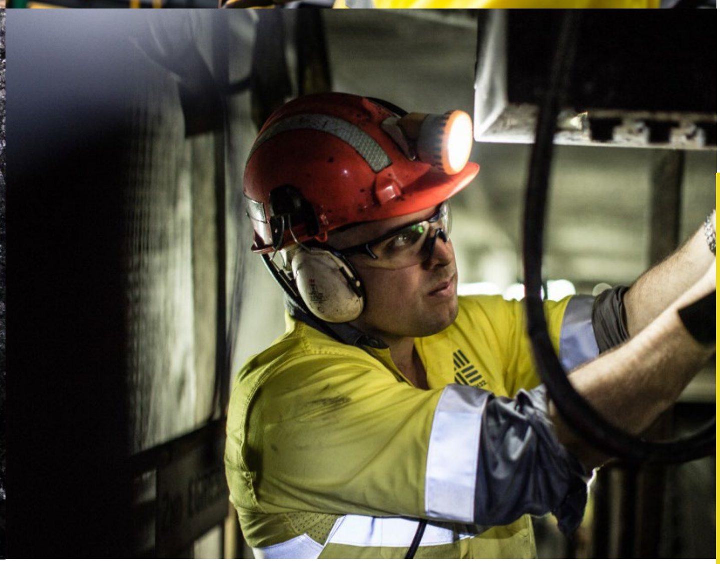
DENDROBIUM
AREA 3C

AUGUST 2020



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

Persons involved in the development of this document

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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 s75W 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 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 Mine revised 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 the proposed Longwalls 20 and 21 (**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 the proposed Longwalls 20 and 21;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed longwalls; and
- The natural features located within 600 m of the extent of the longwall mining area, in accordance with *Condition 8(d)* of the Development Consent.

The depth of cover varies between 290 m and 410 m directly above the proposed Longwalls 20 and 21. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 200 m and 290 m around the extents of the longwall 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), which is described in MSEC (2019).

The features that are located within 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 swamps.

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 swamps located outside the extent of longwall mining which 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 Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 within the Dendrobium Area 3C mining domain. Swamp 15a, as defined in the Dendrobium Development Consent (Schedule 3, Conditions 5, 6a and 6b), is not within the defined area of study relative to the proposed extents of Longwalls 20 and 21.

A number of smaller swamps or swamp-like vegetation are scattered throughout the Study Area. These small patches of swamp like vegetation are often too small to map as discrete swamps and occur in small areas of impeded drainage that contain a mix of plant species common to the upland swamps and fringing eucalypt woodlands of the region. These patches of vegetation have not been identified in the existing swamp mapping of the Study Area (**Figure 1-1**:) and field observations indicate that these patches of vegetation occur randomly in the landscape and are not typically restrained by sandstone rock bars. Further, these vegetation patches do not occur in valley floors and therefore are not likely to be subject to valley closure movements resulting from longwall extraction (Niche 2012).

1.4 Objectives

The objectives of this SIMMCP are to identify swamp features and characteristics within the Dendrobium Longwalls 20 and 21 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

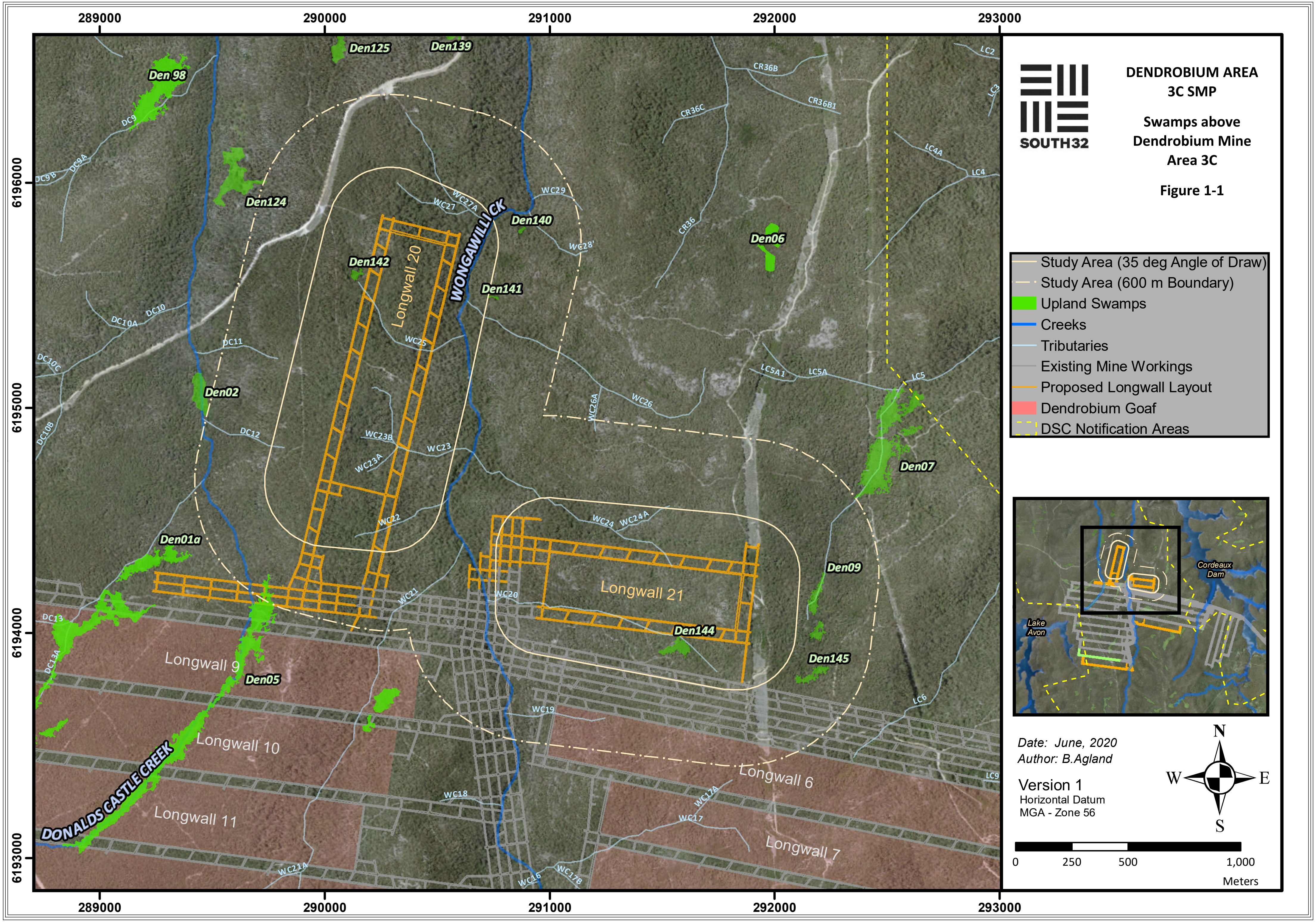
In accordance with the Area 3C SMP Approval Condition 10a, Schedule 3, the WIMMCP was provided to BCD and WaterNSW in June 2020 for consultation. Agency feedback was received with **Table 1-1** providing details of feedback and associated responses.

Table 1-1 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.
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	Shallow groundwater piezometers will be installed in Swamps 142 and 144 a minimum of two years prior to mining.

• Some additional piezometers have been noted (including swamps 142 and 144), however we are unsure about pre-mining duration. This should be clarified.	
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 setback LW21 to ensure a 200mm valley closure is not reached at Wongawilli Creek.	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.

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 5.3.3**.


DENDROBIUM AREA 3C SMP
Swamps above Dendrobium Mine Area 3C
Figure 1-1
SOUTH32
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Date: June, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
S
E
W
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den06
Den02
Den07
Den01a
Den09
Den144
Den145
Den05
Cordeaux Dam
Lake Avon

2 PLAN REQUIREMENTS

Extraction of coal from Longwalls 20 and 21 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 and 21. 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 (i) be implemented to the satisfaction of the Secretary.	**Section 2**

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 of 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.*"

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

Table 2-2 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**
(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	**Section 2.2.2**
(e) reflect the nine monitoring program recommendations included in *Height of Cracking - Dendrobium Area 3B* (PSM, 2017).	**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) which directly relate to impact monitoring, management, remediation and contingency planning in respect of swamps. **Table 2-3** details how the recommendations have been addressed or where the recommendations are addressed in the SIMMCP.

Table 2-3 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,	There are no representative large valley infill swamps within 600 m of the current Longwalls 20 and 21 footprint Figure 1-1: Location of Swamps above Dendrobium Mine Longwalls 20-21.**Figure 1-1**, **Section 3.2**.

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 will install paired piezometers in representative large valley infill swamp sediments and nearby bedrock, and flow gauges at the swamp exit streams within Area 3C swamps, where practical. Future proposed mining Areas 5 and 6 have paired piezometers installed in swamps. For large representative swamps in Areas 5 and 6 and future longwalls in Area 3C, flow gauges will be installed at the exit stream where practical. Vertical leakage data will be used to update the groundwater model to account for water loss.
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 affect 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 3.12**) 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 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 affect 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 Dendrobium Annual Terrestrial Ecology Monitoring Report (**Section 4.6**) assesses several monitoring parameters including photo point monitoring, total swamp area, species composition and species

the current mining area but for previous mining domains	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 Recommendations

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 2-4** details how the recommendations have been addressed or where the recommendations are addressed in the SIMMCP.

Table 2-4 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 where the piezometers are not logged.	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.
• 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)**. Installation is currently scheduled for July 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 3.11.1**). 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.	In the case of the two example piezometers identified by the IEP, a brief summary of the assessment is presented below (note that 05_08 does not exist. It is assumed to be a typographical error). 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 remains very similar in character to the reference site 33_01. 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. A third assessment for "below baseline" frequency, similar to the "cease-to-flow" frequency assessment in the revised surface water TARPs may be useful in detecting impacts. This would require comparison against each reference site. Reference site/s would be selected specific to each impact site based on pre-mining hydrograph 'shape' (e.g. 33_01 for 01b_01). A limitation of this third assessment is the method will require data for both impact and suitable reference sites for the pre- and post-mining periods, and the availability of suitable data is more limited than it is in the corresponding cease-to-flow surface water assessment. IMC will investigate how to efficiently implement this as a third assessment approach.

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). **Table 2-5** details how the recommendations have been addressed or where the recommendations are addressed in the SIMMCP.

Table 2-5 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 Application for Longwalls 20 and 21 includes an independent consultant facilitated risk assessment (Attachment E of the SMP [Axys 2019]) 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 Den09, Den142, Den144 and Den145 has been adopted by IMC.

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. Man-made features are characterised and detailed in the SMP and MSEC (2019). Sensitive features are identified and considered as part of a formal risk assessment (Attachment E of the SMP [Axys 2019]) 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**, Swamps 22, 24, 25, 33, 84, 85, 86, 87 and 88 are established reference monitoring sites 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 (2020), 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 3.11)** 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 3 operations is 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 as shown in **Table 2-6**;
- 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.

Table 2-6 Dendrobium Leases

Mining Lease - Document Number	Issue Date	Expiry Date/ Anniversary Date
CCL 768	7 May 1998	7 September 2026

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 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 Swamp monitoring lines will employ a series of marks along a transect at nominally 20 m intervals. If practical, Upland Swamp 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 five swamps that have been identified wholly or partially within the Study Area based on the 35° angle of draw line. There are five additional swamps that are located wholly or partially within the Study Area based on the 600 m boundary.

Table 3-1: Summary of Swamps within the Area 3C Study Area.

Reference	Area (Ha)	Description
Swamp 2[1]	0.96	Near the valley base of Donalds Castle Creek
Swamp 5	1.71	Partially located above the existing LW9 in Area 3B
Swamp 7[2]	5.67	Near the valley base of Stream LC5B
Swamp 9	0.80	Near the valley base of Stream LC5B
Swamp 124	2.10	On the valley side of Donalds Castle Creek
Swamp 140	0.05	On the valley side of Wongawilli Creek
Swamp 141	0.04	On the valley side of Wongawilli Creek
Swamp 142	0.16	Near the valley base of upper reaches of WC25
Swamp 144	0.54	Near the valley base of Stream WC20
Swamp 145	0.45	At the headwaters of Steam LC5B

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

[1] Swamps 2 has been historically monitored as reference swamp for Areas 3A and 3B.

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

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 the SIMMCP.

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 and photo point monitoring program (as described in this section):

- Monitoring sites;
  - o Swamps 7 (previously reference sites for Area 3B);
  - o Swamps 9, 144 and 145;
- Reference sites:
  - o Swamps 22, 24, 25, 33, 84, 85, 86, 87 and 88.

The monitoring sites above are composed of both existing sites and proposed monitoring sites. Due to the steep terrain and dense vegetation, proposed monitoring sites may be relocated to a more suitable site.

3.4 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.

3.5 Groundwater

A specialist Groundwater Assessment is provided in Attachment B of the SMP (HydroSimulations 2019). 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 3 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.

3.6 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. Within the Longwalls 20 and 21 study area, pool water levels are measured within or adjacent to the following swamps:

- Swamp 84: S84_Pool 10 (reference swamp);
- Swamp 86: S86_Pool 10 (reference swamp); and
- Swamp 88: S88_Pool 10 (reference swamp).

If observed, additional pools within swamps will be added to the monitoring plan.

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

3.7 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 are proposed to be installed within several swamps in Area 3C (**Figure 3-1**). Within Area 3C long-term piezometer records are available for Swamp 2 and Swamp 7. Swamps 22, 24, 25, 33, 84, 85, 86, 87 and 88 are established reference monitoring sites and will continue to be monitored. 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 climate stations are available for analysis and modelling in Dendrobium Area 3C with the most appropriate data used, taking into account proximity, length of record and data quality.

3.8 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 between Longwalls 20 and 21. 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 Donalds Castle and Wongawilli Creeks have been mapped (**Figure 3-4**). All mapped rockbar controlled pools in Wongawilli Creek are significant permanent pools.

3.9 Slopes and Gradients

Slopes within Area 3C have been mapped according to their gradients and are identified on Drawing 8 in MSEC (2019). Monitoring of landscape features such as slopes and swamps will be undertaken in Area 3C.

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.

3.10 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.

3.11 Flora, Fauna and Ecosystem Function

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

An aquatic ecology monitoring program has been established by Cardno for Area 3. 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 is available for Area 3 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;
- The composition and distribution of species within the swamps;
- RCE including a photographic record of each stream assessment site;
- Water quality, including pH, DO, ORP, temperature, turbidity 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).

3.11.1 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 2020). 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 3-2: Upland Swamps and associated sub-communities within the Study Area (Niche 2019)

Swamp No.	Swamp Community/sub-community	Area (ha) 600 m + adjacent	Area (m2) 600 m boundary	Area (ha) angle of draw	Area (ha) proposed longwalls
Swamp 2	Upland Swamps: Banksia Thicket	0.62	0.0006	-	-
	Upland Swamps: Tea-tree Thicket	0.32	0.0009	-	-
Swamp 5	Upland Swamps: Banksia Thicket	0.09	-	-	-
	Upland Swamps: Restioid Heath	0.40	-	-	-
	Upland Swamps: Tea-tree Thicket	1.18	0.13	-	-
Swamp 7	Upland Swamps: Banksia Thicket	3.18	0.004	-	-
	Upland Swamps: Tea-tree Thicket	1.69	-	-	-
Swamp 9	Upland Swamps: Banksia Thicket	0.29	0.29	-	-
	Upland Swamps: Tea-tree Thicket	0.50	0.50	-	-
Swamp 124	Upland Swamps: Restioid Heath	0.55	-	-	-
	Upland Swamps: Sedgeland-Heath Complex	0.90	0.002	-	-
	Upland Swamps: Tea-tree Thicket	0.53	0.01	-	-
Swamp 140	Upland Swamps: Banksia Thicket	0.05	0.05	-	-
Swamp 141	Upland Swamps: Banksia Thicket	0.04	0.04	0.003	-
Swamp 142	Upland Swamps: Banksia Thicket	0.16	0.16	0.6	-
Swamp 144	Upland Swamps: Banksia Thicket	0.54	0.54	0.54	-
Swamp 145	Upland Swamps: Banksia Thicket	0.41	0.41	-	-
Total		**11.45**	**2.13**	**0.7**	**0.00**

Mapping will be replicated prior to mining for Swamps 9, 144 and 145[3], 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.

3.11.2 Swamp Size

Detailed mapping of the boundaries of the swamps and vegetation sub-communities has been undertaken for Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 (Terrestrial Ecological Assessment, Niche 2019).

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

Three reference swamps have been mapped previously: Swamp 85, Swamp 15a[4] and 33. 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.

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**).

3.11.3 Flora - Composition and Distribution of Species

3.11.3.1 Quantitative flora monitoring

Control sites have been established at Swamp 88, Swamp 87, Swamp 86, Swamp 15A(1)[5], Swamp 22 and Swamp 33.

Three 15 m transects consisting of thirty 0.5 m by 0.5 m quadrats have been (and will be for future longwalls) established in upland swamps. The monitoring will record:

- Presence of all species within each quadrat;
- Percentage foliage cover and vegetation height;
- Observations of dieback or changes in community structure; and
- Photo point monitoring at each transect.

Data from other monitoring programs (such as groundwater and observational data) in both mining sites and reference sites will be used to assist in the determination and reporting of any impacts identified by the quantitative vegetation monitoring.

The selection of monitoring sites has been determined by specialists in the ecology of upland swamps based on a multi-criteria analysis. Criteria used to determine locations include:

- The location of the swamp in relation to longwall layout;
- Predicted subsidence, including vertical movements, tilts and strains;
- Location of vegetation sub-communities within the upland swamp, particularly those hypothesised to be most susceptible to changes in groundwater;
- Ensuring a representative sample of vegetation sub-communities in the monitoring program;
- Availability of reference sites; and
- Access requirements and workplace health and safety.

A particular focus has been placed on those vegetation sub-communities expected to undergo the greatest change. Tea-tree Thickets and Cyperoid Heath are considered to be more susceptible to change given their dependency on groundwater, followed by Sedgeland, Restioid Heath and finally Banksia Thicket.

Data will be analysed according to the BACI design. Statistical analyses of species richness and species diversity between control and impact sites is used to determine whether there are statistically significant differences between these sites. This analysis will be compared with baseline data collected prior to mining to assist in determining if these differences could be a result of mining or natural variation in vegetation communities.

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[4] Potentially impacted by Longwall 19 in Dendrobium 3A.

[5] Potentially impacted by Longwall 19. A suitable replacement reference swamp will be established if required.

Where differences are detected in species richness or diversity between control and impact sites then additional analyses, such as Analysis of Similarities (ANNOSIM), will be undertaken to determine where these differences lie and provide a more definitive conclusion on the impacts of mining in Dendrobium Area 3C.

Observation data will also be collected as part of the monitoring program. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

Change to the composition or distribution of species within the swamps will be measured via statistically significant changes in species richness or diversity during a period compared to species richness/diversity in a reference swamp.

3.11.4 Fauna

Seven-part tests concluded that the Area 3 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. Similar sites will be established in Area 3C in representative areas with potential habitat for Littlejohn's Tree frog and Giant Burrowing Frog. 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.

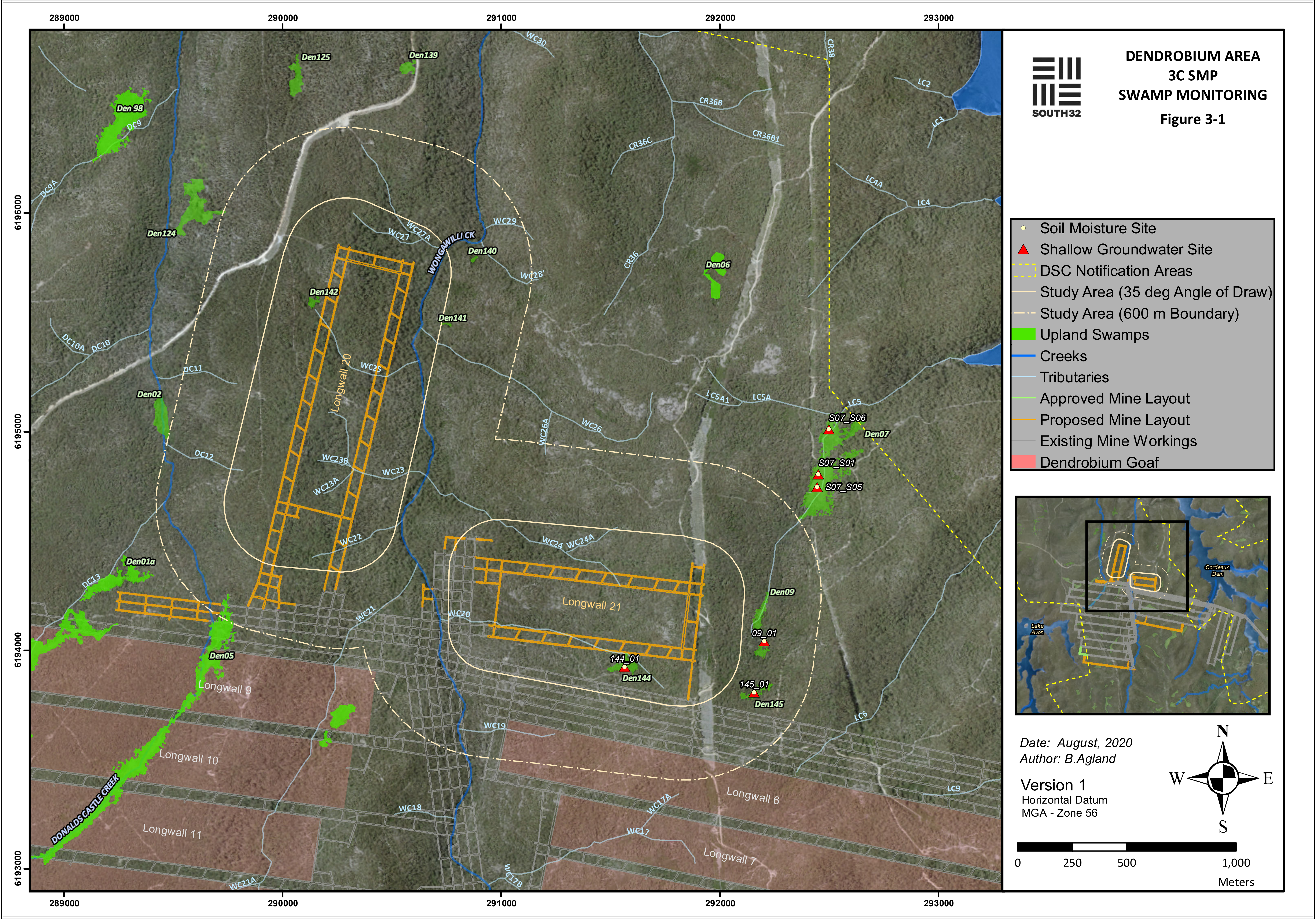
3.12 Reporting

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 AEMR. 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 AREA
3C SMP
SWAMP MONITORING
Figure 3-1
SOUTH32
Soil Moisture Site
Shallow Groundwater Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Approved Mine Layout
Proposed Mine Layout
Existing Mine Workings
Dendrobium Goaf
Date: August, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
Cordeaux Dam
Lake Avon
289000
290000
291000
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293000
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Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den125
Den139
Den 98
Den124
Den140
Den142
Den141
Den06
Den02
Den01a
Den05
Den07
Den09
Den144
Den145
S07_S06
S07_S01
S07_S05
09_01
144_01
145_01
DC9
DC9A
DC10A
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WC24A
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WC19
WC18
WC17A
WC17
WC17B
WC21A
CR38
CR36B
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CR36C
CR36
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LC4A
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LC5A
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LC6
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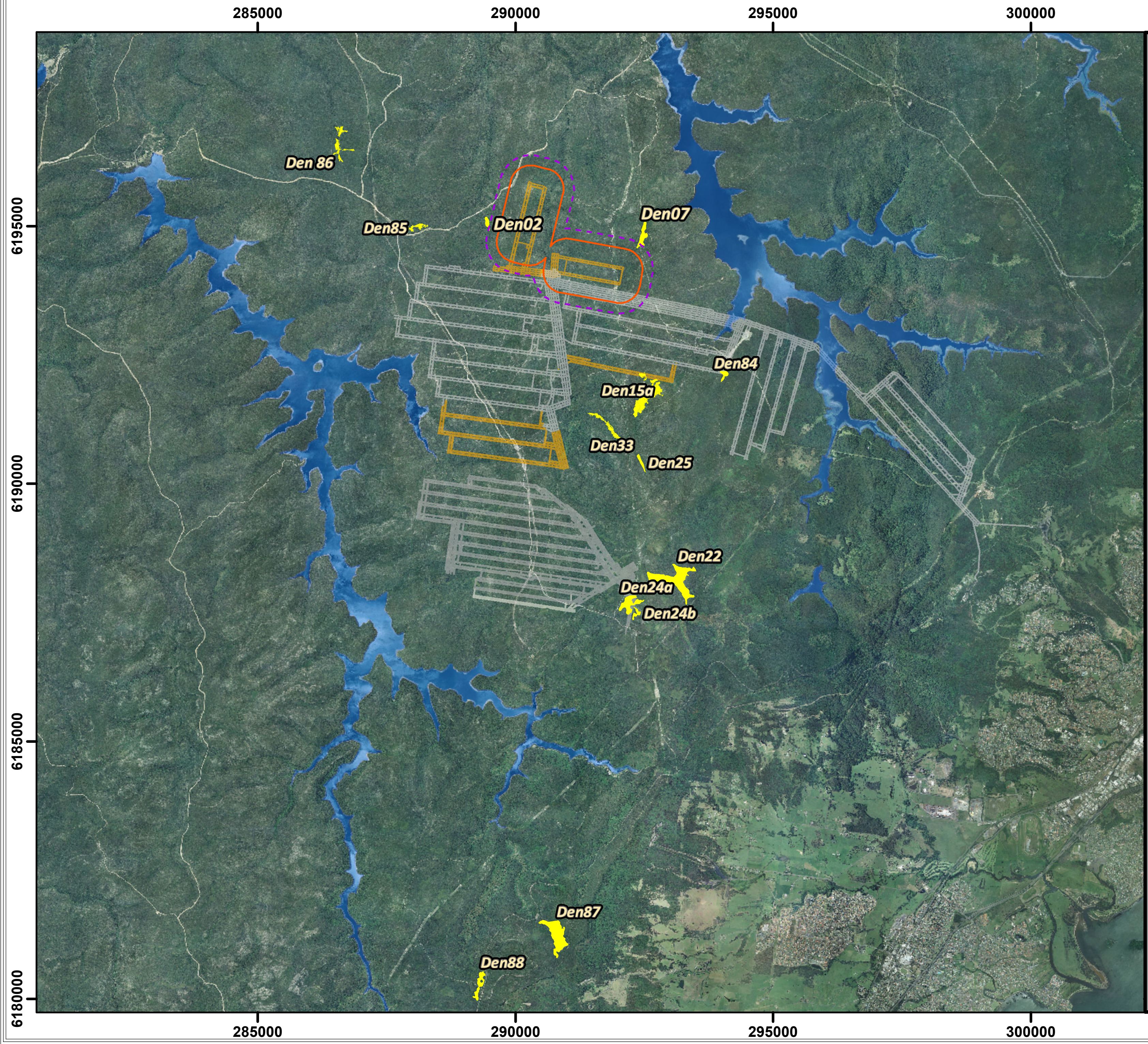

SOUTH32

DENDROBIUM AREA 3C SMP

Reference Swamps

Figure 3-2

Legend

- 35° Angle of Draw Study Area
- 600m Study Area
- Creeks
- Mine Workings
- Proposed Workings
- Reference Swamps

Date: December, 2018
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

N
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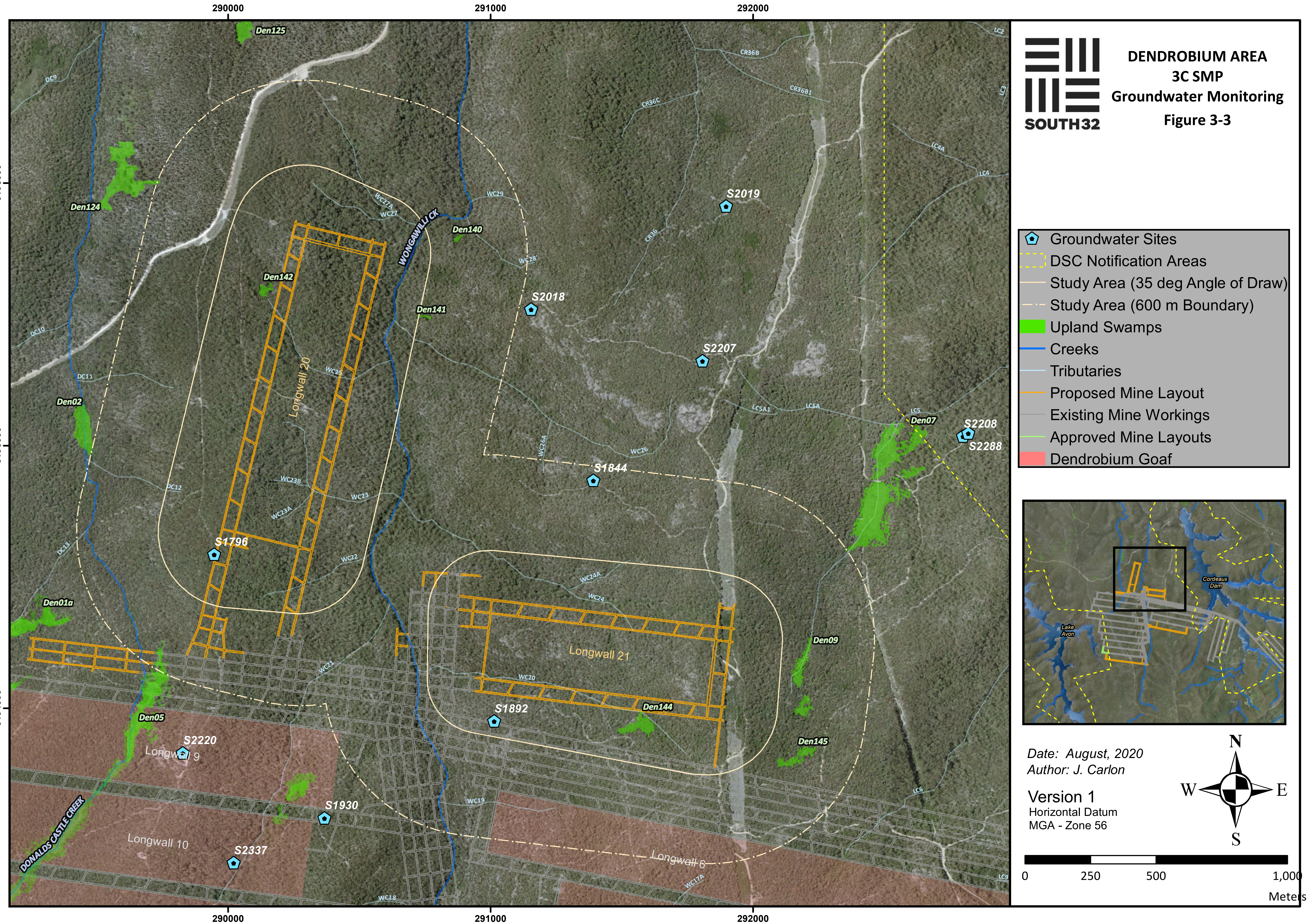
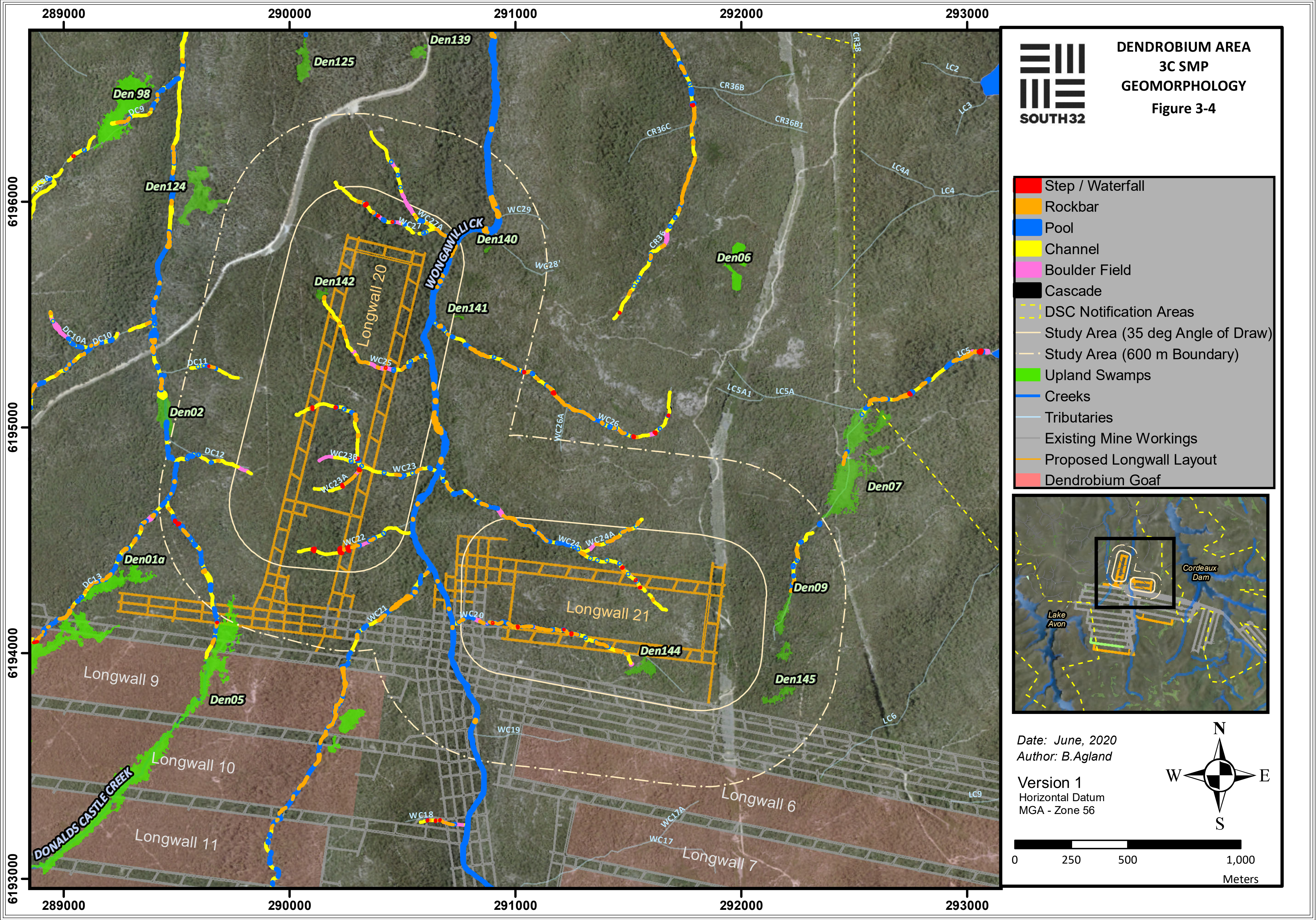
Meters
0 2,500 5,000



DENDROBIUM AREA
3C SMP
Groundwater Monitoring
Figure 3-3



DENDROBIUM AREA
3C SMP
GEOMORPHOLOGY
Figure 3-4
SOUTH32
Step / Waterfall
Rockbar
Pool
Channel
Boulder Field
Cascade
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Cordeaux Dam
Lake Avon
Date: June, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
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Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
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Den142
Den141
Den06
Den02
Den07
Den09
Den01a
Den144
Den145
Den05
DC9
DC10A
DC10
DC11
DC12
DC13
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WC27A
WC27
WG28'
WC26
WC26A
WC25
WC23B
WC23
WC23A
WC22
WC24
WC24A
WC21
WC20
WC19
WC18
WC17A
WC17
CR36B
CR36C
CR36B1
CR36
CR38
LC2
LC3
LC4A
LC4
LC5
LC5A1
LC5A
LC6
LC9

4 PERFORMANCE MEASURES AND INDICATORS

Subsidence impact performance measures have been derived from the Dendrobium Development Consent and from Condition 6, Schedule 3 of the Area 3C SMP Approval. These performance measures will be applied to the extraction of Longwalls 20 and 21.

Table 4-1 Subsidence Impact Performance Measures

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; • no significant change to the composition or distribution of species within the swamp; and • maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.

A detailed list of performance measures and triggers is included in 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 4-2**.

Table 4-2 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 10m/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 (MSEC 2012, 2015 and 2019) 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.

The effects of mining on surface water flow following the completion of Longwall 15 was modelled and assessed in the Longwall 15 EoP Report using the revised surface flow TARPs. The assessments indicate that sub-catchments in the upper part of the Donalds Castle Creek catchment (i.e. DC13S1 and DCS2) have been and continue to be affected by mining, as is the tributary LA4 of Lake Avon (at LA4S1) and probably in the neighbouring tributary LA3 (although analysis is hampered by a very short baseline flow record) (HGEO 2020). The findings for DC13, DCS2 (both at Level 3 for all three flow assessments), and LA4 (effects identified by all three assessments) are similar to those for the EoP report for Longwall 14, as presented in Watershed HydroGeo (2019). LA3 has been affected by mining for the first time by Longwall 15.

Similarly, the flow characteristics at WC21S1 and WC15S1 within the Wongawilli Creek catchment have altered as a result of mining, with these sites trigger Levels 2 and 3 for the three assessments. As with the sub-catchments above, the effects at WC21 and WC15 are similar to those for the previous longwall. WC12 is as yet unaffected by mining HGEO 2020).

Changes to stream flow characteristics are not evident at the downstream gauge on Wongawilli Creek Lower (WWL), despite mining-related effects being clear and significant at upstream tributaries (e.g. WC21, WC15). This suggests that some or all flow lost in headwater catchments is returned downgradient, or that upstream diversions or losses are not significant in relation to the larger catchment water balance given the natural variability and the accuracy of flow measurements. Analysis of available surface water flow observation records for Wongawilli Creek triggered a Level 2 TARP in February 2020. Assessment D was carried out, and indicated that flow reductions due to mining were in the order of 0.008 to 0.015 ML/d.

The assessment against the Performance Measures for Donalds Castle Creek, Wongawilli Creek, Lake Avon and Cordeaux River were all met (HGEO 2020).

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 5.3.1**. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2012, 2015 and 2017). 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 – 15 have been generally consistent with those predicted in the assessments undertaken prior to mining.

In Area 3B, one surface impact (cracking) has been observed in swamps. 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.

Flora monitoring in swamps includes collection of data on species abundance within thirty 0.5 m x 0.5 m quadrats along a 15 m transect. Data is also collected from a number of control sites, to allow comparison both pre- and post-mining with control sites as a part of a Before – After - Control – Impact (BACI) experimental design.

Eleven years of post-mining monitoring is available for Dendrobium Area 2, 7 to 13 years in Dendrobium Area 3A and 4 years in Dendrobium Area 3B. Monitoring includes a minimum of two years baseline surveys for pre-impact sites within Area 2 and Area 3. Monitoring of control sites has been occurring for a minimum of three years for Dendrobium Area 3B and up to a maximum of 11 years for Area 2.

The program includes monitoring and analysis of six upland swamp sites as post-mining sites (Swamp 1 (S1), Swamp 15B (S15B), Swamp 15A(2) (S15A(2)), Swamp 1A (S1A), Swamp 1B (S1B) and Swamp 5 (S5)). The remaining swamps were monitored and analysed as controls or pre-mining sites. Parameters analysed include Total Species Richness (TSR) and species composition as well as swamp size and the extent of groundwater dependent swamp sub-communities.

A statistically significant decline in Total Species Richness (TSR) was detected at Swamp 1 (Dendrobium Area 2) and Swamp 15B (Dendrobium 3A).

Declines in TSR were observed immediately following each site being mined beneath and have continued for at least four years post-mining. Yearly changes in species composition were detected in most sites, regardless of area or treatment. This variation is due to natural turnover of species and is to be expected with changes in rainfall, temperature, natural succession and other seasonal factors. When accounting for the yearly effects, a statistically significant change in species composition in post-mining data to pre-mining data was found at Swamp 1 (Dendrobium Area 2), Swamp 15B (Dendrobium 3A) and Swamp 15A(2) (Dendrobium 3A). The change detected at Swamp 1 however was detected for a four-year period post-mining between 2007 and 2010, however in recent years (2010 to 2016), the change in species composition when compared to pre-mining data was not apparent.

Analysis of LiDAR data indicates the extent of upland swamps has declined at all control and impact swamps in Dendrobium 3A and 3B when compared to the baseline year of 2012. Results indicate that no swamp size TARP trigger levels have been met for impact swamps in Dendrobium Area 3B as the observed decline in swamp extent from 2015 to 2016 was preceded by an increase in swamp extent from 2014 to 2015.

Change in the extent of upland swamp sub-communities from 2012 through to 2016 was similar to the trend observed for total swamp extent. An exception to this trend was Swamp 1A and Swamp 5 where three consecutive years of decline of the sub-community Upland Swamps: Banksia Thicket (Swamp 5 only) and Upland Swamps: Tea-Tree Thicket (Swamp 1A and Swamp 5) were recorded. These declines were greater than the mean (±SE) decline in the control group, indicating a Level 2 ecosystem functionality TARP trigger at these swamps.

Caution is urged when interpreting the results of the swamp size and ecosystem functionality LiDAR monitoring given that a number of factors unrelated to mining-induced impacts may drive some of the observed decreases in swamp size and extent of groundwater dependent sub-communities. Changes in swamp size and extent of groundwater dependent communities observed at each swamp may be the result of responses to natural phenomena such as recent and long-term climate conditions, fire patterns and stochastic events (e.g. storm damage).

Monitoring is continuing to further define any vegetation changes likely to result from reduced groundwater levels.

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 200mm 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.

Site observations recorded during the Dendrobium Annual Terrestrial Ecology Monitoring Program for 2019 in relation to structural changes in vegetation, or indicators of impacts relating to mining, were relatively consistent with those described in 2018. This finding is concurrent with the consistency seen in the statistical analysis between 2018 and 2019. This consistency is likely to have been influenced by the unseasonably dry conditions experienced from 2017 to 2019, with the drying trends associated with low rainfall during these periods and groundwater recharge/flow continuing over time (Biosis 2020).

Following the 2019 terrestrial monitoring it was found that an ecological response had been detected at several impact sites within Dendrobium Areas 3A and 3B where impacts to ecological values have been observed. The impacts remain within prediction levels identified within relevant Environmental Impact Statements and Subsidence Management Plans for Dendrobium Areas 3A and 3B. Management responses are required in these areas to better understand the impacts and, where appropriate, minimise and ameliorate impacts (Biosis 2020).

The ongoing dry conditions that are evident across the region is considered to have heavily influenced the findings and analysis of water dependant species and communities during this survey. The results of the 2019 terrestrial ecological monitoring should therefore be considered in this context. However, long term declines have been identified throughout this monitoring program and any further effects of low rainfall may be a result of a reduction in ecosystem resilience (Biosis 2020).

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 MSEC978 (2019). The maximum valley related movements are predicted to occur in the bases of the streams within the extents of the Valley Fill 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 MSEC978 (2019).

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 Study Area

There are five swamps that have been identified wholly or partially within the Study Area based on the 35° angle of draw line. There are five additional swamps that are located wholly or partially within the Study Area based on the 600 m boundary.

The northern end of Swamp 144 is located above the tailgate (i.e. southern) edge of Longwall 21. The remaining swamps are located outside the extents of the proposed longwalls. A summary of the swamps that are located within the Study Area, based on the 600 m boundary, is provided in **Table 5-1.** The upland swamps can be categorised into two types, the valley infill swamps that form within the drainage lines, and headwater swamps that form within relatively low sloped areas of weathered Hawkesbury Sandstone where hillslope aquifers exist.

Table 5-1: Swamps located within the Study Area based on the 600 m boundary

Reference	Location	Description
Swamp 2	600 m west of LW20	Near the valley base of Donalds Castle Creek
Swamp 5	520 m south-west of LW20	Partially located above the existing LW9 in Area 3B
Swamp 7	590 m north-east of LW21	Near the valley base of Stream LC5B
Swamp 9	290 m east of LW21	Near the valley base of Stream LC5B
Swamp 124	590 m north-west of LW20	On the valley side of Donalds Castle Creek
Swamp 140	320 m north-east of LW20	On the valley side of Wongawilli Creek
Swamp 141	230 m east of LW20	On the valley side of Wongawilli Creek
Swamp 142	70 m west of LW20	Near the valley base of upper reaches of WC25
Swamp 144	50 m south of LW21	Near the valley base of Stream WC20
Swamp 145	330 m south-east of LW21	At the headwaters of Steam LC5B

5.2 Subsidence Predictions

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the swamps located 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 Area 3B and the proposed Longwalls 20 and 21. The section of Swamp 5 that is located above the previously extracted Longwall 9 in Area 3B has not been included in this table as it is located outside the Study Area.

Table 5-2: 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 2	< 20	< 0.5	< 0.01	< 0.01
Swamp 5	< 20	< 0.5	< 0.01	< 0.01
Swamp 7	< 20	< 0.5	< 0.01	< 0.01
Swamp 9	< 20	< 0.5	< 0.01	< 0.01
Swamp 124	< 20	< 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 142	30	1.0	0.05	< 0.01
Swamp 144	30	1.0	0.05	< 0.01
Swamp 145	< 20	< 0.5	< 0.01	< 0.01

Swamps 142 and 144 are predicted to experience 30 mm vertical subsidence due to the extraction of Longwalls 20 and 21. The maximum predicted tilt is 1 mm/m (i.e. 0.1 % or 1 in 1000). The maximum predicted curvature is 0.05 km^{-1} hogging, which represents a minimum radius of curvature of 20 km. The maximum predicted conventional strains for this swamp, based on applying a factor of 15 to the maximum predicted curvatures, are 1 mm/m tensile and less than 0.5 mm/m compressive.

The remaining swamps within the Study Area are predicted to experience less than 20 mm vertical subsidence due to the extraction of Longwalls 20 and 21. Whilst these swamps could experience very-low levels of vertical subsidence, they are not expected to experience measurable conventional tilts, curvatures or strains.

It is noted that Swamp 5 is partially located above Longwall 9 in Area 3B. However, the section of swamp that has been previously mined beneath this longwall is located outside of the Study Area based on the 600 m boundary for Longwalls 20 and 21. The section of swamp within the Study Area is predicted to experience less than 20 mm vertical subsidence.

Swamps 2 and 5 are located near the base of the valley for Donalds Castle Creek; Swamps 7 and 9 are located along Stream LC5B; Swamp Den142 is located at the upper reaches of Stream WC25; and Swamp 144 is located along Stream WC20. 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 5-3.** 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 20 and 21.

Table 5-3: Maximum predicted total upsidence and closure for the swamps

Location	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Swamp 2	< 20	< 20
Swamp 5	100	200
Swamp 7	< 20	< 20
Swamp 9	< 20	20
Swamp 142	40	80
Swamp 144	50	100

Swamp 5 is predicted to experience total valley related effects of 100 mm upsidence and 200 mm closure. The majority of these movements are due to the previous extraction of the longwalls in Area 3B and only low-level additional movements are expected due to Longwalls 20 and 21.

5.3 Impact Assessment

5.3.1 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 142 and 144 are located at minimum distances of 70 m and 50 m, respectively, from the proposed longwalls. The maximum predicted tilt for these swamps is 1 mm/m (i.e. 0.1 %, or 1 in 1000). Swamps 142 and 144 are located along the upper reaches of Streams WC25 and WC20, respectively, where the natural grades are in the order of 100 mm/m (i.e. 10 %, or 1 in 10). The mining induced tilts at Swamps 142 and 144, therefore, are small when compared to the natural surface gradients along the alignments of the drainage lines.

There are no topographical depressions or reversals in grade predicted to develop within the extents of Swamps 142 or 144 due to the extraction of Longwalls 20 and 21. It is unlikely, therefore, that there would be adverse changes in the levels of ponding or scouring in these swamps based on the predicted vertical subsidence and tilt.

The remaining swamps within the Study Area are located on or outside the Study Area based on the 35° angle of draw. These swamps 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.

5.3.2 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.

Swamps 142 and 144 are located along the upper reaches of streams WC25 and WC20, respectively, at distances of 70 m and 50 m from the proposed longwalls. These swamps are predicted to experience conventional tensile strains of 1 mm/m and compressive strains due to valley closure effects of 3 mm/m. Fracturing could therefore occur in the bedrock beneath these swamps.

The estimated fracture widths in the bedrock beneath Swamps 142 and 144, based on the maximum predicted conventional tensile strain of 1 mm/m and a typical joint spacing of 10 m, is in the order of 10 mm.

Wider fractures could develop if the compressive strains due to the valley closure effects result in localised failure of the bedrock. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley closure effects at similar distances from previous longwall mining. It is possible that a series of smaller fractures, rather than one single fracture, could develop in the bedrock. 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 142 and 144 are predicted to experience upsidence movements of 40 mm and 50 mm, respectively. These valley related upsidence movements could result in the dilation of the strata beneath these swamps. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, 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, upstream of Swamps 142 and 144, 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. On the basis that 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 proposed longwalls at minimum distances ranging between 230 m and 600 m. These swamps are predicted to experience additional movements, due to Longwalls 20 and 21, of less than 20 mm vertical subsidence, less than 20 mm upsidence and up to 20 mm closure. These swamps are predicted to experience tensile strains less than 0.5 mm/m and compressive strains less than 2 mm/m due to the extraction of the proposed Longwalls 20 and 21. It is unlikely, therefore, that the bedrock beneath these swamps would experience significant fracturing.

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 the Mine 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 in the Southern Coalfield.

Swamps 2 and 5 are located along Donalds Castle Creek at distances of 600 m to 520 m, respectively, from Longwall 20. Swamp 7 is located along Stream LC5B at a distance of 590 m from Longwall 21. The remaining swamps are located further up the valley sides. It is unlikely, therefore, that significant fracturing would occur at the swamps located on or outside the Study Area based on the 35° angle of draw.

5.3.3 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 in response to significant rainfall events (HGEO 2019).

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 margin (Watershed Hydrogeo, 2019).

Table 5-4: Summary of predicted impacts to Upland Swamps (HGEO 2019)

Swamp	Area (Ha)	Vegetation communities	Distance from LW20/LW21 goaf (m)	Likelihood of shallow groundwater effects
Swamp 2	0.96	Banksia thicket, Tea-tree thicket	600	Unlikely
Swamp 5	1.71	Banksia thicket, Tea-tree thicket, Restioid Heath	550	Unlikely (previously impacted by LW9)
Swamp 7	5.67	Banksia thicket, Tea-tree thicket	595	Unlikely
Swamp 9	0.80	Banksia thicket, Tea-tree thicket	300	Possible

Swamp	Area (Ha)	Vegetation communities	Distance from LW20/LW21 goaf (m)	Likelihood of shallow groundwater effects
Swamp 124	2.10	Sedge-Heath Complex, Restioid Heath, Tea-tree thicket	590	Unlikely
Swamp 140	0.05	Banksia thicket	330	Possible
Swamp 141	0.04	Banksia thicket	230	Possible
Swamp 142	0.16	Banksia thicket	70	Possible
Swamp 144	0.54	Banksia thicket	50	Likely
Swamp 145	0.45	Banksia thicket	336	Possible

5.3.4 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 2019).

Groundwater dependent and riparian vegetation may experience some floristic changes in response to changed groundwater conditions, as a result of subsidence (Niche 2019).

Riparian vegetation may be impacted by subsidence through water diversion or cracking of bedrock. Impacts to riparian vegetation associated with Longwalls 20 and 21 are predicted to be minor in occurrence, being localised if they occurred (Niche 2019).

An assessment of the potential ecological impacts of subsidence on Upland Swamps was completed by Niche (2019), summarised below (**Table 5-5**).

Table 5-5: Ecological impact predictions for upland swamps within and adjacent to the study area (Niche 2019); subsidence predictions from MSEC (2019)

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2019)	Conclusion (Niche 2019)
Swamp 2	Moderate size and complexity.	Edge of swamp within 600 m. Very minor parts of inflow tributaries within angle of draw.	Low likelihood of subsidence impacts given distance from longwalls of the swamp and its tributaries.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
Swamp 5	Large complex swamp.	Small section of swamp within 600 m. Previous direct undermining (LW9 to 11).	Low likelihood of additional subsidence impacts given distance from longwalls of the swamp and its tributaries. Previous longwall mining directly below this swamp impacted the swamp (Biosis 2016).	Unlikely to be measurable additional impacts to this swamp or associated species including threatened species from the current proposal. Monitoring of impacts likely to be confounded from previous direct undermining (LW 9 to 11).
Swamp 7	Large complex swamp with pools observed	Small section of swamp within 600 m.	Low likelihood of subsidence impacts	Unlikely to be measurable impacts to

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2019)	Conclusion (Niche 2019)
	within or on edges of swamp.	No part of mapped predominant inflow tributary within angle of draw.	given distance from longwalls of the swamp and minor proportion of tributaries within angle of draw. The predicted post-mining grades within the swamps are similar to the natural grades and, therefore, it is not expected that there would be adverse changes in ponding or scouring within the Swamps due to tilt (MSEC 2019). It is noted that a track passes through a section of the swamp.	this swamp or associated species including threatened species from the current proposal. The swamp will be monitored for potential impacts.
Swamp 9	Small swamp in two sections – moderately complex. Northern section is along or adjacent to ephemeral watercourse.	Between angle of draw and 600 m study area.	Significant fracturing of the bedrock is not expected to occur nor dilation of strata within a predominant upstream tributary. Possibility of some minor subsidence impacts.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
Swamp 124	Large complex swamp. Offline from major watercourse of Donalds Castle Creek.	Small section of swamp within 600 m. Feeding tributaries within 600 m or previously mined areas.	Low likelihood of subsidence impacts given distance from longwalls of the swamp and its position offline of streams.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
Swamp 140	Small simple swamp, no noticeable pools or watercourses adjacent.	Between angle of draw and 600 m study area.	Possibility of some minor subsidence impacts. Fracturing of the bedrock is not expected to occur nor dilation of strata within a predominant upstream tributary.	While some subsidence impacts are possible, these may not be measurable. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.
Swamp 141	Small simple swamp, no noticeable pools or watercourses adjacent.	Small section of swamp within angle of draw.	Possibility of some subsidence impacts. Fracturing of the bedrock may occur along with dilation of strata.	While some subsidence impacts are possible, these are unlikely to be significant. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.
Swamp 142	Small simple swamp at headwater of WC25.	Within angle of draw.	Fracturing of the bedrock is expected to occur along with dilation of strata within an upstream tributary. This may lead to	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn’s Tree Frog). Areas may trend

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2019)	Conclusion (Niche 2019)
			groundwater changes within the swamp.	towards Fringing Eucalypt Forest if changes are long-term. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.
Swamp 144	Small simple swamp along ephemeral watercourse (WC20)	Swamp within angle of draw.	Fracturing of the bedrock is expected to occur along with dilation of strata within an upstream tributary. This may lead to groundwater changes within the swamp.	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog). Areas may trend towards Fringing Eucalypt Forest if changes are long-term. Swamp is small and simple, however is likely to contribute to Littlejohn's Tree Frog population downstream and or within the swamp.
Swamp 145	Small simple swamp at headwater of watercourse.	Between angle of draw and 600 m study area.	Possibility of some minor subsidence impacts. Fracturing of the bedrock is not expected to occur nor dilation of strata within a predominant upstream tributary.	While some subsidence impacts are possible, these may not be measurable. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.

5.3.4.1 Potential Impacts to Threatened Flora

Nine threatened flora species have been determined to have a moderate to high likelihood of occurring within the study area (Niche 2019). However, a limited number have potential habitat likely to be impacted by subsidence (Niche 2019).

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.

5.3.4.2 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 2019).

5.3.4.3 Potential Impacts to Threatened Fauna

Fifty-four threatened fauna were considered during the likelihood of occurrence assessment. Thirty-seven 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 2019). Nine threatened species are considered to be potentially impacted by subsidence impacts resulting from Longwalls 20 and 21 (Niche 2019).

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 2019).

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 2, 5, 7, 9, 124, 140, 141, 142, 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 2 and 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 2 and 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 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 have been assessed by IMC using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks of the longwalls from key features. These options are reviewed, analysed and modified until an optimised longwall layout in Area 3C is achieved.

Area 3C is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2 and 3A 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 Avon, and Wongawilli Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion. The process of developing the layout for Area 3C has considered the impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

No contingent mining areas containing Wongawilli Seam Coal resources with the possibility for extraction are available to IMC.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues are taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3C mine layout incorporates 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.

The mining layout of the proposed longwalls is designed to avoid Wongawilli and Donalds Castle Creeks. Wongawilli Creek is located between the proposed Longwalls 20 and 21. The thalweg (i.e. base or centreline) of the creek is 125 m east of the tailgate of Longwall 20 and 240 m west of the finishing end of Longwall 21, at the closest points to the proposed longwalls. Donalds Castle Creek is located to the west of the proposed longwalls. The thalweg of the creek is 470 m from the maingate and finishing end of Longwall 20, at its closest point and outside the 35°.angle of draw of Longwall 21.

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.

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 swamps are 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.

A number of grouts are available for use and can be used with or without fillers such as clean sand. Grouts can be mixed on-site and injected into a fracture network or placed by hand. Hand-placed and injection grouting of large fractures were successfully implemented in the Georges River near Appin.

Such operations do have the potential to result in additional environmental impacts and are carefully planned to avoid any 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 Polyurethane 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. IMC sought further clarification from DPIE that the Maddens Plains offset area can be relied upon for the Longwalls 20 and 21 SMP application and also all future Area 3C SMP applications. IMC received confirmation of this position from DPIE on 4 November 2019. 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 3 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 3B, including Swamps 2, 5, 7, 9, 124, 140, 141, 142, 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 AEMR.

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 Water NSW is required to access the land to conduct works and implement 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, Mitigation and Contingent Measures for Swamps

Swamp	Performance Measure	Potential Impacts	Monitoring Method	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; • no significant change to the composition or distribution of species within the swamp; and • 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.
		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

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
				h) investigation and review i) update future predictions		agreement of the Secretary.
Swamps 2, 7, 124, 140, 141 and 142	**No significant environmental consequences** beyond predictions in the Subsidence Management Plan	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	k) upfront mine planning l) erosion monitoring (i.e. ALS, observation) m) coir logs n) knickpoint control o) water spreading p) weeding q) fire management r) reporting s) investigation and review t) 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 base and/or use of other remediation techniques	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	Management Strategies	Exceeding Prediction	Offsets
				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.

Note: 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-conformities, 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 3 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, Shedule 2 of the Development Consent.

8.5 Management Plan Review

A comprehensive review of the objectives and targets associated with the Dendrobium Area 3 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 3 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	Swamps 12, 15A, 15B, 34, 95, 96, 146, 147 and 148 *Reference Sites* Swamps, 2, 22, 24, 25, 33, 84, 85, 86, 87 and 88	Observation and photo point monitoring: • Sites based on an assessment of risk • Swamps • Pools and rockbars • Steep slopes and rock outcrops • Previously observed impacts that warrant follow-up inspection	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, 35B, 149, 150 and 151 *Reference Sites* Swamps 2, 7[1], 15A[2], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 7, 9, 144 and 145 General observation of swamps in active mining areas when longwall is within 400 m of swamp *Reference Sites* Swamps, 2, 15A[3], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
EROSION MONITORING				
Area 3A	Swamps 12, 15A[4], 15B, 34, 95, 96, 146, 147 and 148 *Reference Sites*	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	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

[1] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[2] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

[3] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

[4] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*

	Swamps 2, 7[5], 22, 24, 25, 33, 84, 85, 86, 87 and 88		Ground based surveys to be completed for each longwall after each longwall or to define any new erosions identified by ALS survey	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,35B, 149, 150 and 151. *Reference Sites* Swamps 2, 15A[6], 7[7], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 2, 5, 7[8], 9, 124, 140, 141, 142, 144 and 145 *Reference Sites* Swamps 2, 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
SHALLOW GROUNDWATER LEVEL				
AREA 3A	Swamp 15A: 15a_03, 15a_04, 15a_07, 15a_12, 15a_15a_15, 15a_17 Swamp 15B: 15b_H1, 15b_H2, 15b_H3 Swamp 12: 12_01, 12_03, 12_04 Swamp 146: DA2A_01 Swamp 34, 95, 96, 147 and 148 At least one piezometer site per swamp if sediment depth is appropriate. *Reference Sites* Swamp 2: 02_01 Swamp 7[9]: 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 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02	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

[5] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*
[6] *Reference site for Area 3B; potential impact site when mining recommences in Area 3A.*
[7] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*
[8] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*
[9] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

AREA 3B	Swamp 01A: 01a_01, 01a_02, 01a_03, 01a_04, 01a_04i, 01a_04ii, 01a_04iii, 01a_04iv, 01a_04v Swamp 01B: 01b_01, 01b_02, 01b_02i, 01b_02ii, 01b_02iii, 01b_02iv, 01b_03 Swamp 03: 03_01 Swamp 04: (thin soil profile) Swamp 05: 05_01, 05_02, 05_03, 05_03i, 05_03ii, 05_03iii, 05_04, 05_05, 05_06 Swamp 08: 08_01, 08_02, 08_03, 08_04, 08_05, 08_06 Swamp 10: 10_01 Swamp 11: S11-HI, S11-H2, S11-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. Swamp 149, 150 and 151 At least one piezometer site per swamp if sediment depth is appropriate. *Reference Sites* Swamp 2: 02_01 Swamp 7[10]: 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 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02			

[10] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

AREA 3C	Swamps, 7[11], 9, 141, 142, 144 and 145 At least one piezometer site per swamp if sediment depth is appropriate. *Reference Sites* Swamp 2: 02_01 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 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02			
SOIL MOISTURE				
Area 3A	Install soil moisture at existing shallow groundwater sites Swamp 15A: 15a_03, 15a_04, 15a_07, 15a_12, 15a_15a_15, 15a_17 Swamp 15B: 15b_H1, 15b_H2, 15b_H3 Swamp 12: 12_01, 12_03, 12_04 Swamp 34, 95, 96, 146, 147 and 148 Generally one Soil Moisture site per swamp if sediment depth is appropriate.			

[11] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

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 Swamp 149, 150 and 151 Generally one Soil Moisture site per swamp if sediment depth is appropriate. *Reference Sites* *Swamp 2: S02_S01* *Swamp 7[12]: S07_S05, S07_S06* *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* *Swamp 86: S86_S01, S86_S02* *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	Swamps 7, 9, 124, 140, 141, 142, 144 and 145 Soil moisture sites will be paired with sites with piezometers			

TERRESTRIAL FLORA – COMPOSITION AND DISTRIBUTION OF SPECIES				
AREA 3A	Swamps 15B and 15A *Reference Sites* *Swamp 88, Swamp 87, Swamp 86, Swamp 22 and Swamp 33*	Swamp vegetation transects	Two baseline monitoring campaigns 1 year prior to mining during autumn and spring (Autumn - Photo points; spring - Photo points & transects/quadrat) 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	15 m transects consisting of thirty 0.5 m x 0.5 m quadrats. The monitoring records: • Presence of all species within each quadrat • Percentage foliage cover and vegetation height • Observations of dieback or changes in community structure • Photo point monitoring at each transect
AREA 3B	Swamps 01A, 01B, 05, 11 *Reference Sites* *Swamp 88, Swamp 87, Swamp 86, Swamp 22 and Swamp 33*			

[12] *Reference site for Area 3B; impact site when mining commences in Area 3C.*

AREA 3C	Swamps 9, 144 and 145 (Sites yet to be determined) *Reference Sites* *Swamp 88, Swamp 87, Swamp 86, Swamp 22 and Swamp 33*			
TERRESTRIAL FLORA – SWAMP SIZE AND ECOSYSTEM FUNCTION				
Area 3A	Swamp 15A and 15B *Reference Sites* *Swamps 85 (DC10) and 33*	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, 14 and 23 *Reference Sites* *Swamps 85 (DC10) and 33*			
AREA 3C	Swamps 9, 144 and 145 *Reference Sites* *Swamps 85 (DC10) and 33*			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3A	Swamps 15B and 15A *Reference Sites* *WC10, WC11, 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, SC7, SC7(2), SC7A, SC8, DC8 and NDC*			
AREA 3C	Swamps 9, 144 and 145 (sites yet to be determined) *Reference Sites* *WC10, WC11, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC*			
AQUATIC ECOLOGY				

AREAS 3A, 3B and 3C	**Sandy Creek Catchment** Sites 8, 9, 10, 11, 12 and 13 (Sandy Creek) *Reference Sites* Site 7 (Sandy Creek) **Wongawilli Creek Catchment** Sites 2, 3, 4, 5[13], 19[14], 20[15], X4, X5 and X6 (Wongawilli Creek) Sites X2 and X3 (WC21) *Reference Sites* Site 1 (Wongawilli Creek until LW15) Site 5*(1)* (Wongawilli Creek) Site 6 (WC21) Site X7 (Wongawilli Creek) Site X8 (Wongawilli Creek) **Donalds Castle Creek Catchment** Site X1, 17 and 18 (Donalds Castle Creek) *Reference Sites* Site 14 (Donalds Castle Creek) **Kentish Creek Catchment** *Reference Sites* Sites 15 and 16 (Kentish Creek) ***Note** - Additional impact and reference monitoring sites to be established at least 2 years prior to the extraction of Longwalls 20 and 21.*	Quantitative and observational monitoring	• Two baseline monitoring campaigns prior to mining during autumn and spring • Biennial monitoring during mining in autumn and spring • Biennial monitoring post mining for two years or as otherwise required • Biennial 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 if possible Fish are sampled by visual observations and dip netting in Area 3A and sampled using baited traps in Area 3B

[13] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[14] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

[15] *Reference site for Area 3B; potential impact site when mining commences in Area 3C.*

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 Den 09, Den 144 and Den 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 **No significant change** to the composition or distribution of species within the swamps	Swamp vegetation changes: - Swamp size - Species richness, distribution, composition and diversity - Vegetation sub-communities	**Swamp Size** *Level 1:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the standard error (SE) of the Control Group. *Level 2:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem Functionality**	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. **Species Composition and Distribution** *Level 1:* A **2%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **two** consecutive years; and/or *Level 2:* A **5%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **three** consecutive years. *Level 3:* An **8%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **four** consecutive years. *Exceeding Prediction:* Mining results in a **>10%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **five** consecutive years.	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	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.	

			i) update future predictions		
Minor changes in the ecosystem functionality of the swamps	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.*	<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.	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
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	<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) soil moisture monitoring c) water spreading d) weeding e) fire management f) reporting g) update future predictions		Triggers of soil moisture decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars