW19A.

The Panel was convened on 22 June 2023 and received a presentation by video conference on 27 June 2023 from BCD regarding its concerns with the proposed layout for LW19A. This was followed on 3 July 2023 by receipt of a Dendrobium 3C Impact Report dated 28 June 2023 which was triggered by post-mining groundwater response at a monitoring site in Swamp 144 adjacent to LW21 and, on 10 July 2023, by additional analysis by BCD of field monitoring outcomes, including information relating to the Impact Report of 28 June 2023. Another relevant Impact Report dated 17 July 2023 and triggered by post-mining groundwater response in Swamp 15a adjacent to LW19, was received on 18 July 2023.

Given the evolving situation, the limited amount of information available to the Panel concerning mining-induced impacts associated with the extraction of the adjacent longwall panel (LW19), and the

tight timeline, the Panel provided the Department with a draft copy of its yet-to-be concluded advice on 17 July 2023 (predating the receipt of the latest Impact Report) in order to facilitate the Department progressing the matter with South32. This was followed up with the Panel submitting a set of summary discussion points pertaining to some critical issues for the intention of facilitating discussions with South32 on 26 July 2023 and responses from South32 on 28 July 2023.

The Independent Advisory Panel for Underground Mining (IAPUM), the predecessor of the IEAPM, undertook an assessment of the Subsidence Management Plan for LW19. The Panel advised that a reduction in the length of the longwall or a reduction in width of the panel was required to substantially reduce the likelihood of a change in ecosystem functionality of Swamp 15a. The Panel's recommendation was founded on advice from South32's consultant that rapid drawdown to levels lower than pre-mining levels and increased rate of recession (drainage) in the water tables in colluvial sediments of swamps had not been observed at Dendrobium Mine to that point in time in swamps further than 60 m from a longwall panel. The Panel's advice was highly qualified and included the statement that this past experience *does not necessarily mean that all the impacted sites at Swamp 15a will be within 60 m of the longwall: the potential for impacts beyond 60 m is clear from the previously observed impacts in drainage lines in Areas 3A and 3B.* Subsequently, LW19 was approved after being setback an additional 100 m, which resulted in that proportion of the Swamp 15a located within 60 m of the longwall footprint being more than halved. The remainder was located between 22 m and 60 m from the longwall.

This Panel advice is not based on all the required evidence. The End of Panel Report for LW19, which commenced extraction adjacent to Swamp 15a in June 2022, was only published the day before submitting this advice. Hence, the Panel has not had an opportunity to review relevant aspect of the analysis of subsidence effects, impacts and consequences required to be presented in that report. There is also no comprehensive reporting of soil moisture/groundwater data elsewhere since February 2022 even though some hydrographic data is available for 2023.

Primary Conclusions

1. The definition of ecosystem functionality devised in 2013 and adopted in the Swamp Impact, Monitoring, Management and Contingency Plan (SIMMCP) for Longwalls 19 and 19A (and some other previous longwalls) neither reflects the universal definition of the term that has prevailed for at least the last three decades (and, hence, at the time when it was written into the Consent Conditions for Dendrobium Mine) nor general informed usage of the term.
2. In particular, the established definitions of ecosystem functionality allude to physical processes, a key aspect of which is the swamp soil hydrology; a parameter that is not reflected in the definition of ecosystem functionality in the SIMMCP.
3. Since a change in swamp hydrology at any monitoring site reflects a wider hydrological change, the area of which may be large but unmeasured, a change to the hydrology at any site should be regarded as indicating a change in swamp ecosystem functionality.
4. Any observed changes to the hydrology at any site in Swamp15a are a reflection of a wider hydrological impact, the area of which may be large but undetectable due to the sparseness of shallow groundwater monitoring sites. This cannot be fully resolved by adding more monitoring sites.
5. If the Dendrobium-centric definition of ecosystem functionality continues to prevail, it is incomplete and warrants updating.
6. In respect to advice presented in the SMP for LW19 that rapid drawdown to levels lower than pre-mining levels and increased rate of recession (drainage) in the water tables in colluvial sediments of swamps had not been observed at Dendrobium Mine to that point in time in swamps further than 60 m from a longwall panel, the Panel concludes on the basis of its assessment of recent Impact Reports relating to Swamp 35b, Swamp 144 and Swamp 15a as well as

hydrological and other data, that this is no longer the case. Observations of this behaviour have since been recorded at distances close to 120 m from the edges of longwall panels.

7. Based on the Panel's assessment of information currently available to it, the Panel is of the opinion that that a setback distance of at least 120 m is the minimum distance required to protect the ecosystem functionality of Swamp 15a from being impacted by depressurisation or drainage of shallow groundwater. Still, this may not prove sufficient.
8. This situation is consistent with the IAPUM's advice on the SMP for LW19, which foreshadowed that it could arise with the passage of time and with the benefit of additional monitoring outcomes.
9. Given the high standard set by the Performance Measure for Swamp 15a, the irreversible nature of impacts, the lack of effective controls other than setback distance and the uncertainties in the underpinning knowledge base, prudent risk management may require a significantly greater setback distance than 120 m.
10. Rockbar SC10-RB15a, which is the controlling rockbar for Swamp 15a, is located a sufficient distance from LW19A that it is very unlikely to be impacted by the extraction of LW19A.
11. There are 10 other rockbars within, adjacent or near to Swamp 15a at which predicted valley closures due to the cumulative effects of LW19 and LW19A are significant. The predictions imply a moderate likelihood that fracturing and subsequent pool drainage at one or more of these pools will occur. Reductions in the levels of these pools may locally impact swamp water levels and the riparian ecosystem.
12. The SIMMCP for Longwalls 19 and 19A contains conflicting descriptions of the proximity of Swamp 15a to LW19A and incorrect monitoring network data.
13. The adequacy of the proposed 61 m setback is called into question by the subsidence assessment which states that fracturing of bedrock could occur beneath Swamp 15a and by the SIMMCP which reports that it is *likely that shallow groundwater levels will be affected at Swamp 15A.*
14. Fundamentally, the TARPs incorporated into the SIMMCP are not suitable for managing the risk of impacts to the ecosystem functionality of Swamp 15a because:
    a. There are no real time performance indicators suitable for pre-empting impending mining-induced changes in the ecosystem functionality of a swamp.
    b. The time lag between cause and impact on ecosystem functionality is too long for identifying the need to implement preventative measures (responses) during active mining in time for them to be effective.
    c. Swamp soil moisture, groundwater dependent community and species changes that are the basis for current TARPs for Swamp 15a ecosystem functionality can, themselves, be irreversible impacts of mining.
15. For the above reasons, options for adopting effective, TARP driven, adaptive management during extraction of a longwall panel are virtually non-existent when it comes to managing the risk of impacts to the ecosystem functionality of swamps, including Swamp 15a.
16. For Swamp 15a, the only feasible option for practising adaptive management is the selection prior to the commencement of extraction of each longwall panel, of an appropriate setback distance based on field experience; setback distance from Swamp 15a is the critical (essential) primary control in the case of LW19A.
17. Some of the Performance Indicators and TARPs proposed in the SIMMCP are relevant to mitigating other impacts, such as erosion.
18. Remediation of swamps has yet to be proven technically feasible.
19. Due to the lack of other effective and timely controls and multiple lines of defence (barriers), and in recognition of the lack of options currently available for remediating swamps, risk management principles require a high level of confidence in the adequacy of the setback distance of LW19A from Swamp 15a.

20. The requirement for End of Panel reports to be published within four months of the completion of a longwall panel is not achieving one of its important original objectives of effectively informing adaptive management, as evident in this matter where the End of Panel Report for LW19 has been published, in accordance with Approval Conditions, some 13 months after LW19 was extracted next to Swamp 15a.

Recommendations

Based on the assessment of available information and the potential impacts to Swamp 15a, the Panel recommends that:

1. In order to avoid changes in ecosystem functionality, the setback distance of LW19A from Swamp 15a should be in excess of 120 m. There is insufficient information available to the Panel to recommend at upper bound for setback distance.
2. The definition of Ecosystem Functionality is outdated and inadequate and should be revised to accommodate all processes (such as swamp hydrology) that are essential for swamps and their dependent ecosystems.
3. The performance indicators for assessing compliance with Performance Measures related to the ecosystem functionality of a swamp should include perched groundwater levels in the swamp, in addition to those related to swamp size, species and vegetation communities.
4. An observable change to perched groundwater level at any site in Swamp 15a due to mining should be treated as a change to ecosystem functionality.
5. Performance indicators for pool water levels should be proposed for selected pools, with TARPs including provision for assessing if remediation is warranted and feasible to prevent changes to the swamp ecosystem functionality.
6. The locations of the proposed pool water level, shallow groundwater and deep groundwater monitoring sites that are included in the SIMMCP should, prior to approval of the LW19A SMP, be independently reviewed for adequacy to detect the nature and magnitude of any mining-induced change.
7. The Department should encourage proponents to ensure longer baseline periods to assess potential impacts and ensure that longer monitoring periods occur post-mining (and post End of Panel reporting) to further evaluate performance indicator trends and to confirm whether there are long-term mining-induced impacts.
8. The South32 monitoring program for Swamp 15a should include:
    a. Continued and expanded monitoring of shallow groundwater in the swamp across Swamp 15a to be able to assess compliance with the Condition 5.
    b. Monitoring of groundwater in the underlying sandstone adjacent to the western edge of Swamp 15a given that VWP 1888 will be destroyed once the longwall commences. A nested standpipe location monitoring shallow and deeper aquifers in the Hawkesbury Sandstone west of the swamp at an accessible location is required to confirm whether there is any emerging evidence of connected cracking or further depressurisation impacting these aquifers.
9. Dendrobium Mine should be required to prepare six monthly reports, or suite of reports, that detail monitoring data and analysis relevant to assessing subsidence effects, impacts and environmental consequences.
10. The SIMMPC for LW19 and LW19A should be revised and reissued.

11. In future, in circumstances where the location of a longwall installation roadway determines the setback distance from a feature that requires a degree of protection from mining-induced impacts, approval conditions should require that within three months prior to commencing the drivage of the installation roadway, the appropriateness of the planned location of the installation roadway is to be confirmed/reaffirmed by undertaking a review of all relevant monitoring data to the satisfaction of the Department Secretary

TABLE OF CONTENTS

1.0 SCOPE OF WORKS

On 16 June 2023, the Director Resource Assessments, NSW Department of Planning and Environment (Jessie Evans) requested the Independent Expert Advisory Panel for Mining (IEAPM – "the Panel") to provide advice in relation to the proposed Subsidence Management Plan (SMP) for secondary coal extraction from Longwall 19A (LW19A) in Area 3A at the Dendrobium Coal Mine. Specifically, the focus is on maintaining the ecosystem functionality of Swamp 15a located immediately east of proposed LW19A which is in the headwaters of SC10, a major tributary of Sandy Creek. The significance of Swamp 15a is recognised in a specific condition of the development consent (Condition 5 of Schedule 3), which states:

> ***Swamp Impact Management***
>
> *5. The Applicant must ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Secretary.*

The primary catalyst for requesting the Panel's advice is concerns raised by the Biodiversity and Conservation Division (BCD) of the Department of Planning and Environment (DPE – "the Department") in early June 2023 that based on historical and, in particular, recent monitoring results, the proposed layout for LW19A will not provide adequate protection to the ecosystem functionality of Swamp 15a.

Hence, the Department requested the Panel to provide advice on the appropriateness of the proposed 61 m setback distance of LW19A from Swamp 15a and to consider the likely impacts of the currently proposed mine design in relation to the:

- performance measures required under Schedule 3 Condition 5, including in relation to erosion of the surface or changes in the ecosystem functionality of the swamp, and the structural integrity of its controlling rockbar; and
- performance indicators outlined in the LW19 and 19A Swamp Impact Monitoring, Management and Contingency Plan (SIMMCP – Appendix 3 of the SMP).

The Department also advised that the Panel should feel free to provide any other advice it considers would assist the Department in reviewing the SMP.

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

- Em. Professor Jim Galvin – Chair – Subsidence and Mining
- Mr John Ross – Groundwater
- Em. Professor Rae Mackay – Groundwater (background briefings)
- Professor Neil McIntyre – Surface Water
- Dr Ann Young – Swamps and Ecology
- Mr Nathan Garvey – Biodiversity

2.0 METHOD OF OPERATION

2.1. ACTIVITIES AND TIMELINE

The Panel was convened on 22 June 2023 in response to the Department's request of 16 June 2023. The Department provided access to a range of documents and sourced additional information from stakeholders at the request of the Panel. This reference documentation is listed in Section 2.2.

BCD gave a presentation to the Panel by video conference on 27 June 2023 regarding BCD's concerns with the proposed layout for LW19A. This was followed on 3 July 2023 by receipt of a Dendrobium 3C Impact Report dated 28 June 2023 which was triggered by post-mining groundwater response at a monitoring site in Swamp 144 adjacent to LW21 and, on 10 July 2023, by additional analysis by BCD of field monitoring outcomes, including information relating to the Impact Report of 28 June 2023. Another relevant Impact Report dated 17 July 2023 and triggered by post-mining groundwater response in Swamp 15a adjacent to LW19, was received on 18 July 2023.

In the meantime, the current longwall (LW21 in Area 3C) was nearing completion and there was some urgency associated with the Panel providing its advice as it could have implications for the Department approving the next longwall in the series, being LW19A. The End of Panel Report for LW19, which commenced extraction adjacent to Swamp 15a in June 2022, was published on the eve of the Panel finalising this advice and so the Panel has not had an opportunity to review it. Consequently, the nature of this matter has meant that the Panel has been faced with a tight timeline in which to provide advice on an evolving situation that has required the provision of additional information and analysis. The provision and consideration of further information and analysis that may also have informed this advice has been constrained by time.

Given these circumstances, on the 17 July 2023 the Panel provided the Department with a draft copy of its yet-to-be concluded advice in order to facilitate the Department progressing the matter with South32.[1] This was followed up with the Panel submitting a set of summary discussion points pertaining to some critical issues for the intention of facilitating discussions with South32 on 26 July 2023 and responses from South32 on 28 July 2023.

The timeline relating to the IEAPM's assessment of Dendrobium LW19A SMP is summarised in Table 1.

[1] Noting that this was the day before the receipt of the latest Impact Report

Table 1: Timeline relating to IEAPM's assessment of Dendrobium LW19A SMP.

16/6/23	DPE request for advice from IEAPM
22/6/23	IEAPM Panel convened
27/6/23	BCD presentation to IEAPM (Video Conference)
3/7/23	IEAPM receipt of new Impact Report dated 28/6/23 relating to the response of Swamp 144 after the passage of LW21
10/7/23	IEAPM receipt of additional analysis by BCD, including in relation to Impact Report of 28/6/23
17/7/23	Submission to DPE of IEAPM draft report to date
18/7/23	IEAPM receipt of new Impact Report dated 17/7/23 relating to the response of Swamp 15a after the passage of LW19
24/7/23	Discussion points relating to key issues prepared by IEAPM and submitted to DPE to facilitate meeting with South32
26/7/23	Discussions with South32 and DPE (Video Conference)
28/7/23	Response from South32 and its consultants to discussion points and matters arising from meeting of 26/7/23 (Video Conference)
1/8/2023	Finalisation of IEAPM advice

2.2. REFERENCE DOCUMENTATION

Attachment 1

Pre-Lodgement Agency Advice on LW19A:

- Biodiversity and Conservation Division, November 2022
- Water NSW, November 2022
- South32 Response to pre-lodgement agency advice

Assessment Agency Advice on LW19A:

- Biodiversity and Conservation Division, February 2023
- Water NSW, January 2023
- Water NSW, April 2023
- South32 Response to Agency Advice March 2023

Attachment 2 – LW19A SMP Documents:

- Longwall 19A SMP
- Appendix 1 – SMP Approved Plan
- Appendix 2 – SMP Approved Plan 2

- Appendix 3 – LW19 and 19A SIMMCP
- Appendix 4 – LW19 and 19A WIMMCP
- Appendix 4a – WIMMCP App C – Sandy Creek Waterfall Management Plan

Attachment 2.1a - LW19A SMP Attachments:

- Attachment A – Longwall 19A SMP_AEA_Rev0
- Attachment B - Dendrobium A3A Longwall 19A GW Assessment
- Attachment C – MSEC1234 – Dendrobium LW19A SMP Application Rev B
- Attachment D – AR3536 – Dendrobium Longwall 19A SMP Risk Assessment R2 20221010
- Attachment E – D22175 Dendrobium LW19A SW Impact Assessment
- Attachment F – Dendrobium Area 3A Terrestrial Ecology Assessment RevR1 20220930
- Attachment G – LW19A Geology V2
- Attachment H – Longwall 19A SMP ACHA FNL Rev 0 Combined 20220829

Attachment 2.2 – Consolidated Consent

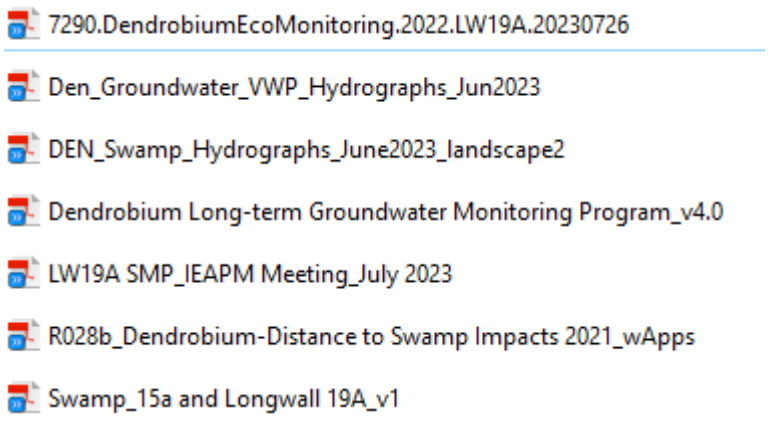
Attachment 2.3 - Watershed HGEO Geographic Review of Mining Effects on Upland Swamps

Attachment 2.4 - BCD Document Setbacks for Biodiversity – Longwall Mining

Attachment C – MSEC1082 – Dendrobium LW19 SMP Application – Rev C

Additional Information:

- BCS Information
    - Additional Information on setbacks for biodiversity for IAPUM Consideration
    - Dendrobium Longwall Coalmining Swamp Setbacks
    - Major Impacts IAPUM June 2023
- Attachment 2.4a Dendrobium Area 3A Trigger Report 230314
- BCD Data Pack May 2023
- Dendrobium Area 3A Impact Report 230529
- Dendrobium Area 3A s148 Impact Report 221222
- Watershed HGEO Update to geographic review of mining effects on Upland Swamps at the Dendrobium Mine.
- The following files provided by South 32:



3.0 BACKGROUND

The sequence, timing, and direction of longwall mining in the region of LW19A and the environmental setting and current monitoring programs and trends in the vicinity of this longwall panel have a significant bearing on the Panel's advice presented later in this document. This section provides summary background material in relation to these aspects.

3.1. MINE LAYOUT

Longwall mining has been undertaken at Dendrobium Mine in Areas 1, 2, 3A, 3B and 3C, shown in Figure 1. LW19A is located in the southern portion of Area 3A, with its location and layout relative to Swamp 15a and other swamps and longwall panels in its vicinity shown in Figure 2. LW19A is proposed to be 281 m wide, 1051 m long and to mine coal to a height of up to 3.9 m.

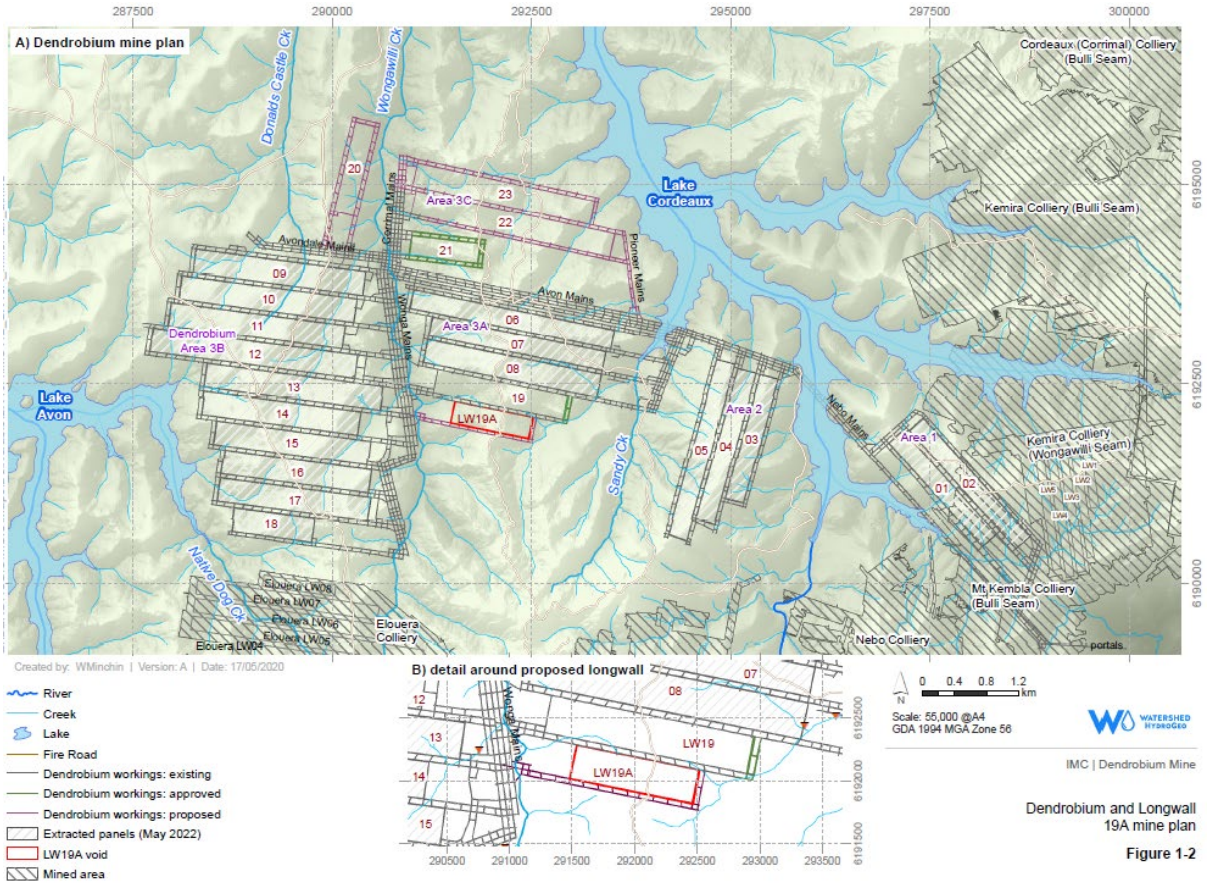


Figure 1: Locations of Areas 2, 3A, 3B and 3C and associated longwall panels within these areas (Figure 1-2 from HGeo, 2022d).

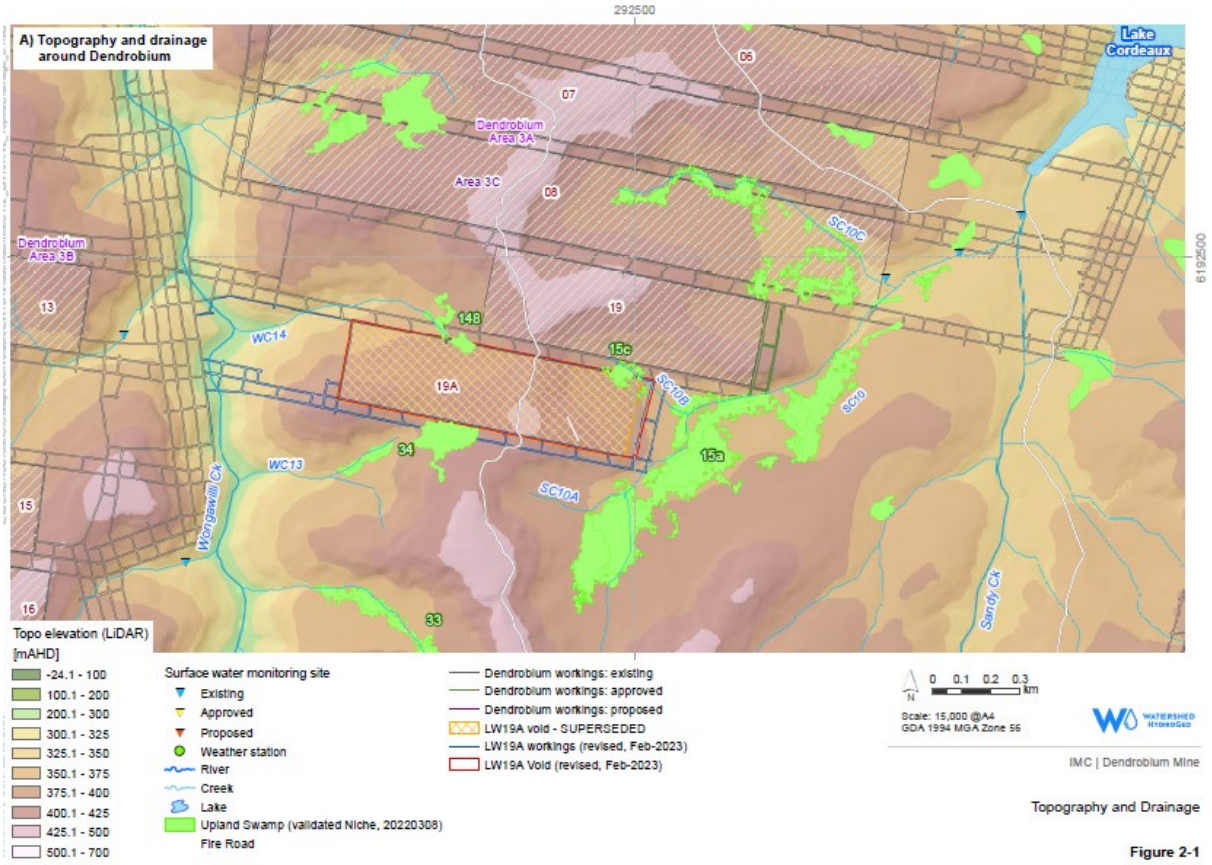


Figure 2: Location and setting of longwall panels 19 and 19A (Figure 2-1 from HGeo, 2023a).

LW19A is the fifth longwall panel to be extracted in Area 3A. The first three longwall panels comprised LW6 to LW8 and retreated from west to east. Mining then progressed to extracting LW9 to LW18 from east to west in Area 3B, before reverting back to Area 3A to extract LW19 from east to west, being the opposite direction to previous longwall panels in this mining domain. Longwall extraction then moved to Area 3C where LW21 is nearing completion at the time of preparing this advice. It is then planned to return to Area 3A to extract an additional longwall panel from east to west, being LW19A.

3.2. ENVIRONMENT AND MONITORING IN THE VICINITY OF LW19A

3.2.1. Geology

The geology overlying LW19A and the Permian Illawarra Coal Measures (ICM) comprises:

- Near surface colluvium (typically 1 to 3 m thick)
- Triassic Hawkesbury Sandstone (ranges from 75 to 120 m thick)
- Triassic Narrabeen Group sandstones and claystones (typically around 200 m thick)

The depth of cover over LW19A ranges from 285 to 360 m (South32, 2022b). Swamp 15a is underlain by sandy colluvium that has been transported from ridgelines downslope and along the axis of drainage line SC10. The colluvium overlies the less permeable Hawkesbury Sandstone.

Structurally there are intrusions, faults, dykes and lineaments mapped around the Dendrobium Mine area. However, there are very few faults in the vicinity of LW19A. Most local geological structures/defects are related to igneous intrusions. A nepheline intrusion to the south and east of LW19 and LW19A presents a constraint on the mine layout. Sills and dykes can be present in and/or just above the coal seams in the ICM. The permeability of these defects is not known but they could be high permeability conduits for overlying aquifers. The Panel notes that the hydrogeological impact of these defects has neither been assessed in the SMP nor considered by the Panel.

None of these features are known to extend into the overlying Triassic strata or impact the very shallow colluvium.

3.2.2. Hydrology

LW19A is located beneath the ridgeline that separates Wongawilli Creek to the west and Sandy Creek to the east (refer Figure 2). SC10 is a major (second order) tributary of Sandy Creek that occurs immediately to the east of LW19 and LW19A. Its catchment area (at flow gauge SC10S1, approximately 200 m upstream of the confluence with Sandy Creek) is 2.77 km^2 (HGeo 2022b). Minor (first order) tributaries SC10A and SC10B drain the ridgeline to the south and north of LW19A respectively and feed into SC10 that flows to the north-east to join Sandy Creek. Minor tributaries WC14 and WC13A drain the western ridgeline area to Wongawilli Creek. All these water courses are fully or partly within the 35° angle of draw determined for LW19 and LW19A (refer Figure 3 and Figure 4). The slope of Swamp 15a transect towards SC10 is steep to mild (approximately 1:50 on the eastern or right-hand slope in Figure 5, which represents a lower than average transect slope, based on the contours in MSEC drawing 1234-09 (MSEC, 2022b)), representing likely strong flow of water from the hillslope to Swamp 15a and SC10. This implies a limited role of SC10 in sustaining swamp moisture.

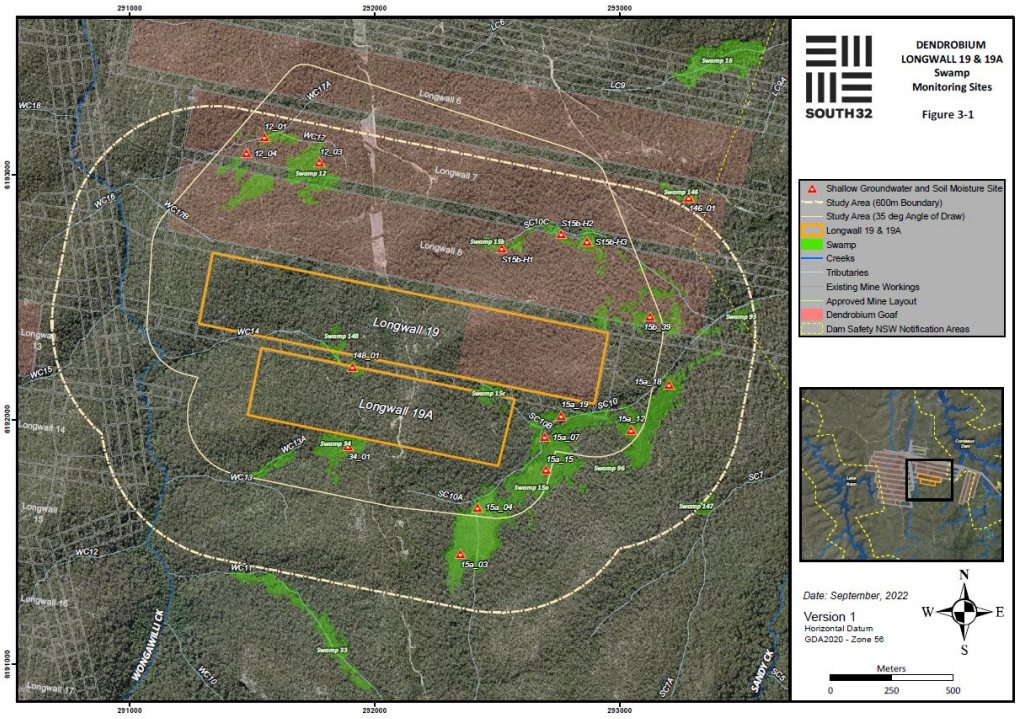


Figure 3: Swamp monitoring sites (joint shallow groundwater and soil moisture sites) (Figure 3-1 from South 32, 2022a)

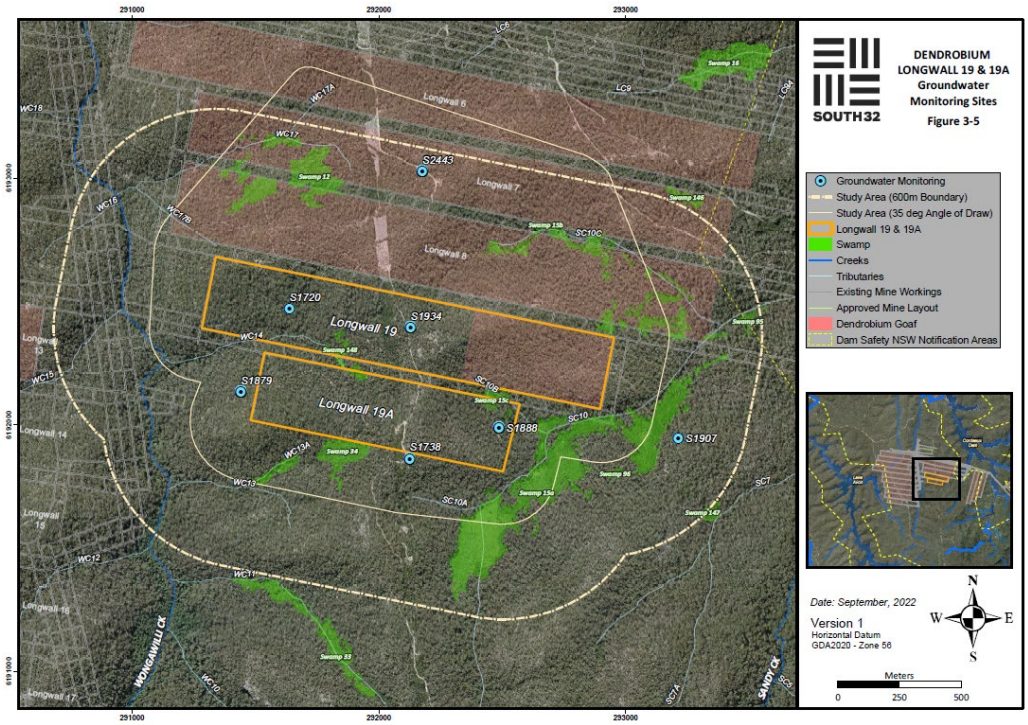


Figure 4: Groundwater monitoring sites (vibrating wire (VWP) monitoring sites) (Figure 3-5 from South 32, 2022a)

3.2.3. Hydrogeology

Perched groundwater occurs in sandy colluvium deposited in the swamp areas (primarily Swamp 15a) and along the valley floor of tributary SC10. Localised perched groundwater also occurs in the underlying weathered Hawkesbury Sandstone to depths of 10 m. This very shallow groundwater can be assumed to discharge following wet weather as ephemeral springs on hillslopes that then contribute to swamp inflows. This groundwater can also be assumed to contribute to baseflows and pools located along watercourse SC10 with a small proportion draining to the regional water table in the Hawkesbury Sandstone.

The regional water table generally occurs within the porous and fractured rock of the deeper Hawkesbury Sandstone. Advice provided by South32 consultant hydrogeologists (HGeo, 2023b) suggests that in 2009 (i.e. pre-mining of Area 3A) the regional water table was elevated and supported groundwater discharge to Swamp 15a and watercourse SC10 from both the eastern and western flanks of the SC10 catchment (see Figure 5).

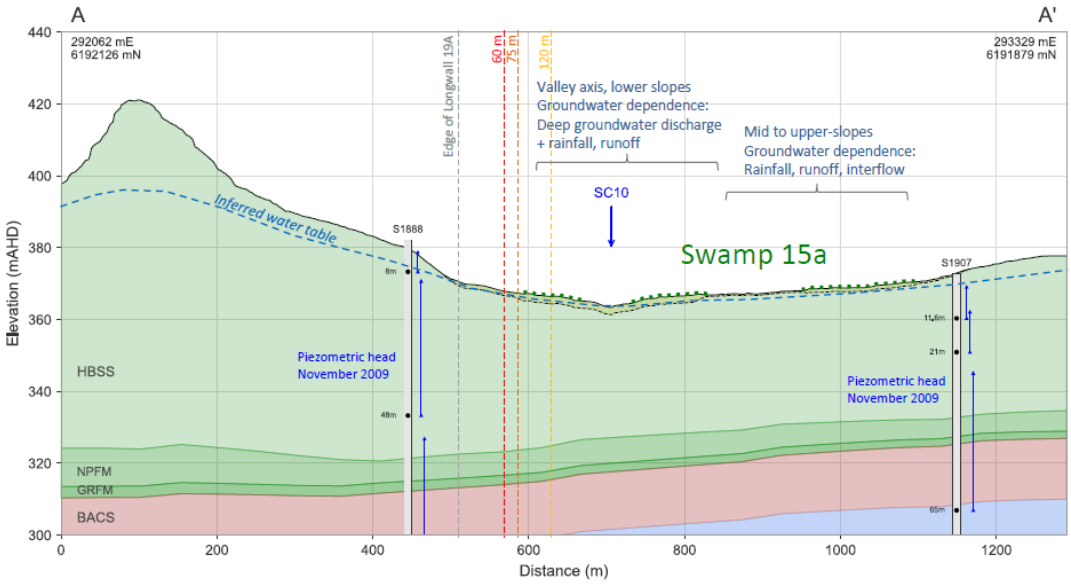


Figure 5: Hydrogeological (west-east) cross-section through Swamp 15a (from HGeo, 2023b)

Unfortunately, there are no nested standpipes adjacent to Swamp 15a to confirm whether there is connectivity between perched groundwater in the colluvium/weathered rock in Swamp 15a and the regional groundwater in the Hawkesbury Sandstone. Several vibrating wire piezometer (VWP) locations do provide an insight into the vertical piezometry through the Hawkesbury Sandstone to the coal seams at depth (S1888 and S1907). The closest location is S1888 which is located 200 m west of swamp monitoring location 15a_07. At this location there are sensors at two levels in the Hawkesbury Sandstone; one at 8 m below ground level (bgl) monitoring shallow groundwater in the weathered sandstone, and the second at 48 mbgl monitoring the regional water table in porous/fractured sandstone.

Most recent groundwater level data at S1888 and S1907 (to April 2023) suggests that the perched water table is unaffected by mining Area 3A but the underlying regional water table in the Hawkesbury Sandstone has dropped 25-30 m beneath the western flank of the SC10 catchment but is unaffected beneath the eastern flank of the SC10 catchment (see Figure 6). This decline in the regional water table beneath the western flank is a mining-induced depressurisation response following the extraction of LW6, LW7 and LW8 in Area 3A. The accelerated water level decline observed since February 2022 is a direct result of the extraction of LW19.

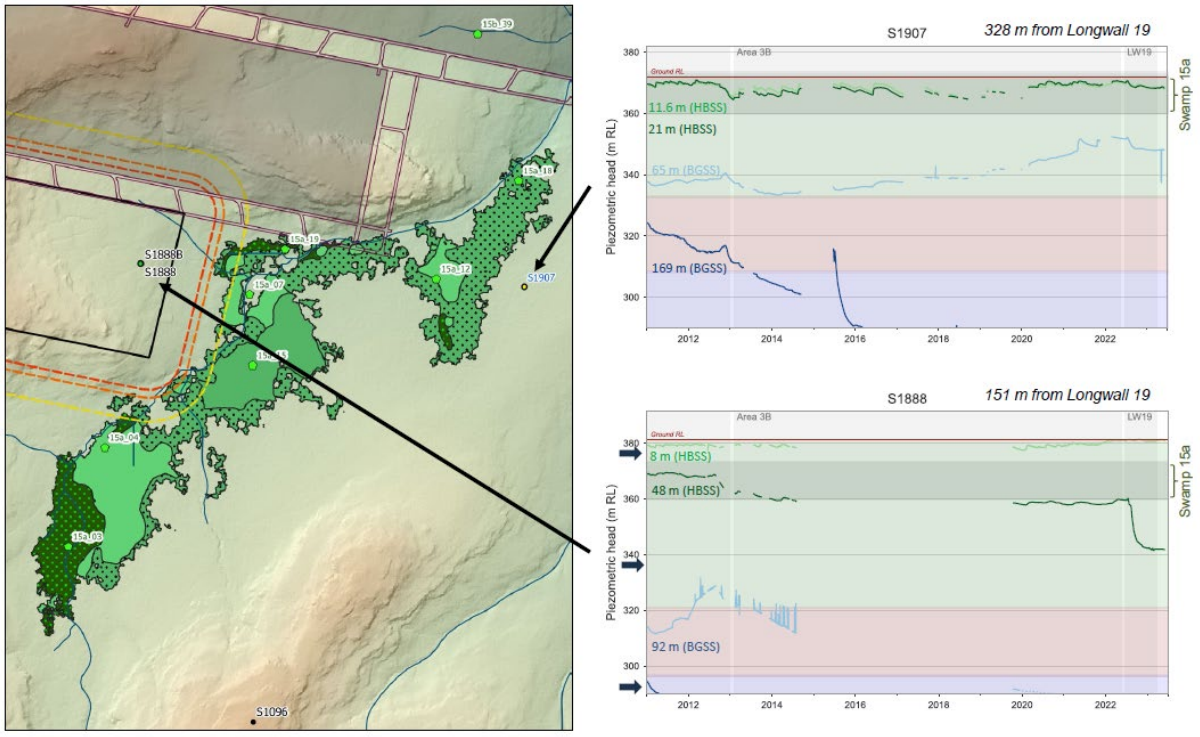


Figure 6: Hydrographs of deep monitoring sensors in VWPs east and west of Swamp 15a (from HGeo, 2023b)

This data suggests a loss of deep groundwater discharge to SC10 and Swamp 15a has already occurred from the western flank of the catchment.

In the vicinity of LW19A, groundwater is (or was) monitored at the following locations, some of which are shown in Figure 3 and Figure 4:

- Seven (active) shallow colluvial locations within Swamp 15a (east of LW19A)
- Six (inactive) shallow colluvial locations within Swamp 15a (east of LW19A)
- One shallow colluvial location within Swamp 148 (northern boundary of LW19A)
- One shallow colluvial location within Swamp 34 (southern boundary of LW19A)
- Deep groundwater at S1720 (VWP – destroyed) and S1934 (VWP – destroyed) overlying LW19 (located in the western portion and central portion respectively)
- Deep groundwater at S1879 (VWP) located adjacent to LW19A (western boundary)
- Deep groundwater at S1888 (VWP) overlying LW19A (located in the eastern portion)
- Deep groundwater at S1738 (VWP – abandoned) located adjacent to LW19A (southern boundary)
- Deep groundwater at S1907 (VWP) located 600m east of LW19A and east of Swamp 15a

The current SIMMCP (South32, 2022a) and its attachments do not adequately describe the current swamp and groundwater monitoring network. Only the current active and proposed locations should be referenced in the plan together with any important control/reference sites. Readers would benefit from time-series baseline water level data (i.e. swamp, shallow and deep groundwater levels) being put into an Appendix in order to be able to identify historical trends.

Currently there is limited monitoring of shallow and deep groundwater levels in the Hawkesbury Sandstone adjacent to Swamp 15a, and with the passage of LW19A, S1888 will be destroyed and monitoring will be reduced to just one location (S1907). This site is located more than 600 m east of the proposed commencement of LW19A and located east of Swamp 15a. It is an inappropriate site to

demonstrate connectivity between perched, shallow and deep groundwater in the Hawkesbury Sandstone immediately adjacent to Swamp 15A, and potential depressurisation impacts resulting from the extraction of LW19A.

Additional monitoring is required of shallow and deep groundwater levels in the Hawkesbury Sandstone in the potential impact area between LW19A and Swamp 15a.

3.2.4. Swamps

The only swamps closer than 60 m to the proposed footprint of LW19A are Swamps 148, 15c (north) and 34 (south). These overlie the roadways and are immediately adjacent to LW19A (refer Figure 2). They are not the subject of this advice, although the Panel considers it predictable with a high level of certainty that LW19A longwall will result in further ecological changes to these three swamps.

Swamps 12 and 15b, are located further north of proposed LW19A and have been previously undermined. They are predicted to experience cumulative upsidence of 175 mm to 350 mm (South32, 2022a). These valley-related effects could result in the further dilation of the strata beneath these swamps and drain any remaining shallow (perched) groundwater.

Swamp 15a is the primary upland swamp adjacent to proposed LW19A. It is a valley infill swamp covering 17.38 Ha (HGeo 2022b). Its controlling rockbar was identified in the SMP for LW19 as being SC10-RB15A, which is reported in the SIMMCP (South32, 2022a) to be over 600 m away. A series of 12 rockbars and 12 pools upstream of SC10-RB15A are within, adjacent or near to Swamp 15a, as shown in Figure 7. Soil cores from piezometer sites (HGeo, 2023b) show highly variable soil classifications over the swamp. Cores under Cyperoid Heath and Banksia Thicket in the lower part of the swamp are dominated by sand with increasing presence of clay and organic material under Restioid Heath and Tea tree thicket in the upper slopes. In all cases sandy layers with low clay and organic content were present in the deeper soils. Swamp soil depth is variable, with recorded depth to bedrock being 1.0 m to 3.2 m.

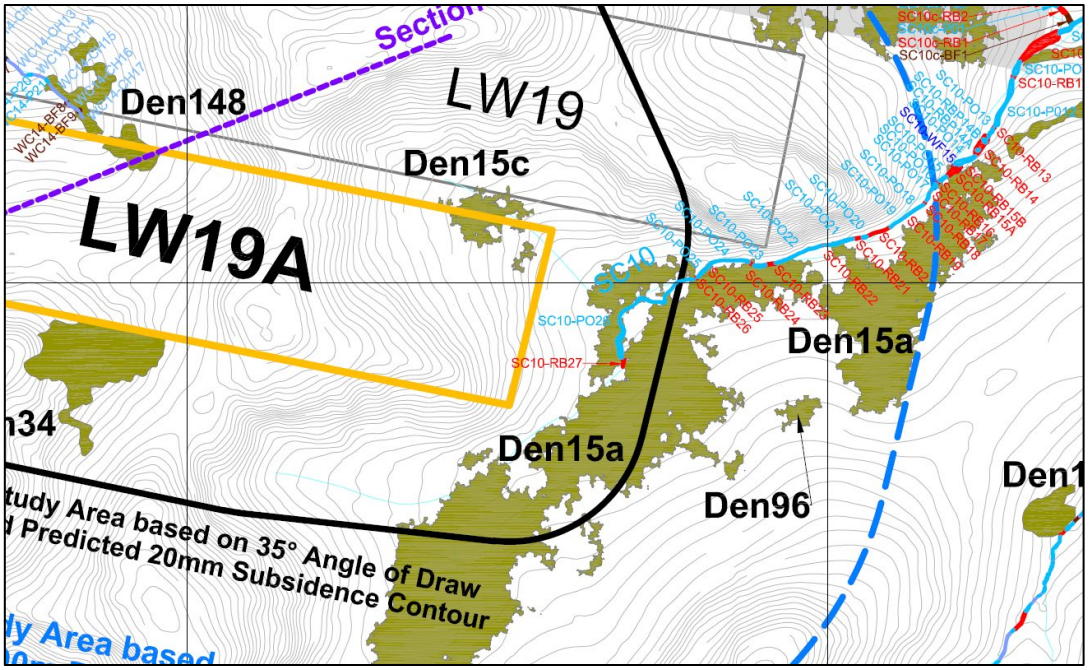


Figure 7: Location of pools and rockbars on SC10 in Study Area (extracted of Drawing No: MSEC1234-09 from MSEC, 2022b).

The SIMMCP contains conflicting descriptions of the proximity of this swamp to LW19A, being:

- *Swamp 15A is located outside and adjacent to the mining area*[2]
- *9% of the mapped area of Swamp 15A is within 60 m of the goaf footprint*[3]
- *7% of the mapped area of Swamp 15A is within 60 m of the goaf footprint*[4]. (This appears to be attributed to HGEO, 2020)

This has caused confusion amongst stakeholders and within the Panel and needs review. The Panel's assessment is based on the Department's advice that at its closest point, Swamp 15a is 61 m from the commencement of LW19A, which appears to be consistent with Figure 2 to Figure 4.

Swamps 96 and 147 are located 400 m and 800 m respectively from LW19A and are situated on valley-sides east of Swamp 15a. These swamps are not predicted to experience measurable fracturing or surface cracking due to mine subsidence and therefore ecosystem impacts due to the mining of LW19A are not anticipated at these distances.

3.3. OPPORTUNITY FOR ADAPTIVE MANAGEMENT

Adaptive management is a procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.[5] Generally, adaptive management is applied in longwall mining to manage subsidence induced environmental impacts through either or both:

- Monitoring the development of subsidence effects and impacts as a longwall panel is being extracted and ceasing to mine when the absolute magnitudes of these and/or the rate of change (velocity or acceleration) of their development approach threshold values.
- On the basis of past experience, designing a longwall panel layout to be setback (or standoff) from features a sufficient distance to avoid exceeding designated tolerable subsidence effects and/or impacts to landscapes, ecosystems, surface water and groundwater.

Adaptive management applied to managing mining-induced environmental impacts and consequences in real time so that they remain within the bounds of designated Performance Measures is highly dependent for success on the monitoring of appropriate parameters, referred to as *performance indicators*, that provide effective and timely indications, or warning signs, of developing behaviour that could jeopardise compliance with Performance Measures. This approach was employed with notable success during the extraction of LW6 to LW8 to determine how close each longwall panel could approach Sandy Creek Waterfall.

However, in the case of any swamp, but particularly Swamp 15a because it has a Performance Measure of subsidence not causing changes in ecosystem functionality, the options for practicing effective adaptive management during extraction of a longwall panel are virtually non-existent; there are no appropriate and effective performance indicators that can be applied in real time for this purpose. The drainage and drawdown of shallow groundwater, which in the Panel's view is the timeliest indicator of impacts to ecosystem functionality of a swamp, may only become apparent months after the passing of the longwall. As a result, it will be very likely too late to constrain and minimise environmental impacts to the swamp.

2 p38 of the SIMMCP (South32, 2022a)
3 p39 of the SIMMCP (South32, 2022a)
4 p43 of the SIMMCP (South32, 2022a)
5 https://www.environment.nsw.gov.au/research/adaptive-management.htm

In the case of Swamp 15a, the only effective control for ensuring compliance with the Performance Measure is the selection of an appropriate setback distance based on field experience; setback distance from Swamp 15a is the critical (essential) primary control. Due to the absence of any controls and lines of defence (barriers), risk management principles require a high level of confidence in the adequacy of the setback distance of LW19A from Swamp 15a.

3.4. REMEDIATION OF SWAMPS

The SIMMCP provides description of a range of techniques that have been used for remediating mining-induced fracturing of rockbars and watercourses and sheet, rill, gully and stream channel erosion. However, it does not address remediation of mining-induced impacts beneath the beds of swamps. The 2008 report of the *Strategic Review – Impacts of Underground Mining on Natural Features in the Southern Coalfield* (DOP, 2008) reported that:

> *The Panel is not aware of any attempts to remediate fracture networks beneath swamps. However, further research is taking place in this area and Illawarra Coal[6] has recently commissioned a consultant to examine potential remediation techniques for impacted wetlands and swamps. …….Further, there has been little work done to successfully demonstrate re-establishment of ecosystems either after remediation of habitat features (such as rock bars or pools) or in the absence of any such remediation.*

The Panel went on to recognise there are a number of limitations on the successful implementation of rehabilitation techniques in the Southern Coalfield.

In 2014, the Independent Expert Scientific Committee (IESC, 2014) commented that:

> *"there is no currently available scientific evidence to demonstrate that remediation activities are able to successfully restore the ecological and hydraulic functions of these threatened ecological communities to preimpact condition"*

In February 2013, as part of the conditions of approval for the SMP for Area 3B at Dendrobium Mine, South 32 was required to develop a Swamp Research and Rehabilitation Plan. As of 2018, work was still to commence on that project. The Independent Expert Panel for Mining in the Catchment (IEPMC, 2019) reported in 2019 that:

> *At the time of this report the Panel is not aware of a finalised plan although the WaterNSW submission states it is "currently facilitating access to [South32] to trial the application of grout (using directional drilling) beneath an affected Swamp 1B to repair the natural aquitard below the swamp" noting that it is "not aware whether this type of remediation has ever been attempted before, and numerous challenges confront this trial".*

The IEPMC went on to conclude that:

> *Currently there is no proven method to rehabilitate swamps or evidence that swamps can be remediated.*

This is still the situation as far as this IEAPM Panel is aware.

[6] Now South32

3.5. PREVIOUS PANEL ADVICE RE LW19

In February 2021, the IAPUM submitted an advice to the Department on the SMP for LW19. At the time, the Panel was not provided with any indication that LW19A may subsequently be developed. The Department's Reasons for Approval included an acknowledgement that *'The SMP shows that LW19 would be the last and most southerly longwall to be extracted from Area 3A'*.

One of the recommendations of the IAPUM Panel for LW19 SMP was that *'As a minimum requirement for meeting Condition 5 regarding no change in ecosystem functionality of Swamp 15a, LW19 should be set back at least 60 m from all edges of Swamp 15a.'* The Panel advised that this would require either a narrowing or a reduction in the length of the longwall to substantially reduce the likelihood of a change in ecosystem functionality.

The Panel's recommendation was highly qualified. It was founded on advice from (Watershed HydroGeo, 2019) that rapid drawdown to levels lower than pre-mining levels and increased rate of recession (drainage) in the water tables in colluvial sediments of swamps had not been observed at Dendrobium Mine to that point in time in swamps further than 60 m from a longwall panel. Extracts from the Panel's advice include:

- *The Panel considers that the (Watershed HydroGeo, 2019) report is the most relevant available evidence regarding potential hydrological impacts to Swamp 15a.*
- *This does not necessarily mean that all the impacted sites at Swamp 15a will be within 60 m of the longwall: the potential for impacts beyond 60 m is clear from the previously observed impacts in drainage lines in Areas 3A and 3B (see for example, MSEC (2020), Section 5.4.4).*
- *The impacts on Swamps within 60 m of a longwall happen quickly and the magnitude of the hydrological change is significant in the analysis presented by Watershed Hydrogeo.*
- *Avoiding mining within 60 m of a Swamp therefore avoids this type of rapid impact but may not avoid more progressive or subtle impacts where vertical permeability changes are smaller and subsurface cracking frequency is much less than within 60 m.*
- *Slower and more subtle impacts for the Swamp areas beyond 60 m of longwalls would need to be measured over longer time frames and be measured both in terms of a change to the median groundwater or soil moisture conditions relative to reference swamps.*
- *The Panel concludes that, at the very least, LW19 would need to be setback a distance of 60 m from the edges of Swamp 15a in order to satisfy Condition 5 regarding ecosystem functionality of the swamp.*
- *Monitoring of shallow groundwater should be re-established and continued across Swamp 15a to assess long term compliance with the Condition.*

Subsequently, LW19 was approved after being setback an additional 100 m. This resulted in the proportion of the Swamp 15a originally located within 60 m of the longwall footprint being more than halved (resulting in 1.84% of Swamp 15a remaining within 60 m of LW19 (DPIE, 2021)).

3.6. LW19 END OF PANEL REPORT

Extraction of LW19 commenced in June 2022 and was completed in March 2023. Condition 9 of the Dendrobium Consent requires that an End of Panel Report be produced within four months of the completion of each longwall panel and that the report describes in detail associated subsidence effects, impacts and consequences and compares these with predictions. Condition 10 requires that an Applicant also includes a comprehensive summary, analysis and discussion of the results of monitoring of subsidence effects, subsidence impacts and environmental consequences in each Annual Review.

The 2022 Annual Review was published some time prior to the Panel finalising this advice. However, the LW19 End of Panel Report, which can be expected to contain much more detailed information on monitoring and analysis of the environmental impacts and consequences associated with the extraction LW19 and to inform adaptive management, was only published on the eve (31/7/23) of the Panel submitting this advice. Hence, the Panel has had to rely on the information provided by South32 when the company addressed the Panel's discussion points. It is aware that at some other mines where up-to-date monitoring data and its analysis are critical to managing environmental impacts and consequences, the Department now requires this information to be produced at set and regular time intervals (e.g. 3 monthly or 6 monthly) in order to better inform adaptive management.

The availability of information that was more up to date because of this arrangement would likely have been very beneficial in informing the design of LW19A, in particular the setback distance, and the Panel's assessment of the LW19A SMP.

4.0 PERFORMANCE MEASURES AND INDICATORS

Current performance measures and indicators for the extraction of longwalls LW19A have been derived from the Dendrobium Development Consent and Longwall 19 SMP Approval. These performance measures are presented in Table 2 (reproduced from the current SIMMCP – South32, 2022a).

Table 2: Subsidence Impact Performance Measures

Dendrobium Development Consent
Condition 5 – Schedule 3 • Operations must not cause erosion of the surface or changes in ecosystem functionality of Swamp 15A and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Secretary.
Longwall 19 SMP Approval Conditions
Condition 8 – Schedule 3 The Applicant must ensure that the development does not cause any exceedance of the performance measures below, to the satisfaction of the Secretary. *Swamp 15A* Negligible environmental consequences including: • negligible erosion of the surface of the swamp; • negligible change in the size of the swamp; • negligible change in the ecosystem functionality of the swamp; • negligible change to the composition or distribution of species within the swamp; and • maintenance or restoration of the structural integrity of rockbar SC10-RB15A.

A detailed list of the performance measures, indicators and triggers relating to the swamps is included in the TARPs for the current SIMMCP for longwalls LW19 and LW19A (Appendix A: Table 1.3 of South 32 2022a). For easy reference this table is reproduced in Appendix A of this Panel advice.

The Panel notes that for the specific case of Swamp 15a, the Performance Measure is absolute with respect to ecosystem functionality – *'must not cause….. changes'*.

The Development Consent does not define *'ecosystem functionality'*. However, dating back to before the framing of the Development Consent Conditions, ecosystem functionality has been defined in literature in terms that reflect biological, chemical and physical processes that occur within an ecosystem made up of plants, animals and microbes that sustain terrestrial life. BCD's presentation to the Panel reports that:

> Ecosystem function is the technical term used to define the biological, geochemical and physical processes and components that take place or occur within an ecosystem (Maynard et al, 2010; Maynard et al 2012; Ricklefs et al 1984)

Two critical considerations arise from the Performance Measure for Swamp 15a in respect of no change in ecosystem functionality:

1. For TARP performance indicators to be effective tools for the purpose of providing timely warning against breaching of the Performance Measure during progression of a longwall, they would need to:
    i. cover mining-related effects, impacts or consequences which can cause a change in ecosystem functionality;
    ii. have been correlated to the thresholds at which changes in ecosystem functionality occur; and
    iii. be measured in time to inform adaptation
2. Where performance indicators are not available to satisfy all the conditions listed in the points above, the primary and, effectively, only control available to assure no change in ecosystem functionality is to apply appropriate setback distances.

Since 2013, vegetation changes – swamp size; species richness, distribution, composition and diversity; and vegetation sub-communities – have been used as surrogates for ecosystem functionality for approvals of mining at Dendrobium Mine. South32 proposes to continue with this approach. The Independent Expert Panel for Mining in the Catchment (IEPMC), the IEAPM/IAPUM and BCD have all expressed concerns about the appropriateness of this approach for assessing ecosystem functionality[7]. This Panel repeats portions of the advice of the IAPUM Panel convened for the Dendrobium LW19 SMP and expands on some aspects.

Section 3.9.1 of the SIMMCP for LW19 and LW19A reports that:

> *At the Agency Consultation Workshop 27 May 2013 there was discussion about the definition of 'ecosystem functionality' in relation to subsidence impact performance measures for swamps. The term 'ecosystem functionality' is included in Table 1 of Condition 13 of the SMP Approval. The term is not included in the definitions of the Approval.*
>
> *At the workshop it was stated that the BCD disagrees with the definition of ecosystem function included in the Plans as they consider it is too simplistic and does not cover shallow groundwater levels. DPIE advised the intent of the performance measure relating to ecosystem functionality for swamps was more general in intent; basically, the swamp will remain a swamp.*
>
> *The outcome of the workshop was that IMC is to propose a definition in the next version of the SIMMCP which was approved in the 3C SIMMCP. Therefore, ecosystem functionality of swamps is to be measured via the following attributes: the sizes of the groundwater dependent communities contributing to the swamps. Specifically, any changes in the proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps.*

The Panel considers that:

1. The definition of ecosystem functionality proposed by the mine operator in 2013 and incorporated into subsequent SIMMCPs:
    i. neither reflects the general informed meaning of the term at the time of the Development Consent (and certainly as at 2013), and
    ii. nor is it appropriate and effective for achieving the intent that a swamp will remain a swamp.
2. The criterion based on '*any changes in the proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps'* does not constitute a logical performance indicator for circumstances where the Performance Measure is one of 'no change'.

[7] Reference, for example, IEPMC, 2019b; IAPUM (2021) and BCD (2013) as quoted in South32, 2022a.

3. In any event, the performance indicator:
    i. is incomplete as it does not adequately address the distribution of the groundwater-dependent communities in Swamp 15a[8];
    ii. does not provide adequate early warning of the need to modify mining activities in order to avoid causing changes in ecosystem functionality (refer to IAPUM advice re SMP for LW19 (IAPUM, 2021)); and
    iii. does not have adequate regard to some of, if not the highest, potential environmental consequences of a reduction in moisture content of a swamp, these being associated with a hotter burn in the event of a bushfire. These consequences apply to flora, fauna and the structural integrity of a swamp.

IEPMC (2019) concluded (Section 4.4.1) that:

> *By definition, swamps are groundwater-dependent ecosystems. Therefore, a change in piezometric levels should be the primary gauge of impacts on the ecosystem. If maintenance of ecosystem functionality is to be mandated for any swamp, then piezometric variation must be used not only in TARPs but also in performance measures.*

The Panel concurs and considers that to avoid changes in ecosystem functionality, the groundwater conditions must be maintained.

It is concluded that:

- There is a need to redefine the meaning of *'ecological functionality'* relied upon by Dendrobium Mine in its SIMMCPs so that it reflects informed general usage.
- Irrespective of whether the meaning of *'ecological functionality'* is redefined, a primary criterion for determining if ecosystem functionality of swamps is being impacted by mining should be changes in hydrology.

Fundamentally, an approach based on a Trigger Action Response Plan (TARP) and associated performance indicators, such as that adopted in the SIMMCP for Swamp 15a, is not suitable for managing risk in order to satisfy a Performance Measure of no change in ecosystem functionality of a swamp. This is because there is a lack of parameters that can function as timely indictors that threshold values for instigating change in ecosystem functionality are being approached. Shallow groundwater behaviour appears to provide the earliest measurable indication of mining-induced impact on a swamp. In the case of Swamp15a, however, it is the Panel's opinion that any impact on the shallow groundwater constitutes a change in the ecosystem functionality of the swamp and hence, an exceedance of the Performance Measure. Therefore, its measurement cannot provide an early warning of potential impacts. Rather, this response finds most value in informing the design of future longwall panels.

Irrespective of the Panel's views on what constitutes ecosystem functionality, the Panel considers that in regard to Table 1.3 of Appendix A of the SIMMPC (South32 (2022a)), the performance measure *"Minor changes in the ecosystem functionality of the swamps"* is not commensurate with a performance measure that includes *"does not cause … changes in ecosystem functionality of Swamp 15a"*. Furthermore, the Panel considers that the swamp groundwater level performance triggers in Table 1.3 could permit an inappropriate number of mining-related impacts to the swamp groundwater prior to a level 3 trigger.

[8] The use of three communities – Banksia Thicket (MU42), Tea Tree Thicket (MU43) and Sedgeland-heath Complex (MU44) – obscures the significance of the differentiation of Sedgeland-heath Complex (MU44) into two relatively dry sub-communities of Sedgeland (MU44a) and Restioid heath (MU44b) plus the sub-community Cyperoid heath (MU44c) which occupies area with permanently highwater tables.

The Panel considers that a mining-related groundwater impact at any monitoring site in Swamp 15a that is outside of the natural variability of water levels as determined by local baseline data and/or a suitable control site should indicate a change to ecosystem functionality of the swamp.

5.0 SUBSIDENCE ASSESSMENT AND IMPACTS

This section is concerned with assessing the potential impacts of the proposed layout of LW19A on Swamp 15a, the likelihood of satisfying Consent Condition 5, Schedule 3 and aspects of monitoring for environmental impacts. The Panel considers that in these circumstances, as a matter of due diligence, the final dimensioning of LW19A and the Panel's deliberations should have regard to the environmental performance of LW19 but the End of Panel Report with this information is not yet due for release.

5.1. RECENT IMPACTS IN ADJACENT AREAS 3B AND 3C

5.1.1. Area 3B

End of Panel impact assessments (incorporated in MSEC 2022a; South32 ,2022c; HGeo, 2022b and 2022c) are available for the last longwall extracted in Area 3B, being LW18 which commenced in December 2021 and was completed in May 2022. The depth of cover over this longwall ranged between 300 m and 370 m. The LW18 End of Panel contains the most comprehensive assessment of environmental impacts (post-mining) immediately available to the Panel since preparing its advice on the LW19 SMP in February 2021.

LW18 is the southernmost and last panel in Area 3B and is located between Lake Avon and Wongawilli Creek. It is located approx. 3 km south-west of proposed LW19A. Impacts to adjacent southerly swamps are described in the End of Panel Assessment Report *Surface Water and Shallow Groundwater* (HGeo, 2022b) and in an Impact Report issued on 14 March 2023 in relation to Swamp 35b (South32, 2023d). The swamps and their respective settings are:

- Swamp 35a – located above roadways on the southern boundary of LW18 (monitored)
- Swamp 35b – located 90-140m south of LW18 (monitored)
- Swamp 150 – located approx. 200m south of LW18 (monitored)
- Swamp 151 – located approx. 400m south of LW18 (monitored)

For Swamp 35a, there is no evidence of mining-induced impacts at the completion of LW18. The hydrograph for the only swamp piezometer shows that shallow groundwater levels have continued to recover following the 2017-2019 drought.

For Swamp 35b, up until September 2022 (when the LW19A SMP was lodged) there was no clear evidence of mining-induced impacts at the completion of LW18 (HGeo, 2022b). However, more recent monitoring (reported on 14 March 2023) has indicated an exceedance of the groundwater recession trigger since December 2022 (South32, 2023d). The piezometer monitoring this swamp is located 116 m south of LW18 and is currently dry. This appears to be a mining-induced impact, which may be due to mining-induced regional groundwater depressurisation or due to fracturing of the swamp's base. Further detailed impact assessment of Swamp 35b is required.

For Swamp 150, up until September 2022 there are high levels of saturation in the swamp with no evidence of mining induced impacts during or following the completion of LW18. In late 2022, approximately 7 months after the end of mining of LW18, based on the data provided to the Panel by BCD, the water level declined rapidly until the piezometer was dry for most of February-March 2023, with partial recovery until the end of the available record in April 2023. The short pre-mining baseline period makes it difficult to determine whether the dry conditions at this site from February-April 2023 were solely due to dry weather or were also affected by mining.

For Swamp 151, up until September 2022 there are high levels of saturation in the swamp with no evidence of mining induced impacts during or following the completion of LW18. In late 2022, approximately 7 months after the end of mining of LW18, based on the data provided to the Panel by BCD, the water level declined rapidly until the piezometer was dry for most of February-March 2023,

with partial recovery until the end of the available record in April 2023. The short pre-mining baseline period makes it difficult to determine whether the dry conditions at this site from February-April 2023 were solely due to dry weather or were also affected by mining.

The shallow (perched) groundwater in these four swamps is sustained by rainfall recharge and runoff from adjacent areas. The connectivity with the regional water table in the Hawkesbury Sandstone is uncertain but available evidence (based on data extracted from HGeo, 2022b and 2022c) suggests the two groundwater systems are unlikely to be in hydraulic connection.

The LW18 End of Panel shallow groundwater report (HGeo, 2022b) concluded there was *'no evidence for hydrological change in shallow groundwater piezometers located more than 60m from the extracted longwall margin'.* This conclusion may no longer apply in light of the probable mining-induced impact subsequently observed in Swamp 35b at a distance of 116 m from the edge of LW18, and potentially the water level declines observed at greater distances in Swamps 150 and 151.

Impacts to the deeper groundwater systems are described in the End of Panel Report for LW18 (HGeo, 2022c). There are four primary VWP monitoring sites located immediately south of LW18 (S2490, S2441, S2443 and S2465). All sensors in the Hawkesbury Sandstone at all four sites indicated static or rising water levels indicative of rainfall recharge. As at July 2022, there was no evidence of mining-induced drainage/depressurisation of this aquifer system, although there is depressurisation of deeper aquifers in the constrained zone in the Narrabeen Group strata. The Panel would need to see data/hydrographs for the last 12 months to confirm that there is still no evidence of depressurisation in the Hawkesbury Sandstone aquifer.

5.1.2. Area 3C

Area 3C is located immediately north of Area 3A and is located beneath the ridgeline area between Wongawilli Creek and Lake Cordeaux. LW21 is the southernmost longwall panel in this area and is 2 km north of proposed LW19A. Extraction of LW21 commenced in April 2023, and in recent months a number of Impact Reports have been submitted to the Department. Most relate to observed landscape impacts (soil cracks and rock fractures); however, one very recent report, dated 28 June 2023, relates to Swamp 144 where the post mining rate of water level recession in the swamp piezometer exceeded the rate recorded at the same depth interval before mining (South32, 2023a). A similar trend was observed in the soil moisture probe data.

This accelerated decline is reported to have been observed when the longwall passed the swamp monitoring site at a distance of 68 m in late May 2023. However, this distance is not consistent with the location of the monitoring site shown on mine plans. This includes Figure 1 of the Impact Report of 28 June 2023, from which the Panel has determined that the site is of the order of 120 m from the longwall. The Panel has subsequently noted that back on 13 June 2023, BCD reported this distance to be 118 m (BCD, 2023). South32 confirmed in its later discussions with the Panel (26/7/23) that the site is close to 120 m from LW21. While the impact is reported to have been observed in late May 2023, the Panel notes that a prior falling water level trend potentially due to the advancing longwall or below average rainfall was evident in April 2023.

5.1.3. Significance of Recent Impact Reports

The Impact Reports of 14 March 2023 in relation to Swamp 35a and the 28 June 2023 in relation to Swamp 144 are very likely indicative of mining-induced hydrological changes in shallow groundwater beneath swamps extending beyond a distance of 120 m from longwall panels. This being the case, the setback distance required to protect the swamp groundwater levels and thus, the ecosystem functionality of the swamps from this impact, is unknown but greater than 120 m.

5.2. Area 3A – Potential Environmental Impacts for Swamp 15a

5.2.1. Recent Impacts in Area 3A Relevant to Swamp Hydrology

The Department has advised that a large number of Impact Reports (approx. 65 to date) have been submitted for LW19, the vast majority of which relate to observed landscape impacts (soil cracks and rock fractures) and are located in the Wongawilli catchment at or near the western portion of LW19. There are three impact reports that relate to swamp groundwater/soil moisture levels associated with LW19 and that are relevant to assessing swamp hydrology – one for Swamp 148 (South32 2023b), one for Swamp 15b (South32 2023c), and one for Swamp 15a (South32 2023e).

At Swamp 148, a soil moisture probe and datalogger indicated soil moisture data lower than the lowest data recorded during the (wet) baseline period. The timing was associated with the passage of LW19 just 47 m to the north. The monitoring site S148_01 entered the 400m buffer zone on 23 September 2022 and was passed by LW19 on 5 December 2022. Graph 1 of the impact report (South32 2023b) shows that the drop in soil moisture began in early November 2022 when the longwall would have been further from the swamp. Swamp 148 has no groundwater monitoring to confirm the loss of saturation.

At Swamp 15b, four soil moisture probes and dataloggers indicated soil moisture data lower than the average soil moisture data recorded during the (wet) baseline period. This 'impact' was triggered during the last months of LW19 panel extraction in early 2023. The Panel believes that this 'impact' could partially be associated with less rainfall at this time rather than the earlier passage of LW8 (completed in December 2012) and the passage of LW19 (completed in March 2023). Impact assessment needs to factor in rainfall patterns (such as comparisons with cumulative rainfall deficit (CRD)) and this impact report is an example of insufficient baseline data to confirm whether a mining induced impact has in fact occurred.

At Swamp 15a, a very recent impact has been reported at shallow swamp piezometer location 15a_19 and soil moisture location S15a_19 due to the passage of LW19. The piezometer is dry and there are substantially reduced soil moisture levels. These sites are located approx. 140 m south-west from the start of LW19 and approx. 70 m from the closest edge of the longwall. Declines commenced in September-October 2022, and there has been no recovery in moisture or water levels in 2023.

The Panel believes this is most likely a mining-induced impact, which may be due to regional groundwater depressurisation or (more likely) due to fracturing of the swamp's base at this location. Further detailed impact assessment is required to ensure that the sudden drop in water/moisture levels is not partially attributable to a climate induced response resulting from recent very dry conditions.

5.2.2. Controlling Rockbar SC10-RB15a

Consent Condition 5 - Schedule 3, requires the structural integrity of the controlling rockbar for Swamp 15a to be maintained or restored, to the satisfaction of the Secretary.

The Consent Condition does not identify the controlling rockbar but Condition 8 – Schedule 3 identifies it as rockbar SC10-RB15a. The subsidence assessment (MSEC, 2022b) does not give any consideration to this rockbar. This is reasonable since, as shown in Figure 7, SC10-RB15a is too remote to fall within the study area for LW19A.

5.2.3. Erosion

Consent Condition 5 - Schedule 3, requires that the Applicant must ensure that subsidence does not cause erosion of the surface of Swamp 15a.

There is potential for a reduction in soil moisture and saturated conditions within Swamp 15a due to the proposed LW19A. This could increase the possibility that Condition 5 will not be achieved in relation to "erosion of the surface" and potentially reduce resilience of swamps to fire and subsequent gullying (IEPMC, (2019), Section 4.2.2). Nevertheless, it is noted that erosion of the surface of the swamps as a result of mining has not yet been observed in Area 3B (South32, 2020)[9] and erosion is unlikely to occur or be observed until well after mining has stopped.

The Panel does not see a useful measure of erosion that can be used to assess compliance within a short time frame and thus suggests that monitoring of erosion and soil moisture as proposed in the SMP be carried out to ensure long-term compliance.

5.2.4. Water inflow to Swamp 15a

The surface water assessment of impacts relating to the extraction of LW19A states *'there is potential for minor and localised increases in ponding and scouring in those drainage lines'* (i.e. the second order tributaries of Wongawilli Creek and Sandy Creek (HGeo, 2022a)) and *'Fracturing and diversions of flow are possible on SC10 and first-order tributaries SC10A and SC10B where those tributaries pass within 400 m of the longwall… Those effects would be most noticeable during periods of low flow and may not result in detectable losses at downstream flow gauges (SC10S1, SCL2), nor at Sandy Creek Waterfall.*

Most of the catchment of SC10B not already undermined by LW19 may lose flow from mining LW19A. Hence, there is potential for loss of flow into Swamp 15a, particularly the long pool SC10-PO26, shown in Figure 7, although it is also possible that the diverted flow will return to the creek prior to reaching this pool. Further, a small loss of baseflow and considerable increase in zero-flow days is predicted in SC10 due to groundwater depressurisation associated with LW19A and cumulative impacts (HGeo, 2022a). This is another potential factor that could have environmental consequences for Swamp 15a.

5.2.5. Connective Fracturing

The potential for near surface water to be drained from Swamp 15a into a subsidence-induced connective fracturing network between the surface and the mining horizon is an important consideration. The zone of vertically connected fracturing above a longwall goaf is generally conceptualized as being cone shaped and, therefore, not overlapping with the connective fracturing network above an adjacent longwall panel. However, water may still flow laterally from well beyond these fracture zones and between these fracture zones along natural and mining-induced 'horizontal' conduits. Mining-induced conduits include fractures, bedding partings and bedding plane shears that are formed or enhanced by mining.

The LW19A SMP does not specifically consider these factors and their significance for maintaining the hydrology of Swamp 15a. A significant aspect which does not appear to have been considered in the SMP is the potential implications associated with a portion of Swamp 15a already falling within 22 m of the footprint of LW19. This is an important consideration given the sandy nature of Swamp 15a. If there is lateral connection between near surface water in Swamp 15a and the zone of connective fracturing above LW19 then the possibility that, at least in the longer term, LW19 has a greater impact

[9] Section 4.4

on Swamp 15a than LW19A cannot be discounted on the basis of the information that supports the SMP.

A core consideration is the height of connective fracturing. Analysis undertaken by the Panel indicates that if the Tammetta Model for predicting the height of connective fracturing prevails, then connective fracturing will extend to the surface above LW19 and LW19A. On the other hand, if the Ditton Model prevails then, depending on model input assumptions, the depth of near-surface fracturing and error bands, there should be at least 50 m , and possibly up to 100 m, of strata above the top of the zone of connective fracturing.

This is a matter that warrants specific consideration in the SMP.

5.2.6. Structural Integrity of the SC10 Rockbars within Swamp 15a

T6.1 of South32 (2022a) Performance Measure: "Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps"

Figure 7 shows the location of 12 rockbars on SC10 (RB16-27) that are upstream of the main controlling rockbar (RB15A). All these rockbars control SC10 pool water levels and, therefore, potentially control interaction of SC10 flows with the swamp hydrology. Predicted cumulative valley closures up to the completion of LW19 corresponded to low probabilities of Type 3 fractures (*fracturing in rockbar or upstream pool resulting in reduction in standing water level based on current rainfall and surface flow*[10]) according to the MSEC rock bar model, being a maximum of 5% at rockbar SC10-RB24. The extraction of the proposed LW19A is predicted to result in incremental closure of up to 50 mm (Table 5.12 of MSEC, 2022b). While this incremental increase may appear relatively small, it is significant because at 10 of the rockbars it results cumulative predicted closure values that are associated with significantly higher likelihoods of Type 3 fractures.[11]

The predicted probability of any one (or more) of the 10 rockbars fracturing following LW19 and prior to LW19A was approximately 26% (Panel calculation applying the rock bar model independently to each of the 10 rockbars). Incremental valley closure due to LW19A increases the probability at RB24 to 15% and at any one of the rockbars to 44%. The Panel concludes that there is a moderate likelihood of a Type 3 fracture and associated loss of pool water levels at one or more of the SC10 pools. However, considering in particular that the swamp in the area appears to be on a hill-slope that would limit the flow of water from creek to swamp, it is unclear whether and to what extent loss of pool water would affect the swamp ecosystem. Further, it is reasonable to manage the risk of pool drainage by remediation, assuming that access is practicable. This does not discount the likelihood of fractures in the sandstone directly underlying the swamp away from the creek, which in the Panel's opinion could not be successfully remediated and need to be managed by appropriate setback distances.

5.2.7. Conventional Subsidence Impacts within Swamp 15a

The assessment of conventional surface subsidence for LW19A has been based on an angle of draw of 35° (MSEC, 2022b). This corresponds to a lateral distance from the goaf edge of LW19A of 0.7 depth, or approximately 210 m in the vicinity of Swamp 15a. MSEC (2022b) reports that fracturing of bedrock could occur beneath Swamps 12, 15a, 15b, 15c and 148 and that dilated strata beneath the drainage lines could result in the diversion of some surface water flows beneath parts of the swamps where they are located above and adjacent to the proposed LW19A. It is stated that where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of

[10] p35 of MSEC, 2022b
[11] Refer to Fig 5.4 and Table 5.14 of MSEC, 2022b

fracturing and dilation. The subsidence assessment does not give any consideration to the consequences of these impacts on Swamp 15a, both at the site of the impacts and upstream of the impact sites, instead deferring to other specialist consultants.

5.2.8. Non-conventional Subsidence Impacts within Swamp 15a

The proposed layout of LW19A results in an incremental increase in predicted valley closure for Swamp 15a of 100 mm and a maximum predicted total closure of 225 mm. This is predicted to result in a total compressive strain, based on a 95% confidence level, of 5mm/m. MSEC, 2022b reports that fracturing of bedrock as a result of longwall mining has been observed in the past where compressive strains have been greater than approximately 2 mm/m.

5.2.9. SIMMCP Conclusions Re Shallow Groundwater Impacts

The SIMMCP (South32, 2022a) concludes in several places that it is *'likely that shallow groundwater levels will be impacted at Swamp 15a'*.[12] That conclusion calls into question the adequacy of the proposed 61 m setback.

5.2.10. Adequacy of the 61 m setback threshold

Together, the recent impact reports from Areas A, B and C appear to provide clear evidence that a setback distance of 60 m is inadequate for ensuring that moisture levels in Swamp 15a will not be impacted by longwall mining. They provide new evidence to suggest mining-induced dewatering impacts to swamps may extend to, at least, 120 m from the edge of a longwall within a relatively short time after mining. The ultimate extent is currently unknown.

Slower and more subtle impacts for the swamp areas beyond 120 m of longwalls need to be measured over longer time frames and be measured in terms of changes to the median groundwater level and/or soil moisture trends relative to reference swamps. The requirement for longer periods of baseline data covering different climatic cycles and nearby control sites cannot be overstated. However, in the case of Swamp 15a, that time frame is not available. The Consent Condition requires that the ecosystem functionality not be changed. Therefore, only an extremely low risk of impact can be considered acceptable and the only effective control to achieve this is a judicious setback distance that errs on the side of caution.

The Panel concludes that:

- LW19A should be setback at a distance greater than 120 m from the closest edge of Swamp 15a in order to satisfy Condition 5 regarding ecosystem functionality of the swamp.
- There is a lack of monitoring data and analysis available to the Panel for it to express an opinion on what the setback distance of LW19A should be for it not to result a change in ecosystem functionality in the long term. That is not to say that the relevant information may not exist.
- Monitoring of shallow perched groundwater should be continued across Swamp 15a to assess long term compliance with Condition 5. Monitoring of shallow and deep groundwater in the Hawkesbury Sandstone adjacent to the swamp is also required to confirm the current hydrogeological conceptualisation.

[12] p39, p40 & p43 of SIMMPC (South32, 2022a)

The Panel recommends that:

- As a minimum requirement to meet Condition 5 regarding ecosystem functionality of Swamp 15a, LW19A should be setback at a distance of, at least, 120 m from the closest edge of Swamp 15a. The may or may not prove to be adequate with the passage of time.
- Monitoring of shallow groundwater in the swamp should be continued and expanded across Swamp 15a in order to assess compliance with the Condition 5.
- Monitoring of groundwater in the underlying sandstone adjacent to the western edge of Swamp 15a is required given that VWP 1888 will be destroyed once the longwall commences. A nested standpipe location monitoring shallow and deeper aquifers in the Hawkesbury Sandstone west of the swamp at an accessible location is required to confirm whether there is any emerging evidence of connected cracking or further depressurisation impacting these aquifers.

6.0 SUMMARY CONCLUSIONS

This Panel advice is not based on all the required evidence. The End of Panel Report for LW19, which commenced extraction adjacent to Swamp 15a in June 2022, was only published the day before submitting this advice. Hence, the Panel has not had an opportunity to review relevant aspect of the analysis of subsidence effects, impacts and consequences required to be presented in that report. There is also no comprehensive reporting of soil moisture/groundwater data elsewhere since February 2022 even though some hydrographic data is available for 2023.

Conclusions

21. The definition of ecosystem functionality devised in 2013 and adopted in the Swamp Impact, Monitoring, Management and Contingency Plan (SIMMCP) for Longwalls 19 and 19A (and some other previous longwalls) neither reflects the universal definition of the term that has prevailed for at least the last three decades (and, hence, at the time when it was written into the Consent Conditions for Dendrobium Mine) nor general informed usage of the term.
22. In particular, the established definitions of ecosystem functionality allude to physical processes, a key aspect of which is the swamp soil hydrology; a parameter that is not reflected in the definition of ecosystem functionality in the SIMMCP.
23. Since a change in swamp hydrology at any monitoring site reflects a wider hydrological change, the area of which may be large but unmeasured, a change to the hydrology at any site should be regarded as indicating a change in swamp ecosystem functionality.
24. Any observed changes to the hydrology at any site in Swamp15a are a reflection of a wider hydrological impact, the area of which may be large but undetectable due to the sparseness of shallow groundwater monitoring sites. This cannot be fully resolved by adding more monitoring sites.
25. If the Dendrobium-centric definition of ecosystem functionality continues to prevail, it is incomplete and warrants updating.
26. In respect to advice presented in the SMP for LW19 that rapid drawdown to levels lower than pre-mining levels and increased rate of recession (drainage) in the water tables in colluvial sediments of swamps had not been observed at Dendrobium Mine to that point in time in swamps further than 60 m from a longwall panel, the Panel concludes on the basis of its assessment of recent Impact Reports relating to Swamp 35b, Swamp 144 and Swamp 15a as well as hydrological and other data, that this is no longer the case. Observations of this behaviour have since been recorded at distances close to 120 m from the edges of longwall panels.
27. Based on the Panel's assessment of information currently available to it, the Panel is of the opinion that that a setback distance of at least 120 m is the minimum distance required to protect the ecosystem functionality of Swamp 15a from being impacted by depressurisation or drainage of shallow groundwater. Still, this may not prove sufficient.
28. This situation is consistent with the IAPUM's advice on the SMP for LW19, which foreshadowed that it could arise with the passage of time and with the benefit of additional monitoring outcomes.
29. Given the high standard set by the Performance Measure for Swamp 15a, the irreversible nature of impacts, the lack of effective controls other than setback distance and the uncertainties in the underpinning knowledge base, prudent risk management may require a significantly greater setback distance than 120 m.
30. Rockbar SC10-RB15a, which is the controlling rockbar for Swamp 15a, is located a sufficient distance from LW19A that it is very unlikely to be impacted by the extraction of LW19A.

31. There are 10 other rockbars within, adjacent or near to Swamp 15a at which predicted valley closures due to the cumulative effects of LW19 and LW19A are significant. The predictions imply a moderate likelihood that fracturing and subsequent pool drainage at one or more of these pools will occur. Reductions in the levels of these pools may locally impact swamp water levels and the riparian ecosystem.
32. The SIMMCP for Longwalls 19 and 19A contains conflicting descriptions of the proximity of Swamp 15a to LW19A and incorrect monitoring network data.
33. The adequacy of the proposed 61 m setback is called into question by the subsidence assessment which states that fracturing of bedrock could occur beneath Swamp 15a and by the SIMMCP which reports that it is *likely that shallow groundwater levels will be affected at Swamp 15A.*
34. Fundamentally, the TARPs incorporated into the SIMMCP are not suitable for managing the risk of impacts to the ecosystem functionality of Swamp 15a because:
    a. There are no real time performance indicators suitable for pre-empting impending mining-induced changes in the ecosystem functionality of a swamp.
    b. The time lag between cause and impact on ecosystem functionality is too long for identifying the need to implement preventative measures (responses) during active mining in time for them to be effective.
    c. Swamp soil moisture, groundwater dependent community and species changes that are the basis for current TARPs for Swamp 15a ecosystem functionality can, themselves, be irreversible impacts of mining.
35. For the above reasons, options for adopting effective, TARP driven, adaptive management during extraction of a longwall panel are virtually non-existent when it comes to managing the risk of impacts to the ecosystem functionality of swamps, including Swamp 15a.
36. For Swamp 15a, the only feasible option for practising adaptive management is the selection prior to the commencement of extraction of each longwall panel, of an appropriate setback distance based on field experience; setback distance from Swamp 15a is the critical (essential) primary control in the case of LW19A.
37. Some of the Performance Indicators and TARPs proposed in the SIMMCP are relevant to mitigating other impacts, such as erosion.
38. Remediation of swamps has yet to be proven technically feasible.
39. Due to the lack of other effective and timely controls and multiple lines of defence (barriers), and in recognition of the lack of options currently available for remediating swamps, risk management principles require a high level of confidence in the adequacy of the setback distance of LW19A from Swamp 15a.
40. The requirement for End of Panel reports to be published within four months of the completion of a longwall panel is not achieving one of its important original objectives of effectively informing adaptive management, as evident in this matter where the End of Panel Report for LW19 has been published, in accordance with Approval Conditions, some 13 months after LW19 was extracted next to Swamp 15a.

7.0 SUMMARY RECOMMENDATIONS

Based on the assessment of available information and the potential impacts to Swamp 15a, the Panel recommends that:

1. In order to avoid changes in ecosystem functionality, the setback distance of LW19A from Swamp 15a should be in excess of 120 m. There is insufficient information available to the Panel to recommend at upper bound for setback distance.
2. The definition of Ecosystem Functionality is outdated and inadequate and should be revised to accommodate all processes (such as swamp hydrology) that are essential for swamps and their dependent ecosystems.
3. The performance indicators for assessing compliance with Performance Measures related to the ecosystem functionality of a swamp should include perched groundwater levels in the swamp, in addition to those related to swamp size, species and vegetation communities.
4. An observable change to perched groundwater level at any site in Swamp 15a due to mining should be treated as a change to ecosystem functionality.
5. Performance indicators for pool water levels should be proposed for selected pools, with TARPs including provision for assessing if remediation is warranted and feasible to prevent changes to the swamp ecosystem functionality.
6. The locations of the proposed pool water level, shallow groundwater and deep groundwater monitoring sites that are included in the SIMMCP should, prior to approval of the LW19A SMP, be independently reviewed for adequacy to detect the nature and magnitude of any mining-induced change.
7. The Department should encourage proponents to ensure longer baseline periods to assess potential impacts, and ensure that longer monitoring periods occur post-mining (and post End of Panel reporting) to further evaluate performance indicator trends and to confirm whether there are long-term mining-induced impacts.
8. The South32 monitoring program for Swamp 15a should include:
    a. Continued and expanded monitoring of shallow groundwater in the swamp across Swamp 15a to be able to assess compliance with the Condition 5.
    b. Monitoring of groundwater in the underlying sandstone adjacent to the western edge of Swamp 15a given that VWP 1888 will be destroyed once the longwall commences. A nested standpipe location monitoring shallow and deeper aquifers in the Hawkesbury Sandstone west of the swamp at an accessible location is required to confirm whether there is any emerging evidence of connected cracking or further depressurisation impacting these aquifers.
9. Dendrobium Mine should be required to prepare six monthly reports, or suite of reports, that detail monitoring data and analysis relevant to assessing subsidence effects, impacts and environmental consequences.
10. The SIMMPC for LW19 and LW19A should be revised and reissued.
11. In future, in circumstances where the location of a longwall installation roadway determines the setback distance from a feature that requires a degree of protection from mining-induced impacts, approval conditions should require that within three months prior to commencing the drivage of the installation roadway, the appropriateness of the planned location of the installation roadway is to be confirmed/reaffirmed by undertaking a review of all relevant monitoring data to the satisfaction of the Department Secretary.

REFERENCES

BCD. (2023). *Additional information on setbacks for biodiversuty for IAPUM consideration.* Biodiversity and Conservation Division. NSW Department of Planning and Environment. 13 June 2023

DPIE. (2020). *Dendrobium Mine Extension Project. Assessment Report for: State Significant Development SSD-8194. NSW Department of Planning, Industry and Environment*.

Hebblewhite, B. K. (2020a). Dendrobium Mine - Longwall 14-18. Independent Review - Height of Fracturing (Stage 3). Unpublished Report to NSW Department of Planning and Environment.

Hebblewhite, B. K. (2020b). Dendrobium Mine - Longwall 14-18. Independent Review - Height of Fracturing (Stage 4). Unpublished Report to NSW Department of Planning and Environment.

HGeo (2022a). Assessment of surface water flow and quality effects of proposed Dendrobium Longwall 19A. Report D22175 dated September 2022.

HGeo (2022b). End of Panel Surface Water and Shallow Groundwater Assessment:Longwall 18 (Area 3B). Report D22190 dated October 2022.

HGeo (2022c). End of Panel Groundwater Assessment:Longwall 18 (Area 3B). Report D22191 dated September 2022.

HGeo (2022d). Dendrobium Area 3A: Longwall 19a Groundwater Assessment. RevC dated September 2022.

HGeo (2023a) Addendum to Groundwater Assesment of Longwall 19A re:revised longwall geometry dated February 2023.

HGeo (2023b). Discussion with IEAPM: Dendrobium Swamp 15a and Longwall 19A SMP. Presentation slides dated 28 July 2023.

IEPMC. (2019). Independent Expert Panel for Mining in the Catchment (IEPMC) Report: Part 2. Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment. (Galvin, J.M., McIntyre, N., Young, A., Williams, R.M., Armstrong, C., Canbulat, I.). Office of Chief Scientist and Engineer. Sydney: Office of Chief Scientist and Engineer.

MSEC. (2019). Subsidence Report for Dendrobium Mine - Plan for the Future Coal for Steelmaking. Mine Subsidence Engineering Consultants. Report No. MSEC856 Rev. B.

MSEC. (2020). Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extaction of the Proposed Longwall 19 in Area 3A at Dendrobium Mine. Mine Subsidence Engineering Consultants. Report No. MSEC1082 Rev. C.

MSEC (2022a). End od Panel Subsidence Monitoring Review for Dendrobium Longwall 18. Report No. MSEC1267 Rev. A dated August 2022

MSEC (2022b). Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extaction of the Proposed Longwall 19A in Area 3A at Dendrobium Mine. Mine Subsidence Engineering Consultants. Report No. MSEC1234 Rev. B dated September 2022.

South32. (2020). Area 3A Swamp Impact Monitoring, Management and Contingency Plan. Appendix 3 of Dendrobium Area 3A LW19 Subsidence Management Plan.

South32. (2021). Area 3A Sandy Creek Waterfall Management Plan (Version 4).

South32 (2022a). Longwalls 19 and 19A - Swamp Impact, Monitoring, Management and Contingency Plan dated September 2022

South 32 (2022b). Geology of Longwall 19A dated March 2022

South 32 (2022c). Dendrobium Area 3B Longwall 18 End of Panel Landscape Report dated October 2022

South32 (2023a). Dendrobium Area 3C, IMC Impact Report_Swamp 144 dated 28 June 2023

South32 (2023b). Dendrobium Area 3A, IMC Impact Report_Swamp 148 dated 22 December 2022

South32 (2023c). Dendrobium Area 3A, IMC Impact Report_Swamp 15b dated 29 May 2023

South32 (2023d) Dendrobium Area 3A, IMC Update Report dated 14 March 2023

South32 (2023e). Dendrobium Area 3A, IMC Impact Report_Swamp 15a dated 17 July 2023

Watershed HydroGeo. (2019). Geographic Review of Mining Effects on Upland Swamps at Dendrobium Mine.

APPENDIX A – DENDROBIUM LW19 AND 19A –SWAMP TARP

Performance Measures	*Potential Impacts*	*Performance Triggers*	*Management Strategies*	*Offsets*	*Other Actions*
Negligible erosion of the surface of the swamp	Gully erosion or similar	*Level 1:* The increase in length of erosion within a swamp (compared to its pre-mining length) is **2%** of the swamp length or area; and/or Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring. *Level 2*: The increase in length of erosion within a swamp (compared to its pre-mining length) is **3%** of the swamp length or area; and/or Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention; and/or Gully knickpoint forms or an existing gully knickpoint becomes active. *Level 3:* The increase in length of erosion within a swamp (compared to its pre-mining length) is **4%** of the swamp length or area; and/or Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention. *Exceeding Prediction* Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase **>5%** of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (ie increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is **>5%**).	a) upfront mine planning b) erosion monitoring (ie ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	**Offset required immediately**, if no remediation considered practicable. **Offset required 2 years** following remediation, if it is ineffective. This period can be **extended to 5 years**, with the agreement of the Secretary.	
Minor changes in the size of the swamps **Minor changes** in the ecosystem functionality of the swamps **No significant change** to the composition or distribution of species within the swamps	Swamp vegetation changes: - Swamp size - Species richness, distribution, composition and diversity - Vegetation sub-communities	**Swamp Size** *Level 1:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the standard error (SE) of the Control Group. *Level 2:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem Functionality** *Level 1:* A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.	a) upfront mine planning b) vegetation monitoring c) water spreading d) seeding/planting e) weeding f) fauna monitoring g) fire management h) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques i) reporting j) investigation and review k) update future predictions	**Offset required immediately**, if no remediation considered practicable. **Offset required 5 years** following remediation, if it is ineffective. This period can be **extended to 10 years**, with the agreement of the Secretary.	Monitoring period for swamp size is related to capture of Lidar data at the end of each longwall ~ 1 year Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring

		Level 2: A trending decline in the extent of any groundwater dependent community within a swamp for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of any groundwater dependent community within a swamp for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Species Composition and Distribution** *Level 1:* A 2% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for two consecutive years; and/or *Level 2:* A 5% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for three consecutive years. *Level 3:* An 8% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for four consecutive years. *Exceeding Prediction:* Mining results in a >10% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for five consecutive years.			
Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	*Level 1:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of 10% compared to baseline for the pool (in addition to any decrease in reference pools). *Level 2:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of 20% compared to baseline for the pool (in addition to any decrease in reference pools). *Level 3:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of 20% compared to baseline for the pool for >20% of the time over a period of 1 year (in addition to any decrease in reference pools). *Exceeding Prediction* Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, ie pool water level within the swamp after CMAs continues to be >20% lower than baseline for >20% of the time over a period of 1 year.	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting h) investigation and review i) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the ecosystem	Falls in surface or near-surface	*Level 1:* Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or	a) upfront mine planning		Triggers for groundwater decline

functionality of the swamps	groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *Level 2:* Groundwater level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a **50%** of monitoring sites (within 400m of mining) within the swamp. *Level 3:* Groundwater level lower than baseline level at >**80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at >**80%** of monitoring sites (within 400 m of mining) within the swamp.	b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps). *Level 2:* Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). *Level 3:* Soil moisture level lower than baseline level at >**80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps).	a) upfront mine planning b) soil moisture monitoring c) water spreading d) weeding e) fire management f) reporting g) update future predictions		Triggers of soil moisture decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars