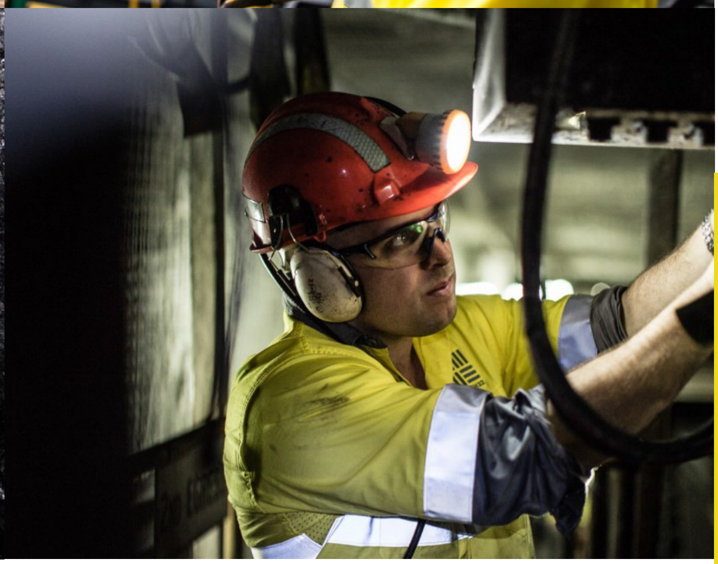
DENDROBIUM
AREA 3C

SEPTEMBER
2021



AREA 3C

SWAMP IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

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Review History

Revision	Description of Changes	Date	Approved
A	New Document	September 2019	GB
B	Minor updates	September 2019	GB
C	Figure updates	November 2019	GB
D	Updates to address Conditions 11 of the 3C SMP Approval (granted 19 December 2019)	June 2020	GB
E	Updated to address BCD and WaterNSW Feedback	August 2020	GB

F	Updated to include Longwalls 22 and 23	June 2020	GB
G	Updated with Agency feedback	September 2021	GB

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1 INTRODUCTION

1.1 Project Background

Illawarra Metallurgical Coal (IMC) operates underground coal mining operations at Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam have been mined in Areas 1, 2 and 3A. Longwalls in Area 3B are currently being extracted.

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007, IMC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

On 8 December 2008, the Minister for Planning approved a modification to DA_60-03-2001 for the Dendrobium Underground Coal Mine and associated surface facilities and infrastructure under section 75W of the EP&A Act.

Schedule 3, Condition 7 of the Development Consent, requires the development of a Subsidence Management Plan (SMP) for approval prior to carrying out mining operations in Area 3C.

This document satisfies Schedule 3 Condition 6 of the Development Consent, which requires the development of a Swamp Impact Monitoring, Management and Contingency Plan (SIMMCP) for approval prior to carrying out mining operations in Area 3C.

1.2 Scope

The SIMMCP has been prepared to comply with the Dendrobium Development Consent which requires a SIMMCP subject to Schedule 3, Condition 6 as provided below.

6. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:

(a) demonstrate how the subsidence impact limits in condition 5 are to be met;

(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) of each Area 3A Longwall on Swamp 15a;

(c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;

(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on swamps, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;

(e) address headwater and valley infill swamps separately and address each swamp individually;

(f) be prepared in consultation with DECC, SCA and DPI;

(g) incorporate means of updating the plan based on experience gained as mining progresses;

(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on swamps in the relevant Area; and

(i) be implemented to the satisfaction of the Secretary.

1.3 Study Area

The Study Area is defined as the surface area that could be affected by the mining of Longwalls 20, 21, 22 and 23 (Longwalls 20 to 23) (**Figure 1-1**). The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- The 35° angle of draw line from the extents of Longw alls 20 to 23;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the Longw alls 20 to 23; and
- The natural features located w ithin 600 m of the extent of the longw all mining area, in accordance w ith Condition 8(d) of the Development Consent.

The depth of cover varies betw een 290 m and 420 m directly above the proposed Longw alls 20 to 23. The 35° angle of draw line, therefore, has been determined by draw ing a line that is a horizontal distance varying betw een 200 m and 290 m around the extents of the longw all voids.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method (IPM), w hich is described in MSEC (2021).

The features that are located w ithin the 600 m boundary that are predicted to experience valley related movements and could be sensitive to these movements have been included in the assessments provided in this report. These features include streams and upland sw amps.

There are additional features that are located outside the 600 m boundary that could experience either far field horizontal movements or valley related movements. The surface features that could be sensitive to such movements have been identified and have also been included in the assessments provided in this report.

The sw amps located outside the extent of longw all mining w hich could experience far-field or valley related movements, and could be sensitive to these movements, have been identified and included in the assessments provided in this report.

This SIMMCP applies to Sw amps 2, 5, 6, 7, 9, 16, 124, 140, 141, 142, 144, 145, 152, 153, 154, 155, 156 and 157 w ithin the Dendrobium Area 3C mining domain (Sw amps 2, 5, 6, 16, 89 124, 145, 152 are 157 are located outside the Longw alls 20 to 23 Study Area based on the angel of draw boundary) (**Figure 1-1**). Sw amp 15a, as defined in the Dendrobium Development Consent (Schedule 3, Conditions 5, 6a and 6b), is not w ithin the defined area of study relative to the proposed extents of Longw alls 22 and 23.

A number of smaller sw amp areas or sw amp-like vegetation are scattered throughout the study area. These small patches of sw amp like vegetation are often too small to map as discrete sw amps and occur in small areas of impeded drainage that contain a mix of plant species common to the upland sw amps and fringing eucalypt w oodlands of the region. These patches of vegetation have not been identified in the existing sw amp mapping of the study area and field observations indicate that these patches of vegetation occur randomly in the landscape, are not typically restrained by sandstone rockbars and are unlikely to be sustained by groundw ater seeps (Niche 2021a). These small and less significant sw amp areas (less than 1500 m2 in area) have not been named and mapped as part of the terrestrial ecology assessment, w ith monitoring efforts focused on larger representative sw amps. Tw o exceptions for the current study area include Sw amp 141 and Sw amp 157, both have been included despite their small size due to being incorporated in previous mapping for adjoining longw alls and/or regional mapping (NPWS 2003). Further, these vegetation patches do not occur in valley floors and therefore are not likely to be subject to valley closure movements resulting from longw all extraction (Niche 2012).

Dendrobium operations have been longw all mining in the catchment since 2005, beginning w ith Dendrobium Area 1 w hen monitoring of upland sw amps w as established. Mining operations have expanded into Areas 2, 3A and 3B since then w ith the monitoring program evolving over this period to incorporate results, findings and lessons learnt. In parallel w ith this, IMC has undertaken extensive biophysical surveys, assessment and research of the Dendrobium mining area w hich have contributed to the understanding of how upland sw amps are impacted by mining. Recommendations on upland sw amp monitoring from various agencies, independent panels, consultants and research institutions have been adopted and incorporated into the monitoring program.

Condition 11c of the Area 3C SMP requires IMC to update the SIMMCP to fully reflect the recommendations of the IEP on the Longw alls 20 and 21 SMP application dated 13 December 2019; relating to monitoring of sw amp impacts w hich directly relate to impact monitoring, management, remediation and contingency planning in respect of sw amps. Condition 11d requires IMC to update the SIMMCP to fully reflect the advice of the IEP on the Longw alls 20 and 21 SMP application dated 13 December 2019 relating to monitoring of sw amp impacts. The SIMMCP has been updated to address these conditions w hich form part of the foundation of the monitoring approach proposed for Area 3C. A key monitoring recommendation from IEP (2019b) is:

"18. Future swamp monitoring and modelling programs should be designed to:

a. Provide a hydrological balance for representative swamps, sufficient to identify any mining-induced changes in soil moisture and in baseflow down the exit stream; and to provide vertical leakage rates as inputs to groundwater models, in order to quantify how much of the leakage is diverted back into the catchment or elsewhere."

The majority of impacts to upland swamps are likely to occur above the proposed longwall and within the groundwater impact zone (60 m buffer). The severity and risk of impacts will reduce with distance from longwalls up to the 35 degree angle of draw study area, which includes the 20 mm subsidence contour. Beyond the 35 degree angle of draw study area, impacts to features such as swamps and watercourses are expected to be minor or negligible. A recent assessment at Dendrobium Mine concluded that hydrological change in upland swamps is not evident in shallow groundwater piezometers located more than 60 m from the extracted longwall (Watershed HydroGeo, 2019).

The Independent Advisory Panel for Underground Mining's (IAPUM) advice on the Longwall 19 SMP application regarding Swamp 15A is relevant to swamp monitoring in Area 3C.

The Panel considers that the (Watershed HydroGeo, 2019) report (which concluded that no changes to swamp hydrology have been observed greater than 60 m horizontal distance from a longwall panel in the Dendrobium mining area) is the most relevant available evidence regarding potential hydrological impacts to Swamp 15a…

… Nevertheless, the evidence regarding the 60 m threshold allows the existence of swamp groundwater level impacts within 60 m to be predicted with high confidence.

The swamp monitoring approach for Area 3C is comprised of four key principals which are stated below along with how each is proposed to be implemented in Area 3C.

1. Monitoring swamps which are considered "likely" impacted by HGEO (2021a) and HGEO (2019). Swamps considered likely impacted by Longwalls 22 and 23 include Swamps 7 and 153. The only swamp considered likely impacted by Longwalls 20 and 21 is Swamp 144.
2. Monitoring the hydrogeological balance of representative swamps with flow gauges at the downstream exit stream.
3. Monitoring swamps which are within 60 m of the longwall goaf. Research shows that shallow groundwater impacts are highly likely in swamps within this 60 m zone (Watershed HydroGeo 2019).
4. Monitoring swamps which are subject to specific performance measures.

Monitoring efforts for Longwalls 20 to 23 will focus on Swamps 7, 9, 144, 145, 153 and 154. Monitoring equipment was established in Swamp 9, 144 and 145 for the Longwalls 20 and 21 SMP application. Swamps 6, 16, 140, 141, 152, 156 and 157 are all smaller marginal swamps which are either unlikely to be impacted by the extraction of Longwalls 22 and 23 or are unsuitable for establishing monitoring. Further to this, IMC has undertaken monitoring of swamps throughout Dendrobium Area 2 and 3 over a substantial period, impacts to shallow groundwater in swamps that are mined beneath are well documented. The ongoing monitoring of swamps in Areas 3A and 3B will provide information on potential ecological impacts over time.

1.4 Objectives

The objectives of this SIMMCP are to identify swamp features and characteristics within the Dendrobium Longwalls 20 to 23 Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on swamps.

1.5 Consultation

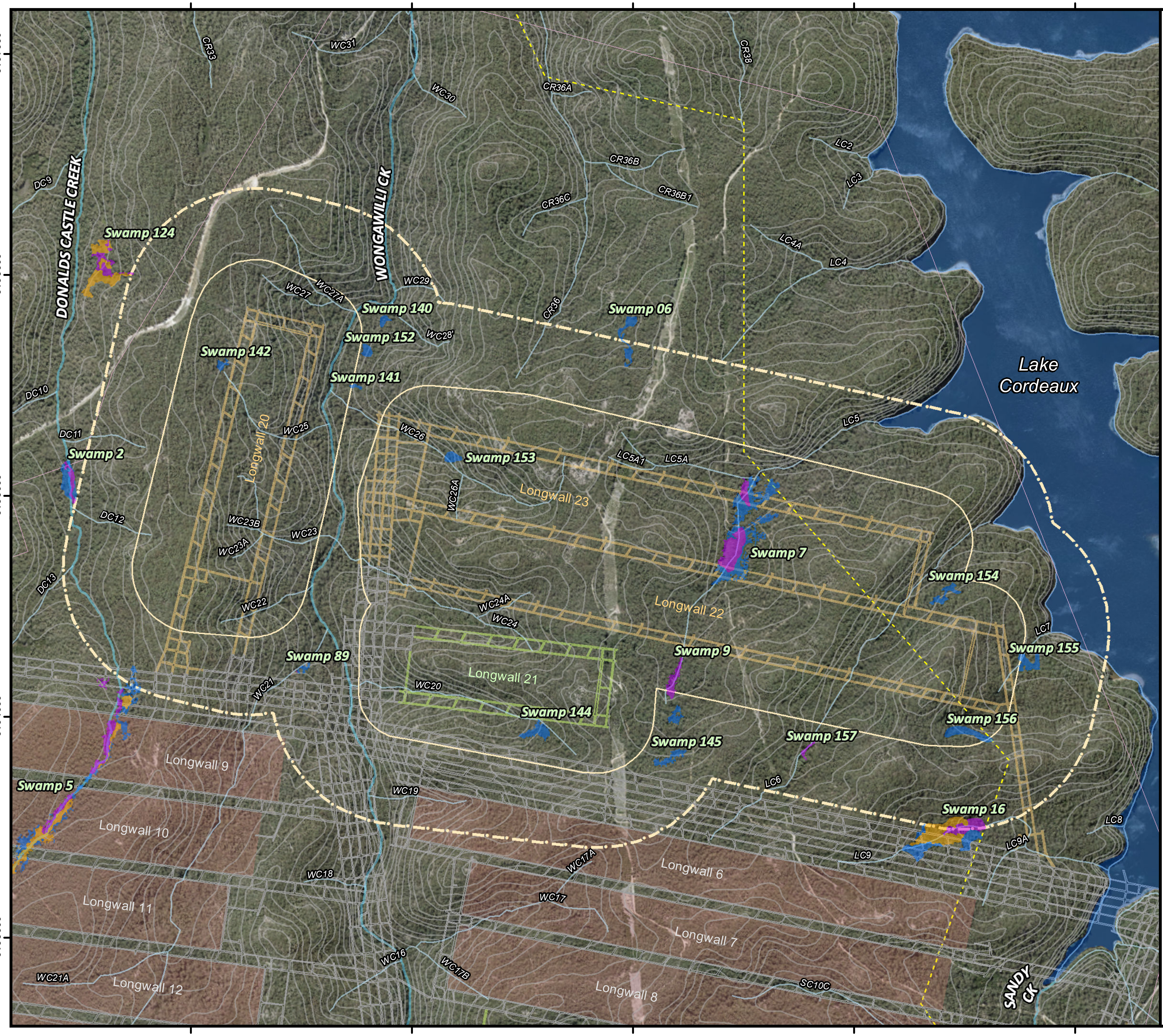
The Dendrobium SIMMCP has been developed by IMC in consultation with:

- Department of Planning, Infrastructure and Environment (DPIE);
- Biodiversity Conservation Division (BCD) within DPIE; and
- WaterNSW.

The SIMMCP and other relevant documentation are available on the IMC website (Schedule 8, Condition 11).

1.5.1 Longwall 21 SMP Approval

In accordance with the Area 3C SMP Approval Condition 10a, Schedule 3, the SIMMCP was provided to BCD and WaterNSW in June 2020 for consultation. Agency feedback was received, with **Table 9-1** providing details of feedback and associated responses. The Longwalls 20 and 21 SIMMCP (Revision E) was provided to the Department for consideration. The Department provided comments and recommendations in writing to IMC in July 2021. The SIMMCP has been updated to address these comments (Revision G of this document).



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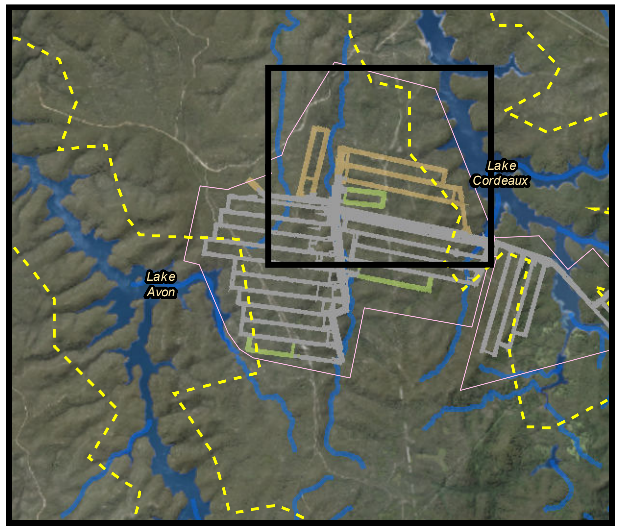
DENDROBIUM LONGWALLS 20 to 23 SMP Overview

Figure 1-1

- Study Area (600m Boundary)
- Study Area (35 deg Angle of Draw)
- 10m Contours
- Dendrobium Development Consent Area
- Creeks
- Tributaries
- Existing Mine Workings
- Approved Mine Layout
- Proposed Longwall Layout
- Dendrobium Goaf
- Dam Safety NSW Notification Areas

Swamp Vegetation Community

- Tea-tree Thicket
- Banksia Thicket
- Sedgeland-Heath Complex



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Author: B.Agland

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2 PLAN REQUIREMENTS

Extraction of coal from longwalls in Area 3C will be in accordance with the conditions set out in the Dendrobium Development Consent as well as conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence from the extraction of Longwalls 20 to 23. The baseline studies have identified monitoring sites in these areas based on the Before After Control Impact (BACI) design criteria.

A comprehensive monitoring program for swamps is outlined in this SIMMCP (**Appendix A: Table 1.1**).

A summary of swamp monitoring within Dendrobium Area 3C is provided in the following sections. In the event that monitoring reveals impacts greater than what is authorised by the Development Consent, modifications to the project and mitigation measures would be considered to minimise impacts. The monitoring locations for swamps within Dendrobium Area 3C will be reviewed as required and can be modified (with agreement) accordingly.

2.1 Dendrobium Development Consent

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under section 75W of the EP&A Act on 8 December 2008. **Table 2-1** lists the Conditions of Consent relevant to the SIMMCP and where the conditions are addressed.

Table 2-1 Dendrobium Development Consent Conditions

Dendrobium Development Consent Condition	Relevant SIMMCP Section
Condition 5 – Schedule 3 The Applicant shall 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 rock-bar is maintained or restored, to the satisfaction of the Secretary.	Not Applicable to Area 3C
Condition 6 – Schedule 3 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in condition 5 are to be met;	Not Applicable to Area 3C
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) of each Area 3A Longwall on Swamp 15a;	Not Applicable to Area 3C
(c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;	**Section 3** and **Appendix A**
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on swamps, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;	**Section 6** and **Appendix A**
(e) address headwater and valley infill swamps separately and address each swamp individually;	**Section 3**
(f) be prepared in consultation with DECC, SCA and DPI;	**Section 1.5**
(g) incorporate means of updating the plan based on experience gained as mining progresses;	**Section 8.5** **Section 1.4**

Dendrobium Development Consent Condition		Relevant SIMMCP Section
(h)	be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on swamps in the relevant Area; and	**Section 2**
(i)	be implemented to the satisfaction of the Secretary.	

2.2 Subsidence Management Plan Approval

The Dendrobium Area 3C SMP Approval was granted by the Executive Director of DPIE on 19 December 2019. IMC are required to seek further approval from the Department for Longwall 20 as per Condition 1, Schedule 4 which states "*This Subsidence Management Plan Approval does not include approval of Longwall 20. The Applicant must obtain the approval of the Secretary (under condition 7 of Schedule 3 of the development consent) for the extraction of Longwall 20 prior to commencing development of the maingate and/or tailgate for that longwall*."

The Dendrobium Mine Area 3C SMP performance measures for swamps are provided in Table 2-2 below.

Table 2-2 Subsidence impact performance measures

Performance Measures for Area 3C 13. The Applicant must ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary. Swamps Den 9, Den 144 and Den145 Minor environmental consequences including: • negligible erosion of the surface of the swamps; • minor changes in the hydrology of the swamp; • minor changes in the size of the swamps; • minor changes in the ecosystem functionality of the swamp; • maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp. *Note: The Applicant may meet the requirements of this condition either by avoidance, mitigation, remediation or offsetting, or any combination of these measures.*

Table 2-3 lists the Conditions of the Approval relevant to revising the SIMMCP and where the conditions are addressed.

Table 2-3 Dendrobium Dendrobium Area 3C SMP Approval Conditions

Dendrobium Area 3C SMP Approval Condition		Relevant WIMMCP Section
Condition 11 – Schedule 3 The Applicant must submit a revised Area 3C SIMMCP (including its associated TARP) to the Secretary by 30 June 2020 for approval. The revised Area 3C WIMMCP must:		
(a)	be prepared in consultation with WaterNSW and BCD;	**Sections 1.5**
(b)	include a TARP which contains quantitative triggers which are directly to maintaining achievement of the performance measures for swamps set out in in Table 1;	**Section 6.2** and **Appendix A**
(c)	fully reflect the recommendations of the Independent Expert Panel which directly relate to impact monitoring, management, remediation and contingency planning in respect of swamps;	**Section 2.2.1**

Dendrobium Area 3C SMP Approval Condition	Relevant WIMMCP Section
(d) fully reflect the advice of the Independent Expert Panel dated 13 December 2019 on Subsidence Management Plan 2019 relating to monitoring of swamp impacts; and (e) reflect the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2017).	**Section 2.2.2** **Section 2.2.3**

2.2.1 Condition 11(c), Schedule 3 – Independent Expert Panel's Recommendations

In accordance with Condition 11(c), Schedule 3 of the Area 3C SMP Approval, the SIMMCP has been updated to fully reflect the recommendations of the Independent Expert Panel (IEP) on the Longwalls 20 and 21 SMP application dated 13 December 2019; relating to monitoring of swamp impacts which directly relate to impact monitoring, management, remediation and contingency planning in respect of swamps. **Table 2-4** details how the recommendations have been addressed or where the recommendations are addressed in the SIMMCP. The Longwalls 20 and 21 SIMMCP (Revision E) was provided to the Department for consideration. The Department provided comments and recommendations in writing to IMC in July 2021. The SIMMCP has been updated to address these comments (Revision G of this document).

Table 2-4 IEP (2019b) recommendations

IEP Recommendation	Relevant SIMMCP Section
18. Future swamp monitoring and modelling programs should be designed to: a) Provide a hydrological balance for representative swamps, sufficient to identify any mining-induced changes in soil moisture and in baseflow down the exit stream; and to provide vertical leakage rates as inputs to groundwater models, in order to quantify how much of the leakage is diverted back into the catchment or elsewhere.	Monitoring the hydrogeological balance of representative swamps with flow gauges at the downstream exit stream is proposed for three swamps in Area 3C(**Figure 1-1**, **Section3.4**): • Swamp 7 is a large and "complex" valley infill swamp. Note it is the only swamp considered "complex" in the Longwalls 20 to 23 Study Area. A gauging station has been established on the exit stream for Swamp 7. • Swamp 153 is a small and "simple" headwater swamp. A gauging station is proposed to be installed on the exit stream for Swamp 153. • Swamp 144 is a small and "simple" headwater swamp. IMC have sought approval from WaterNSW to establish a gauge on the exit stream for Swamp 144. Once a suitable dataset has been recorded for these swamps. IMC will incorporate this data into future groundwater modelling to account for water loss scenarios.
b) Link any changes in swamp vegetation to changes in water table position, soil moisture content and soil organic carbon content.	Impacts to swamp ecology are not immediately obvious after groundwater changes as a result of mining (**Section 4.5**). There appears to be a lagging effect for swamps that have been undermined, slowly transition to drier upland swamp community subtypes. For large representative swamps in Area 3C, swamp monitoring reporting such as End of Panel (EoP) Reports (**Section 3.13**) and the Dendrobium Annual Terrestrial Ecology Monitoring Program will assess changes in swamp vegetation to changes in groundwater, soil moisture and soil organic carbon content. The Dendrobium Annual Terrestrial Ecology Monitoring Program currently assesses this for swamps in Areas 3A and 3B. Piezometric data indicates changes in shallow groundwater levels following extraction of longwalls beneath or near swamps. Ecological trends of monitored swamps is assessed in consideration of shallow

	groundwater and soil moisture, this is discussed in Section 4.1 of Biosis Research 2020.
c) Identify the presence of and any changes in obligate swamp fauna such as the giant dragonfly (Petalura gigantea).	As part of the Dendrobium Swamp Rehabilitation and Research Program (**Section 6.6**), Giant Dragonfly surveys have been conducted over the past two years. Findings from this research will be analysed against pre and post impact for large representative swamps. It should be noted that part of the purpose of this research is to better understand the distribution of the Giant Dragonfly as it is often not observed in similar abundance over successive years, indicating that variables that are not currently understood may be influencing the sightings.
20. Annual performance reports, end-of-panel reports and reports on studies required by development consent conditions, should: a) integrate hydrological and ecological impact and consequence assessments	Impacts to swamp ecology are not immediately obvious after they have been impacted by mining. There appears to be a lagging effect for swamps that have been undermined, slowly transition to drier upland swamp community subtypes. EoP Reports consider these lagging and cumulative effects where no immediate impact is apparent (**Section 4.5**). The Dendrobium Annual Terrestrial Ecology Monitoring Program will incorporate findings from the surface water impact assessments that are carried out for EoP Reporting to integrate hydrogeological impacts to swamps (**Section 4.6**).
b) include discussion of the inter-related changes in hydrological and ecological consequences for swamps, rather than having only discrete chapters on each	As detailed above, discussion of the inter-related changes in hydrological and ecological consequences for swamps will be included in the Dendrobium Annual Terrestrial Ecology Monitoring Report (**Section 4.6**).
c) include results for the entire period of monitoring, rather than just the previous year, that should be assessed, not only for the current mining area but for previous mining domains	The Dendrobium Annual Terrestrial Ecology Monitoring Report (**Section 4.6**) assesses several monitoring parameters including photo point monitoring, total swamp area, species composition and species composition over several years e.g. total swamp area for a number of swamps is compared from 2014 to 2019 (Biosis 2020).

2.2.2 Condition 11(d), Schedule 3 – Independent Expert Panel's Advice

In accordance with Condition 11(d), Schedule 3 of the Area 3C SMP Approval, the SIMMCP has been updated to fully reflect the advice of the IEP on the Longwalls 20 and 21 SMP application dated 13 December 2019 relating to monitoring of swamp impacts. **Table 2-5** details how the recommendations have been addressed or where the recommendations are addressed in the SIMMCP. The Longwalls 20 and 21 SIMMCP (Revision E) was provided to the Department for consideration. The Department provided comments and recommendations in writing to IMC in July 2021. The SIMMCP has been updated to address these comments (Revision G of this document).

Table 2-5 IEP (2019c) advice

IEP Advice	Relevant SIMMCP Section
In respect of monitoring as specified in the Swamp Impact, Monitoring, Management and Contingency Plan (SIMMCP), several points may be noted: • Variations in monitoring frequency before, during and after mining may preclude assessment of mining-related impacts, especially in swamps	Swamp monitoring within Area 3C will be installed ahead of mining to achieve at least 2-years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring is generally conducted through the mining period and for 2-years following active subsidence (**Appendix A**). Where impacts are observed the monitoring period will be reviewed and this review will be reported in Impact Assessment Reports and EoP Reports (**Section 6.2**). Shallow swamp piezometers (**Figure 3-1**) and deep monitoring bores (**Figure 3-3**) at Dendrobium mine are routinely logged.

where the piezometers are not logged.	The monitoring approach for Area 3C is discussed in detail in **Section 1.3**. In summary, monitoring resources are targeted at swamps which have been determined and identified through robust assessment to have a higher likelihood of impact. These swamps would have suitable baselines which can be used to assess mining related impacts.
• To assess possible mining-related impacts, the proposed monitoring points in Swamps 144, 145 and 09 should be installed as soon as possible.	Swamp monitoring Area 3C will be installed ahead of mining to achieve at least 2-years baseline data (subject to timing and approval timeframes of any request to install additional monitoring) (Appendix A). Paired piezometers and soil moisture probes were established in swamps: • Swamp 9 – piezometer 09_01 was established 07/08/2020. • Swamp 144 piezometer 144_01 was established 28/08/2020. • Swamp 145 piezometer 145_01 was established 04/12/2020.
• Use of vegetation change to monitor ecosystem functionality is of continuing concern, despite recognition of the less resilient sub-communities identified in the Panel's Part 2 Report (teatree thicket, cyperoid heath), because of the inability so far to distinguish possible mining-related changes from past monitoring data. While the implication may be that no mining-related change has occurred, it is equally possible that the techniques and data have been inadequate to discern the differing extents or causes of change.	At the Agency Consultation Workshop between IMC, WaterNSW, DPIE and BCD on 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 3B SMP Approval. The term is not included in the definitions of the Development Consent or SMP Approval (**Section 3.12.1**). At the workshop it was stated that 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 swamp triggers in the TARP (**Appendix A**) include groundwater level as the primary identification of impact. Falls in surface or near-surface groundwater levels in swamps: • Groundwater level lower than baseline level at any monitoring site 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 any monitoring site (measured as average mm/day during the recession curve).
• The shallow groundwater impacts are assessed by 'fall below baseline' or change in the recession rate. However, it is unclear in the analysis by Watershed HydroGeo whether a change to more frequent falls to baseline (analogous to a stream no-flow condition) and brief spiking only after rainfall is counted as an impact. Swamps 01b_01 and 05_08 are examples.	Watershed HydroGeo (2018) assessed impacts against the two agreed modes, as in the SIMMCP. Where identification of an impact from those two quantifiable measures was unclear, qualitative comparison against reference site behaviour was also undertaken. Watershed HydroGeo (2018) did not include a change to more frequent falls to baseline as an impact. For the Dendrobium Longwall 16 EoP, HGEO developed a graphical representation of swamp saturation levels by monthly intervals, as presented in Figure 43. That provides a means of visualising increased periods of dry or less saturated conditions compared to Reference Sites. This method could be extended to allow a quantitative assessment of potential impacts, but we consider that the visual comparison is effective, even for the intermittently wet swamps in the headwaters or on valley sides. In the case of the two example piezometers identified by the IEP, a brief summary of the assessment is presented below (note that a piezometer "05_08" does not exist. It is assumed to be a typographical error, and that 05_05 was meant to be referred to).

	01b_01 (280 m from Longwall 9): has a very short baseline, which hampers definitive assessment. However, assessments by two hydrogeologists (carried out independently for the purpose of the Watershed, 2018 report) both indicated that an impact was unlikely. Furthermore, the pre- and post-mining behaviour of 01b_01 remained very similar in character to the reference sites 33_01, 33_03, and 88_02. 05_05 (above chain pillar between Longwalls 11 and 12): as above, assessment is hampered by a short baseline. Effects on recession rate and falling below baseline were unclear. Considering duration of below baseline or the saturation (compared to 33_03 and possibly against 23_01), an impact is likely to have occurred in August-November 2015 (it is very difficult to define exactly when). This occurred in the second half of Longwall 11, which passed within 40 m of 05_05 in early July 2015.

2.2.3 Condition 11(e), Schedule 3 – PSM (2017) Recommendations

In accordance with Condition 11(e), Schedule 3 of the Area 3C SMP Approval, the SIMMCP has been updated to reflect the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2017) on the Longwalls 20 and 21 SMP application dated 13 December 2019 relating to monitoring of swamp impacts. **Table 2-6** details how the recommendations have been addressed or where the recommendations are addressed in the SIMMCP. The Longwalls 20 and 21 SIMMCP (Revision E) was provided to the Department for consideration. The Department provided comments and recommendations in writing to IMC in July 2021. The SIMMCP has been updated to address these comments (Revision G of this document).

Table 2-6 PSM (2018) recommendations

PSM (2018) Recommendation	Relevant SIMMCP Section
1. The monitoring must be holistic and conceptualised from sound models including: a) Geological; b) Geotechnical; c) Groundwater; and d) Surface water.	South32 and consultant experts maintain and manage sophisticated models for geology, geotechnical, groundwater and surface water. Mine layouts for Dendrobium Area 3C have been developed using South32s Integrated Mine Planning Process (IMPP). This process considers mining and surface impacts when designing mine layouts. During this process, monitoring programs required to safely, efficiently and responsibly operate are developed. South32 and consultant experts participate in the IMMP (**Section 6.3**). Additionally, the SMP Applications for Longwalls 20 and 21 and Longwalls 22 and 23 include an independent consultant facilitated risk assessment (Axys 2019 and Axys 2021) in accordance with the IEP's recommendation (2019a). This risk assessment was attended by experts in the fields of; aquatic ecology, terrestrial ecology, subsidence, groundwater and surface water. This risk assessment was reviewed by an independent expert, Professor Bruce Hebblewhite. The Longwalls 20 and 21 Surface Water Assessment (HGEO 2019) also considered shallow groundwater monitoring sites. The recommendation of establishing monitoring sites in Swamps 9, 142, 144 and 145 has been adopted by IMC. As part of the Longwalls 22 and 23 SMP application, IMC proposes to install shallow groundwater monitoring sites in Swamps 9 (additional site), 153 and 154.
2. All the natural and man-made infrastructure must be identified, characterised and the sensitivities identified.	Natural features such as swamps and watercourse are described and characterised in **Section 3** of the SIMMCP and WIMMCP. The sensitivities of mining to each of these are assessed in the specialist assessments attached to the SMP applications. Man-made features are characterised and detailed in the SMP documents and the subsidence assessments.

	Sensitive features are identified and considered as part of a formal risk assessment (Attachment E of the SMPs [Axys 2019 and 2021]) process in accordance with the IEP's recommendation (2019a). Potential impacts to these sensitive features are assessed in this risk assessment.
3. Hence the monitoring program is objective driven by the characteristics of the site conditions and the demands of the infrastructure that need to be protected and/or managed.	The Area 3C monitoring program (**Section 3**) has been designed for the natural features located within the Study Area and addresses the sensitivities of the natural features e.g. swamps have a number of parameters monitored including observational monitoring, shallow groundwater, soil moisture, ecosystem function, swamp size and flora composition.
4. The monitoring must be installed early enough to give an effective baseline.	Swamp monitoring within Area 3C has been installed to provide a minimum of 2 years of baseline data (where timing and approval timeframes of any request to install additional monitoring can be reasonably met) (**Appendix A**).
5. The monitoring must continue throughout and after the mining has been completed.	Swamp monitoring within Area 3C will be conducted throughout the mining period and for at least 2 years following active subsidence. A review of the continuation of post mining monitoring will be carried out in consultation with DPIE, WaterNSW and other relevant agencies where required (**Appendix A**). Where impacts exceeding prediction are observed, the monitoring period may be extended and this will be reported in Impact Assessment Reports and EoP Reports.
6. The monitoring must be cognisant of potential interactions between the mining areas.	The potential impacts to swamps and the monitoring sites in Areas 3A, 3B and 3C will be reviewed to ensure monitoring sites, particularly reference sites are not influenced by interactions between the mining areas. This will occur on a periodic basis as detailed in **Section 8.5**. Cumulative effects from mining areas is addressed in the specialist assessments that support the SMP application e.g. subsidence assessment. The monitoring programs are informed by the recommendations from the specialist assessments. EoP assessments will identify any monitoring site which may have experienced influence from other mining areas. This will be taken into consideration and an alternate site may be established where appropriate (**Section 8.5**).
7. There must be sufficient monitoring remote from the mining to define the extent of the effects and impacts.	As detailed in **Section 3**, reference monitoring sites have been established and will continue to be monitored. Data from these reference swamps is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Reference sites are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions. As mining operations progress to Area 3C, impacts to swamps will be reviewed to ensure monitoring sites, particularly reference sites are not influenced by interactions between the mining areas. This will occur on a periodic basis as detailed in **Section 8.5**. Far field impacts (remote from mining) are monitored during longwall extraction at Dendrobium via a network of survey monitoring marks which form the regional 3D GNSS network. This is supplemented by airborne based digital terrain modelling to determine absolute and incremental ground subsidence over entire mining areas.

	Monitoring of impacts is generally undertaken within 400m of active mining, and further from mining for features sensitive to far field movements e.g. valley closure. Results from monitoring are assessed in the EoP Reports to determine if far-field movements were within predictions.
8. Each new mine or area will require a specific monitoring program.	There is a SIMMCP for each of the three Dendrobium mining areas: Dendrobium Area 3A SIMMCP (2021), Dendrobium Area 3B SIMMCP (2020) and Dendrobium Area 3C SIMMCP (this document). Each of these plans have been specifically developed in consideration of the natural features within each of the mining areas. These monitoring plans are integrated in assessments such as the Dendrobium annual terrestrial ecology monitoring and aquatic ecology monitoring programs (**Section 3.12)** which assess impacts across Areas 3A and 3B, and 3C.
9. The monitoring program must be flexible and may require a number of cycles of design in order to ensure all the aspects of the "complex system" are captured.	A review of the objectives and targets associated with the Dendrobium Area 3C operations will be undertaken on an annual basis via the IMC planning process. These reviews, which include involvement from senior management, assess the performance of the mine over the previous year and develop goals and targets for the following period (**Section 8.5**). The IMC Subsidence Review Meeting is held monthly and attended by various specialists within IMC. As part of this meeting, environmental impacts and the current monitoring program is presented and reviewed by the attendees, allowing for adjustments to monitoring practices and regimes where necessary. Where a Level 2 or 3 TARP is reached a specialist consultant reviews the monitoring data and assesses whether the monitoring program needs to be modified (**Section 6.2**). The EoP Reporting process includes an assessment of the adequacy of the monitoring program and recommends any changes required (**Section 6.2**). Any changes required to monitoring programs are to be approved by DPIE.

2.3 Leases and Licences

The following licences and permits may be applicable to IMC's operations in Dendrobium Area 3C:

- Dendrobium Mining Lease CCL 768, issued 7 May 1998 and expires 7 September 2026;
- Environmental Protection Licence 3241 which applies to the Dendrobium Mine. A copy of the licence can be accessed at the EPA website via the following link: http://www.environment.nsw.gov.au/poeo;
- Dendrobium Mining Operations Plan FY 2016 to FY 2022;
- Relevant Occupational Health and Safety approvals; and
- Any additional leases, licences or approvals resulting from the Dendrobium Development Consent.

3 MONITORING

3.1 Subsidence Monitoring

Survey monitoring techniques will be employed at upland swamps and watercourses throughout the Study Area to measure subsidence movements. Additionally, regional 3D Global Navigation Satellite System (GNSS) marks will be placed at strategic positions throughout the Study Area to monitor absolute surface movements.

Pending site access and approval, survey monitoring lines will be established across watercourses and representative large upland swamps within the 20 mm predicted subsidence contour. The monitoring lines will target controlling rockbars and steps. Additionally, survey monitoring lines will be installed across the Wongawilli Creek valley to measure closure (or opening) of the valley. Wongawilli Creek monitoring lines will be subject to site constraints

Watercourse and upland swamps monitoring lines will employ a series of marks along a transect at nominally 20 m intervals. If practical, upland swamps transects will be related to a GNSS control network to provide absolute 3D movements in addition to level, tilt and strain changes.

Nominal accuracy will be +/- 5 mm relative between marks and +/- 20 mm for horizontal and vertical accuracy if the swamp is related to a GNSS control network. Survey closure lines across the Wongawilli Creek valley will be measured for closure only; nominal accuracy will be +/- 5 mm.

Survey monitoring sites will be chosen for suitability and detailed in the Dendrobium Survey Monitoring Program, separate to the SMP. Baseline monitoring will be conducted prior to active subsidence.

3.2 Area 3C Swamps

Upland swamps are commonly known as vegetated freshwater wetlands occurring in shallow basins located in low hills or mountains. They occur in either low sloped headwater tributary valleys (headwater swamps) that are characteristically derived from colluvial sand eroded from the ridgelines or along the riparian zone of the creeks (valley infill swamps) within the headwater valleys.

There are nine swamps that have been identified wholly or partially within the Study Area based on the 35° angle of draw line. There are 10 additional swamps that are located wholly or partially within the Study Area based on the 600 m boundary. The swamps within the Study Area are detailed in **Table 3-1**.

The swamps have bedrock bases and are associated with shallow groundwater aquifers. A number of the swamps in Area 3C terminate in rocky outcrops, exposed rock platforms or small waterfalls. Swamp material builds up behind these obstructions (e.g. prominent rock outcrop) and in-fills the depression upslope of the obstruction to form a beach like feature which also traps organic material. The Hawkesbury Sandstone is the predominant source of sediment for the swamps.

The Endangered Ecological Communities (EECs) which make up the upland swamps in the Study Area, specifically, the Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex, as defined by the NSW Scientific Committee's 2012 determination, have been mapped and are presented in Niche (2021a).

Table 3-1 Summary of swamps within the Longwalls 20 to 23 Study Area

Reference	Total Area (Ha)	Location of Swamp	Distance from Nearest Longwall (m) and Impact Category
Swamp 2	0.94	Near the valley base of Donalds Castle Creek	~600 m west of Longwall 20 (fractionally within 600 m Study Area)
Swamp 5	6.72	520 m south west of Longwall 20	Partially located above the existing Longwall 9 in Area 3B (fractionally within 600 m Study Area)
Swamp 6	0.57	On valley side of CR36	~ 490 m north of Longwall 23 (partially within the 600 m Study Area)
Swamp 7 [1]	5.44	Near the valley base of LC5B	Partially above Longwall 22 and directly above Longwall 23 (within shallow groundwater 60 m impact zone)
Swamp 9	0.79	Near the valley base of LC5B	~90 m south of Longwall 22 (partially within angle of draw)
Swamp 16	3.75	Near the valley base of LC1	~540 m south of Longwall 22 (partially located within 600 m Study Area)
Swamp 89	0.12	Near the valley base of WC21	~445 m from Longwall 20 (located within the 600 m Study Area)
Swamp 124	1.98	590 m north west of Longwall 20	On the valley side of Donalds Castle Creek (fractionally within the 600 m Study Area)
Swamp 140	0.16	On the valley side of Wongawilli Creek	~525 m north west of Longwall 23 (within 600 m Study Area)
Swamp 141	0.08	On the valley side of Wongawilli Creek	~360 m west of Longwall 23 (partially within Longwall 20 angle of draw)
Swamp 142	0.16	Near the valley base of upper reaches of WC25	~70 m west of Longwall 20 (within Longwall 20 angle of draw)
Swamp 144	0.54	Near the valley base of WC20	~500 m south of Longwall 22 (within Longwall 21 angle of draw)
Swamp 145	0.41	At the headwaters of LC5	~500 m south of Longwall 22 (within 600 m Study Area)
Swamp 152	0.22	On the valley side of Wongawilli Creek	~435 m north west of Longwall 23 (within 600 m Study Area)
Swamp 153	0.29	Near the valley base of WC26	Directly above Longwall 23 (within shallow groundwater 60 m impact zone)
Swamp 154	0.40	On the valley side of LC6	~70 m north of Longwall 22 and 95 m east of Longwall 23 (within angle of draw)
Swamp 155	0.50	On the valley side of LC7	~210 m east of Longwall 22 (partially within the angle of draw)
Swamp 156	0.71	On side of ridgeline south of mining area	~130 m south east of Longwall 22 (majority is within angle of draw)
Swamp 157	0.12	Near the valley base of LC6	~335 m south of Longwall 22 (within 600 m Study Area)

Swamp 5 is monitored as part of the Dendrobium Area 3B swamp monitoring program and is not considered in this Plan further.

[1] Swamps 7 is an impact swamps for Area 3C and has been historically monitored as reference swamp for Areas 3B.

Swamps that would be impacted by Longwall 20 only are not currently monitored as further approval of the Secretary is required. These swamps and monitoring sites specific for Longwall 20 would be re-instated at least 2 years prior to mining to capture sufficient baseline data.

3.2.1 Reference Swamps

The monitoring design is structured around the BACI concept: Before, After, Control and Impact. Predicted impact areas are compared with control areas and measurements taken both before and after an impact event (longwall mining) occurs. Where measurable impacts occur, comparisons of before and after data should reveal changes at an impact site after mining. Reference or controls sites remain unimpacted before and after mining, where the mining plan evolves and has the potential to impact on a previous reference swamp, this will be updated to reflect the on-ground works (e.g. the data that was previously listed as control is now listed as pre-mining Impact data (Before) and is no longer included in the analysis as a control). Where both reference and impact sites change in a similar manner, observed changes may be due to other wider-ranging factors such as rainfall.

Impacted areas are those within the 400 m risk management zone (RMZ) which are sensitive to valley closure, uplifts, strains, and fracturing. This is in accordance with recommendations made by the Department of Planning (2008).

The Impact sites are referred to as pre-impact (Before) prior to mining activity, until the closest point of secondary extraction is located within the RMZ of the site. This allows for baseline (Before) data to be collected at each potential impact site. Once the point of secondary extraction is located within a RMZ the site is then referred to as post-impact but not yet mined beneath, this allows for the potential of observing any indirect impacts that have been predicted. Given that any observed impacts to natural features become most evident after the natural feature is mined beneath, the date the site has been mined beneath has also been considered in the assessment and analysis of trends over time. At this point the sites are referred to as post-impact and mined beneath.

Reference swamps for Area 3C have been selected in consideration of the following criteria:

- Distance from longwalls – outside 400 m risk management zone;
- Size of swamp;
- Suitable subcommunities comparable to impacted swamps;
- Not to be impacted by mining within foreseeable future;
- Swamp also used as a control for groundwater monitoring;
- Proximity to drainage features;
- Valley infill/headwater swamps;
- Natural disturbances (e.g. fire); and
- Rainfall patterns.

Reference swamps within each of the mining domains are generally monitored for a minimum of two years prior to mining to gather baseline data. There are some Upland Swamps and creeks that will remain in the RMZ, as they are not planned to be mined beneath.

Table 3-2 provides a summary of the control swamps for Dendrobium Area 3C monitoring.

Table 3-2 Summary of reference swamps for Dendrobium Area 3C

Reference	Total Area (Ha)	Swamp Characteristics	Swamp Community/Sub-Community	Monitoring Type	Paired Impact Swamps
Swamp 2	0.94	Valley infill	Tea-tree thicket and Banksia thicket	Observational, photo point and water monitoring Erosion monitoring Shallow groundwater level Swamp size and ecosystem function	Swamp 144, 145, 153 and 154

Swamp 6	0.57	Valley infill	Banksia thicket	Swamp size and ecosystem function	Swamp 144, 145, 153 and 154
Swamp 22	21.38	Headwater	Tea-tree thicket and Sedgeland-heath complex	Observational, photo point and water monitoring Erosion monitoring Shallow groundwater level Swamp size and ecosystem function	Swamp 7 and 9
Swamp 33	6.2	Headwater	Tea-tree thicket, Banksia thicket and Sedgeland-heath complex	Observational, photo point and water monitoring Erosion monitoring Shallow groundwater level Swamp size and ecosystem function	Swamp 7 and 9
Swamp 87	15.7	Headwater	-	Observational, photo point and water monitoring Shallow groundwater level	Swamp 7, 9, 144, 145, 153 and 154
Swamp 88	4.64	Valley infill	-	Observational, photo point and water monitoring Shallow groundwater level Water flow and pool observations	Swamp 7, 9, 144, 145, 153 and 154
Swamp 132	8.6	Headwater	Tea-tree thicket, Banksia thicket and Sedgeland-heath complex	Swamp size and ecosystem function	Swamp 7 and 9

3.3 Observational and Photo Point Monitoring

IMC has conducted ongoing monitoring of upland swamps in the Dendrobium area since 2001. This monitoring builds upon the understanding of processes within the swamps, along with identifying and assessing any episodic or temporal changes.

This monitoring (along with other monitoring programs described in the SIMMCP) is consistent with (in part) Schedule 3, Condition 6 of the Dendrobium Development Consent "*include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function*".

The IMC Environmental Field Team undertakes structured monitoring assessments including:

- Water: location, volume and flow characteristics;
- Significant features: rockbars, pools and flow channels;
- Vegetation: location, species, height and observed health; and
- Sediment: composition, depth and moisture.

Monitoring sites and frequencies are provided in **Appendix A; Table 1.1**. Additional monitoring within Dendrobium Area 3C will be installed ahead of longwall mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Proposed monitoring sites are subject to minor locality changes due to field inspections which determine the suitability of the site.

Observations of any surface water and vegetation health for prominent species are undertaken. Where surface water is present within a swamp or a watercourse the data collected includes water quality parameters (using a monitoring probe) and water levels from installed benchmarks established at the pool (**Figure 3-3**). Observations of any surface flow are also made during monitoring.

This data is used to compare differences in site conditions of swamps and watercourses before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and sites not mined under during different climatic conditions.

The following Area 3C impact and reference swamp sites are included in the observational monitoring program (as described in this section):

- Monitoring sites;
  - Swamps 7 (previously reference sites for Area 3B); and
  - Swamps 9, 144, 145, 153 and 154.
- Reference sites:
  - Swamps 2, 6, 22, 33, 86, 87, 88 and 132.

The monitoring sites above include existing and proposed monitoring sites. Due to the steep terrain, dense vegetation and shallow sediment depth, proposed monitoring sites may be relocated to a more suitable site. Additionally, proposed monitoring site locations have not been assigned site identification numbers at this time, as they may be subject to change until site suitability is confirmed.

3.4 Swamp Hydrological Balance

Under natural conditions, uplands swamps store water from rainfall, runoff, groundwater and interflow. After rainfall, this water may drain into the underlying sandstone if there is a downward hydraulic gradient, or flow horizontally through the swamp sediments or over the surface to provide downstream flow in the exit stream, or be lost by evapotranspiration.

The water table represents the depth below which the swamp sediment is saturated. In an undisturbed swamp where there is significant groundwater input to the sediments, the water table remains close to the swamp surface throughout long dry periods. Above this depth, in the unsaturated zone near the ground surface, the soil moisture can vary between very dry and very wet. In swamps where rainfall is the dominant water source, slow recession of the water table indicates loss by evapotranspiration and outflow to streams (IEP 2019b).

The IEP (2019b) recommended future swamp monitoring programs should be designed to:

Provide a hydrological balance for representative swamps, sufficient to identify any mining-induced changes in soil moisture and in baseflow down the exit stream; and to provide vertical leakage rates as inputs to groundwater models, in order to quantify how much of the leakage is diverted back into the catchment or elsewhere.

IMC proposes to establish flow monitoring gauges on the exit streams of select representative swamps in Area 3C, including Swamps 7, 144 and 153. The following details the suitability of the selected swamps and the progress of installing the gauges:

- Swamp 7 is a large and “complex” valley infill swamp. Note it is the only swamp considered “complex” in the Longwalls 20 to 23 Study Area. A gauging station has been established on the exit stream for Swamp 7.
- Swamp 144 is a small and “simple” headwater swamp. IMC have sought approval from WaterNSW to establish a gauge on the exit stream for Swamp 144.
- Swamp 153 is a small and “simple” headwater swamp. A gauging station is proposed to be installed on the exit stream for Swamp 153 pending a site inspection for suitability.

3.5 Water Quality Chemistry

Monitoring undertaken by IMC since 2003 (**Figure 3-4**) includes water quality monitoring of parameters such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and temperature. Monitoring sites where these parameters are sampled are indicated as water quality sites.

Water quality is also monitored for analytes including DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si. Water samples are retrieved from the monitoring sites and analytes are tested in a laboratory. Monitoring sites where water samples are taken for laboratory testing are indicated as water chemistry sites.

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3C will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining are monitored to allow for a comparison against sites not influenced by mining. Pools will be measured at weekly intervals during active subsidence and monthly before and following mining. The monitoring of water chemistry provides a sensitive means of detecting and providing quantitative assessment of effects in the early stages of streambed fracturing or induction of ferruginous springs. Assessment of water quality data will be supported by geochemical modelling using PHREEQC, where applicable (Parkhurst and Appelo 1999).

Water quality monitoring is covered in detail in the WIMMCP.

3.6 Groundwater

A specialist Groundwater Assessment is provided in Attachment B of the SMP (Watershed HydroGeo 2021). An existing groundwater monitoring program is in place for Dendrobium, which includes Area 3C (**Figure 3-3)**. The Dendrobium Long Term Groundwater Monitoring Program is available in **Appendix B** of the Area 3C WIMMCP.

Groundwater monitoring is undertaken in:

- Surficial and shallow systems associated with upland swamps and the weathered near-surface bedrock; and
- Consolidated rock strata comprising the deeper Hawkesbury Sandstone, the underlying Narrabeen Group and Illawarra Coal Measures.

Pre-mining and post-mining monitoring holes have been installed within Area 3C to investigate and monitor the highly connected fracture network above the goaf and the upwards migration of the phreatic surface.

Monitoring pore pressures at Dendrobium Mine uses vibrating wire piezometers installed at different depths within the same borehole, thereby creating a vertical array which can be used for 3D mapping and analysis of the pore pressure regime (IEP 2019a).

Before and after mining piezometers are routinely installed along the centreline of longwall panels to identify the maximum groundwater effects and the height of depressurisation within the subsidence zone.

3.7 Surface Water Flows and Pool Water Levels

Pool water levels in swamps and associated streams are measured using installed benchmarks in impact sites and reference sites. Not all swamps have pool features within their boundary. Pool water levels are measured within or adjacent to the following reference swamps. Where pools within swamps in Area 3C are identified, the following sites will be used as references:

- Swamp 84: S84_Pool 10 (reference swamp); and
- Swamp 88: S88_Pool 10 (reference swamp).

Water level/flow gauges and data loggers are installed at key stream flow monitoring sites (see Area 3C WIMMCP for details).

3.8 Near-Surface Groundwater and Soil Moisture

The surface area above Dendrobium Area 3C is characterised by a series of drainage basins separated by steep ridges. The drainage basins drain to Wongawilli Creek, Donalds Castle Creek and directly into Lake Cordeaux.

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers have been installed in several swamps in Area 3C (**Figure 3-1**). Within Area 3C long-term piezometer records are available for Swamp 2 and 7. This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Reference sites are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles up to a maximum depth of 1.2 m. Key monitoring sites will be installed with loggers to provide a continuous soil moisture record (**Figure 3-1**).

The shallow groundwater piezometers and soil moisture probe data is compared with the Cumulative Monthly Rainfall Residuals (a key parameter for interpreting temporal soil and shallow groundwater data). Comparisons of the Cumulative Monthly Rainfall Residuals against mean monthly water heads in shallow groundwater piezometers and soil moisture profiles will take into account the known distribution of rainfall isohyets (contours of equal annual precipitation) in the local region (these being denser and less smooth closer to the Illawarra Escarpment and much wider proceeding northwest).

Several rainfall gauges are available for analysis and modelling in Dendrobium Area 3 with the most appropriate data used, taking into account proximity, length of record and data quality.

3.9 Pools and Controlling Rockbars

Dendrobium Mine lies in the southern part of the Permo-Triassic Sydney Basin. The geology mainly comprises sedimentary sandstones, shales and claystones, which have been intruded by igneous sills.

The sandstone units vary in thickness from a few metres to as much as 120 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.

The major sedimentary units at Dendrobium are, from the top down:

- The Hawkesbury Sandstone.
- The Narrabeen Group (including the Bulgo Sandstone).
- The Eckersley Formation.

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (**Figure 3-4**).

Area 3C is broadly sited on a plateau dissected by a number of relatively deep sub-catchments draining either into Cordeaux River via Wongawilli Creek or Donalds Castle Creek or five un-named 1st and 2nd order streams draining directly to Lake Cordeaux.

The largest watercourse within the Study Area is Wongawilli Creek, which is located between Areas 3A and 3B; and to the west of Longwalls 22 and 23. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west.

Donalds Castle Creek and its tributaries also drain the north-western part of Area 3B through a weakly incised plateau. Donalds Castle Creek catchment on this plateau is characterised by low topography, upland swamps and numerous unconfined shallow hillslope aquifers. Much of the soil is derived from weathering of shale-rich Mittagong Formation and is more clayey and of lower permeability than residual soils developed purely on Hawkesbury Sandstone outcrop.

Wongawilli, Sandy and Donalds Castle Creeks are permanent to perennial flowing streams with small base flows and increased flows for short periods of time after each significant rain event.

Beds of the creeks are typically formed within Bulgo Sandstone, which overlies the Stanwell Park Claystone; however, there are sections of the headwaters of these creeks which are formed within the Hawkesbury Sandstone.

Three distinct channel types may be recognised in the main channel uplands, and in the tributaries of Wongawilli Creek:

- Narrow indistinct channels associated with low sedge/heath type vegetation cover and a relatively thick sandy riparian soil profile. The streambed consists of weathered bedrock and/or sandy materials. This is the situation in which valley infill swamps may be found.
- Rock rockbars of variable width which are usually smooth except for minor depressions on joint planes and occasional potholes. These platforms normally grade to a thinly vegetated sandy soil on both sides and usually exhibit the effects of chemical deposition of hydrated iron oxides. This deposition ranges from a slight colouration of the surface strata to intense replacement of the rock fabric.
- Channels that are erosive into cross-bedded sandstone and exhibit a rough riffle like surface usually with accumulations of boulders and other sediments. These channels are usually bounded by solid rock outcrop.

A number of semi-permanent pools may be found within the channels of these drainage lines and creeks. The mechanisms of pool stability are variable and uniquely depend on local stratigraphy, structure and gradient. Pools range from:

- Water accumulations in depression of an impermeable bedrock shelf (analogous to a bathtub) that is fed by direct precipitation, seepage or flood events; to

- Pools within eroded sections of sandy sediment and a free water surface that is dependent on surface flows and the local groundwater regime for stability.

Pools within unconsolidated (sandy) sediments are in a state of equilibrium between water in (from a higher part of the phreatic groundwater surface either upstream or laterally) and water out (flowing down the phreatic surface).

Most bedrock pools and riffle complexes rely on equilibrium between excess water in compared to water out. If the water inflow is less than the outflow, then the pool water level declines. The nature of this equilibrium is ultimately dependent on the position of the pool on the overall stream gradient. Many pools in the streams naturally develop at rockbars and at sediment and debris accumulations.

Rockbars and pools in Wongawilli Creeks have been mapped (**Figure 3-4**). All mapped rockbar controlled pools in Wongawilli Creek are significant permanent pools.

3.10 Slopes and Gradients

Slopes within Area 3C have been mapped according to their gradients and are identified on Drawing 8 in MSEC (2021). Monitoring of landscape features such as slopes and swamps will be undertaken in Area 3C, see Area 3C WIMMCP.

Monitoring of steep slopes allows for the measurement of any changes to the surface including soil cracking, erosion and/or sedimentation impacts resulting from subsidence.

The inspections and monitoring includes the following monitoring sites:

- Monitoring sites based on an assessment of risk of impact where pre-mining measurements have been undertaken and reported;
- Areas of steep slopes that are en route or near monitoring sites;
- Rock outcrops that are en route or near monitoring sites;
- Any other sites where impacts have been previously observed that warrant follow-up inspection (i.e. rockfalls and soil cracking); and
- The general areas above the current mining location at the time of inspection.

The monitoring sites include comprehensive investigation as described below, and the wider area around the monitoring site is subject to inspection during monitoring events.

Observations on landform and land surface at the monitoring sites are recorded to account for the Australian Soil and Land Survey, Field Handbook, 2nd Edition (McDonald, Isbell, Speight, Walker and Hopkins 1990) as modified for subsidence monitoring.

Observations have been made of the landform elements in accordance with the Landform section of the Field Handbook. The landform element has generally been described in terms of the following attributes:

- Slope;
- Morphological type;
- Dimensions;
- Mode of geomorphological activity; and
- Geomorphological agent.

In addition, observation has been made of the land surface in accordance with the Land Surface section of the Field Handbook. The land surface has generally been described in terms of the following attributes:

- Aspect, elevation and drainage height;
- Disturbance at the site, including erosion and aggradations;
- Micro relief;
- Inundation;
- Coarse fragments and rock outcrop;
- Depth to free water; and

- Runoff.

Not all attributes for Landform Element and Land Surface referred to in the Field Handbook are recorded for each monitoring site. The previous monitoring experience for Areas 1, 2, 3A and 3B indicate that many of the attributes are of little importance to subsidence, and the monitoring for Area 2 and Area 3 has focused on recording those attributes and characteristics that are most relevant to subsidence impacts.

A watercourse reach of between ten and twenty times the channel width is monitored to cover local geomorphological units (e.g. pool/riffle).

For each watercourse monitoring site (including those associated with swamps), a range of measurements and observations of the watercourse characteristics are recorded along with established photo points. Measurements and observations incorporate the relevant parts of the Field Handbook, and relevant parts of the Riparian-Channel-Environmental Assessment (RCE) methodology (Petersen 1992).

While in most cases, impacts on steep slopes are likely to be restricted to surface cracks, there remains a low probability of large-scale downslope movements. Steep slopes, including those occurring within the proximity of swamps, are therefore monitored throughout the mining period and until any necessary rehabilitation is complete. Slopes and gradients are monitored prior to mining as well as monthly during active subsidence during mining. The monitoring is undertaken at six-monthly intervals for two years following completion of mining.

3.11 Erodibility

Most of the surface of Area 3C has been identified as highly weathered Hawkesbury Sandstone outcrops and Sandstone derived-soils. This soil landscape has been identified to have high to extreme erosion susceptibilities to concentrated flows. This results in potential flow on effects to slope stability and erosion from any cracking resulting from subsidence (Ecoengineers 2012).

Studies undertaken by Earth Tech (2005) identified that if shear stress thresholds are not exceeded then swamps are most likely to remain intact. Swamps at risk of erosion include those that have vegetation of poor condition or those that lie on higher order streams. Tomkins and Humphrey (2006) concluded that the occurrence of wildfires can also lead to erosion of swamps. Landscape monitoring of slopes and swamps will be undertaken in Area 3C to identify any erosion of the surface.

The types of erosion which could manifest within swamps are sheet, rill, gully, tunnel and stream channel. These types of erosion will be monitored in swamps in the mining area as well as in reference swamps not in the mining area. The types and magnitude of any erosion identified in swamps in the mining area will be compared to any erosion away from the mining area. In the event of a bushfire any comparison between mining area and reference swamps will take into account the increased potential for erosion following a fire.

Due to terrain, vegetation and access restrictions, the primary method of identifying any gully erosion over Area 3C will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any gully erosion developing within the swamps. The maximum length, area and depth of gully erosion will be measured by standard survey methods and compared to the areas and lengths of the swamps.

Base surveys over Area 3C using ALS were completed in December 2005. A verification base survey will be conducted prior to the commencement of mining of the proposed longwalls. Subsidence landscape models using the same methodology after the completion of subsidence at each longwall will provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to identify new or increases in existing erosion. Erosion will be quantified by comparison of the immediate post subsidence landscape model with the long-term monitoring model. Targeted ALS scans will be completed where erosion is observed via the observational and landscape monitoring programs or after significant events such as bushfire and flooding.

The nominal accuracy of ALS derived subsidence contours is in the order of +/- 0.10 m and effective algorithms have been developed to allow the use of ground strike data only within the assessment. This effectively allows the analysis to see through vegetation to the ground surface.

General observational inspections of swamps will be undertaken at regular intervals, during active subsidence of the swamp. In addition to erosion, these observations aim to identify any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, and slope and gradient changes. The observational monitoring program will also include specific attention to the condition of controlling rockbars and will incorporate both impact and reference sites.

3.12 Flora, Fauna and Ecosystem Function

Terrestrial flora and vegetation communities in the Study Area are described in the *Dendrobium Area 3C Longwalls 22 and 23 Terrestrial Ecological Assessment* (Niche 2021a) and Dendrobium Area 3C Longwalls 20 and 21 Terrestrial Ecological Assessment (Niche 2019).

An aquatic ecology monitoring program has been established by Cardno for Area 3C. The monitoring program includes sites within Wongawilli and Donalds Castle Creeks.

Annual Reporting (Biosis 2016, 2017, 2018, 2019 and 2020) documents the ecological monitoring program undertaken within Dendrobium Areas 2, 3A and 3B. Subsidence related impacts following mining in these areas include lowering of shallow groundwater in uplands swamps and loss or alteration in the quality of pool water for first and second order streams.

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence will be implemented in the Area 3C Study Area. As recommended by the IEP (2019a), the monitoring program will be based on a BACI design, as implemented in Area 3B, with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction (**Figure 3-1**).

Over two years of baseline data will be available for Area 3C and this data indicates that the habitat in this area is relatively undisturbed. There is sufficient baseline data to enable the detection of changes to ecology associated with mining related impacts.

The study focuses on flora, fauna and ecosystem function of swamps and watercourses and is measured via the following attributes:

- The size of the swamps and the groundwater dependent communities contributing to the swamps;
- RCE including a photographic record of each stream assessment site;
- Water quality, including pH, DO, ORP, temperature and EC;
- Aquatic macrophytes, including presence, species composition and total area of coverage;
- Aquatic macroinvertebrates using the Australian River Assessment System (AUSRIVAS) sampling protocol and artificial aquatic macroinvertebrate collectors;
- Fish presence and numbers using backpack electro fisher and/or baited traps; and
- Presence of threatened species (including Macquarie perch, Littlejohn's Tree Frog, Giant Burrowing Frog, Adams Emerald Dragonfly, Giant Dragonfly and Sydney Hawk Dragonfly).

3.12.1 Ecosystem Function

The upland swamps in the Study Area fit the description of *Coastal Upland Swamps in the Sydney Basin Bioregion*, which has been listed as an EEC under the *Biodiversity Conservation Act 2016* (BC Act) (Niche 2021a). Specifically, the Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex are considered part of the Coastal Upland Swamp EEC as defined by the NSW Scientific Committee's 2012 determination.

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 3B SMP Approval. The term is not included in the definitions of the Development Consent or SMP Approval.

At the workshop it was stated that 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 function of swamps is measured via the following attribute: the size 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.

Any change in area of a groundwater dependent community within a swamp will be compared to its pre-mining area and any change in area of that groundwater dependent community within reference swamps (**Figure 3-2**).

Table 3-3 Upland swamps and associated sub-communities within the Study Area (Niche 2021a)

Swamp	Swamp Community/sub-community	Area (ha) 600 m boundary	Area (ha) angle of draw	Area (ha) within 60 m buffer	Area (ha) above Longwall 22	Area (ha) above Longwall 23
Swamp 6	Upland Swamps: Banksia Thicket	0.24	-	-	-	-
Swamp 7	Upland Swamps: Banksia Thicket	3.18	3.18	2.67	1.65	0.13
	Upland Swamps: Tea-tree Thicket	1.69	1.69	1.58	1.31	-
Swamp 9	Upland Swamps: Banksia Thicket	0.29	0.29	-	-	-
	Upland Swamps: Tea-tree Thicket	0.50	0.50	0.42	-	-
Swamp 16	Upland Swamps: Restioid Heath	-	-	-	-	-
	Upland Swamps: Sedgeland-Heath Complex	0.47	-	-	-	-
	Upland Swamps: Tea-tree Thicket	0.51	-	-	-	-
Swamp 140	Upland Swamps: Banksia Thicket	0.16	-	-	-	-
Swamp 141	Upland Swamps: Banksia Thicket	0.08	-	-	-	-
Swamp 144	Upland Swamps: Banksia Thicket	0.54	-	-	-	-
Swamp 145	Upland Swamps: Banksia Thicket	0.41	-	-	-	-
Swamp 152	Upland Swamps: Banksia Thicket	0.22	-	-	-	-
Swamp 153	Upland Swamps: Banksia Thicket	0.29	0.29	0.29	0.29	-
Swamp 154	Upland Swamps: Banksia Thicket	0.40	0.40	-	-	-
Swamp 155	Upland Swamps: Banksia Thicket	0.50	0.03	-	-	-
Swamp 156	Upland Swamps: Banksia Thicket	0.71	0.65	-	-	-
Swamp 157	Upland Swamps: Tea-tree Thicket	0.12	-	-	-	-
Total	**-**	**10.31**	**6.66**	**4.54**	**3.25**	**0.13**

Mapping will be replicated prior to mining for Swamps 9, 144 and 145[2], following mining and on an ongoing basis for the life of the mine or as agreed by the Secretary. This will allow direct comparison of changes in the size of the EECs within upland swamps. It is envisaged that this monitoring will be ongoing for up to ten years.

3.12.2 Swamp Size

Detailed mapping of the boundaries of the swamps and vegetation sub-communities has been undertaken for Swamp 6, 7, 9, 16, 140, 141, 144, 14, 152, 13, 154, 155, 156, 157 (Terrestrial Ecological Assessment, Niche 2021a).

Reference swamps have been paired with the impact swamps. These swamps were selected based on size, similar vegetation sub-communities, geographic proximity and a lack of previous mining near them.

The detailed mapping included the use of LiDAR data to indicate the location and extent of upland swamp boundaries followed by ground-truthing of these boundaries and the vegetation sub-communities.

This mapping will allow for detailed comparison of the size of upland swamps following mining, as well as detailed comparison of the extent of sub-communities within upland swamps over time. Mapping will be replicated for Swamps 9, 144 and 145 following mining and on an ongoing basis for the life of the mine or as agreed by the Secretary. This will allow direct comparison of changes in the size of upland swamps as well as the distribution of vegetation sub-communities within upland swamps.

[2] Swamp 9, 144 and 145 are subject to performance measures in accordance with Condition 6, schedule 3 of the Area 3C SMP Approval.

Any change in the total area of a swamp will be compared to its pre-mining area and any change in area of reference swamps (**Figure 3-2**).

3.12.3 Fauna

Seven-part tests concluded that the Area 3C mining operations would likely cause a significant impact to local populations of Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet, Stuttering Frog (*Mixophyes balbus*) and Giant Dragonfly (*Petalura gigantean*) (Biosis 2007). The possible mechanisms of subsidence and physical effects of subsidence were determined to have a direct impact on known and potential habitat for the threatened fauna, which included waterways, upland swamps, riparian vegetation, ridge lines and rock overhangs.

In consideration of the possible presence of threatened macroinvertebrate species within the SMP Area, all dragonfly larvae collected in invertebrate sampling will be identified to the taxonomic level of family. Any individuals of the genus Petalura, Austrocorduliidae and Gomphomacromiidae will be further identified to species level if possible, and if there is uncertainty, specimens will be referred to a specialist taxonomist. The confirmed presence of a threatened species will trigger further investigation into the species and its habitats in relation to potential subsidence impacts.

Standardised transects in potential breeding habitat for the threatened frog species Littlejohn's Tree frog and Giant Burrowing Frog have been established in Dendrobium Area 3A and 3B. These repeatable surveys enable direct comparison of the numbers of individuals recorded at each site from one year to the next. The sites have been established within creeks associated with and/or downstream of swamps. Sites will be established on LC5 and LC6 in Area 3C (**Figure 3-5**). Niche (2021) found populations of Littlejohn's Tree frog and potential habitat for Giant Burrowing Frog during recent surveys. Results from these surveys will be presented in the Dendrobium Annual Terrestrial Ecology Monitoring Program.

Observations of the sites, photo points and pool water level data will also be collected as part of the frog and observational monitoring programs. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

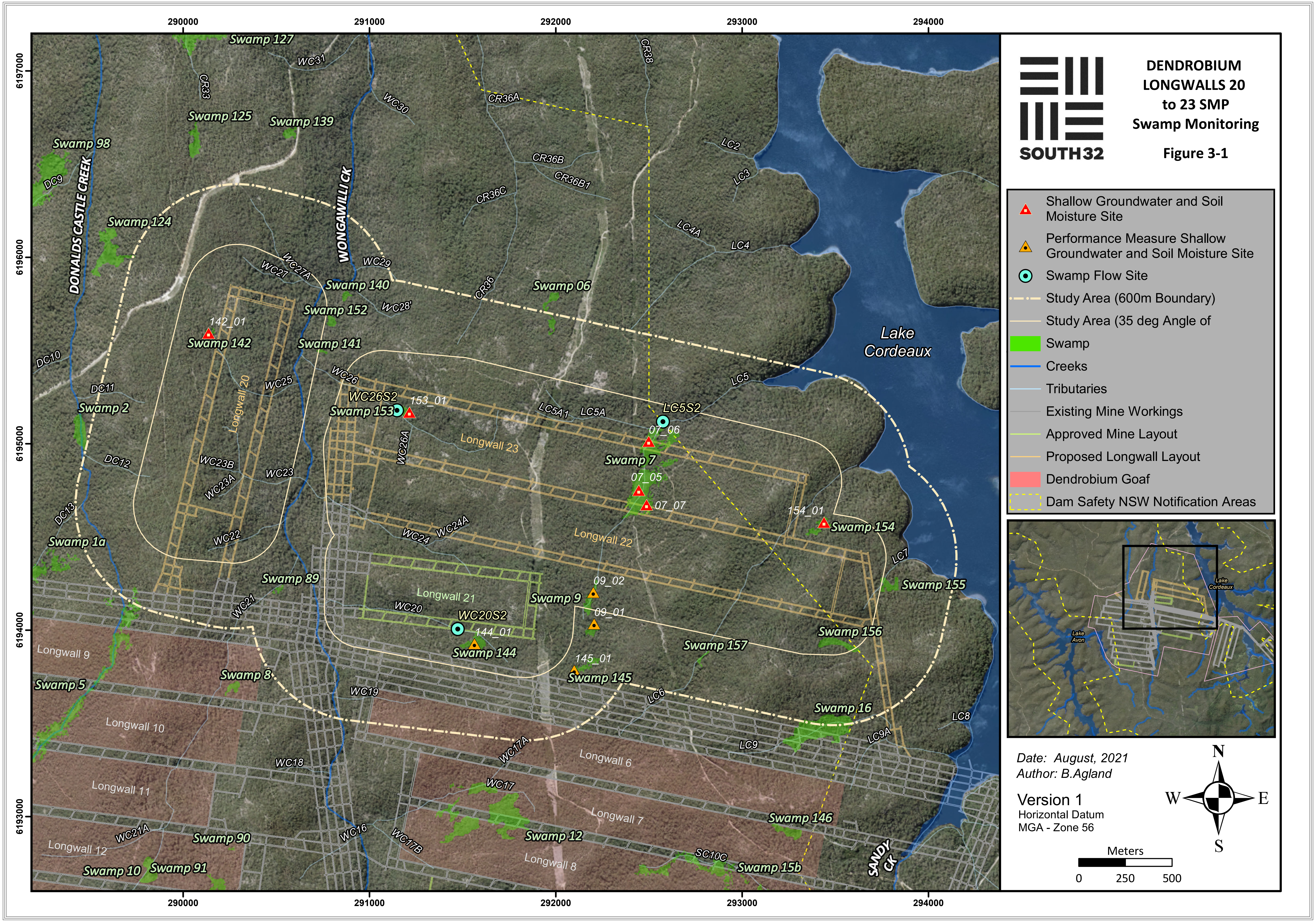
IMC continues to fund and support research into a regional understanding of the context and cumulative impact of the Dendrobium Mine on populations of Littlejohns Treefrog and Giant Dragonfly.

3.13 Reporting

EoP Reports are prepared in accordance with Condition 9, Schedule 3 of the Dendrobium Development Consent. Results from the monitoring program are included in the EoP Report and in the Annual Review. These reports detail the outcomes of monitoring undertaken; provide results of visual inspections and determine whether performance indicators have been exceeded.

Monitoring results will be reviewed monthly by the IMC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Principal Approvals will initiate the requirements of the TARPs shown as Appendix A.

Monitoring results are included in the Annual Reporting requirement under Condition 5, Schedule 8 in accordance with the Dendrobium Development Consent and are made publicly available in accordance with Condition 11 Schedule 8.


DENDROBIUM
LONGWALLS 20
to 23 SMP
Swamp Monitoring
Figure 3-1
SOUTH32
Shallow Groundwater and Soil Moisture Site
Performance Measure Shallow Groundwater and Soil Moisture Site
Swamp Flow Site
Study Area (600m Boundary)
Study Area (35 deg Angle of
Swamp
Creeks
Tributaries
Existing Mine Workings
Approved Mine Layout
Proposed Longwall Layout
Dendrobium Goaf
Dam Safety NSW Notification Areas
Date: August, 2021
Author: B.Agland
Version 1
Horizontal Datum
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Meters
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SANDY CK
Longwall 20
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Longwall 23
Longwall 6
Longwall 7
Longwall 8
Longwall 9
Longwall 10
Longwall 11
Longwall 12
Swamp 127
Swamp 125
Swamp 139
Swamp 98
Swamp 124
Swamp 140
Swamp 152
Swamp 142
Swamp 141
Swamp 2
Swamp 153
Swamp 06
Swamp 7
Swamp 154
Swamp 155
Swamp 156
Swamp 157
Swamp 9
Swamp 89
Swamp 1a
Swamp 144
Swamp 145
Swamp 8
Swamp 5
Swamp 16
Swamp 146
Swamp 12
Swamp 15b
Swamp 90
Swamp 10
Swamp 91
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153_01
WC26S2
LC5S2
07_06
07_05
07_07
154_01
09_02
09_01
WC20S2
144_01
145_01
CR33
CR38
CR36A
CR36B
CR36B1
CR36C
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WC23A
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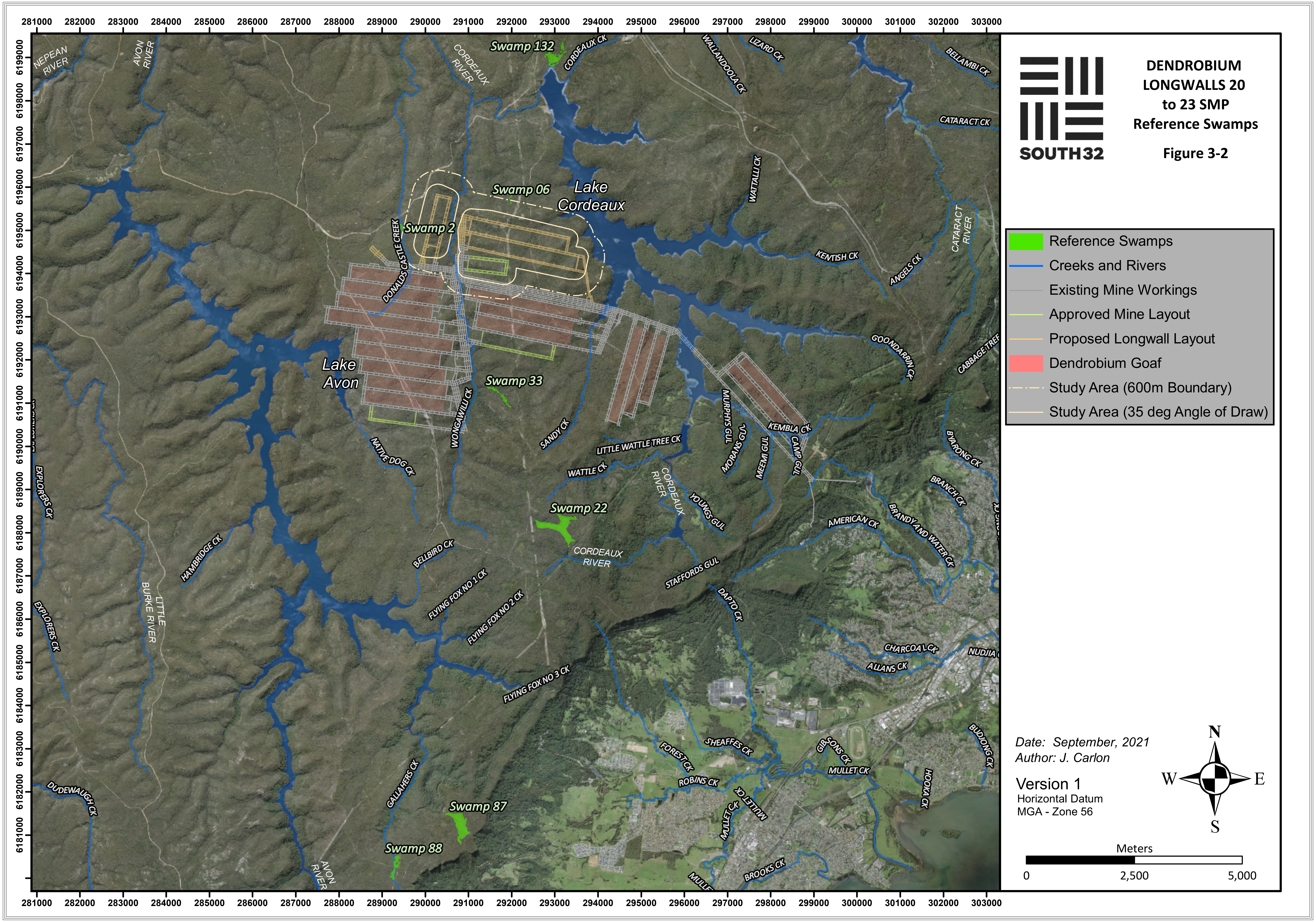

DENDROBIUM LONGWALLS 20 to 23 SMP Reference Swamps
Figure 3-2
SOUTH32
Reference Swamps
Creeks and Rivers
Existing Mine Workings
Approved Mine Layout
Proposed Longwall Layout
Dendrobium Goaf
Study Area (600m Boundary)
Study Area (35 deg Angle of Draw)
Date: September, 2021
Author: J. Carlon
Version 1
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Swamp 132
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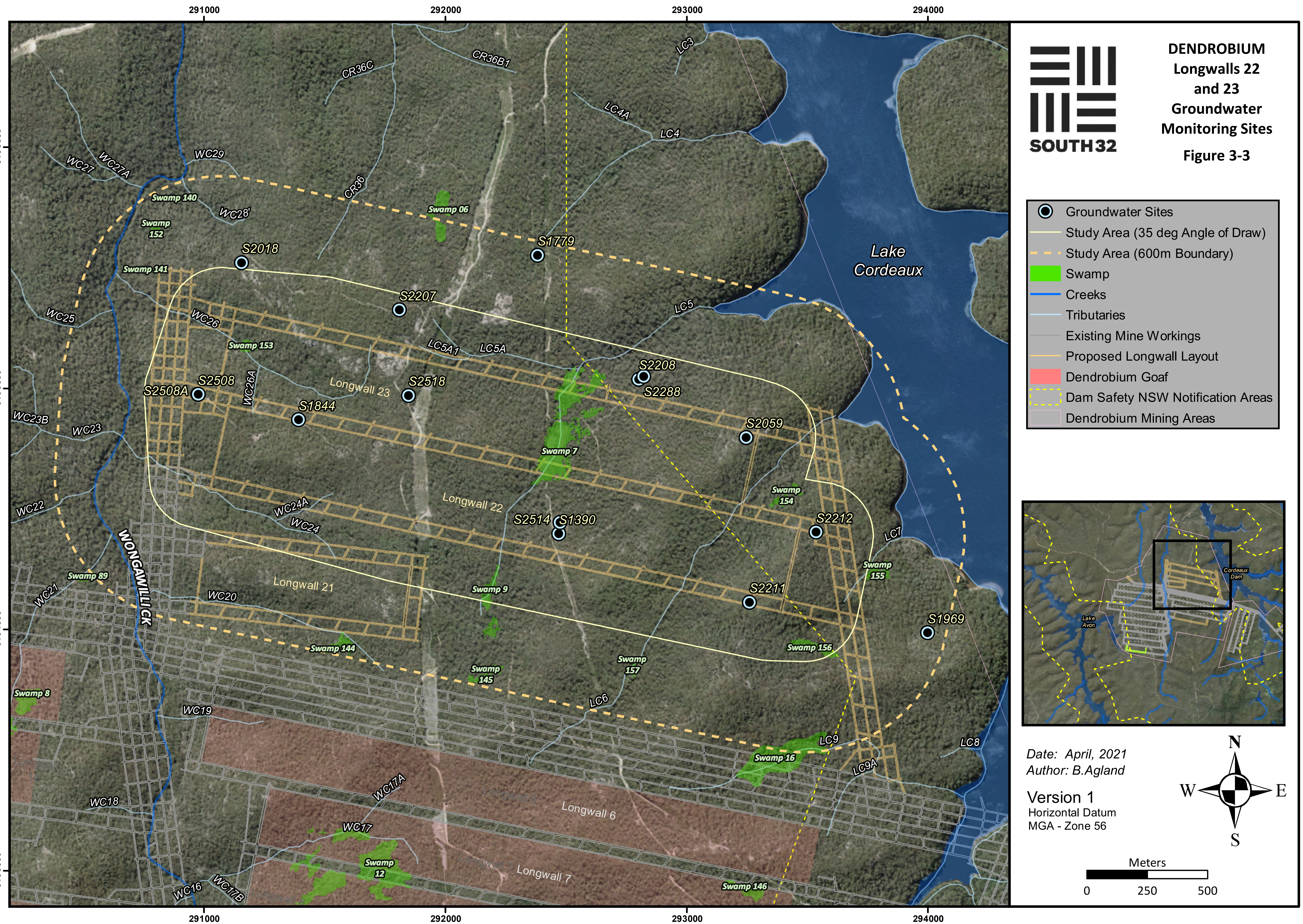
Lake Avon
NEPEAN RIVER
AVON RIVER
CORDEAUX RIVER
CORDEAUX CK
WALLANDOOLA CK
LIZARD CK
BELLAMBI CK
CATARACT CK
WATTALLI CK
KENTISH CK
ANGELS CK
CATARACT RIVER
GOONDARRIN CK
CABBAGE TREE
DONALDS CASTLE CREEK
WONGAWILLI CK
NATIVE DOG CK
SANDY CK
LITTLE WATTLE TREE CK
WATTLE CK
MURPHYS GUL
MORANS GUL
MEEMI GUL
KEMBLA CK
CAMP GUL
YOUNGS GUL
BYARONG CK
BRANCH CK
AMERICAN CK
BRANDY AND WATER CK
EXPLORERS CK
HAMBRIDGE CK
BELLBIRD CK
LITTLE BURKE RIVER
FLYING FOX NO 1 CK
FLYING FOX NO 2 CK
FLYING FOX NO 3 CK
STAFFORDS GUL
DAPTO CK
CHARCOAL CK
ALLANS CK
SHEAFFES CK
FOREST CK
ROBINS CK
MULLET CK
HOOKA CK
BUDJONG CK
DUDEWAUGH CK
GALLAHERS CK
BROOKS CK


DENDROBIUM
Longwalls 22 and 23
Groundwater Monitoring Sites
Figure 3-3
SOUTH32
Groundwater Sites
Study Area (35 deg Angle of Draw)
Study Area (600m Boundary)
Swamp
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Dam Safety NSW Notification Areas
Dendrobium Mining Areas
Date: April, 2021
Author: B.Agland
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Swamp 140
Swamp 152
Swamp 141
Swamp 06
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Swamp 155
Swamp 9
Swamp 89
Swamp 144
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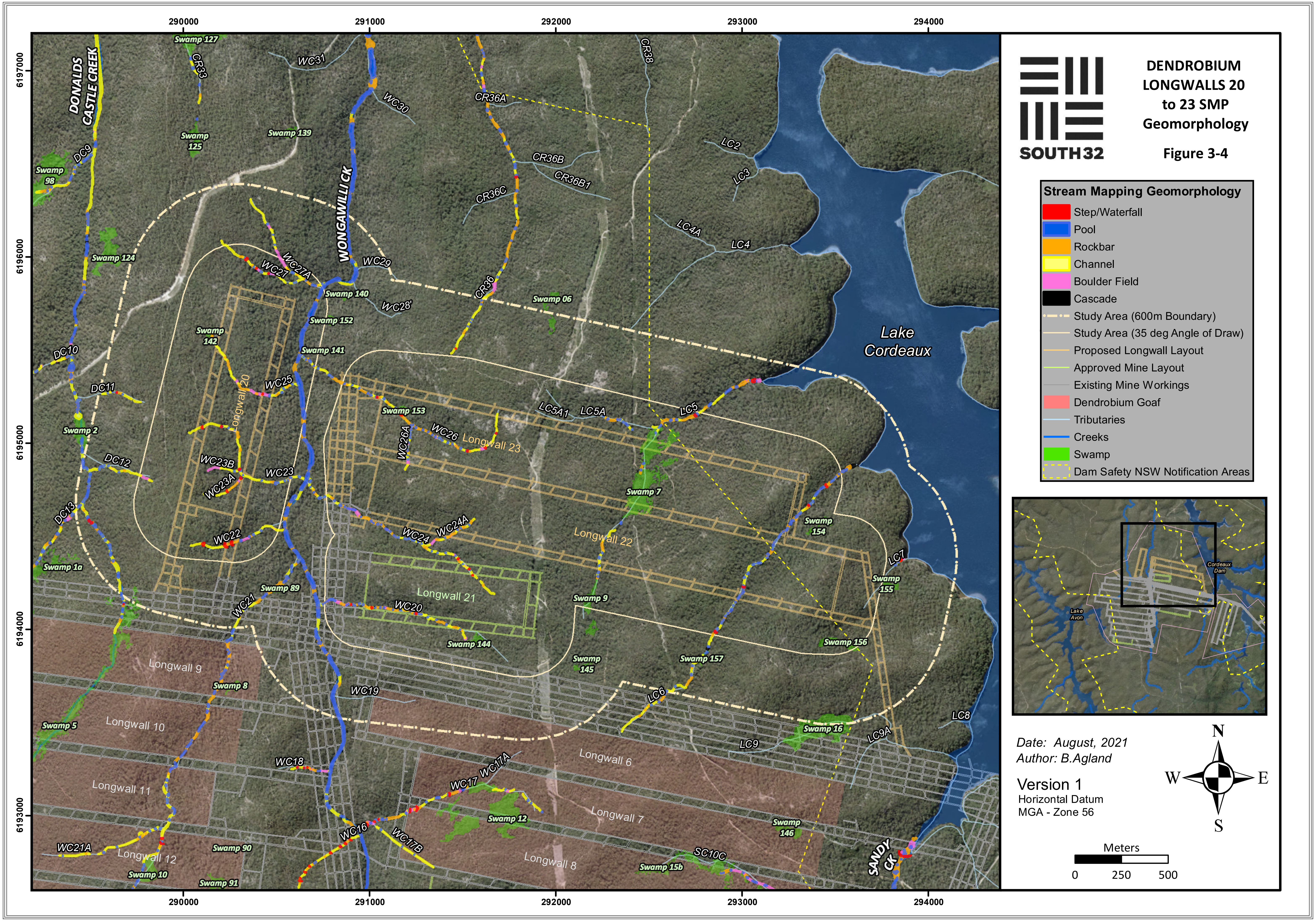
SOUTH32
DENDROBIUM LONGWALLS 20 to 23 SMP Geomorphology
Figure 3-4
Stream Mapping Geomorphology
Step/Waterfall
Pool
Rockbar
Channel
Boulder Field
Cascade
Study Area (600m Boundary)
Study Area (35 deg Angle of Draw)
Proposed Longwall Layout
Approved Mine Layout
Existing Mine Workings
Dendrobium Goaf
Tributaries
Creeks
Swamp
Dam Safety NSW Notification Areas
Date: August, 2021
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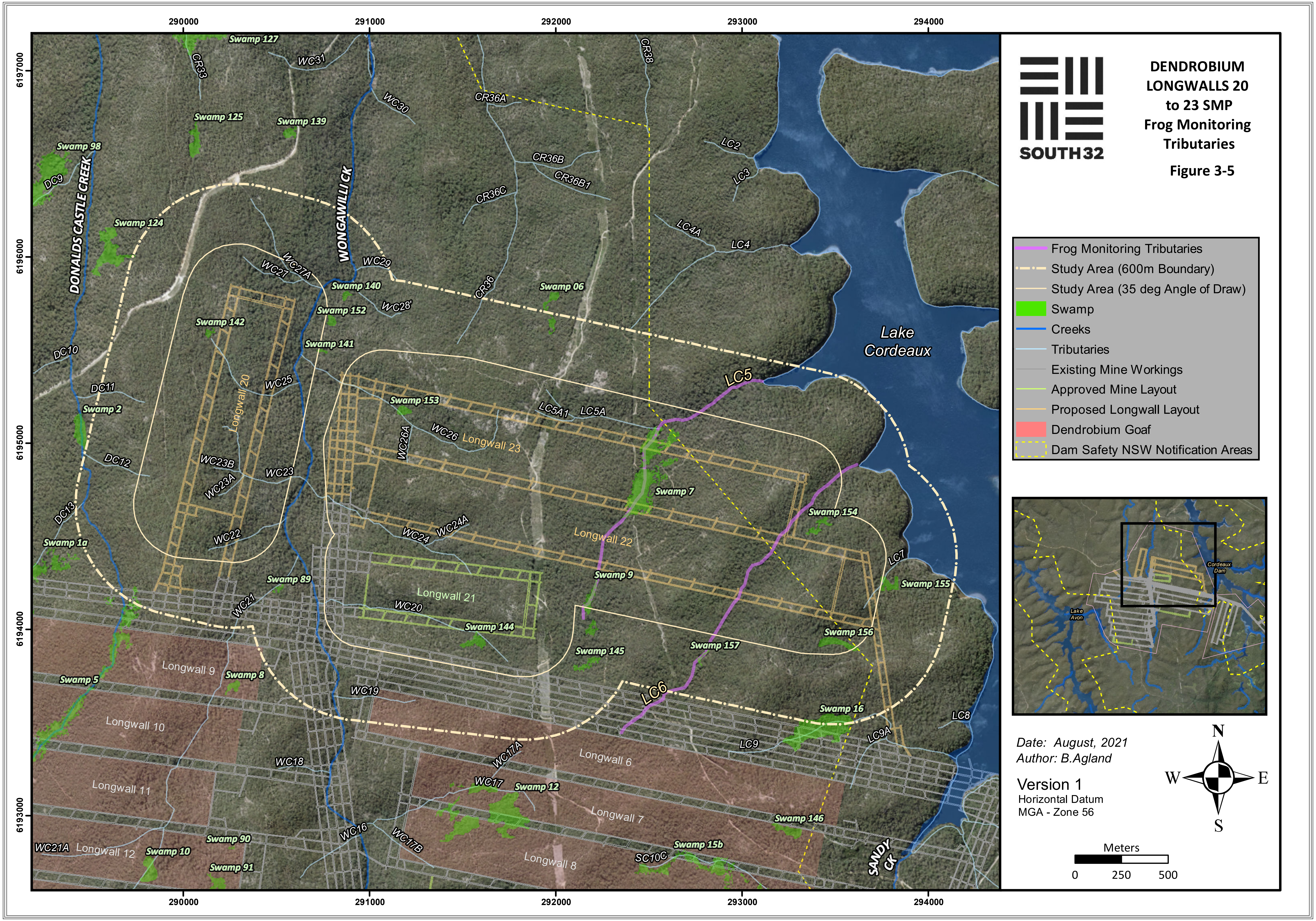

DENDROBIUM LONGWALLS 20 to 23 SMP
Frog Monitoring Tributaries
Figure 3-5
SOUTH32
Frog Monitoring Tributaries
Study Area (600m Boundary)
Study Area (35 deg Angle of Draw)
Swamp
Creeks
Tributaries
Existing Mine Workings
Approved Mine Layout
Proposed Longwall Layout
Dendrobium Goaf
Dam Safety NSW Notification Areas
Date: August, 2021
Author: B.Agland
Version 1
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Lake Avon
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4 PERFORMANCE MEASURES AND INDICATORS

Subsidence impact performance measures for Swamps 9, 144 and 145 are included within Condition 6, Schedule 3 of the Area 3C SMP Approval. Under the requirements of this approval and the Dendrobium Development Consent, these performance measures must be applied to the extraction of Longwalls 20 and 21.

A detailed list of performance measures and triggers is included in the Table 2-2 and the TARPs in **Appendix A**.

4.1 Impact Mechanisms

Subsidence is an unavoidable consequence of longwall mining and includes vertical and horizontal movement of the land surface. Subsidence effects include surface and sub-surface cracking, buckling, dilation and tilting. These effects can result in changes to the hydrology of watercourses.

Changes to watercourse hydrology and water quality can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The potential consequences of mining on groundwater and surface water in the Special Areas are (IEP 2019a):

- Groundwater depressurisation
  - The creation of an excavation below the water table can affect groundwater in a number of basic ways. In all cases, because the fluid pressure in an excavation is much lower than that of the fluid that originally occupied the space, a flow system is established with the excavation acting as a sink into which surrounding groundwater flows. The rate of flow and observed extent of depressurisation depend on the hydrogeological properties of the rock mass. If the excavated area is sufficiently large, the spatial extent and rate of flow into the sink can be enhanced by the formation of fractures.
- Surface water diversions
  - Diversions into a shallow, localised fracture network, where loss of flow from a surface water is likely to return to the system at some point downstream, which based on observations of the SCI (2008) may vary from 20 m for specific rockbars to more than 200 m.
- Surface water permanent losses
  - Diversions into deeper, dilated shear surfaces on bedding planes, where these form a conduit for lateral water flow, which may or may not report to the same catchment (i.e. it may become a permanent loss).
- Groundwater depressurisation
  - Groundwater within the Hawkesbury Sandstone and Narrabeen Group as well as the Permian coal measures is recharged from rainfall and water bodies where the lithologies occur at outcrop, as well as potential downward leakage from overlying strata (Hydrosimulations 2018).
- Water quality
  - Water quality within watercourses is affected by numerous factors including runoff from swamps and interactions between bedrock and water, with fracturing of bedrock due to mining causing local water quality impacts.

The environmental consequences which could relate to changes in hydrology and water quality include:

- Species composition change and/or changes in vegetation communities.
- Loss of aquatic ecology and/or changes in aquatic habitat resulting from a reduction of surface water quality and/or flows and standing pools.
- Water-borne inputs to Lake Avon, Lake Cordeaux and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates.
- Reduced inflows into Lake Avon, Lake Cordeaux and Cordeaux River.

An overview of the potential impacts and consequences of mining on swamps, surface flows and storages is presented in **Table 4-1**.

Table 4-1 Summary of subsidence effects, impacts and consequences for surface flows, storages and swamp hydrology (IEP 2019b)

Subsidence effects	Impacts	Consequences
• Tensile cracking, tensile, compressive or shear movement of joint and bedding plane • Fracturing of sandstone blocks • Buckling and localised upsidence in the stream bed below the swamp • Tilting of bedrock	• Cracking of rock bars • Lowered water tables and soil moisture • Potential erosion and scouring • Altered water chemistry e.g. enhanced release of iron • Change to the size of swamps	• Loss of surface flow and storage through leakage • Loss of baseflow generation including from swamps • Vulnerability of swamps to fire and further erosion and reduction in baseflow generation capacity • Increased loads of contaminants to water storages

4.2 Potential for Connectivity to the Mine Workings

The fracture zone comprises in-situ material lying immediately above the caved zone, which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation (Singh and Kendorski, 1981; Forster, 1995). Where the panel width-to-depth ratio is high, and the depth of cover is shallow, the fracture zone would extend from the seam to the surface. Where the panel width-to-depth ratio is low, and where the depth of cover is high, the fracture zone would not extend from the seam to the surface.

The possible height of the fracture zone is dependent upon the angle of break, the width of the panel, the thickness of seam extracted and the spanning capacity of a competent stratum at the top of the fracture zone (MSEC 2012). Based on mining geometry, the height of the fracture zone equals the panel width, minus the span, divided by twice the tangent of the angle of break.

It should be noted that the height of the fracture zone should be viewed in the context of fracturing only and should not be directly associated with an increase in vertical permeability. There are numerous models for the height of fracturing and height of desaturation. A review of these matters was conducted for the Bulli Seam Operations Project Response to PAC deliberations (Hebblewhite 2010).

The Regional Groundwater Models at Dendrobium uses site specific data to determine the height of desaturation. Dendrobium monitors in excess of 1,000 piezometers in ~100 boreholes (including a comprehensive array of piezometers above the centreline of longwall goafs) and has analysed many thousands of samples for field parameters, laboratory analysis, algae and isotopes.

The results of water analysis and the interpretation of the height of connective fracturing was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux".

Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield. On the basis of the available data and the Parson Brinckerhoff (2012) review it is considered that the height of desaturation used by Heritage Computing (2009 & 2011) is conservative.

In January 2015 SRK Consulting conducted a detailed independent review of the Dendrobium water chemistry data, to:

- Assess the level of detail, quality of science, depth and technical appropriateness of the water chemistry data.
- Evaluate associated interpretations in relation to underground operations of Dendrobium Mine, with specific focus on how these address the question of hydraulic connectivity between the mined areas and the reservoirs.

Based on the review SRK concluded that the observed geochemical trends are not consistent with a high degree of hydraulic connectivity between the underground workings and the surface water bodies.

As reported in Coffey (2012) most of the change in aquifer properties occurs within the collapsed zone.

Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storativity. Groundwater drawdown due to sudden storativity increases will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow.

Predictions of fracture zone dimensions for Dendrobium (MSEC 2012 and Coffey 2012) refer to geotechnical fracturing behaviour and are not necessarily directly related to a groundwater response resulting from increased vertical permeability.

Parson Brinckerhoff and IMC have completed testing to characterise the pre- and post-mining permeability above Longwall 9, the first longwall in a new domain, not affected by previous mining. After Longwall 9 mined under the site it was tested to quantify the change to vertical and horizontal permeability of the strata, including the Bulgo and Hawkesbury Sandstones and the Bald Hill Claystone. The testing involved core, packer and borehole interference testing, groundwater flow and tracer testing.

Mining of Longwall 9 resulted in a significant increase in subsurface fracturing compared with pre-mining. Down-hole camera surveys identified a number of open horizontal and inclined fractures with apertures of several centimetres. Groundwater ingress was noted at several open fractures.

Most post-mining test bores showed decreases in groundwater level and strong downward hydraulic gradients, particularly in the lower Bulgo Sandstone. Significantly however, groundwater levels in the shallow Hawkesbury Sandstone remained perched at the study site.

Horizontal hydraulic conductivity increased between one to three orders of magnitude due to mine subsidence and strata fracturing. Increases in hydraulic conductivity are observed in every geological unit but are greatest below the base of the Hawkesbury Sandstone.

In contrast to pre-mining testing in which no breakthrough was observed, horizontal tracer testing after the passage of Longwall 9 resulted in breakthrough in about 40 minutes. This indicates a bulk hydraulic conductivity in the order of 10 m/day; at least two orders of magnitude higher than pre-mining conditions.

No breakthrough in tracer was observed in either the pre-mining or the post-mining tests of the Bald Hill Claystone and this indicates that the vertical conductance at the research site was below the detection limit of the test, estimated to be approximately 0.7 m/day.

Activated carbon samplers deployed in streams adjacent to the research site detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths either existing or induced between the research site and adjacent streams.

Sampling of water from the underground mine detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths induced between the research site and the workings.

Although current observations do not allow a precise definition of the height of intense fracturing using any criteria (and the boundaries are gradational in any case), most evidence suggests that the zone of most intense and vertically connected fracturing within Area 3B extends into the Bulgo Sandstone.

Estimates for the height of fracturing at Dendrobium based on published methods range from 122 m to 357 m. This range in estimates is large and presents a challenge to those wishing to model hydrogeological impacts of mining on a regional scale based on mine site data.

The pre- and post-mining investigations carried out in this research study provide important constraints on the extent of mining related disturbance and its effect on groundwater systems.

In August 2015 HydroSimulations' completed an assessment of the estimated height of connected fracturing at Dendrobium. The assessment included:

- The effects of longwall mining and subsidence on overburden strata;
- A summary of previous research in relation to estimating the extent of the deformed strata above longwall mining, both in general and at Dendrobium;
- Revised estimates of the height of connected fracturing for Dendrobium longwalls using the Ditton 'Geology Model' (Ditton and Merrick, 2014) and the Tammetta (2013) method.

The assessment concluded that the Ditton 'Geology model', as outlined in Ditton and Merrick (2014), is the most appropriate method for estimating the vertical extent of connected fracturing above longwalls at Dendrobium. This is supported by the research above Longwall 9 by Parsons Brinkerhoff (2015) and earlier studies by GHD (2007) and Heritage Computing (2011).

A review of methods for estimating the height of fracturing above longwall panels at Dendrobium Mine was commissioned by DPIE and carried out by geotechnical consultants Pells Sullivan Meynink (PSM). The PSM report was finalised in June 2017 and made available to South32 on 7 September 2017.

Recommendations by PSM regarding additional monitoring and research to add to our understanding of the catchment are generally sensible and many of these have already been acted on.

The IEP (2019b) Part 2 Report further considered mining operations within the special areas and reiterated its earlier position stated in IEP (2019a):

The Panel has given detailed consideration to the equations in the Part 1 Report and concluded that it cannot endorse either at this point in time. For a range of reasons, neither or either may ultimately prove to be sufficiently reliable. It recommended erring on the side of caution and deferring to the Tammetta equation until:

i. *field investigations quantify the height of complete drainage at Metropolitan and Dendrobium mines; and/or*

ii. *geomechanical modelling of rock fracturing and fluid flow are shown to be sufficiently reliable for informing the calibration of groundwater models at mine sites in the catchment.*

The Regional Groundwater Model for Dendrobium Mine has been revised to consider the findings of the PSM report and IEP Reports (2019a), including the use of the Tammetta model and modelling connectivity to the surface. HydroSimulations state that regardless of the method used to assess fracturing, they believe the current groundwater modelling approach is sound.

In accordance with Schedule 3, Condition 19(c) of the Area 3B SMP Approval, height of connective fracturing investigations across longwalls in Area 3B are undertaken and reported to the Department prior to each longwall extraction. The most recent report, Hebblewhite (2020) states:

… comments and conclusions are drawn in relation to the overall concept of height of depressurisation, and the status of predictive models:

- *… mining-induced impacts are occurring above all panels throughout the overburden sequence, through to, or very close to the surface in all cases. This includes increased defect/fracture impacts; significant increases in permeability; and reduction to near-zero pressure head throughout the strata.*
- *There is some evidence of very localised retained groundwater in perched aquifers at some locations, and at different vertical horizons, but these are not extensive.*
- *On the basis of this evidence, it is reasonable to conclude that the height of depressurisation is close to, or equal to the total depth of overburden above the working coal seam, i.e. extending to the surface in each instance.*

- *In spite of the reduced longwall panel width in Area 3A (LW6 and LW7), the height of depressurisation has still effectively extended to the surface, albeit with a reduced strata fracture density above the mined panels. It is likely that a more significant panel width reduction and or mining height reduction would be necessary to cause a significant reduction in height of depressurisation in this particular mining region.*
- *The lack of significant differential in height of depressurisation with the reduced panel widths means that the range of the dataset available to assist with developing an improved prediction model remains inconsistent, and insufficient to enable any further model development based on empirical methods.*
- *There is strong evidence at all locations of significant depressurisation occurring ahead of under-mining, due to the effect of adjacent mining panels, and earlier mining development. These effects are evident at most of the strata horizons, extending towards the surface.*
- *… the Tammetta model is clearly the most appropriate one to continue using in the future. It provides a reasonably accurate prediction – given the variability of factors such as depth across any particular panel.*

4.3 Potential for Fracturing Beneath the Swamps

Based on the predicted systematic and non-systematic subsidence movements (2021) the bedrock below the swamps and any significant permanent pools within the swamps are likely to fracture as a consequence of subsidence induced strains.

Surface flows captured by the surface subsidence fracture network resulting from valley related movements which do not connect to a deeper aquifer or the mine workings will re-emerge further downstream. This prediction is based on an assessment of the depth of valley closure induced vertical fracturing from the surface and measurements of water balance during the modelled periods of recessional, baseflow and small storm unit hydrograph periods downstream of mining areas.

The depth of fracturing in the “surface zone” is addressed in the Bulli Seam Operations Environmental Assessment: Section 5.2.1, Appendix A, Appendix B and Appendix C as well as in the Response to Submissions and Response to the NSW Planning Assessment Commission. The BSO Independent Peer Review of strata deformation provided by Professor Bruce Hebblewhite concurs with the concept of the “surface zone” fracture network related to down-slope or valley movements. Several studies have determined the depth of these vertical fracture networks are restricted to approximately 15 m to 20 m below the surface.

The depth and other attributes of the surface fracture zone have been comprehensively determined using the following instruments and techniques:

- Calliper logging;
- Straddle packer permeability testing;
- Overcore stress measurements;
- Core logging and geotechnical testing;
- Geophysical testing;
- Water level monitoring;
- Borehole cameras;
- Subsidence, extensometer monitoring and shear deformation monitoring;
- Stress change and fracture logging;
- Permeability testing and falling head tests; and
- Mapping of pressured air drilling fines.

The following sites have been comprehensively investigated to demonstrate the dimensions of the “surface fracture zone”:

- Two rockbars on the Waratah Rivulet; and
- Four rockbars on Georges River.

Monitoring from Dendrobium Mine indicates the surface fracture network over the goaf connects to or is concurrent with the fracture network which propagates from the seam to the surface. In this instance the diversion of surface flow to deep strata or the mine relates to vertical permeability increases associated with this fracturing.

Prior to any remediation works within Area 3B that target surface/shallow fracture networks, the depth of the fracturing will be characterised by standard techniques such as drilling, down hole cameras and calliper measurements. The hydraulic conductance of these fracture networks will also be determined prior to implementing any rehabilitation.

At reference swamp sites, shallow groundwater levels recovered in 2020, with saturation levels similar to those prior to the 2017-2019 drought (HGEO 2021b).

Longwall 16 passed beneath (or within 400 m of) Swamps 23, 13 and 14 during 2020. Those swamps were partially mined under by Longwall 15. At Swamp 23, one piezometer (23_01) out of two installed in the swamp records a change in saturation duration following rainfall and represents a Level 2 TARP. At Swamp 14, both piezometers installed in the swamp recorded a decrease in saturation and an increase in recession rate following the passage of Longwall 15 and 16, representing a Level 3 TARP. At swamp 13, peak groundwater level and duration of saturation remain somewhat lower than in pre-drought conditions, and relative to reference sites (TARP Level 3). The observed effects at swamps are in line with impacts anticipated in the SMP (HGEO 2021b).

At Swamp 14 there is evidence for a decline in moisture levels at S14_S01 following passage of Longwall 16 which contrasts with the recovery in soil moisture at reference swamps. Soil moisture recovered at S14_S02 during 2020 with no clear evidence of a mining effect. Observed effects represent a TARP level 2 trigger. At Swamp 23, soil moisture levels recovered during 2020 following the 2017-2019 drought, to a range similar to the baseline period. On this basis, a soil moisture TARP was not triggered (revised from Level 2 in the previous assessment). Similarly, the soil moisture TARP level at Swamp 13 has been revised down to Level 2 due to recovery in 2020 at one piezometer (HGEO 2021b).

4.4 Potential for Erosion Within the Swamps

Tilting, cracking, desiccation and/or changes in vegetation health could result in concentration of runoff and erosion which intern could alter water distribution in the swamp. Changes to swamp hydrology can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The possible impacts of the drying of swamps due to mining-induced changes in hydrology include (IEP 2019b):

- reduction of soil moisture levels and loss of cohesiveness of the swamp sediments
- enhanced risk of channelization and consequent susceptibility to erosion of swamp sediments, with potential water quality implications
- decline of groundwater-dependent plant species and consequent changes in vegetation structure
- decline of groundwater-dependent fauna including macroinvertebrates and stygofauna
- oxidation of peaty sediments resulting in increased hydrophobicity, lower water-holding capacity and potential changes in nutrient status and cycling
- increased risk of erosion, which may lead to gully formation.
- swamps have less resilience to bushfires which, in turn, can lead to an increased susceptibility to erosion and loss of baseflow (NSW Threatened Species Scientific Committee, 2012).

Subsidence predictions were carried out to assess the potential impacts of longwall mining in Area 3C. The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the swamps is provided in **Section 5**.

Tilting of sufficient magnitude could change the catchment area of a swamp or re-concentrate runoff leading to scour and erosion, potentially reducing the water flowing onto a swamp or allowing water to escape from the swamp margins. These effects could be observed within the whole swamp or alter water distribution in parts of the swamp, thus favouring some flora species associations over others.

Changes in gradients predicted to occur following mining are discussed in **Section 5.2.1**. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2021). The assessment takes into account the nature of the drainage channel and whether the predicted tilt is significant when compared to the existing slopes.

Landscape monitoring commenced in 2004 for Dendrobium Area 1. This monitoring program has been continued and updated throughout the mining period for Areas 2, 3A and 3B. The monitoring includes inspections of swamps at regular intervals prior to mining, during active subsidence and following the completion of subsidence movements. In addition to erosion (increased incision and/or widening), these observations target any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, slope and gradient changes, the condition of rock-bars and peat condition.

The observed impacts on natural features above Longwalls 1 – 16 have been generally consistent with those predicted in the assessments undertaken prior to mining.

In Area 3B, to date there has been no instance of erosion resulting from this cracking. No erosion of the surface of the swamps as a result of mining observed to date. For Area 3B to completion of Longwall 13, 126 surface impacts have been identified. Many of these are very minor impacts and of very limited environmental consequence. For example, 91% of the cracking identified at the surface has a width of less than 100 mm. To date there has been no instance of erosion resulting from this cracking (Illawarra Coal 2018).

Swamp 18 is a swamp that some have reported to be impacted by mining. An important observation of Tomkins and Humphreys (2006) is that in 1951, Swamp 18 was more extensive and included a continuous, intact swampy unit infilling the valley of Native Dog Creek for several hundred meters downstream of the main body of the swamp to link with Swamp 19. Furthermore, the gully erosion of the lower extension of the swamp had commenced before 1951 and had reached the main body of Swamp 18 by 1990, well before underground coal mining in this area.

In 2003 approximately 450 m of gully erosion was identified in Swamps 1A and 1B and the associated stream before any mining influence in the area. These case studies demonstrate that erosion within swamps can be active without any influence of mining.

4.5 Potential for Vegetation Changes Within the Swamps

Where there are changes to swamp hydrology that are large and persistent there is likely to be a vegetation response. Swamp vegetation is likely to be relatively resilient to short term changes in groundwater level and soil moisture, demonstrated by the persistence of the swamp vegetation communities during extended periods of drought. For this reason, any response to changes in swamp hydrology are likely to be over the medium to longer time period as the vegetation equilibrates to the new hydrological regime. Vegetation change may be observed in the rates of species composition change and/or changes in vegetation communities over and above what is measured in nearby swamps due to natural variation.

The IEP Report (2019b) recognised that improvements in monitoring data supported by a substantial body of research has improved understanding of the impacts and consequences of longwall mining for swamps. The report also established that longwall mining directly under swamps in the Southern Coalfield can result in significant changes to swamp hydrology and redirection of surface runoff which currently appear to be irreversible. Additionally, the IEP Report (2019b) concluded:

- Impacts on swamps and on the streams exiting from them are evident, however currently there is no strong evidence to date of consequences of swamp impacts on catchment-scale water supplies.
- When shallow groundwater levels in a swamp decline, soil moisture levels also decline, with a lag time of weeks or months.
- Quantifying the consequences of changes for flows in exit streams requires the development of water balance models of the swamps.
- Mining-induced changes to upland swamp vegetation communities are still not able to be differentiated from natural changes.
- Vegetation change assessment does not provide a clear and timely measure of possible changes in ecosystem functionality of the upland swamps. While changes in methodology, such as using targeted obligate swamp-dependent species (either plants or animals) may improve assessment, the decadal nature of many changes remains.

4.6 Achievement of Performance Measures

Due to the relatively recent inclusion of BACI designed monitoring programs related to long-term monitoring parameters there is some uncertainty related to the achievement of long-term performance measures. However, mining has been occurring for a number of years beneath swamps and this allows an opportunity to do some relatively simple back analysis of impacts to these features over the long-term. This approach has the disadvantage of a relatively simple experimental design whereby only obvious changes as a result of the mining are likely to be identified.

Subsidence predictions for swamps in historic mining areas were reviewed as part of the Bulli Seam Project Environmental Assessment (Resource Strategies 2009).

Field investigations were carried out in these swamps to assess impacts and consequences from various levels of back-predicted levels of subsidence movement. This data was used to inform the assessment of risk of impacts and environmental consequences for the Bulli Seam Operation Project. A summary of the review findings is provided below.

Back predictions have been undertaken for 34 swamps previously subject to subsidence in the Southern Coalfield. The back predictions indicate that six of these swamps would have been subject to closure values of greater than 200 mm, namely:

- Swamp STC-S4 (221mm predicted closure) at West Cliff;
- Swamp STC-S1c (276mm predicted closure) at West Cliff;

- Swamp STC-S1a (278mm predicted closure) at West Cliff;
- Swamp 12 (335mm predicted closure) at Dendrobium;
- Swamp STC-S1b (461mm predicted closure) at West Cliff; and
- Swamp STC-S2 (542mm predicted closure) at West Cliff.

Site inspections have been conducted of the swamps listed above. An additional ten swamps predicted to have been previously subject to less than 200 mm valley closure were also inspected. The inspection methods included walking the length of the swamp and recording observations of any significant environmental impacts or consequences, for example:

- Significant subsidence-induced buckling or cracking.
- Any significant erosion or scour.
- Significant vegetation dieback on a broad scale.
- Significant desiccation of vegetation or peat materials on a broad scale.

It is recognised that there are limitations associated with the assessment. As stated above, the assessment is based on back predictions of subsidence effects, as opposed to observed (i.e. monitored) subsidence effects. However, these back predictions are being compared with predictions using the same methodology for analysis at Dendrobium, thus ensuring consistency within the comparative assessment.

Evidence of cracking and minor erosion was observed during the site inspections; however, no evidence of significant environmental consequences was observed.

Observational monitoring of upland swamps on the Woronora Plateau has been conducted by IMC since 2003. The results of this observational monitoring are in the report Understanding Swamp Conditions (BHPBIC 2010).

The report identifies any morphological, geological, hydrological and/or botanical changes observed in the swamps since inspections were initiated in winter 2003. Data is collected and analysed in such a way to identify and record any episodic or temporal changes to these swamp features.

Data is collected with the use of field instruments and through visual inspections of the dominant features within each swamp. The monitoring includes location and extent of any surface water or moisture, the health and location of vegetation, sediment and peat distributions and depths, as well as any cracking, erosion or sedimentation. Observation sites are recorded and plotted on plans with relevant comments.

A total of 28 swamps were visited and inspected between October 2010 and November 2010. A field sheet and plan with defined "Swamp Characteristics" were used to collect the data. Field officers visit each swamp and photograph and record data at various accessible sites. Data collection methodologies are consistent with previous swamp inspections. Swamp characteristics photographed and recorded include:

- Water: Location, volume and flow characteristics.
- Vegetation: Location, species, height and observed health.
- Sediment: Composition, depth and moisture.

The data is used to compare the conditions of sites in swamps before and after mining and under different climatic conditions. Data is also used to outline differences in swamp conditions due to geological and morphological conditions.

5 PREDICTED IMPACTS TO UPLAND SWAMPS

Subsidence has the potential to impact swamps overlying the proposed longwalls due to either transient or relatively permanent changes in porosity and permeability of a swamp or hillslope aquifer. Underlying sandstone substrate is likely to fracture as a result of the predicted differential subsidence movements.

If a swamp overlies a longwall panel it may undergo temporary extensional "face line" cracking (perpendicular to the long axis of the panel) as the panel retreats, followed by re-compression as the maximum subsidence occurs.

In addition, a swamp may also undergo both longer term extensional "rib line" cracking (parallel to the long axis of the panel) along the outer edge and compression within the central portion of the subsidence trough.

Non-conventional movements can also occur, and have occurred, in the NSW Coalfields as a result of, amongst other things, anomalous movements, valley closure and downslope movements. Many of the swamps are located in the bases of drainage lines and, therefore, could experience valley and slope related movements. The predicted valley related movements are provided in MSEC (2021). The maximum valley related movements are predicted to occur in the bases of the streams within the extents of the valley infill swamps. The headwater swamps are located partly up the valley sides and, therefore, in these cases the predicted valley related movements (upsidence and closure) for these swamps are less than the maxima provided in MSEC (2021).

Conventional closures result from sagging curvature; these predictions are provided separately to the valley related closures, as the associated conventional strains are distributed across the longwalls, as opposed to the valley related compressive strains, which are concentrated in the valley bases. Generally, the valley related closures and conventional closures are orientated obliquely to each other.

Fracturing would be visible at the surface where the bedrock is exposed, or where the thickness of the overlying sediment is relatively shallow. It is predicted that fractures would develop beneath any sediments within the swamps of a similar nature and magnitude to those observed at the surface on exposed bedrock.

In accordance with the findings of the Southern Coalfield Inquiry and the IEP (2019a):

- **Subsidence effects** are defined as the deformation of ground mass such as horizontal and vertical movement, curvature and strains.
- **Subsidence impacts** are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata.
- **Environmental consequences** are then identified, for example, as a loss of surface water flows and standing pools.

5.1 Description of Upland Swamps Within the Longwalls 22 and 23 Study Area

There are six swamps that have been identified wholly or partially within the Longwalls 22 and 23 Study Area based on the 35° angle of draw line. There are eight additional swamps that are located wholly or partially within the Longwalls 22 and 23 Study Area based on the 600 m boundary. Swamps 7 and 153 are located directly above the proposed longwalls. Further swamp details are provided in **Table 3-1**.

Incremental impacts predicted to upland swamps from Longwalls 20 and 21 are stated in the Longwalls 20 and 21 SMP. Subsidence predictions discussed in this Plan are focused on the proposed Longwalls 22 and 23. Where swamps may be influenced by multiple longwalls, maximum predictions include cumulative predictions.

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the swamps located within the Longwalls 22 and 23 Study Area is provided in **Table 5-1**. The values are the maxima within 20 m of the mapped extents of each of the swamps within the Study Area due to the extraction of the existing longwalls of the existing and proposed longwalls in Areas 3A, 3B and 3C.

Table 5-1: Maximum predicted total vertical subsidence, tilt and curvatures for the swamps

Reference	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Swamp 6	< 20	< 0.5	< 0.01	< 0.01
Swamp 7	2650	35	0.90	0.70
Swamp 9	< 20	< 0.5	< 0.01	< 0.01

Swamp 16	30	< 0.5	< 0.01	< 0.01
Swamp 140	< 20	< 0.5	< 0.01	< 0.01
Swamp 141	< 20	< 0.5	< 0.01	< 0.01
Swamp 144	< 20	< 0.5	< 0.01	< 0.01
Swamp 145	< 20	< 0.5	< 0.01	< 0.01
Swamp 152	< 20	< 0.5	< 0.01	< 0.01
Swamp 153	2100	30	0.50	0.60
Swamp 154	< 20	< 0.5	< 0.01	< 0.01
Swamp 155	< 20	< 0.5	< 0.01	< 0.01
Swamp 156	< 20	< 0.5	< 0.01	< 0.01
Swamp 157	< 20	< 0.5	< 0.01	< 0.01

Swamps 7 and 153 are located directly above the proposed longwalls. These two swamps are predicted to experience subsidence effects up to 2650 mm vertical subsidence, 35 mm/m tilt (i.e. 3.5 %, or 1 in 29), 0.90 km-1 hogging curvature (1.1 km minimum radius) and 0.70 km-1 sagging curvature (1.4 km minimum radius).

The maximum predicted conventional strains for Swamps 7 and 153, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 14 mm/m tensile and 11 mm/m compressive. The maximum predicted strains directly above the mining area are 8 mm/m tensile and compressive based

The remaining swamps are located outside the mining area, at minimum distances ranging between 70 m and 540 m from the proposed longwalls. These swamps are predicted to experience up to 30 mm vertical subsidence due to the mining of Longwalls 22 and 23. While the swamps located outside the mining area could experience low levels of vertical subsidence, they are not expected to experience measurable conventional tilts, curvatures or strains.

Swamps 7, 9, 16, 144, 153 and 157 are located near the bases of the valleys associated with the streams. These swamps could experience valley-related effects due to the extraction of the proposed longwalls. The remaining swamps within the Study Area are located further up the valley sides and, therefore, are unlikely to experience upsidence or compressive strain due to valley closure effects.

A summary of the maximum predicted total upsidence and closure for the swamps within the Study Area is provided in **Table 5-2.** The values are the maxima within 20 m of the mapped extents of each of the swamps within the Study Area due to the extraction of the existing longwalls in Areas 3A and 3B and the proposed longwalls in Area 3C.

Table 5-2 Maximum predicted total upsidence and closure for the swamps

Location	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Swamp 7	325	475
Swamp 9	125	200
Swamp 16	40	60
Swamp 144	125	225
Swamp 153	275	400
Swamp 157	80	150

Swamps 7 and 153 are located directly above the proposed longwalls and they are within valleys with equivalent heights ranging between 25 m and 50 m. The maximum predicted compressive strain for the parts of these two swamps located directly above the proposed mining area is 17 mm/m based on the 95 % confidence level.

The remaining swamps are located outside the mining area, at minimum distances ranging between 70 m and 540 m from the proposed longwalls, and they are within valleys with equivalent heights ranging between 5 m and 25 m. The maximum predicted compressive strain for these swamps is 3 mm/m based on the 95 % confidence level.

5.2 Impact Assessment

5.2.1 Potential for changes in surface water flows due to the mining-induced tilts

Mining can impact surface water flows through swamps, if the mining-induced tilts are much greater than the natural gradients, potentially resulting in increased levels of ponding or scouring, or impacting the distribution of water within the swamps.

Swamps 7 and 153 are located directly above the proposed longwalls. The maximum predicted tilt for these two swamps is 35 mm/m (i.e. 3.5 %, or 1 in 29). The natural grades within the swamps are lowest along the streams in the bases of the valleys.

There are predicted reductions in grade along LC5 and within the extent of Swamp 7. There is potential for minor and localised increased ponding upstream of these locations and within this swamp. The topographical depressions are predicted to be less than 0.4 m deep and 60 m long and are localised in the base of the valley.

The areas of the swamp further up the valley sides have higher natural grades and there are no predicted reductions in grade away from the valley base. There are no predicted reductions in grade along WC26 nor within the extent of Swamp 153. Similarly, there are no predicted reductions in grade along the remaining streams nor within the remaining swamps in the Study Area, as they are located outside the mining area and they are predicted to experience tilts of less than 0.5 mm/m (i.e. less than 0.5 %, or 1 in 2000). It is unlikely, therefore, that these swamps would experience adverse changes in the levels of ponding or scouring based on the predicted vertical subsidence and tilt.

5.2.2 Potential for cracking in Upland Swamps and fracturing of bedrock

Fracturing of the bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than approximately 0.5 mm/m or where the compressive strains have been greater than approximately 2 mm/m.

As Swamps 7 and 153 are located directly above the proposed longwalls, The maximum predicted compressive strain due to the valley-related effects for the parts of these swamps located directly above the proposed mining area is 17 mm/m based on the 95 % confidence level. Away from the valley base, the maximum predicted strains for the parts of these two swamps located directly above the proposed mining area are 8 mm/m tensile and compressive based on the 95 % confidence levels.

The typical fracture widths in the bedrock beneath Swamps 07 and 153 could be similar to the surface deformations previously observed at the Mine. Fracturing would only be visible at the surface where the bedrock is exposed, or where the thickness of the overlying soil is relatively shallow.

Swamps 7 and 153 are also predicted to experience up to 325 mm upsidence and 475 mm closure. These valley-related effects could result in the dilation of the strata beneath these two swamps. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley-related effects, is generally in the order of 10 m to 15 m (Mills 2003, Mills 2007, and Mills and Huuskes 2004).

The dilated strata beneath the drainage lines and within Swamps 7 and 153 could result in the diversion of some surface water flows beneath parts of these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation.

The remaining swamps are located outside the mining area, at minimum distances ranging between 70 m and 540 m from the proposed longwalls. Fracturing has been observed in streams located outside the extents of previously extracted longwalls in the NSW coalfields. Fracturing has been observed in the drainage lines at distances of up to 290 m from the previously extracted longwalls in Area 3B. Minor and isolated fracturing has also been observed up to 400 m outside of longwalls extracted elsewhere in the Southern Coalfield.

Swamp 9 is located near the base of LC5 and it is at a minimum distance of 90 m from the proposed longwalls. Fracturing could occur in the base of the valley and within this swamp. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley-related effects at similar distances from previous longwall mining.

Swamp 157 is located near the base of LC6 and it is at a minimum distance of 335 m from the proposed longwalls. It is possible, but unlikely, that fracturing could occur in the base of the valley and within this swamp. Fracture widths less than 20 mm have been observed due to valley-related effects at similar distances from previous longwall mining.

The remaining swamps within the Study Area are either located on the valley sides or are more than 400 m outside the proposed mining area. It is unlikely therefore that fracturing would develop in the bedrock beneath these remaining swamps.

5.2.3 Potential changes to Upland Swamp Hydrology

Swamps that have been mined beneath commonly display hydrological changes shortly following the passage of the longwall beneath the shallow groundwater monitoring site; specifically:

- A decrease in the average shallow groundwater elevation;
- A decrease in the duration of saturation of the swamp sediments following a significant rainfall event; or
- A change in the shape of saturation peak and recession curves (and recession rate) in response to significant rainfall events.

Potential changes to swamp hydrology within the Longwalls 22 and 23 Study Area is detailed in **Table 5-3.**

Watershed HydroGeo undertook an assessment at Dendrobium Mine concluded that hydrological change in upland swamps is not evident in shallow groundwater piezometers located more than 60 m from the extracted longwall margin (Watershed HydroGeo, 2019). A total of 4.54 ha of upland swamps is located within 60 m of the proposed longwalls (**Table 3-3**).

Table 5-3 Summary of predicted impacts to upland swamps

Swamp	Distance from longwall (m)	Likelihood of shallow groundwater effects (HGEO 2021a)	Potential ecological impacts (Niche 2021a)
Swamp 6	488	Unlikely	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Swamp 7	0	Likely	Possible ecological impacts including changes in vegetation. Wetter Swamp types (such as Tea-tree Thicket) may trend towards Banksia Thicket or Fringing Eucalypt Woodland if changes are long-term. Vegetative dieback may be experienced due to reduction in water holding capacity of the swamp.
Swamp 9	90	Possible	Possible ecological impacts including changes in vegetation, with areas trending towards Banksia Thicket or Fringing Eucalypt Woodland if changes are long-term.
Swamp 16	542	Unlikely	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Swamp 140	527	Unlikely	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Swamp 141	360	Possible	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall, the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Swamp 144	503	Unlikely	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.

Swamp	Distance from longwall (m)	Likelihood of shallow groundwater effects (HGEO 2021a)	Potential ecological impacts (Niche 2021a)
Swamp 145	498	Unlikely	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Swamp 152	436	Unlikely	Unlikely to be measurable impacts, given the distance from the longwall and that subsidence effects are generally only experienced up to 400 m from a longwall.
Swamp 153	0	Likely	Possible ecological impacts including changes in vegetation, trending towards Fringing Eucalypt Woodland. Vegetative dieback may be experienced due to reduction in water holding capacity of the swamp.
Swamp 154	73	Possible	Unlikely to be measurable impacts, given the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Swamp 155	209	Possible	Unlikely to be measurable impacts, given the distance from the longwall, the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Swamp 156	130	Possible	Unlikely to be measurable impacts, given the distance from the longwall, the MSEC (2021) predictions, the small size of the swamp and the fact that it supports one of the drier swamp types (Banksia Thicket).
Swamp 157	336	Possible	Possible ecological impacts including changes in vegetation, trending towards Banksia Thicket and Fringing Eucalypt Woodland. Vegetative dieback may be experienced If fracturing occurs due to reduction in water holding capacity of the swamp.

5.2.4 Potential impacts on Upland Swamp Ecology

Vegetation communities which are not dependent on groundwater are unlikely to be impacted by subsidence due to underground mining (Niche 2021a).

Groundwater dependent and riparian vegetation may experience some floristic changes in response to changed groundwater conditions, as a result of subsidence (Niche 2021a).

Riparian vegetation may be impacted by subsidence through water diversion or cracking of bedrock. Impacts to riparian vegetation associated with Longwalls 22 and 23 are predicted to be minor in occurrence, being localised if they occurred.

An assessment of the potential ecological impacts of subsidence on upland swamps was completed by Niche (2021a), summarised below (**Table 5-3**).

5.2.4.1 Potential Impacts to Threatened Flora

Ten threatened flora species have been determined to have a moderate to high likelihood of occurring within the study area (Niche 2021a). However, a limited number have potential habitat likely to be impacted by subsidence (Niche 2021a).

Four species (*Epacris purpurascens var. purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius*) are considered to have habitat within the study area that may be impacted by subsidence. Each of these species has potential habitat within upland swamps or creek vegetation communities, however none of these species are reliant on such habitat and occur throughout a range of other habitats within the study area.

5.2.4.2 Potential Impacts to Fauna

Subsidence may have a direct impact on known and potential habitat for threatened fauna such as watercourses, upland swamps, riparian vegetation, rock overhangs, rocky outcrops, cliffs and crevices.

Woodland and forest habitat types make up the majority of the study area. These habitat types which are not dependent on groundwater are unlikely to be impacted by subsidence. Microhabitat features such as tree hollows and exfoliating bark are also unlikely to be impacted (Niche 2021a).

5.2.4.3 Potential Impacts to Threatened Fauna

Sixty-eight threatened fauna were considered during the likelihood of occurrence assessment. Thirty-nice of these species were determined to have a moderate or high likelihood of occurrence within the Study Area. Subsidence impacts from the proposed longwalls are likely to be negligible for the majority of these species (Niche 2021a). Nine threatened species are considered to be potentially impacted by subsidence impacts resulting from Longwalls 22 and 23 (Niche 2021a).

An assessment of potential impacts for each of the identified threatened species likely to be impacted is provided in the Area 3C Terrestrial Ecology Assessment (Niche 2021a).

6 MANAGEMENT AND CONTINGENCY PLAN

The potential impacts of mine subsidence to upland swamps in Area 3C are provided below, together with a summary of the avoidance, minimising, mitigation and remediation measures proposed.

6.1 Objectives

The aims and objectives of this Plan include:

- Avoiding and minimising impacts to significant environmental values where possible;
- Implementing TARPs to identify, assess and respond to impacts to swamps;
- Carrying out mitigation and remediation works in a manner that protects to the greatest practicable extent the environmental values of the area;
- Achieving the Performance Measures outlined in the SMP Approval, to the satisfaction of the Secretary; and
- Monitoring and reporting effectiveness of the Plan.

To achieve these aims, monitoring, management, mitigation and remediation has been incorporated into the mining activity proposed by IMC.

6.2 Trigger Action Response Plan

The TARPs relate to identifying, assessing and responding to potential impacts to swamps (including impacts greater than predicted) from subsidence in Dendrobium Area 3C including Swamps 7, 9, 144 and 145. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3C swamps are included in **Appendix A: Table 1.2**.

The TARPs represent reporting and/or other actions to be taken upon reaching each defined trigger level. A Corrective Management Action (CMA) is developed in consultation with stakeholders in order to manage an observed impact in accordance with relevant approvals. The SIMMCP provides a basis for the design and implementation of any mitigation and remediation. Generic CMAs will be developed as required, in consultation with WaterNSW, to provide for a prompt response to a specific impact that requires a specific CMA. If appropriate these discussions will consider whether pre-approvals for the CMA can be obtained where immediate implementation is required.

Monitoring of environmental aspects provides key data when determining any requirement for mitigation or rehabilitation. The triggers are based on comparison of baseline and impact monitoring results. Specific triggers will continue to be reviewed and developed in consultation with key stakeholders as the impact monitoring phase matures. Where required the triggers will be reviewed and changes proposed in impact assessment reports provided to government agencies or in EoP Reports.

Level 3 TARPs result in further investigations and reporting by appropriately qualified people. Impact assessment reports will include:

- Study scope and objectives;
- Consideration of relevant aspect from this Plan;
- Analysis of trends and assessment of any impacts compared to prediction;
- Root cause analysis of any change or impact;
- Assessment of the need for contingent measures and management options;
- Any recommended changes to this Plan; and
- Appropriate consultation.

The Level 3 TARPs may require the development of site specific CMAs which include:

- A description of the impact to be managed;
- Results of specific investigations;
- Aims and objections for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;
- Roles and responsibilities;
- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

6.3 Avoiding and Minimising

Mine layouts for Dendrobium Area 3C have been developed using IMC's Integrated Mine Planning Process (IMPP). This process considers mining and surface impacts when designing mine layouts.

IMC has assessed mining layout options for Dendrobium Area 3C against the following criteria:

- Extent, duration and nature of any community, social and environmental impacts;
- Coal customer requirements;
- Roadway development and longwall continuity;
- Mine services such as ventilation;
- Recovery of the resource for the business and the State; and
- Gas drainage, geological and geotechnical issues.

Several layout alternatives for Area 3C were assessed by IMC using a multi-disciplinary team including environment, community, mining, geological and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks of the longwalls from key surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3C was achieved.

Area 3C is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2, 3A and 3B to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of Area 3C including major surface water features such as Lake Cordeaux and Wongawilli Creek; and a number of geological constraints such as dykes and faults. The process of developing the layout for Area 3C has considered predicted impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3C mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPIE and BCD during the consultation process. Mine plan changes result in significant business and economic impact, including:

- Reduction in coal extracted;
- Reduction in royalties to the State;
- Additional costs to the business;
- Risks to longwall production due to additional roadway development requirements; and
- Constraints on blending which can disrupt the supply of coal to meet customer requirements.

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;
- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;

- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;
- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and
- Requires specialised equipment and skilled personnel with limited availability.

Longwalls 22 and 23 have been setback 345 and 320 m respectively from Wongawilli Creek and minimum of 300 m from Lake Cordeaux. This reduction in extraction also reduces subsidence movements at surface features in proximity to Wongawilli Creek and Lake Cordeaux, including the tributaries WC26, WC24, LC6, LC7 and CR36, and Swamps 141, 152,154,155 and 156.

The mining layout of Longwalls 22 and 23 is designed to avoid Lake Cordeaux, Wongawilli Creek and geological constraints.

Wongawilli Creek is situated on the western side of the longwalls in Area 3C. The thalweg (i.e. base or centreline) of the creek is 320 m from the finishing (i.e. western) end of Longwall 23, at its closest point. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Longwall 6 in Area 3A and 290 m for Longwall 9 in Area 3B.

6.4 Mitigation and Rehabilitation

If the performance measures in the Development Consent are not met, then following consultation with BCD, WaterNSW and DRG the Secretary of DPIE may issue a direction in writing to undertake actions or measures to mitigate or remediate subsidence impacts and/or associated environmental consequences. The direction must be implemented in accordance with its terms and requirements, in consultation with the Secretary and affected agencies.

Coastal Upland Swamps were determined to be an endangered ecological community under the then *Threatened Species Conservation Act 1995* (TSC Act) by the NSW Scientific Committee in 2012. As indicated in Schedule 2, Conditions 1 and 14 of the Development Consent (Minister for Planning 2008) and Condition 10 of the Area 3B SMP Approval (Secretary DoPI 2013), the mitigation and rehabilitation described in this Plan is required for the development and an integral component of the proposed mining activity. To the extent these activities are required for the development approved under the Dendrobium Mine Development Consent no other license under the TSC Act is required in respect of those activities.

At the time of grant of the Dendrobium Development Consent there was no requirement for concurrence in respect of threatened species or ecological communities. The requirement for concurrence was, at that time, governed by section 79B of the EPA Act. At the time of grant of the Dendrobium Consent there was a requirement for consultation with the Minister administering the then TSC Act and this consultation was undertaken.

6.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within Wongawilli Creek is impacted from subsidence and where there is limited ability for these fractures to seal naturally they will be sealed with an appropriate and approved grout. Grouting will be focused where fractures result in diversion of flow from pools or through the controlling rockbar. Significant success has been achieved in the remediation of the Georges River where four West Cliff longwalls directly mined under the river and pool water level loss was observed (BHP Billiton Illawarra Coal, 2006).

Such operations do have the potential to result in additional environmental impacts and are carefully planned to avoid contamination. Mixing areas will be restricted to cleared seismic lines or other open areas wherever possible. Bunds are used to contain any local spillage at mixing points. Temporary cofferdams can be built downstream of the grouting operations to collect any spillage or excess grouting materials for disposal off-site. The selection of grouting materials is based on demonstrated effectiveness and ensuring that there is no significant impact to water quality or ecology.

6.4.2 Injection Grouting

Injection grouting involves the delivery of grout through holes drilled into the bedrock targeted for rehabilitation. A variety of grouts and filler materials can be injected to fill the voids in the fractured strata intercepted by the drill holes. The intention of this grouting is to achieve a low permeability 'layer' below any affected pool as well as the full depth of any controlling rockbar.

Where alluvial materials overlie sandstone, grouts may be injected through grout rods to seal voids in or under the soil or peat material. This technique was successfully used at Pool 16 in the Georges River to rehabilitate surface flow by-pass to Pool 17. In this case 1-2 m of loose sediment was grouted through using purpose built grouting pipes.

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 1 m x 1 m to 2 m x 2 m. The most efficient way to drill the holes taking into account potential environmental impact is by using handheld drills. The drills are powered by compressed air which is distributed to the work area from a compressor. The necessary equipment will be sited on cleared seismic lines or other clear areas wherever possible with hoses run out to target areas.

Grout is delivered from a small tank into the ground via mechanical packers installed at the surface. All equipment can be transported with vehicles capable of travelling on tracks similar to seismic lines. If necessary, equipment or materials can be flown to nearby tracks or open spaces by a helicopter. Helicopter staging has previously occurred from Cordeaux Mine where there is appropriate logistical support. The grout is mixed and pumped according to a grout design. A grout of high viscosity will be used if vertical fracturing is believed to be present since it has a shorter setting time. A low viscosity grout will be used if cross-linking is noted during grouting. Once the grout has been installed the packers are removed and the area cleaned.

After sufficient time for the product to set the area may be in-filled with additional grouting holes that target areas of significant grout take from the previous pass. The grouting program can normally be completed with hand held equipment. Wherever possible the setup and mixing areas will be restricted to cleared seismic lines and other open areas. Bunds are used to contain any local spillage at mixing points.

Grouting volumes and locations are recorded, and high-volume areas identified. Once the grout take in the area is reduced and the material has set, the grouted section of the pool is isolated and tested with local or imported clean water. The rate at which the water drains is measured and compared to pre-grouting results. The grouting process is iterative; relying on monitoring of grout injection quantities, grout backpressures and measurements of water holding capacity. In the Georges River, the majority of pools were sealed with two to three grout passes.

If flow diversion through a swamp rockbar occurs it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via directional drilling technologies. Grouting should preferentially be undertaken at the completion of subsidence movements in the area to reduce the risk of the area being re-impacted. **Figure 6-1** shows grouting operations in progress within the Georges River.

(a) Drilling into the bedrock

(b) Grout pump station setup

(c) Injecting grout into bedrock via a specially designed packer system

Figure 6-1 Rockbar grouting In The Georges River

6.4.3 Erosion Control

The types of erosion which could manifest within swamps are sheet, rill, gully, tunnel and stream channel. These types of erosion will be monitored in swamps in the mining area as well as in reference swamps not in the mining area. The types and magnitude of any erosion identified in swamps in the mining area will be compared to any erosion away from the mining area.

Erosion can create preferred flow paths and where this erosion creates a topographic low point within a swamp it could act to dewater the swamp sediments. To arrest this type of erosion, 'coir log dams' are installed at knick points, channelised flow paths and/or at the inception of tunnel/void spaces (**Figure 6-2**). The square coir logs used for the construction of these small dams were developed specifically for swamp rehabilitation and have been successfully used during a number of swamp rehabilitation programs of recent years in the Blue Mountains and Snowy Mountains.

Figure 6-2 Square coir logs for knick point control

As the coir log dams silt up they are regularly added to by the placement of additional layers of logs until the pooled water behind the 'dams' is at or above the level of the bank of the eroded channel, or the peat bed of the swamp. The coir logs are held in place by 50 x 50mm wooden tree stakes and bound together with wire (**Figure 6-3**).

The coir log dam slows the flows in the eroding drainage line such that the drainage line will silt up and water in the swamp will once again flow through the swamp rather than being concentrated in the eroding channel.

Figure 6-3 Installation of square coir logs

The most important aspect of these coir dams is the positioning of the first layer of coir logs. A trench is cut into the swamp soil so the first layer sits on the underlying substrate or so the top of the first coir log is at ground level (**Figure 6-4**).

Figure 6-4 Trenching & positioning of the first layer of coir logs and construction of a small dam in an eroding swamp channel

The coir log dams are constructed at intervals down the eroding channel, the intervals being calculated on the depth of erosion and predicted peak flows and added to until the pooled water behind the 'dams' is at or above the level of the bank of the erosion. At this point the stream becomes, once again, a net water contributor to the swamp and not a net drainer of water from the swamp. Where increased filtering of flows is required the coir logs are wrapped in fibre matting (**Figure 6-5**).

Figure 6-5 Small coir log dams with fibre matting

6.4.4 Water Spreading

Where sheet and rill erosion forms, these processes can reduce vegetation on the surface and/or be a precursor to the formation of gully and stream channel erosion. Treatment of these areas can prevent the formation of channels and maintain swamp moisture. The treatment proposed includes water spreading techniques, involving long lengths of coir logs and hessian 'sausages' linked together across the contour such that water flow builds up behind them and slowly seeps through the water spreaders (**Figure 6-6**). Where required the water spreaders would be installed in shallow trenches within the swamp and along the higher margins.

Figure 6-6 Round coir logs installed to spread water

Erosion control and water spreading involves soft-engineering materials that will contribute to and function as part of the swamp system but will eventually degrade (biodegradable) and become integrated into the soil of the swamps. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the swamp. This also removes the requirement for any post-rehabilitation removal of structures or materials.

6.4.5 Alternative Remediation Approaches

IMC has successfully implemented a subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams. This rehabilitation focused on grouting of mining induced fractures and strata dilation to reinstate the structural integrity and water holding capacity of the bedrock. Metropolitan Colliery is currently undertaking work aimed at rehabilitating areas impacted by subsidence using Poly-urethane Resin (PUR) and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these new and emerging technologies. Should rehabilitation be necessary in Dendrobium Area 3B, the best option available at the time of the rehabilitation work will be identified and with appropriate approval, implemented by IMC.

Cracking due to subsidence will tend to seal as the natural processes of erosion and deposition act on them. The characteristics of the surface materials and the prevailing erosion and depositional processes of a specific area will determine the rate of infill of cracks and sealing of any fracture network.

6.4.6 Monitoring Remediation Success

Baseline studies have been completed within the Study Area in order to record biophysical characteristics of the mining area. Monitoring is conducted in the area potentially affected by subsidence from the Area 3B extraction as well as areas away from mining to act as control sites. The studies in these areas are based on the Before After Control Impact (BACI) design criteria.

A comprehensive swamp monitoring program is in place for swamps identified in this Plan. A summary of swamp monitoring within Dendrobium Area 3B is provided in **Section 3**. In the event that monitoring reveals impacts greater than what is authorised by the approval, modifications to the project, mitigation measures and environmental offsets would be considered to minimise impacts.

The monitoring program would remain in place prior to, during and following the implementation of any mitigation measures in Area 3B. The monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of mitigation, during mitigation and after the completion of the mitigation actions. The monitoring locations/points for swamps within Dendrobium Area 3B will be reviewed as required and can be modified (with agreement) accordingly.

Data will be analysed according to the BACI design. Statistical analyses between control, impact and mitigation sites will be used to determine whether there are statistically significant differences between these sites. This analysis will assist in determining the success of any mitigation or natural reduction of mining impacts over time.

Observation data will also be collected as part of the monitoring program and be used to provide contextual information to the above assessment approach. Monitoring data and observations will be mapped, documented and reported.

The water levels of all significant permanent pools within swamps will be monitored prior to and during mining. These pool water levels will provide a direct comparison of pre-mining and post mining conditions within the pool. Where rehabilitation activities are required to restore the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar, the pool water level will also be monitored after the CMAs are implemented. The rehabilitation will be successful if the measured pool water levels after a rainfall recharge event are re-established to pre-mining conditions. The rainfall recharge event is required to fill the pool so that the success of the CMA can be tested. A rainfall recharge event is where the watercourse flows into the significant permanent pool to such an extent that it is filled.

6.5 Biodiversity Offset Strategy

A biodiversity offset strategy has been developed in consultation with BCD and WaterNSW for the approval of the Secretary of DPIE. The Secretary DPIE approved the Strategic Biodiversity Offset in accordance with Condition 15 of Schedule 2 of the Development Consent for the Dendrobium Coal Mine 16th December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of Condition 9 of the SMP for Area 3. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of the SMP for Areas 3A, 3B and 3C. The biodiversity offset strategy:

- provides a suitable offset for all the predicted impacts of the Project on upland swamps;
- gives priority to like-for like physical environmental offsets, but also consider measures that result in beneficial effect on water quality, water quantity, aquatic ecosystems and/or the ecological integrity of the special areas or water catchments, other potential physical environmental offsets, and potential financial

environmental offset contributions payable to a relevant public trust or authority, where physical offsets or other measures are unavailable or insufficient to provide a suitable offset;

- proposes a process whereby the actual impacts of the development on upland swamps are regularly reviewed (at least every 2 years) against predicted impacts and reported on to all affected agencies, including detailed consideration of the predictions in the SMP, performance measures in the SMP Approval, monitoring results, application, success and predicted success of measures to mitigate or remediate subsidence impacts and/or associated environmental consequences, predicted and actual long-term impacts, and views of BCD and WaterNSW; and
- proposes a process whereby a suitable residual environmental offset is provided where the actual impacts on upland swamps exceed those predicted in the SMP.

6.6 Research

To assist in further understanding the impacts of subsidence and rehabilitation of swamps IMC will undertake research to the satisfaction of the Secretary. The research is directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps.

The program of research will continue through the mining of Area 3C and be adaptive to results as the program is implemented. The research will be conducted as provided by a Swamp Rehabilitation Research Program which is currently focussing on Swamps 1B and 14.

6.7 Contingency and Response Plan

In the event the TARP parameters are considered to have been exceeded, or are likely to be exceeded, IMC will implement a Contingency Plan to manage any unpredicted impacts and their consequences. This contingency and response plan is applicable for all swamps within Area 3C, including Swamps 9, 144 and 145.

This would involve the following actions:

- Identify and record the event.
- Notify Government agencies and specialists as soon as practicable.
- Conduct site visits with stakeholders as required.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Establish weekly monitoring frequency for the site until stabilised.
- Inform relevant Government agencies of investigation results.
- Develop site CMA in consultation with key stakeholders and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Review the SIMMCP in consultation with key Government agencies.
- Report in EoP Report and Annual Review.

A site-specific rehabilitation action plan detailing the location and specific works to be implemented will be prepared following the identification of mining induced swamp degradation that exceeds the trigger levels specified in the TARPS.

The site-specific swamp rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. Approval from WaterNSW is required to access the land to conduct works and the implementation of environmental controls.

Table 6-1 provides a summary of the avoidance, mitigation and contingency measures proposed to manage mining impacts where predicted impacts are exceeded.

Table 6-1 Performance measures, potential impacts, monitoring, mitigation and management strategies and offsetting for swamps

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Mitigation and Management Strategies	Exceeding Prediction	Offsets
Swamps 9, 144 and 145	**Minor environmental consequences including:** • negligible erosion of the surface of the swamps; • minor changes in the size of the swamps; • minor changes in the ecosystem functionality of the swamp; • minor changes in the hydrology of the swamps; • maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.	Gully erosion or similar	• Observation of swamps for new erosion or changes to existing erosion • Identification and measurements of erosion via ALS and on ground survey	a) upfront mine planning b) erosion monitoring (i.e. 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	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 (i.e. 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%).	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.
		Swamp vegetation changes: • Swamp size • Vegetation sub-communities	• Detailed mapping including the use of LiDAR data to indicate the location and extent of upland swamp boundaries. Ground-truthing of these boundaries and the vegetation sub-communities will be undertaken if subsequent LiDAR data shows swamp boundary movements	a) upfront mine planning b) erosion monitoring (i.e. ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting	**Swamp size** 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** Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring	Offset required immediately, if no remediation considered practicable. Offset required 5 years following remediation, if it is ineffective. This period can be extended to

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Mitigation and Management Strategies	Exceeding Prediction	Offsets
				i) investigation and review update future predictions	periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.	10 years, with the agreement of the Secretary.
		• Falls in surface or near-surface groundwater levels in swamps • Falls in soil moisture levels in swamps	• Piezometric and dip meter monitoring of shallow groundwater level • Installed dielectric soil moisture sites down to 1.2 m to measure deep soil moisture	a) upfront mine planning b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions	*NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	
		Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	• Observation of swamps, streams and pools • Measurements of pool water level	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	Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, i.e. 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.	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.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Mitigation and Management Strategies	Exceeding Prediction	Offsets
				h) investigation and review i) update future predictions		
Swamps 2, 5, 6, 7, 16, 89, 124 140, 141, 142, 152, 154, 155, 156, 157	**No significant environmental consequences** beyond predictions in the Subsidence Management Plan (2021).	Gully erosion or similar	• Observation of swamps for new erosion or changes to existing erosion • Identification and measurements of erosion via ALS and on ground survey	h) upfront mine planning i) erosion monitoring (i.e. ALS, observation) j) coir logs k) knickpoint control l) water spreading m) weeding n) fire management o) reporting p) investigation and review q) update future predictions	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 (i.e. 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%).	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.
		Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	• Observation of swamps, streams and pools • Measurements of pool water level	j) upfront mine planning k) subsidence monitoring l) surface water monitoring m) groundwater monitoring n) grouting of controlling of controlling rockbars and bedrock	Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, i.e. 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.	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Mitigation and Management Strategies	Exceeding Prediction	Offsets
				base and/or use of other remediation techniques o) CMAs p) reporting q) investigation and review r) update future predictions		This period can be extended to 5 years, with the agreement of the Secretary.

<u>Note:</u> The mitigation measures will be assessed for appropriateness (in consultation with key stakeholders), as the need arises, on the individual swamps being impacted to ensure significant additional impacts to the swamps are not created by the carrying out of these mitigation measures. The provision of residual environmental offsets will be considered where the potential impacts of mitigation measures are greater than the impacts of mining or where the mitigation measures are not successful. Additional actions are required as per the TARPs, including informing stakeholders, review of monitoring and further assessments as required. The upland swamps in the Study Area are groundwater dependent communities which fit the description of Coastal Upland Swamps in the Sydney Basin Bioregion. Changes in area of the Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex are considered in the assessment of ecosystem functionality of the swamps.

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

IMC will notify DPIE and other relevant agencies of any incident associated with Area 3C operations as soon as practicable after IMC becomes aware of the incident. IMC will provide DPIE and any relevant agencies with a report on the incident within seven days of confirmation of any event.

7.2 Complaints Handling

IMC will:

- Provide a readily accessible contact point through a 24-hour toll-free Community Call Line (1800 102 210). The number will be displayed prominently on IMC sites in a position visible by the public as well as on publications provided to the local community.
- Respond to complaints in accordance with the IMC Community Complaints and Enquiry Procedure.
- Maintain good communication lines between the community and IMC.
- Keep a register of any complaints, including the details of the complaint with information such as:
  - Time and date.
  - Person receiving the complaint.
  - Complainant's name and phone number.
  - Description of the complaint and where complaint relates to.
  - Details of any response where appropriate.
  - Details of any corrective actions.

7.3 Non-Conformance Protocol

The requirement to comply with all approvals, plans and procedures is the responsibility of all personnel (staff and contractors) employed on or in association with Dendrobium Mine operations. Regular inspections, internal audits and initiation of any remediation/rectification work in relation to this Plan will be undertaken by the Principal Approvals.

Non-conformances, corrective actions and preventative actions are managed in accordance with the following process:

- Identification and recording of non-conformance and/or non-compliance.
- Evaluation of the non-conformance and/or non-compliance to determine specific corrective and preventative actions.
- Corrective and preventative actions to be assigned to the responsible person.
- Management review of corrective actions to ensure the status and effectiveness of the actions.

An Annual Review will be undertaken to assess IMC's compliance with all conditions of the Dendrobium Development Consent, Mining Leases and other approvals and licenses.

An independent environmental audit will be undertaken (Schedule 8, Condition 6) to review the adequacy of strategies, plans or programs under these approvals and if appropriate, recommend actions to improve environmental performance. The independent environmental audit will be undertaken by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of DPIE.

8 PLAN ADMINISTRATION

This SIMMCP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Development Consent Conditions. A summary of the administrative requirements is provided below.

8.1 Roles and Responsibilities

Statutory obligations applicable to Dendrobium Mine operations are identified and managed via an online compliance management system (TICKIT). The online system can be accessed by the responsible IMC managers from the link below.

https://illawarracoal.tod.net.au/login.

The overall responsibility for the implementation of this SIMMCP resides with the Manager Approvals who shall be the SIMMCP's authorising officer.

Responsibilities for environmental management in Dendrobium Area 3C and the implementation of the SIMMCP include:

Manager Approvals

- Ensure that the requisite personnel and equipment are provided to enable this SIMMCP to be implemented effectively.
- Authorise the SIMMCP.

Principal Approvals

- Develop the SIMMCP and any amendments thereto.
- To document any approved changes to the SIMMCP.
- Provide regular updates to IMC on the results of the SIMMCP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the SIMMCP.
- Organise and participate in assessment meetings called to review mining impacts.
- Respond to any queries or complaints made by members of the public in relation to aspects of the SIMMCP.
- Organise audits and reviews of the SIMMCP.
- Address any identified non-conformances, assess improvement ideas and implement if appropriate.
- Arrange implementation of any agreed actions, responses or remedial measures.
- Ensure surveys required by this SIMMCP are conducted and record details of instances where circumstances prevent these from taking place.

Coordinator Environment

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.
- Identify and report any non-conformances with the SIMMCP.
- Participate in assessment meetings to review subsidence impacts.
- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the SIMMCP provisions or ideas aimed at improving the SIMMCP.

Survey Team Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.
- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the SIMMCP.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Principal Approvals and provide expert opinion.

Person(s) Performing Inspections

- Inform the Coordinator Environment of any non-conformances identified with the Plan, or ideas aimed at improving the SIMMCP.
- Conduct inspections in a safe manner.

8.2 Resources Required

The Approvals Manager provides resources sufficient to implement this SIMMCP.

Equipment will be needed for the TARP provisions of this SIMMCP. Where this equipment is of a specialised nature, it will be provided by the supplier of the relevant service. All equipment is to be appropriately maintained, calibrated and serviced as required in operations manuals.

The Approvals Manager shall ensure personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

8.3 Training

All staff and contractors working on IMC sites are required to complete the IMC training program which includes:

- An initial site induction (including all relevant aspects of environment, health, safety and community).
- Safe Work Method Statements and Job Safety Analyses, Toolbox Talks and pre-shift communications.
- On-going job specific training and re-training (where required).

It is the responsibility of the Principal Approvals to ensure that all persons and organisations having responsibilities under this SIMMCP are trained and understand their responsibilities.

The person(s) performing regular inspections shall be under the supervision of the Coordinator Environment and be trained in observation, measurement and reporting. The Coordinator Environment shall be satisfied that the person(s) performing the inspections are capable of meeting and maintaining this standard.

8.4 Record Keeping and Control

Environmental Records are maintained in accordance with the IMC document control requirements.

IMC document control requirements include:

- Documents are approved for adequacy by authorised personnel prior to use.
- Obsolete documents are promptly removed from circulation.
- Documents are reissued, or made available, to relevant persons in a timely fashion after changes have been made and the authorisation process is complete.

The SIMMCP and other relevant documentation will be made available on the South32 website in accordance with Condition 11, Schedule 2 of the Development Consent.

8.5 Management Plan Review

A comprehensive review of the objectives and targets associated with the Dendrobium Area 3C operations is undertaken on an annual basis via the planning process. These reviews, which include involvement from senior management and other key site personnel, assess the performance of the mine over the previous year and develop goals and targets for the following period.

An annual review of the environmental performance of Dendrobium Area 3C operations will also be undertaken in accordance with Schedule 8, Condition 5. More specifically this SIMMCP will be subject to review (and revision if necessary, to the satisfaction of the Secretary) following:

- The submission of an annual review under Schedule 8, Condition 5.
- The submission of an incident report under Schedule 8, Condition 3.
- The submission of an audit report under Schedule 8, Condition 6.
- Any modification to the conditions of this Dendrobium Development Consent or SMP approval.

If deficiencies in the EMS and/or SIMMCP are identified in the interim period, the plans will be modified as required. This process has been designed to ensure that all environmental documentation continues to meet current environmental requirements, including changes in technology and operational practice, and the expectations of stakeholders.

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Appendix A – Swamp Monitoring and Trigger Action Response Plan

Appendix A: Table 1.1

Swamp monitoring within Dendrobium Area 3 will be installed ahead of mining to achieve at least 2-years baseline data (subject to timing and approval timeframes of any request to install additional monitoring). Monitoring is generally conducted through the mining period and for 2-years following active subsidence. Where impacts are observed the monitoring period will be reviewed and this review will be reported in Impact Assessment Reports and End of Panel Reports. For Level 2 and 3 Triggers and for impacts exceeding prediction this review is conducted in consultation with key stakeholders. The location of monitoring sites is indicated on the figures of the relevant SIMMCP.

Table 1.1 – Dendrobium Area 3 Swamp Monitoring Program

Monitoring Site		Site Type	Monitoring Frequency	Parameters
OBSERVATIONAL, PHOTO POINT AND WATER MONITORING				
Area 3A	Longwall 19 Study Area Swamps 15A, 34, 96 and 147 Area 3A Swamps 12, 15A, 15B and 95 Swamps 146 and 148 *Reference Sites* Swamps, 22, 24, 25, 33, 84, 85, 86, 87 and 88	Observation and photo point monitoring: Sites based on risk Swamps Pools and rockbars Steep slopes and rock outcrops Previously observed impacts that warrant follow-up inspection Mining areas	Pre and post mining for 2 years, monthly when longwall is within 400 m of monitoring site Weekly inspection and pool water levels when longwall is within 400 m of monitoring site Reference sites 6-monthly	Visual signs of impacts to swamps and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Key water quality parameters in pools within and downstream of swamps analysed to identify any changes resulting from mining
AREA 3B	Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A and 35B *Reference Sites* Swamps 2, 7[1], 15A[2] 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Performance measure sites: Swamps 9, 144 and 145 Other monitoring sites: Swamps 7, 153 and 154 General observation of swamps in active mining areas when longwall is within 400 m of swamp *Reference Sites* Swamps 2, 22, 33, 87 and 88			
EROSION MONITORING				

[1] Reference site for Area 3B; impact site when Longwall 22 commences.

[2] Reference site for Area 3B; impact site when Longwall 19 commences.

Area 3A	Longwall 19 Study Area Swamps 15A, 34, 96 and 147 Area 3A Swamps 12, 15A 15B, 34, 95 and 96 Swamps 146 and 148	Airborne Laser Scanning Surveyed cross-sections, areas and lengths	ALS base surveys were completed in December 2005, with a verification base survey performed in 2013, immediately prior to the commencement of Longwall 9 extraction Ground based surveys to be completed for each longwall after each longwall or to define any new erosions identified by ALS survey	Raw ground strike ALS data will be contoured with a 0.2 m interval after the completion of subsidence at each longwall to provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to assess for new or increases in existing erosion. The maximum area/length and depth of any erosion identified by ALS will be measured by standard survey methods
AREA 3B	Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A and 35B *Reference Sites* Swamps 2, 7[3], 15A[4], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 9, 144 and 145 *Reference Sites* Swamps 2, 22 and 33,			
SHALLOW GROUNDWATER LEVEL				
AREA 3A	Longwall 19 Study Area Swamps 15A: 15a_03, 15a_04, 15a_07, 15a_15, 34, 96 and 147 Area 3A Swamp 15a_12[5], 15a_18, 15b_H1, 15b_H2, 15b_H3, 12_01, 12_03, 12_04 Swamp 146 and 148 At least one piezometer site per swamp if sediment depth is appropriate.	Monitoring bore drilled into the soil profile	For open hole sites: Monthly monitoring pre, during and post mining for two years to be reviewed annually Reference sites 6 monthly For instrumented sites: Automatic groundwater level monitoring pre, during and post mining (1-hour interval or similar) Monitoring post mining for five years to be reviewed annually	Piezometric and dip meter monitoring of shallow groundwater level

[3] Reference site for Area 3B; impact site when Longwall 22 commences.

[4] Reference site for Area 3B; impact site when Longwall 19 commences.

[5] Reference site for Area 3B; impact site when Longwall 19 commences.

AREA 3B	Swamp 01A: 01a_04ii, 01a_04iii Swamp 01B: 01b_02iii, 01b_02iv Swamp 03: 03_01 Swamp 04: (thin soil profile) Swamp 05: 05_01, 05_04 Swamp 08: 08_01, 08_04 Swamp 10: 10_01 Swamp 11: 11-HI, 11-H2, 11-H3 Swamp 13: 13_01 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35A_01 Swamp 35B: 35B_01 Note: Swamp 4 is too shallow for a piezometer to be installed. *Reference Sites* Swamp 2: 02_01 Swamp 7[6)]: 07_05, 07_06 Swamp 22: 22_01, 22_02 Swamp 24: 24_01 Swamp 25: 25_01 Swamp 33: 33_01, 33_03 Swamp 84: 84_02 Swamp 85: 85_01, 85_02, 85_03 Swamp 86: 86_01, 86_02, 86_03 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02			
AREA 3C	Performance measure sites: Swamps 9, 144 and 145 Other monitoring sites: Swamps 7, 153 and 154 At least one piezometer site per swamp if sediment depth is appropriate.			
SOIL MOISTURE				

[6] Reference site for Area 3B; impact site when Longwall 22 commences.

Area 3A	Install soil moisture at existing shallow groundwater sites Longwall 19 Study Area Swamp 15A: 15a_03, 15a_04, 15a_07 and_15a_15, At least one Soil Moisture site per swamp if sediment depth is appropriate at Swamp 34, 96 and 147 Area 3A: Swamp 15a_12, 15a_18, 15b_H1, 15b_H2, 15b_H3, 12_01, 12_03, 12_04 Swamp 146 and 148			

AREA 3B	Swamp 03: (thin soil profile) Swamp 04: (thin soil profile) Swamp 05: S05_S01, S05_S02, S05_S05, S05_S08 Swamp 08: S08_S05 Swamp 11: S11_S01, S11_S02, S11_S05 Swamp 13: S13_S01, S13_S02, S13_S03 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35a_01 Swamp 35B: 35b_01 *Reference Sites* Swamp 2: S02_S01 Swamp 7)[7]: S07_S05, S07_S06 Swamp 15A[8]: S15a_S03, S15a_S04, S15a_S07, S15a_S12, S15a_S15, S15a_S18 Swamp 22: 22_01, 22_02 Swamp 24: S24_S01 Swamp 25: S25_S01 Swamp 33: S033_S01, S033_S03 Swamp 84: S84_S02 Swamp 85: S85_S01, S85_S02, S85_03 Swamp 86: S86_S01, S86_S02, S86_03 Swamp 87: S87_S01, S87_S02 Swamp 88: S88_S01, S88_S02	Monitoring bore drilled into the soil profile	For manually measured sites: Monthly monitoring for 2 years baseline and post mining and 6-monthly reference sites Weekly monitoring when longwall is within 400 m of monitoring site For instrumented sites: Automatic soil moisture monitoring pre, during and post Monitoring post mining for five years to be reviewed annually	Installed dielectric soil moisture sites down to 1.5 m to measure deep soil moisture
AREA 3C	Performance measure sites: Swamps 9, 144 and 145 Other monitoring sites: Swamps 7, 153 and 154 Soil moisture sites will be paired with sites with piezometers			
TERRESTRIAL FLORA – COMPOSITION AND DISTRIBUTION OF SPECIES				
AREA 3A	Swamps 15B and 15A	Swamp vegetation transects	Two baseline monitoring campaigns 1 year prior to mining during autumn and spring (Autumn - Photo points; spring - Photo points and transects/quadrat)	15 m transects consisting of thirty 0.5 m x 0.5 m quadrats. The monitoring records: • Presence of all species within each quadrat;

[7] Reference site for Area 3B; impact site when Longwall 22 commences.

[8] Reference site for Area 3B; impact site when Longwall 19 commences.

AREA 3B	Swamps 01A, 01B, 05, 11, 13, 14 and 23 *Reference Sites* Swamp 15A(1)[9], 22, 33, 86 and 87		Quarterly monitoring during mining 6-monthly monitoring post mining for two years or as otherwise required General observation of active mining areas during all other monitoring	• Percentage foliage cover and vegetation height; • Observations of dieback or changes in community structure; and • Photo point monitoring at each transect
TERRESTRIAL FLORA – SWAMP SIZE AND ECOSYSTEM FUNCTION				
Area 3A	Swamp 15A, 15B	Size of the groundwater dependent communities (Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex) and the total size of the swamps	Baseline mapping prior to mining with repeat mapping after each longwall or as determined by observational monitoring i.e. if dieback or invasion of non-swamp species is observed	Detailed mapping including the use of LiDAR data to indicate the location and extent of upland swamp boundaries. Ground-truthing of these boundaries and the vegetation sub-communities will be undertaken if subsequent Lidar data shows swamp boundary movements
AREA 3B	Swamps 01A, 01B, 05, 8, 11, 13, 15A, 15B, 14 and 23 *Reference Sites* Swamp 85 and 33			
AREA 3C	Swamps 9, 144 and 145 *Reference Sites* Swamp 2, 6, 22, 33 and 132			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3A	Swamps 15B and 15A *Reference Sites* WC10, WC11, SC6, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC	Frog monitoring	Surveys are undertaken in winter each year to target active breeding periods (these can be variable depending on prevailing conditions) To address recommendation from Niche (2019), rainfall or hydrometric trigger values for surveys will be developed for surveys to allow for greater consistency between years which would aid in comparison of results (pre- versus post- mining and impact versus control). To address recommendation from Niche (2019), a baseline survey focussed on tadpole survey for Littlejohn's Tree Frog and aural detection of Red-crowned Toadlet is proposed to be conducted after sufficient rainfall and within the appropriate season.	For swamps frog surveys are conducted along associated creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals recorded at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line
AREA 3B	DC13, DC1, WC21, LA4A, ND1 and WC15 *Reference Sites* WC10, WC11, SC6, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC			
AREA 3C	LC5 and LC6 – sites to be established *Reference Sites* WC10, WC11, SC6, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC			

[9] Reference site for Area 3B; impact site when Longwall 19 commences.

AQUATIC ECOLOGY				
AREAS 3A, 3B and 3C	**Sandy Creek Catchment** Site 11 and 13 (SC10) Sites 9 and 12 (Sandy Creek) *Reference Sites* Site 7 and 8 (Sandy Creek) Sites 15 and 16 (Kentish Creek) **Wongawilli Creek Catchment** Sites 6, X2 and X3 (WC21) Sites 1, 2, 3, 4, 5, 21, 22, X4, X5 and X6 (Wongawilli Creek) *Reference Sites* Sites X7 and X8 Sites 15 and 16 (Kentish Creek) **Donalds Castle Creek Catchment** Site 14, X1 (Donalds Castle Creek) *Reference Sites* Sites X7 and X8 Sites 15 and 16 (Kentish Creek)	Quantitative and observational monitoring	Two annual baseline monitoring campaigns prior to mining during autumn and spring (providing 2 years of baseline data) Monitoring during mining in autumn and spring Monitoring post mining for two years or as otherwise required Monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors. In consideration of Adams Emerald Dragonfly and Sydney Hawk Dragonfly, individuals of the genus *Austrocorduliidae* and *Gomphomacromiidae* are identified to species level to confirm any potential identifications, as required. General fish surveys undertaken during each survey using dip nets, baited traps and visual observations. Targeted surveys for Macquarie perch undertaken using backpack electrofishing, as required.

In accordance with Condition 6, Schedule 3 of the Area 3C SMP Approval granted 19 December 2019, the performance measures stated in Table 1.2 below are applicable to Swamps 9, 144 and 145 in Dendrobium Area 3C.

Table 1.2 - Dendrobium Area 3 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 (i.e. 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 (i.e. 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	Swamp vegetation changes: - Swamp size - 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**	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	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 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. *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.	k) update future predictions		
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, i.e. 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 functionality of the swamps **Minor** changes in the hydrology of the swamp	Falls in surface or near-surface groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.* 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.*	**Shallow Groundwater Levels** *<u>Level 1:</u>* Groundwater level lower than baseline level at any monitoring site 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 any monitoring site (measured as average mm/day during the recession curve). *<u>Level 2:</u>* 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. *<u>Level 3:</u>* 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. **<u>Soil Moisture</u>** *<u>Level 1:</u>* Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps). *<u>Level 2:</u>* Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). *<u>Level 3:</u>* 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) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars 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

Appendix B – Longwalls 21 SMP Approval Conditions

Table 9-1 Agency feedback and responses

BCD Submission	Response
Performance measures not measurable and specific • We note no changes in performance measures. As per previous advice: "The performance measures suggested for use in Area 3C by Illawarra Coal in the SMP are poorly defined and are not specific or measurable. Given the predictions for significant, permanent impacts to natural features, measurable performance measures are required to enable clear identification of impacts that are allowable under the SMP and development consent. Performance measures and associated TARPs for use in Area 3C should be comprehensively reviewed with involvement of appropriate agencies and independent peer review."	Refer to Section 3.6 of the WIMMCP for details of the Dendrobium Area 3B TARP review that was undertaken between WaterNSW, DPIE and South32 between 2018 and 2020. These TARPs have been adopted for Area 3C.
Upland swamps The IEPMC recognises that TARP's, which are linked to performance measures, do not reflect the groundwater-dependence of the upland swamp ecosystem. Monitoring of groundwater using piezometers in swamps is already carried out broadly in Dendrobium Mine domains and should be utilised in informing environmental consequences of mining by inclusion of a specific performance measure relating to changes in groundwater within swamps. We suggest that this should be consistent with the definition of 'Negligible environmental consequences' from the Biodiversity Offsets Policy for Major Projects (Upland Swamps) Addendum, specifically: • Negligible change to the shallow groundwater regime of a swamp compared with control swamps; and/or • Negligible change to the composition or distribution of swamp dependent vegetation communities. The IEPMC recognised that the nature of existing performance measures and TARPs in relation to swamps were slow to respond to mine impacts and would not be detected until much later. Groundwater monitoring with piezometers has the benefit of allowing detection of mine impacts immediately and being measurable and quantifiable.	The IEP (2019b) states: "The Panel's conclusion in the Initial Report that TARPs "do not reflect the groundwater dependence of the upland swamp ecosystems" was challenged in Peabody's response that "swamp impact TARPs do include triggers associated with piezometer monitoring" (Peabody, 2019b).48 The Panel recognises that TARPs for changes to piezometric levels in shallow groundwater are defined for both Dendrobium and Metropolitan mines." The TARPs for groundwater changes in swamps for Dendrobium Area 3C are detailed further in Appendix A: Level 1: Groundwater level lower than baseline level at any monitoring site 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 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 400 m of mining) within the swamp. Level 3: Groundwater level lower than baseline level at >80% 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 >80% of monitoring sites (within 400 m of mining) within the swamp.

Adequate baseline monitoring of swamps not undertaken • Some additional piezometers have been noted (including swamps 142 and 144), however we are unsure about pre-mining duration. This should be clarified.	Shallow groundwater piezometers paired with a soil moisture probe will be installed in Swamp 142 a minimum of two years prior to mining if Longwall 20 is to be extracted. Swamp 144 (piezometer 144_01) was established 28/08/2020.
No offsets for swamps 142 and 144 • South32 have received confirmation from DPIE that the 2016 Strategic Biodiversity Offset can be relied upon for the Longwall 20 and 21 SMP and also all future Area 3C SMP applications. However some swamps (142 & 144) have not been specifically identified in the SBO.	DPIE has advised " … the Department is of the view that the Maddens Plains offset can be relied upon to offset the impacts of mining operations at Area 3C."
WaterNSW Submission	**Response**
The plans only apply to the approved LW 21 whose finishing end is 240 m from Wongawilli Creek.	This is correct, Longwall 20 requires SMP Approval.
The reports are sound and adequate information has been provided with regards to monitoring and managing impacts due to LW21. In particular, the recently revised water flow assessment and TARP methodology has been incorporated for assessing water quantity impacts on Wongawilli Creek.	Noted.
Impacts and Monitoring of Wongawilli Creek - A detailed email from Howard Reed to South32 (D2020/15623 - DPIE Planning email - Dendrobium Coal Mine - Request for Further Information re Area 3C Longwall 20) is referred to in this regard. The focus of the email is a request for more information with regards to predicted LW20 impacts on Wongawilli Creek. The key issue raised by DPIE is the non-acceptance and query on the 10% rockbar fracturing model being used for assessment. This should be followed up with DPIE.	SMP approval for Longwall 20 is not being sought by South32 at this time. Further assessment is required to be undertaken to support the Longwall 20 SMP Application.
There is adequate flow and pool water level measurement locations on Wongawilli Creek as well as groundwater bores to determine groundwater depressurization near LW21 and Wongawilli Creek. However the sensitivity of the proposed monitoring and TARP system is not adaptive i.e. to stop LW21 should impacts and consequences be seen to approach Trigger Level 3 for pool level changes. South32's position is that they have	IMC will update the subsidence impact and valley closure model prior to completion of extraction of Longwall 21. Future SMP applications in Area 3C will use the revised model as an adaptive management measure directed to avoiding exceedances of the performance measures for Wongawilli Creek.

setback LW21 to ensure a 200mm valley closure is not reached at Wongawilli Creek.	
There is only one swamp near LW 21 in Area 3C - Den144 near the valley base of Stream WC20 and it is not directly undermined by LW21. Some impacts in terms of change in groundwater and moisture levels in this swamp is predicted and proposed to be monitored.	See **Section 5.2.3**.