SOUTH32

DENDROBIUM
LONGWALL 19

FEBRUARY 2021

LONGWALL 19

SWAMP IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

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Review History

Revision	Description of Changes	Date	Approved
A	New Document-DRAFT	March 2020	GB
B	Updated for Longwall 19	February 2021	GB

Persons involved in the development of this document include:

Name	Title	Company
Billy Agland	Environmental Officer	Illawarra Metallurgical Coal
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1 INTRODUCTION

1.1 Project Background

Illawarra Metallurgical Coal (IMC), a wholly owned subsidiary of South32 Pty Ltd (South32), operates the underground 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 with current operations in Area 3B.

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 that could cause subsidence.

1.2 Scope

The Swamp Impact Monitoring, Management and Contingency Plan (SIMMCP) has been prepared to comply with the Dendrobium Development Consent and the SMP Approval in respect to swamp management within Longwall 19 Study Area.

The Dendrobium Development Consent 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 Longwall 19 (**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 Longwall 19;

- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed longwall; and
- The natural features located within 600 m of the extent of the longwall mining area, in accordance with Schedule 3, Condition 8(d) of the Development Consent.

The depth of cover varies between 280 m and 370 m directly above the proposed Longwall 19. The 35° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 196 m and 259 m around the extents of the longwall void.

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 (2020). The predicted incremental 20 mm subsidence contour extends beyond the 35° angle of draw above the existing Longwalls 6 to 8. Elsewhere, the contour is located inside the angle of draw.

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 the streams, upland swamps and Aboriginal heritage sites.

There are additional features that are located outside the 600 m boundary that could experience either far-field horizontal or valley related effects. 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 12,15A, 15B, 34, 95, 96, 146, 147 and 148 as they are located wholly or partially within the 600 m Study Area within the Longwall 19 Study Area. Swamp 15A, as defined in the Dendrobium Development Consent (Schedule 3, Conditions 5, 6a and 6b), is located partially above Longwall 19.

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

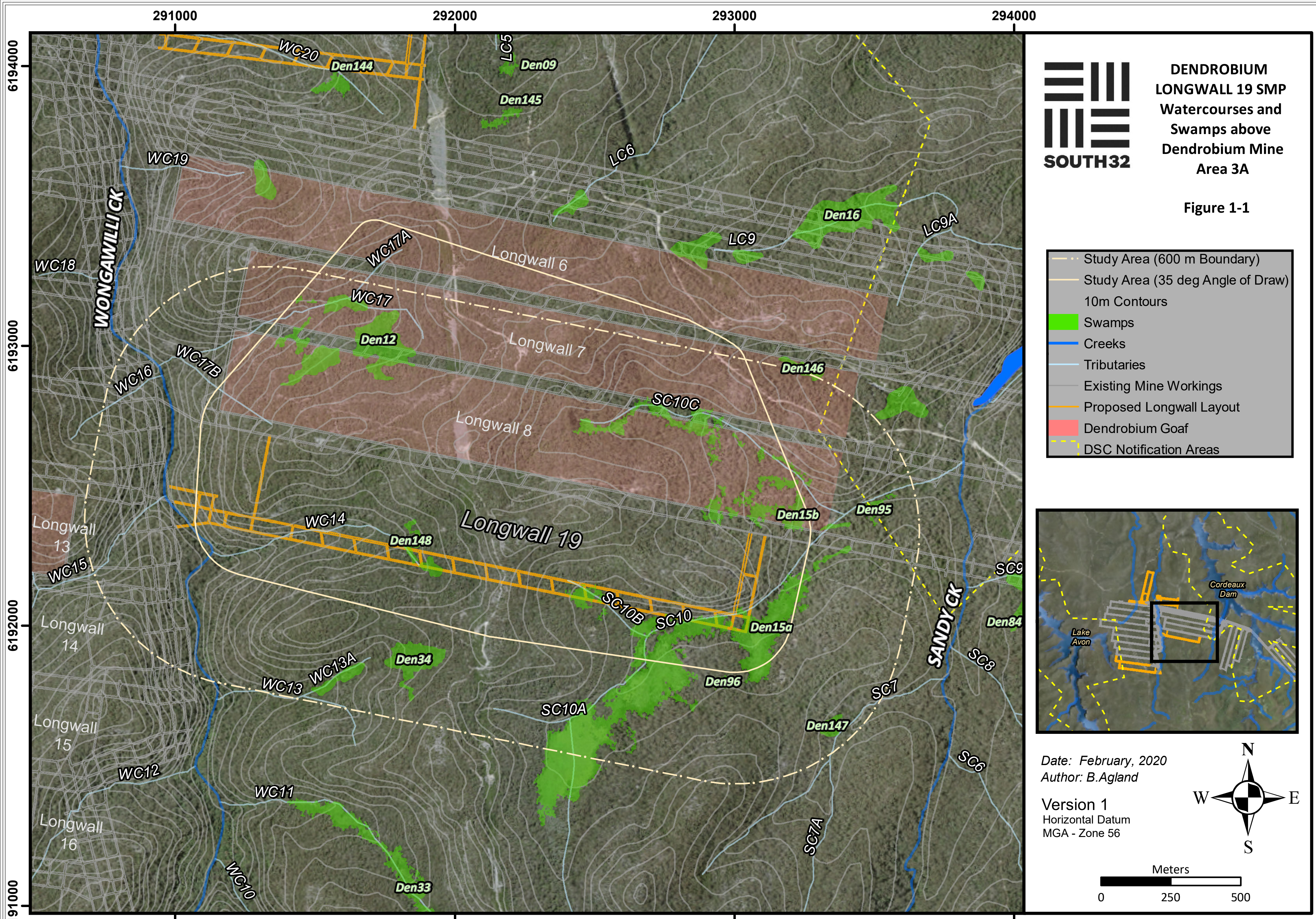
The objectives of this SIMMCP are to identify at risk swamp features and characteristics within the Longwall 19 Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on swamps. The SIMMCP also provides updated monitoring for the Area 3A mining domain. This Longwall 19 SIMMCP is intended to operate in parallel with the Area 3A SIMMCP (approved 28 June 2010).

1.5 Consultation

The Dendrobium SIMMCPs and other Management Plans have been developed by IMC in consultation with:

- DPIE; the Biodiversity Conservation Division within the Department (BCD), DRG; and
- WaterNSW.

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



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DENDROBIUM LONGWALL 19 SMP Watercourses and Swamps above Dendrobium Mine Area 3A

Figure 1-1

Date: February, 2020
Author: B.Agland

Version 1
Horizontal Datum
MGA - Zone 56

2 PLAN REQUIREMENTS

Extraction of coal from Longwall 19 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 Longwall 19 Study Area. The baseline studies have identified monitoring sites in these areas based on the Before After Control Impact (BACI) design criteria.

A comprehensive monitoring program which details the monitoring to be undertaken for swamps is outlined in the SIMMCP (**Appendix A: Table 1.1**).

A summary of swamp monitoring within the Longwall 19 Study Area 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 the Longwall 19 Study Area 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

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.	Section 5
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;	Section 6
(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;	Section 3
(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 5
(f) be prepared in consultation with DECC, SCA and DPI;	Section 1.5

Dendrobium Development Consent Condition	Relevant SIMMCP Section
(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.	Section 7 Section 1.4

2.2 Leases and Licences

The following licences and permits may be applicable to IMC's operations in the Longwall 19 Study Area:

- Dendrobium Mining Lease as shown in **Table 2-2**;
- 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 2-2 Dendrobium Leases

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

3 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 a selection of 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. Installation of additional Wongawilli Creek monitoring lines will be subject to site access and any other 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. Baseline monitoring will be conducted prior to active subsidence.

3.1 Observational Monitoring

IMC has conducted ongoing monitoring of watercourses in the Dendrobium area since 2001 (**Figure 3-1**). This monitoring builds upon the understanding of processes within the watercourses, along with identifying and assessing any episodic or temporal changes.

This monitoring (along with other monitoring programs described in the WIMMCP) is consistent with (in part) Condition 4 Schedule 3 "*include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function*".

The IC Environmental Field Team is continuing to undertake 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 Longwall 19 Study Area 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 sites along watercourses and swamps the Longwall 19 Study Area are included in the observational and photo point monitoring program:

- Monitoring sites:
  - Sandy and Wongawilli Creeks (commenced 2001);
  - WC13, WC14, WC15, WC16, WC17, SC7, SC10 and SC10C;

  - Swamps 12, 15A, 15B, 34, 95, 96, 146, 147 and 148.
- Reference sites:
  - Swamps 2, 7, 22, 24, 25, 33, 84, 85, 86, 87 and 88.
  - Wongawilli Creek, LC5, CR36, Sandy Creek, WC11 (Swamp 33), SC9A (Swamp 84), DC10 (Swamp 85), D10 and Gallahers Creek (Swamp 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.

3.2 Water Quality and 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 the Longwall 19 Study Area 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 detailed in the WIMMCP.

3.3 Groundwater

A Groundwater Assessment is provided in Attachment B of the SMP (SLR 2020). An existing groundwater monitoring program is in place for Dendrobium, which includes the Longwall 19 Study Area (**Figure 3-5**). The Dendrobium Long Term Groundwater Monitoring Program is available in Appendix B of the WIMMCP.

Groundwater monitoring is undertaken in:

- Surficial and shallow systems associated with upland swamps and the weathered near-surface bedrock.
- 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.

3.4 Surface Water Flow and Pool Water Level

Existing surface water flow gauges and data loggers are installed at key stream flow monitoring sites; additional sites are proposed be installed to effectively monitor streams that may potentially experience influence from mining Longwall 19 (**Figure 3-6**). Water level data loggers are also installed at stream flow monitoring sites (**Figure 3-2**) along with manual benchmark water level monitoring sites. Data has been collected since 2003 and has been compiled within monitoring and field inspection reports (Illawarra Coal 2011), EoP Reports and regular impact update reports. Pool water level and flow monitoring sites have been established in the Longwall 19 Study Area for monitoring before, during and after mining (see WIMMCP for details).

3.5 Near-Surface Groundwater and Soil Moisture

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

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers have been installed in several swamps within and around Area 3 (**Figure 3-1**), including the hill-slope aquifers on the eastern side of Sandy Creek; within Swamp 15B and Swamp 12. Within Area 3B long-term piezometer records are available for Swamp 11 as well as additional sites installed since 2011 (**Figure 3-2**).

Swamps 2 (Donalds Castle Creek), 7 (LC5 Lake Cordeaux tributary), 22, 24, 25, 33 (WC11), 84 (SC9), 85 (DC10), 86, 87 and 88 (Gallahers Creek) have been selected as reference monitoring sites (**Figure 3-2**). Shallow groundwater monitoring has been installed in reference swamps. This data is used to compare differences in shallow groundwater levels within swamps and hill-slope aquifers before and after mining. Sites that will not be mined under are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

Groundwater monitoring bores (and other monitoring) is provided in **Figure 3-5**.

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

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 3A with the most appropriate data taking into account proximity, length of record and data quality (**Figure 3-4**).

A comprehensive array of multi-level piezometers have been installed on the centreline of panels at Dendrobium Mine in order to monitor pore pressure changes associated with subsidence. These monitoring holes include at least five transducers per borehole with installation at least 2 years prior to undermining, in line with the recommendations of the IEP (2019a). Where these monitoring sites are damaged as a result of undermining they are reinstalled after subsidence movements cease. Daily monitoring of local rainfall and mine water ingress from overlying and surrounding strata, and separation of rainfall correlated inflows for base flow volumetric analyses is also undertaken (IEP 2019 a and b).

3.6 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 a large portion of Dendrobium Area 3, including the location of significant features in the watercourses (**Figure 3-7**).

The eastern area is broadly sited on a plateau dissected by a number of relatively shallow 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 the southern end of Lake Avon.

The largest watercourse within the Study Area is Wongawilli Creek (**Figure 1-1**) which is located between Areas 3A and 3B. 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. Sandy Creek is a third order perennial stream with a small baseflow which is located to the east of the proposed Longwall 19. Sandy Creek flows into Lake Cordeaux and has a number of 1st and 2nd order tributaries reporting flows.

The geomorphology of tributary sub-catchments in Area 3A is typically characterised by upland plateau and a series of 'benches' comprised of catenary hill-slopes and swamps enclosed in roughly crescent-shaped cliff lines

The upstream southern end of the catchment consists of a ridge containing a thin sandy soil profile accumulated on a generally dome shaped outcrop. This outcrop exhibits pronounced removal of the sandstone's kaolinite clay cement and is typically white and friable (Hazelton and Tille 1990).

Drainage is to the north east and south west down slopes, with little evidence of surface drainage channels. This is consistent with headwater hill-slope aquifer zones and overland sheet flow during extreme rainfall events.

Wongawilli, Sandy and Donalds Castle Creeks are 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 Sandy and Wongawilli Creeks:

- 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 of Wongawilli Creeks within the 600 m Study Area boundary (**Figure 3-7**) were mapped in February 2020 by IMCEFT. All mapped rockbar controlled pools in Sandy and Wongawilli Creeks are significant permanent pools.

3.7 Slopes and Gradients

Slopes within the Longwall 19 Study Area have been mapped according to their gradients and are identified on Drawing 8 in MSEC (2020). Monitoring of landscape features such as cliffs, slopes and rock outcrop was previously undertaken in Area 3A. Monitoring sites relevant to Longwall 19 are proposed to be reinstated, additional sites will be identified and monitored as required (**Figure 3-8**).

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

The inspection and monitoring include the following:

- 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.

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, 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 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.

3.8 Erodibility

Most of the surface of Area 3A 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). Landscape monitoring of slopes is undertaken in the Longwall 19 Study Area to identify any erosion of the surface (**Figure 3-8**).

An extensive survey network will be implemented, which includes relative and absolute horizontal and vertical movements. Additional sites will be added to the monitoring program prior to subsidence movements impacting the sites.

Due to terrain, vegetation and access restrictions, the primary method of identifying any erosion over the Longwall 19 Study Area will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwall and mining domains and will also provide identification of any erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

Base surveys over Area 3A using ALS were completed in December 2005. A verification base survey will be conducted prior to the commencement of mining of the proposed longwall. 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 the mining area will be undertaken at regular intervals, during active subsidence. 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.

3.9 Flora, Fauna and Ecosystem Function

Terrestrial flora and vegetation communities in the Study Area are described in the Terrestrial Ecology Assessment (Niche 2020). Aquatic flora and fauna in the Study Area are described in the Aquatic Ecology Assessment (Cardno Ecology Lab 2020).

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

Annual Reporting (Biosis 2016, Biosis 2017, Biosis 2018 and Biosis 2019) 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 has been implemented for Area 3. As recommended by the IEP (2019a), the monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction.

Over two years of baseline data is available for the Longwall 19 Study Area 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).

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. These repeatable surveys enable direct comparison of the numbers of individuals recorded at each site from one year to the next.

Additional monitoring will commence in other streams two years prior to mining. Monitoring is also undertaken away from mining to act as control sites for the mining versus non-mining comparative assessment. Although there has been mining upstream of Sites SC6, SC8 and NDC, data to date indicates there are strong numbers of frogs in these areas for monitoring purposes.

Along each transect the monitoring includes: counts of frogs, an assessment of pools being used for breeding as well as counts of tadpoles and egg masses. This will enable a quantitative as well as qualitative assessment of breeding habitat for these species prior to, during and after mining.

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.

Aquatic ecology monitoring includes direct measures of aquatic flora and fauna as well as biophysical measures. Aquatic ecology monitoring sites for the Longwall 19 Study Area are shown in the Aquatic Ecology Assessment (Cardno 2020). These sites are located in watercourses that contain “significant” or “moderate” aquatic habitat and are suitable for AUSRIVAS assessment (i.e. are at least 100 m long).

During the baseline study the condition of the aquatic habitat at each site was assessed using a modified version of RCE (Chessman *et al*. 1997).

At each site where instream aquatic macrophytes are present, their species composition and total area of coverage is recorded. Features such as the presence of algae or flocculent on the surface of macrophytes would also be noted.

Two methods are used to sample aquatic macroinvertebrates: the AUSRIVAS protocol for NSW streams (Turak *et al*. 2004) and artificial aquatic macroinvertebrate collectors, a quantitative method developed by CEL for freshwater environmental impact assessment.

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 any confusion, 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.

Fish are sampled using a back-pack electrofisher (model LR-24 Smith-Root) and baited traps. At each site, eight baited traps are deployed in a variety of habitats such as amongst aquatic plants and snags, in deep holes and over bare substratum. The back-pack electrofisher is operated around the edge of pools and in riffles. At each site, four, two-minute shots are performed. Fish stunned by the current are collected in a scoop net, identified and measured. Native species are released unharmed while exotics are not returned to the water.

Ongoing monitoring uses the BACI design with two types of monitoring sites included in the program:

- Potential impact sites - these may be subject to mine subsidence impacts during and after longwall extraction; and
- Control sites - these will provide a measure of background environmental variability within the catchments as distinct from any mine subsidence impacts.

Monitoring site locations are detailed in **Appendix A: Table 1.1** and in Aquatic Ecology Assessment (Cardno 2020).

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.

3.9.1 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 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 SMP Approval. The term is not included in the definitions of the 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**). Details of upland swamp communities within the 600 m Study Area are detailed in **Table 3-1**.

Table 3-1 Upland Swamps and associated sub-communities within the Study Area (Niche 2020)

Swamp	Swamp community/sub-community	Area (ha)			
		Within 600 m boundary + adjacent	Within 600 m boundary	Within angle of draw	Above Longwall 19
12	Upland Swamps: Banksia Thicket	5.37	5.37	5.37	-
15A	Upland Swamps: Banksia Thicket	8.57	8.14	5.02	0.01
	Upland Swamps: Sedgeland-Heath Complex (Restoid Heath)	4.40	3.40	1.37	<0.01
	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)	2.49	2.49	0.38	-
	Upland Swamps: Tea-tree Thicket	2.56	0.73	0.32	-
15B	Upland Swamps: Banksia Thicket	3.35	3.35	3.20	0.01
	Upland Swamps: Tea-tree Thicket	1.04	1.04	1.04	-
	Upland Swamps: Sedgeland-Heath Complex (Cyperoid Heath)	0.57	0.57	0.55	-
	Upland Swamps: Sedgeland-Heath Complex (Sedgeland)	0.01	0.01	0.01	-
34	Upland Swamps: Mallee-Heath	1.90	1.90	-	-
	Upland Swamps: Banksia Thicket	0.40	0.40	-	-
	Upland Swamps: Tea-tree Thicket	0.10	0.10	-	-
95	Upland Swamps: Banksia Thicket	1.09	0.81	-	-
96	Upland Swamps: Banksia Thicket	0.17	0.17	-	-
146	Upland Swamps: Tea-tree Thicket	0.60	0.08	-	-
147	Upland Swamps: Banksia Thicket	0.45	0.45	-	-
148	Upland Swamps: Banksia Thicket	0.86	0.86	0.86	-
Total		**33.93**	**29.87**	**18.12**	**0.02**

Mapping will be replicated prior to mining (where needed), 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.

3.9.2 Swamp Size

Detailed mapping of the boundaries of the swamps and vegetation sub-communities has been undertaken for Swamps 12, 15A, 15B, 34, 95, 96, 146,147 and 148 (**Figure 3-1**). Reference swamps have previously been mapped, including Swamp 2, 7, 22, 24, 25, 33, 84, 85, 86, 87 and 88. (**Figure 3-2**). 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 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.

3.9.3 Flora - Composition and Distribution of Species

Control sites have been established at Gallahers Creek Swamp (Swamp 88), Fire Trail 15e Swamp (Swamp 87), Fire Trail 6x Swamp (Swamp 86), Swamp 15A(1), 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.

Twelve transects have been installed within the 400 m zone of influence of the longwall. Ten of these are directly over the proposed goaf where the subsidence movements are predicted to be greatest, with five of these close to the centre of the longwall. One transect is over a chain pillar and one transect is off the goaf area within the 400m zone of influence of the longwall.

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, Restoid 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.

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 Longwall 19.

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.

3.9.4 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 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.

Creeks DC13, DC(1), WC21, LA4A, ND1 and WC15 are monitored as a part of the Dendrobium Area 3B monitoring program, with additional monitoring commencing in other streams two years prior to mining. Monitoring is also undertaken away from mining to act as control sites for the mining versus non-mining comparative assessment. Although there has been mining upstream of Sites SC6, SC8 and NDC, data to date indicates there are strong numbers of frogs in these areas for monitoring purposes.

Baseline surveys commenced in winter 2013 and included counts of frogs along each transect, an assessment of pools being used for breeding and counts of tadpoles and egg masses in each pool. This will enable a quantitative as well as qualitative assessment of breeding habitat for these species prior to, during and after mining.

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.

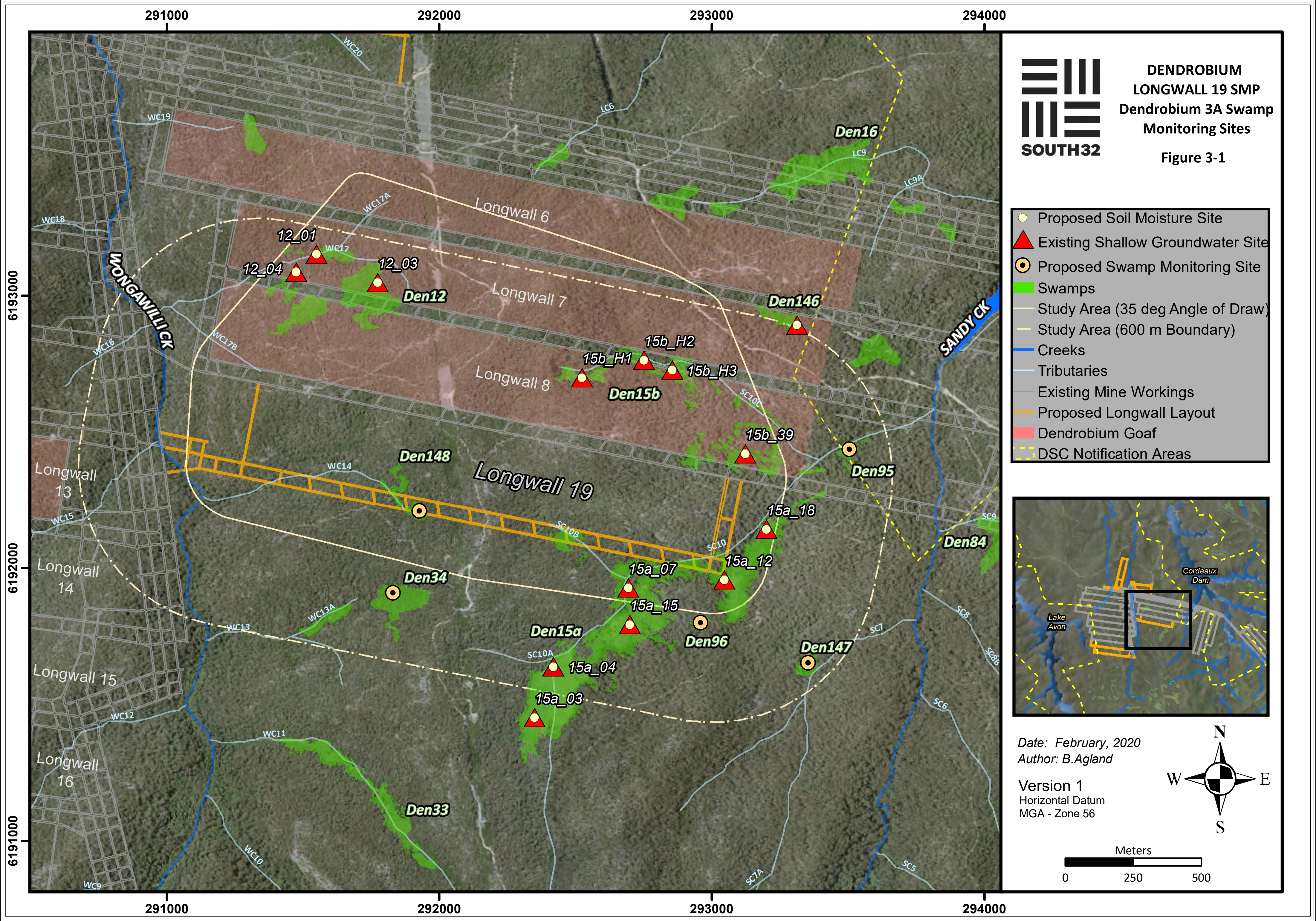
IMC continues to fund and support research into a regional understanding of the context and cumulative impact of the Dendrobium Mine on populations of Little John's Treefrog and Giant Dragonfly.

3.10 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
LONGWALL 19 SMP
Dendrobium 3A Swamp
Monitoring Sites
Figure 3-1
SOUTH32
Proposed Soil Moisture Site
Existing Shallow Groundwater Site
Proposed Swamp Monitoring Site
Swamps
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
Meters
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WONGAWILLI CK
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Den84
15a_18
15a_12
15a_07
15a_15
15a_04
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Den147
Den33
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WC19
WC18
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WC17A
WC17B
WC16
WC15
WC14
WC13
WC13A
WC12
WC11
WC10
WC9
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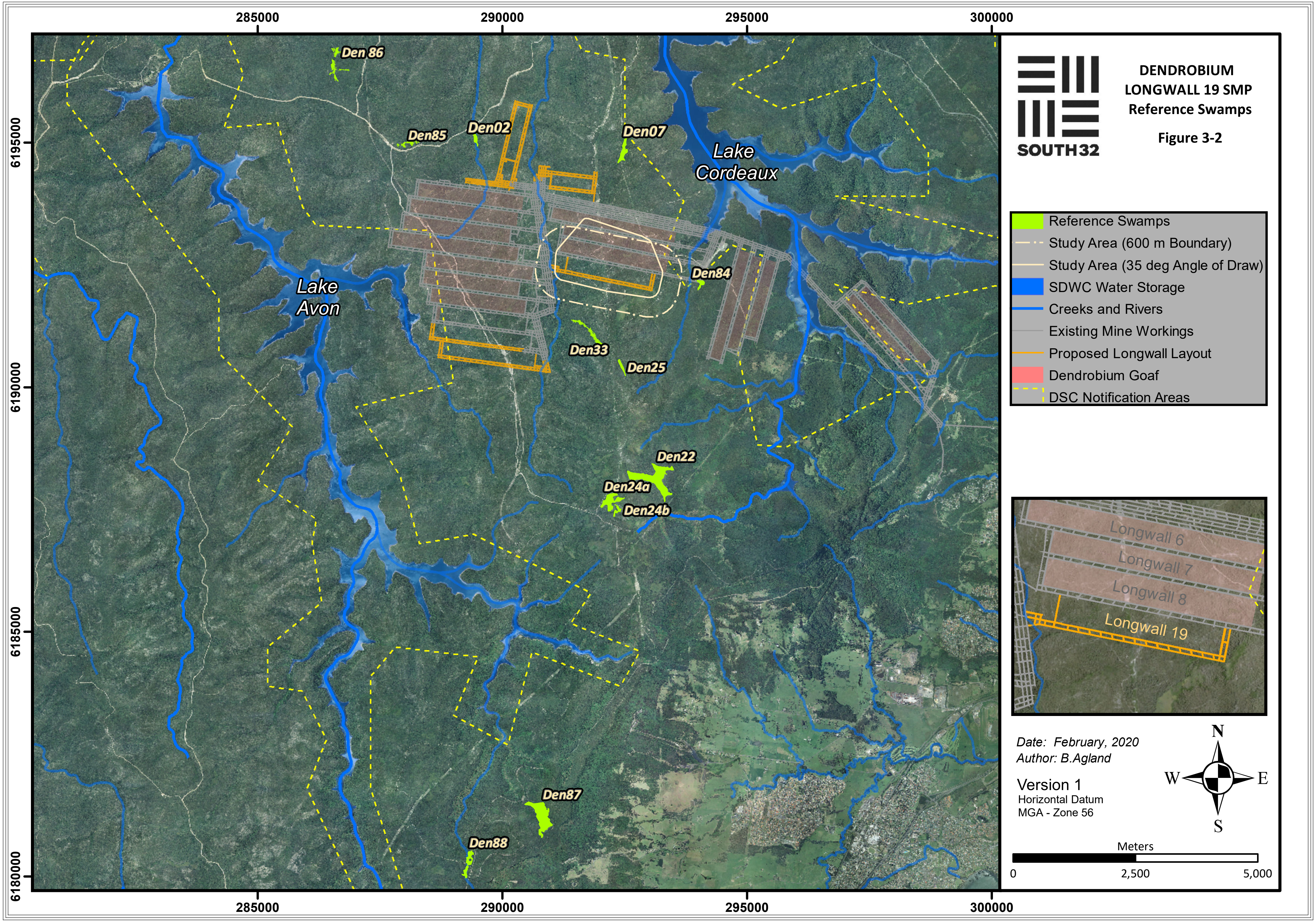

DENDROBIUM
LONGWALL 19 SMP
Reference Swamps
Figure 3-2
SOUTH32
Lake Cordeaux
Lake Avon
Den 86
Den85
Den02
Den07
Den84
Den33
Den25
Den22
Den24a
Den24b
Den87
Den88
Reference Swamps
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
SDWC Water Storage
Creeks and Rivers
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Longwall 6
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Date: February, 2020
Author: B.Agland
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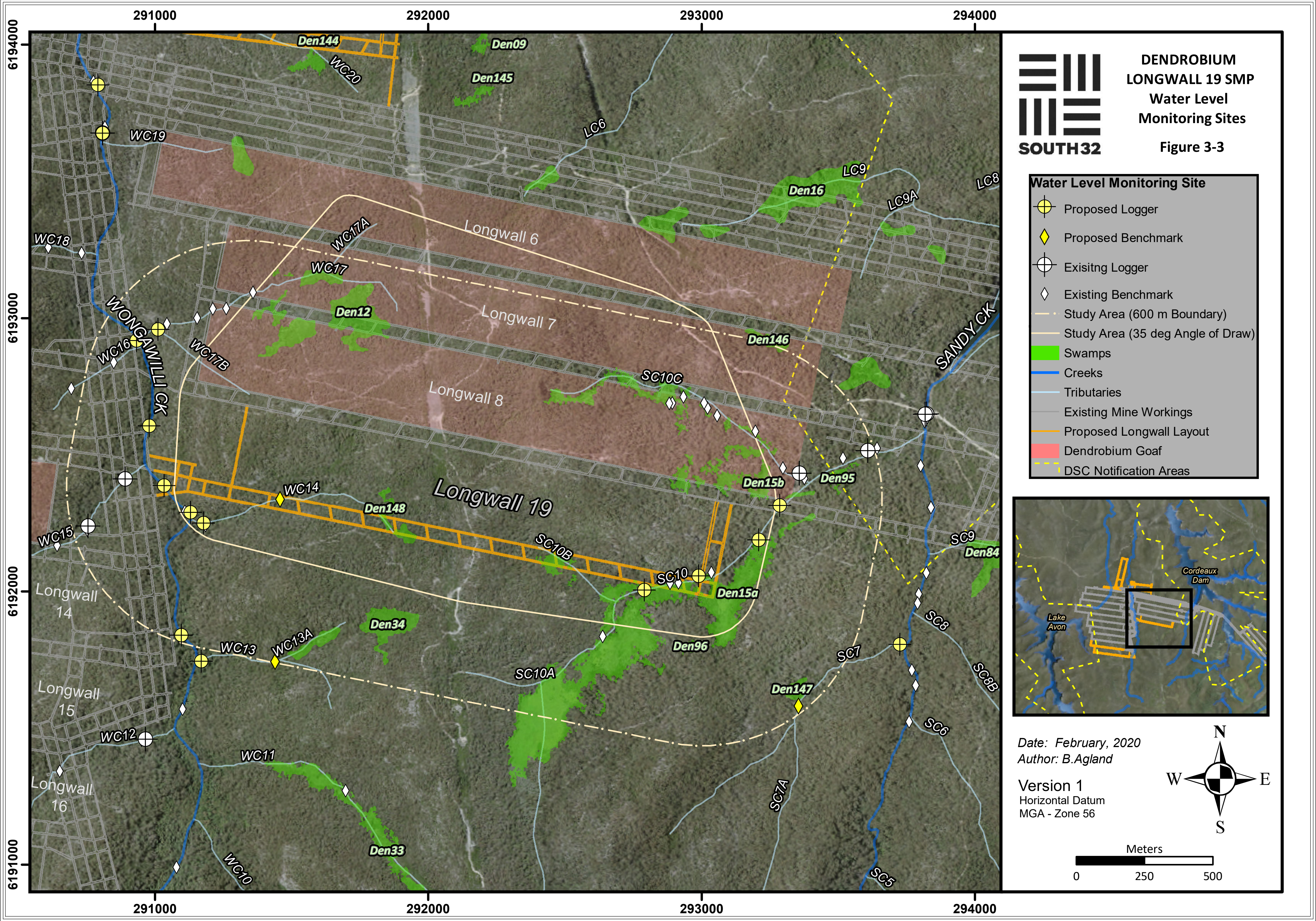

DENDROBIUM
LONGWALL 19 SMP
Water Level
Monitoring Sites
Figure 3-3
SOUTH32
Water Level Monitoring Site
Proposed Logger
Proposed Benchmark
Exisitng Logger
Existing Benchmark
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
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Den147
Den33
WC20
WC19
WC18
WC17A
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WC17B
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WC13
WC13A
WC12
WC11
WC10
LC6
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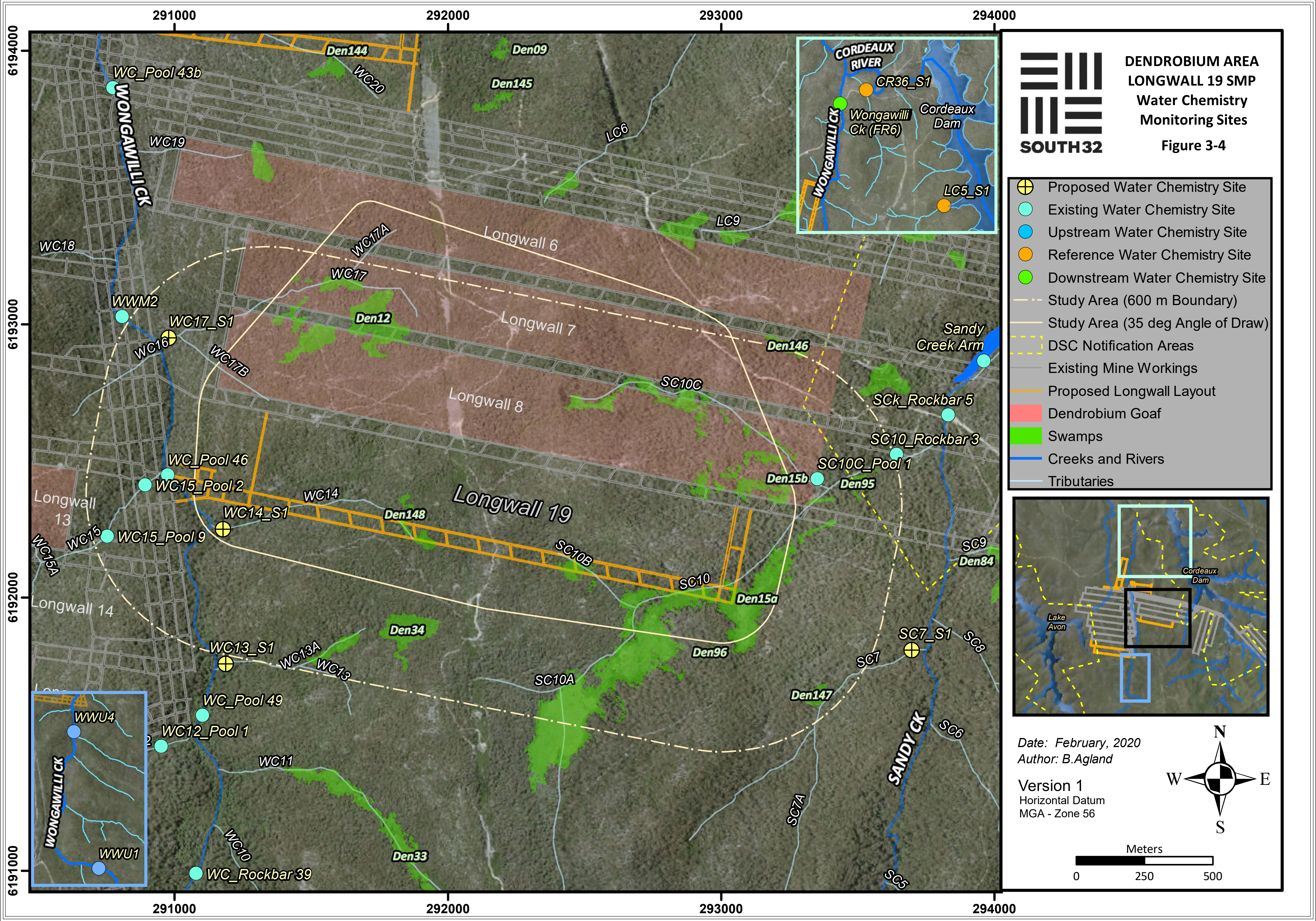
SC6
SC5



DENDROBIUM AREA
LONGWALL 19 SMP
Water Chemistry
Monitoring Sites
Figure 3-4
SOUTH32
Proposed Water Chemistry Site
Existing Water Chemistry Site
Upstream Water Chemistry Site
Reference Water Chemistry Site
Downstream Water Chemistry Site
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
DSC Notification Areas
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Swamps
Creeks and Rivers
Tributaries
Date: February, 2020
Author: B.Agland
Version 1
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WONGAWILLI CK
SANDY CK
CORDEAUX RIVER
CR36_S1
Wongawilli Ck (FR6)
Cordeaux Dam
LC5_S1
Sandy Creek Arm
Lake Avon
WC_Pool 43b
WWM2
WC17_S1
WC_Pool 46
WC15_Pool 2
WC14_S1
WC15_Pool 9
WC13_S1
WC_Pool 49
WC12_Pool 1
WC_Rockbar 39
WWU4
WWU1
SCk_Rockbar 5
SC10_Rockbar 3
SC10C_Pool 1
SC7_S1
WC20
WC19
WC18
WC17A
WC17
WC17B
WC16
WC15
WC15A
WC14
WC13A
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WC11
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LC6
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SC10C
SC10B
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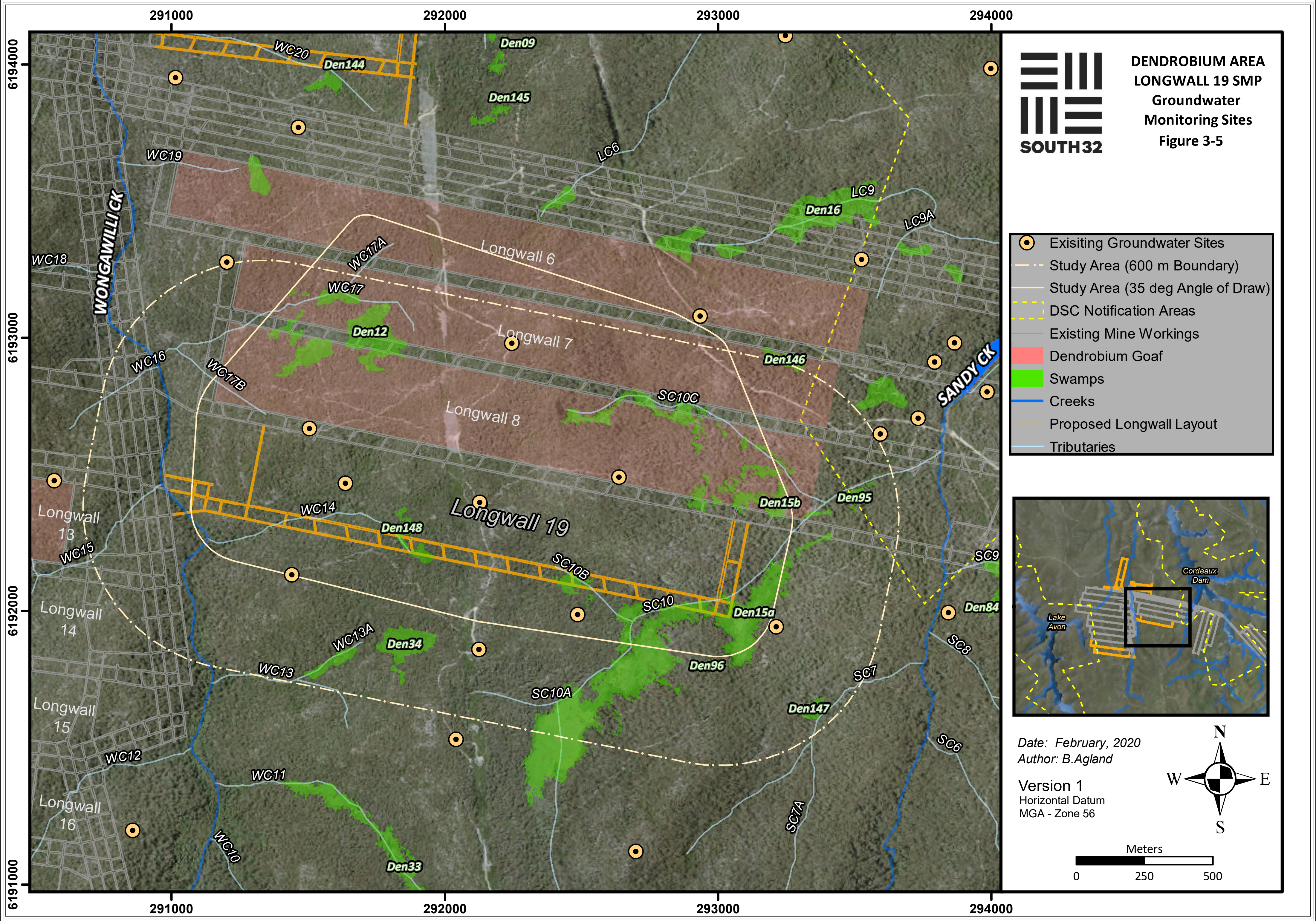

DENDROBIUM AREA
LONGWALL 19 SMP
Groundwater
Monitoring Sites
Figure 3-5
SOUTH32
Exisiting Groundwater Sites
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
DSC Notification Areas
Existing Mine Workings
Dendrobium Goaf
Swamps
Creeks
Proposed Longwall Layout
Tributaries
Date: February, 2020
Author: B.Agland
Version 1
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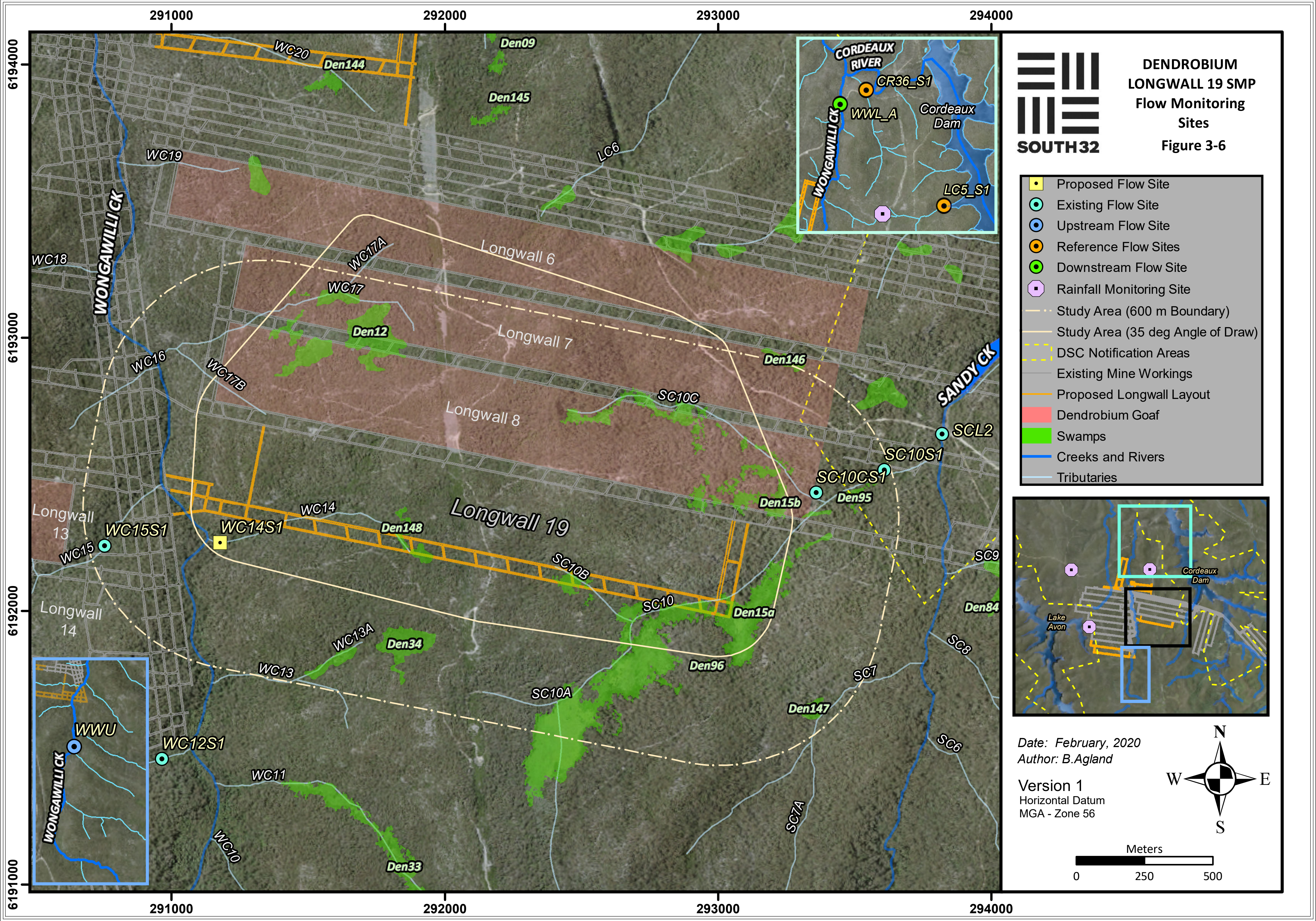

DENDROBIUM
LONGWALL 19 SMP
Flow Monitoring
Sites
Figure 3-6
SOUTH32
Proposed Flow Site
Existing Flow Site
Upstream Flow Site
Reference Flow Sites
Downstream Flow Site
Rainfall Monitoring Site
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
DSC Notification Areas
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Swamps
Creeks and Rivers
Tributaries
Date: February, 2020
Author: B.Agland
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SANDY CK
CORDEAUX RIVER
Cordeaux Dam
Lake Avon
CR36_S1
WWL_A
LC5_S1
WWU
WC14S1
WC15S1
WC12S1
SC10S1
SC10CS1
SCL2
WC20
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WC18
WC17A
WC17
WC17B
WC16
WC15
WC14
WC13A
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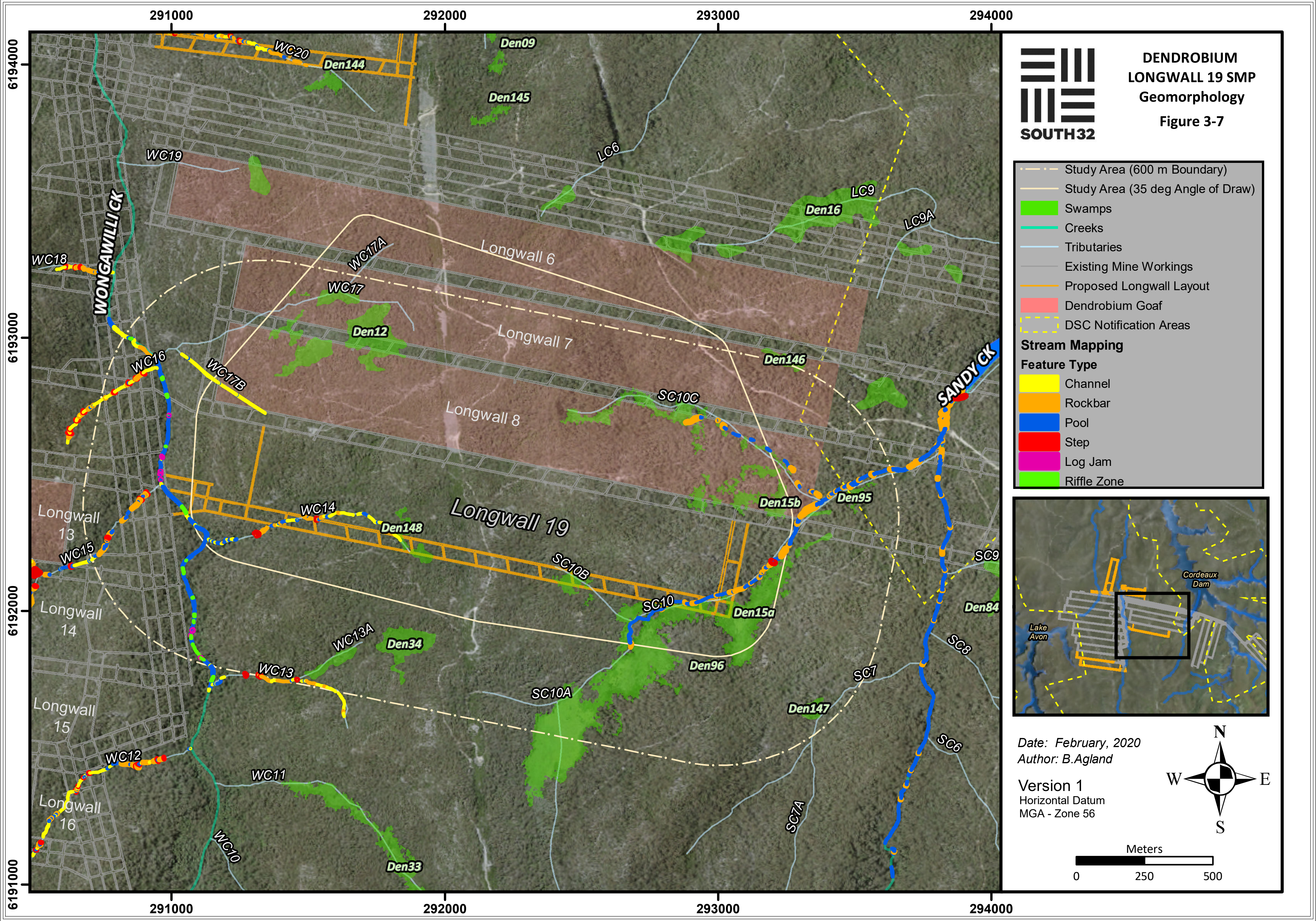

DENDROBIUM
LONGWALL 19 SMP
Geomorphology
Figure 3-7
SOUTH32
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Stream Mapping
Feature Type
Channel
Rockbar
Pool
Step
Log Jam
Riffle Zone
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
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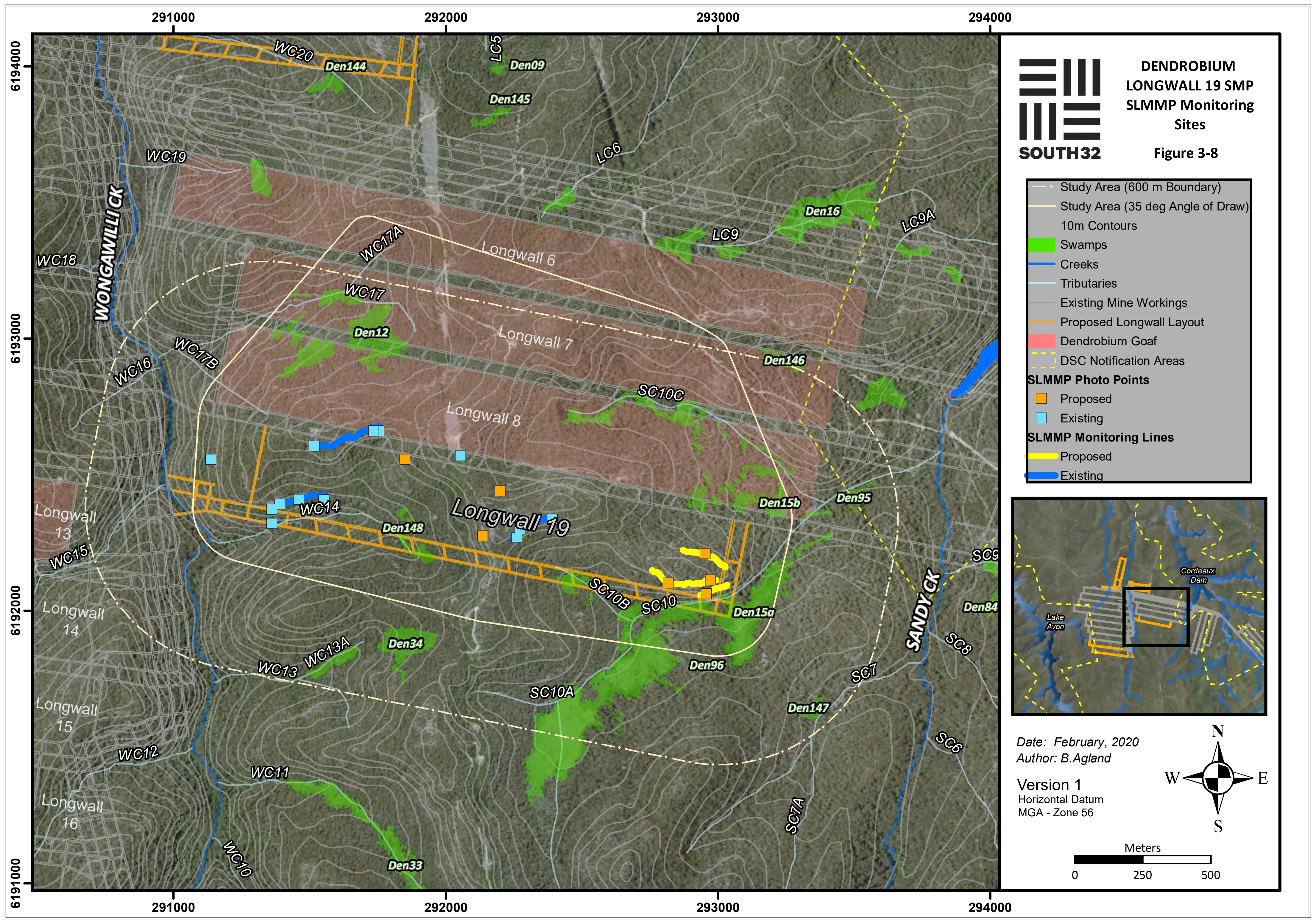
DENDROBIUM
LONGWALL 19 SMP
SLMMP Monitoring
Sites
SOUTH32
Figure 3-8
Study Area (600 m Boundary)
Study Area (35 deg Angle of Draw)
10m Contours
Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
SLMMP Photo Points
Proposed
Existing
SLMMP Monitoring Lines
Proposed
Existing
Cordeaux Dam
Lake Avon
Date: February, 2020
Author: B.Agland
Version 1
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293000
294000
6194000
6193000
6192000
6191000
Longwall 6
Longwall 7
Longwall 8
Longwall 19
Longwall 13
Longwall 14
Longwall 15
Longwall 16
WONGAWILLI CK
SANDY CK
WC20
WC19
WC18
WC17A
WC17
WC17B
WC16
WC15
WC14
WC13
WC13A
WC12
WC11
WC10
LC5
LC6
LC9
LC9A
SC10C
SC10B
SC10
SC10A
SC9
SC8
SC7
SC7A
SC6
Den144
Den09
Den145
Den16
Den12
Den146
Den15b
Den95
Den148
Den15a
Den84
Den34
Den96
Den147
Den33

4 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium Development Consent. These performance measures will be applied to the extraction of Longwall 19. These performance measures are presented in **Table 4-1**.

Table 4-1 Subsidence impact performance measures

Dendrobium Development Consent
Condition 5 – Schedule 3 • Operations shall not cause erosion of the surface or changes in ecosystem functionality of Swamp 15A and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Secretary.

A detailed list of performance measures and triggers are included in the TARPs in **Appendix A: Table 1.2**.

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

Changes to swamp hydrology can result in environmental consequences, particularly drying of swamps. 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).

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 necessarily be directly associated with an increase in vertical permeability. There are numerous models for the height of fracturing and height of depressurisation. 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 depressurisation.

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.

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 storability. 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 groundwater responses resulting from increased vertical permeability.

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

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

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

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

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

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

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

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

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

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 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 supported and many of these have 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 2020) 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 the Longwall 19 Study Area 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 14 was modelled and assessed in the Longwall 14 EoP Report (IMC 2019). This assessment has identified that mining-related effects on the flow regime have occurred in tributaries to Donalds Castle Creek (DCS2, DC13S1), Lake Avon tributary (LA4) and tributaries to Wongawilli Creek (WC15S1 and WC21S1).

There is also a possible change to runoff characteristics at the dow nstream gauge of Donalds castle Creek (DCU) and Wongaw illi Creek (WWL), although there is no clear causal link to Longw all 14 mining.

This suggests that, w ithin the limitations of the monitoring, a high proportion of diverted flow in Wongaw illi Creek headw ater catchments is returned dow ngradient. Modelling also suggests that high flow s in the mined under catchments are less affected than the low er, recession-limb flow s.

It w as predicted that Sw amps 01a, 01b, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35a and 35b w ould be affected by mine subsidence due to mining in Area 3B (South32 2018a). Assessment of shallow groundw ater levels in the Longw all 14 EoP Report (HGEO 2019) indicates that TARPs have been triggered at the follow ing sw amps, most of w hich, w ere found to have been triggered in previous EoP assessments:

- Sw amp 01a - Level 3;
- Sw amp 01b – Level 2;
- Sw amp 03 - Level 3 ;
- Sw amp 05 – Level 3;
- Sw amp 08 – Level 2;
- Sw amp 10 - Level 3;
- Sw amp 11 - Level 3 (identified in Longw all 13 EoP Report); and
- Sw amp 13 Possible impact (Longw all 14 EoP Report).

Both shallow groundw ater levels and soil moisture levels in reference sw amps w ere anomalously low during the Longw all 14 EoP assessment period in response to very low rainfall conditions in 2017-2018. Some reference sw amp sites show ed no or limited saturation of sw amp sediments for 12 months or more for the first time since the start of monitoring (e.g. Sw amps 85, 86 and 87).

Average soil moisture declined to below baseline levels at Sw amp 11 and Sw amp 13 locations and w ere previously reported as Level 3 TARPs in the Longw all 13 EoP review . Soil moisture hydrographs for sensors at Sw amps 14 and 23 show no evidence for change related to the passage of Longw all 14 (HGEO 2019).

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 w hich intern could alter w ater distribution in the sw amp. Changes to sw amp 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 sw amps due to mining-induced changes in hydrology include (IEP 2019b):

- reduction of soil moisture levels and loss of cohesiveness of the sw amp sediments
- enhanced risk of channelization and consequent susceptibility to erosion of sw amp sediments, w ith potential w ater quality implications
- decline of groundw ater-dependent plant species and consequent changes in vegetation structure
- decline of groundw ater-dependent fauna including macroinvertebrates and stygofauna
- oxidation of peaty sediments resulting in increased hydrophobicity, low er w ater-holding capacity and potential changes in nutrient status and cycling
- increased risk of erosion, w hich may lead to gully formation.
- sw amps have less resilience to bushfires w hich, in turn, can lead to an increased susceptibility to erosion and loss of baseflow (NSW Threatened Species Scientific Committee, 2012).

Subsidence predictions w ere carried out to assess the potential impacts of longw all mining in the Longw all 19 Study Area. The assessment indicated that the levels of impact on the natural features w ere likely to be similar to the impacts observed w ithin Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the sw amps 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 shown in **Section 5**. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2020). 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 14, 154 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.

Following the 2018 terrestrial ecology 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.

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 2018 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 2019).

5 PREDICTED IMPACTS TO UPLAND SWAMPS

Subsidence has the potential to impact swamps overlying the proposed longwall 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. MSEC1034 (2019) analysed the effects of surface lineaments on the measured ground movements at Dendrobium Area 3B based on the measured LiDAR contours. No interactions or anomalous movements were found in between the surface lineaments and the subsidence movement. Many of the swamps are located in the bases of drainage lines and, therefore, could experience valley and slope related movements. The predicted valley related movements are provided in MSEC (2020). 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 MSEC (2020).

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 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 four 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.

Swamp 148 is partially located above the proposed Longwall 19. Small parts of Swamps 15A and 15B are located above the maingate and tailgate, respectively, of Longwall19. The remaining swamps are located outside the extents of the proposed longwall. A summary of the swamps 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

Swamp	Location	Description
12	Directly above Longwalls 7 and 8, 180 m north of Longwall 19	Base and side of valley for Stream WC17
15A	Partially above the maingate of Longwall 19	Base and side of valley for Stream SC10
15B	Directly above Longwalls 7 and 8, partially above Longwall 19 tailgate	Base and side of valley for Stream SC10C
34	Outside the mining area, 310 m south of Longwall 19	Base and side of valley for Stream WC13
95	Partially above Longwall 8, 230 m east of Longwall 19	Side of valley for Stream SC10
96	Outside the mining area, 210 m south of Longwall 19	Side of valley for Stream SC10
146	Directly above Longwall 7, 580 m north of Longwall 19	On the side of a ridgeline
147	Outside the mining area, 490 m south-east of Longwall 19	Side of valley for Stream SC7
148	Partially above Longwall 19	Base and side of valley for Stream WC14

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 Longwalls 6 to 8 and the proposed Longwall 19.

Table 5-2 Maximum predicted total vertical subsidence, tilt and curvatures for the swamps

Swamp	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})
12	2750	30	0.50	0.70
15A	425	13	0.35	0.03
15B	3050	35	0.90	0.80
34	<20	<0.5	<0.01	<0.01
95	60	2	0.04	0.02
96	<20	<0.5	<0.01	<0.01
146	2350	30	0.40	0.70
147	<20	<0.5	<0.01	<0.01
148	2850	40	0.90	0.70

The maximum predicted total tilt for the swamps is 40 mm/m (i.e. 4.0 %, or 1 in 25). The maximum predicted total conventional curvatures are 0.90 km-1 hogging and 0.80 km-1 sagging, which represent minimum radii of curvatures of 1.1 km and 1.3 km, respectively. The maximum predicted conventional strains for the swamps, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 14 mm/m tensile and 12 mm/m compressive.

Swamp 146 is predicted to experience incremental vertical subsidence of less than 20 mm due to the mining of the proposed Longwall 19. While this swamp could experience very low levels of incremental vertical subsidence, it is not expected to experience measurable incremental tilts, curvatures or strains.

Swamp 95 is located partially above the existing Longwall 8 and Swamps 34, 96 and 147 are located outside the mining area. These swamps are predicted to experience vertical subsidence of 60 mm, or less, due to the mining of Longwalls 6 to 8 and Longwall 19. Swamp 95 could experience low levels of tilt, curvature and strain. While 34, 96 and 147 could experience very low levels of vertical subsidence, they are not predicted to experience measurable conventional tilts, curvatures or strains.

Swamps 12, 15A, 15B, 34 and 148 are located near the bases of drainage lines WC17, SC10, SC10C, WC13 and WC14, respectively. These swamps could experience valley related effects due to the extraction of the existing and proposed longwall 19. The remaining swamps within the Study Area are located on the valley sides and, therefore, they are unlikely to experience upsidence or compressive strain due to the 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 maximum predicted valley related effects for each of the swamps due to the mining of Longwalls 6 to 8 and Longwall 19.

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

Swamp	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
12	350	525
15A	150	200
15B	275	425
34	50	90
148	125	225

Swamps 12 and 15B are located above Longwall 7 and 8 and, therefore, the predicted valley related effects are partly due to these existing longwalls.

The swamps will also experience compressive strains due to the valley related effects where they are located near the valley bases. The predicted total compressive strains for 12 and 15B, due to the valley related effects, are in the order of 10 mm/m to 20 mm/m. The majority of the predicted compressive strains for these swamps occur due to the existing longwalls.

The predicted total compressive strains based on the 95 % confidence levels are 5 mm/m for 15A and 148 and 2 mm/m for 34. The majority of the predicted strains for these swamps occur due to the proposed Longwall 19 (MSEC 2020).

5.3 Impact Assessment

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

Mining can potentially affect 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 affecting the distribution of the water within the swamps.

The maximum predicted total tilt for the swamps is 40 mm/m (i.e. 4.0 %, or 1 in 25). The greatest tilts (i.e. 30 mm/m to 40 mm/m) occur at Swamps 12, 15B, 146 and 148 which are located directly above the existing Longwall 7 and 8 and the proposed Longwall 19. Swamp 15A and 95 are predicted to experience tilts of 13 mm/m (i.e. 1.3 %, or 1 in 77) and 2 mm/m (i.e. 0.2 %, or 1 in 500), respectively. The remaining swamps within the Study Area are located outside the mining area and are predicted to experience tilts of less than 0.5 mm/m (i.e. less than 0.05 %, or 1 in 2000).

Swamps 12, 15A, 15B, 34 and 148 are located near the bases of drainage lines WC17, SC10, SC10C, WC13 and WC14, respectively. There are no predicted reversals of stream grade along drainage lines nor within the extents of the swamps.

There are small reductions in grades along drainage lines SC10C and WC17, upstream of the chain pillars and the edges of the mining area. There is potential for minor and localised increased ponding upstream of these locations and within or near to Swamps 12 and 15B.

However, these swamps are located above the existing Longwall 7 and 8 and, therefore, the potential for increased ponding occurs due to these existing longwalls rather than the proposed Longwall 19.

The remaining swamps are located on the valley sides where the natural grades are greater than 100 mm/m (i.e. 10 %, or 1 in 10). These swamps are also located outside the extents of the proposed Longwall 19 and, therefore, are predicted to experience lower mining-induced tilts. It is unlikely, therefore that increased ponding would occur within the extents of these swamps due to mining-induced tilt. It is considered unlikely, therefore, that there would be adverse changes in the levels of ponding or scouring for the swamps within the Study Area 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 12 and 15Bb are located above the existing Longwalls 7 and 8. The maximum predicted compressive strains for these swamps due to the valley related effects are in the order of 10 mm/m to 20 mm/m. However, the valley related effects for these swamps predominately occur due to the existing Longwalls 7 and 8, rather than the proposed Longwall 19. It is likely, therefore, that fracturing would occur in the bedrock beneath these swamps, predominately in areas located above and adjacent to the mining area.

The typical fracture widths in the bedrock beneath Swamps 12 and 15B could be similar to the surface deformations previously observed, soil crack and rock fracture widths were generally observed to be less than 50 mm (i.e. 88 % of the cases) (MSEC 2020). However, the widths of the surface deformations were between 50 mm and 150 mm in 7 % of cases, between 150 mm and 300 mm in 3 % of cases and greater than 300 mm in 2 % of cases. 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 12 and 15B are located directly above the mining area and are predicted to experience upsidence of 275 mm to 350 mm. The sections of Swamps 15A and 148 located above the proposed Longwall 19 are predicted to experience upsidence of 125 mm to 150 mm. These valley related effects 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).

Swamp 95 is located partially above the existing Longwall 8 and Swamps 34, 96 and 147 are located outside the mining area. These swamps are located at minimum distances ranging between 210 m and 490 m from the proposed Longwall 19. These swamps are predicted to experience vertical subsidence of 60 mm, or less, due to the proposed longwall. It is unlikely, therefore, that fracturing would occur in the bedrock beneath these swamps. While Swamp 34 is located along a drainage line, fracturing due to valley related effects have not been previously observed at similar distances outside mining areas elsewhere at the Mine.

5.3.2.1 Swamp 15A

Swamps 15A and 148 are partially located above the proposed Longwall 19. The maximum predicted compressive strain for these swamps is 5 mm/m based on the 95 % confidence level. Fracturing could also occur beneath these swamps, near the valley base and where they are located above and adjacent to the proposed longwall. 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.

The dilated strata beneath the drainage lines upstream of Swamps 12 and 15B, and to a lesser extents 15A and 148, could result in the diversion of some surface water flows beneath parts of these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Swamps 12 and 15B are located directly above Longwalls 7 and 8 and, therefore, the potential impacts predominately occur due to these existing longwalls, rather than the proposed Longwall 19. Only small areas of Swamps 15A and 148 are located directly above the proposed Longwall 19.

The downstream controlling feature for Swamp 15A is SC10-Rockbar15A. The nearest of this rockbar is located 160 m east of the proposed Longwall 19. The predicted subsidence effects for rockbar SC10-Rockbar15A are less than 20 mm vertical subsidence, 90 mm upsidence and 125 mm closure.

The potential impacts on rockbar SC10-Rockbar15A cannot be assessed using the rockbar impact model because drainage line SC10 is partially located above the existing Longwall 8 and the proposed Longwall 19. This rockbar has therefore been assessed based on the observations from Area 3B.

Fracturing of rockbars has been observed in Area 3B at distances ranging between 30 m and 300 m outside of the mining area. There have been nine Type 3 impacts (i.e. fracturing in a rockbar or upstream pool resulting in reduction in standing water level based on current rainfall and surface water flow) along the drainage lines that are located outside but within 400 m of the completed Longwalls 9 to 14. However, there are also 61 other rockbars that are located outside and within 400 m of the longwall mining area that did not experienced Type 3 impacts.

The observed impact rate of Type 3 impacts for the rockbars located along the drainage lines located outside and within 400 m of Longwall 9 to 14 was 13 %. Five of the 9 impact sites (i.e. 56 %) occurred at distances of less than 150 m from the mining area, i.e. at distances less than that of rockbar SC10-RB15A from the proposed Longwall 19. It has been assessed, therefore, that the potential for Type 3 impacts at rockbar SC10-RB15A due to the mining of the proposed Longwall 19 is in the order of 13 %.

5.3.3 Potential changes to Upland Swamp Hydrology

Swamps that have been undermined commonly display hydrological changes shortly following the passage of the longwall beneath the monitoring site. Hydrographs of piezometers at affected locations may show one or more of the following:

- 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.

A recent assessment of shallow groundwater impacts due to mining at Dendrobium was carried out by (Watershed Hydrogeo, 2019). The assessment concluded that almost all shallow piezometers that are directly mined under by longwalls extracted in Dendrobium Area 3A and 3B show responses to mining. Changes in shallow groundwater levels or groundwater fluctuation characteristics are not evident in shallow piezometers located in swamp sediments more than 60 m from the extracted longwall margin.

Observations at the Springvale Mine in the Western Coalfield show that hydrological impacts can occur in swamps overlying connected geological structures (faults or other lineaments) at distances greater than 1200 m from the longwall (Galvin *et al*., 2016). The same effect is not apparent at Dendrobium. Recent studies have identified no anomalous subsidence specifically related to mapped lineaments (MSEC, 2020), and no hydrological impacts at swamp piezometers located near mapped lineaments that are greater than 60 m from the goaf (Watershed Hydrogeo, 2019).

The hydrological changes are most likely due to the development of surface fracturing and bedding plane openings in the sandstone substrate of the swamp and/or a rock-bar at the swamp outlet. The formation of fractures in the substrate may change the swamp from a perched system to a connected system. The impact on the swamp will be dependent on the head difference between the swamp sediments and the sandstone substrate. Where the hydraulic gradient is downwards (into the sandstone, which is common) then the fracturing will lead to greater flows of water from the swamp and a decline in average swamp groundwater levels. It is not yet known whether the hydrological characteristics recover to some degree as fractures are filled with fine sediments and on-going monitoring is required to assess longer-term impacts (HGEO 2020).

The locations of mapped swamp vegetation communities relative to the planned longwall are shown in Figure 3 of Niche (2020). Swamps located within 600 m of the planned longwall are listed in **Table 5-4**, with a qualitative assessment of the likelihood that the shallow groundwater regime will be affected by subsidence related ground movements associated with Longwall 19 (as described above). The likelihood is based on observations at swamps in Area 3B during and after longwall extraction (e.g. HGEO, 2018b; Watershed Hydrogeo, 2019b) and predictions of subsidence related to longwall extraction and other ground movement related to valley closure (MSEC, 2020).

Given their proximity to the proposed longwall panel, it is likely that shallow groundwater levels will be affected at Swamp 15A (9% of the mapped area of Swamp 15A is within 60 m of the goaf footprint), and it is possible that effects will be seen in Swamps 96 and 47 (between 60 m and 400 m from the goaf). Swamps 15B, 12, and 147 either directly overlie, or are entirely within 60 m of, previously extracted Longwalls 7 and 8 and are known or likely to have been impacted already. It is possible that additional impacts may occur in Swamp 15B. The remaining swamps are unlikely to be impacted since they are located more than 400 m from the proposed goaf and/or are predicted to experience negligible ground movement related to valley closure.

Table 5-4 Summary of predicted impacts to upland swamps

Swamp	Total Swamp Area (ha)[1]	Upland Swamp Vegetation Communities	% Swamp Area within 60 m of Longwall	Distance from Longwall 19 Goaf (m)	Likelihood of Shallow Groundwater Effects
12	5.37	Banksia Thicket	100	180	Previously undermined
15A	18.0	Banksia Thicket, Sedgeland-Heath Complex (Cyperoid Heath), Sedgeland-Heath Complex (Restoid Heath), Tea-tree Thicket	7	0	Likely (for ~7% of swamp area)
15B	5.0	Banksia Thicket, Sedgeland-Heath Complex (Cyperoid Heath), Sedgeland-Heath Complex (Restoid Heath), Tea-tree Thicket	100	0	Previously undermined
34	2.4	Mallee-Heath, Banksia Thicket, Tea-tree Thicket	0	330	Unlikely
95	1.09	Banksia Thicket	0	400	Unlikely
96	0.17	Banksia Thicket	0	230	Unlikely
146	0.60	Tea-tree Thicket	100	570	Previously undermined
147	0.45	Banksia Thicket	0	340	Unlikely
148	0.86	Banksia Thicket	98	0	Likely

[1] Includes all swamps that are located wholly or partially within the 600 m Study Area boundary.

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 2020).

Groundwater dependent and riparian vegetation may experience some floristic changes in response to changed groundwater conditions, as a result of subsidence (Niche 2020).

Riparian vegetation may be potentially impacted by subsidence through water diversion or cracking of bedrock. Impacts to riparian vegetation associated with the Proposal are predicted to be minor in occurrence, being localised if they occurred (Niche 2020).

An assessment of the potential ecological impacts of subsidence on Upland Swamps was completed by Niche (2020) which is summarised below (**Table 5-5)**.

5.3.4.1 Potential Impacts to Threatened Flora

Eleven threatened flora species have been determined to have a moderate to high likelihood of occurring within the Study Area. However, a limited number have potential habitat likely to be impacted by subsidence (Niche 2020).

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 potentially impacted by subsidence. Each of these species has potential habitat within upland swamps or creek line 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 2020).

5.3.4.3 Potential Impacts to Threatened Fauna

Fifty-six threatened fauna were considered during likelihood of occurrence assessment. Thirty-nine of these species were determined to have a moderate or high likelihood of occurrence within the Study Area. Subsidence impacts from the proposed longwall are likely to be negligible for the majority of these species (Niche 2020). Nine threatened species are considered to be potentially impacted by subsidence impacts resulting from the proposal (Niche 2020).

An assessment of potential impacts from the current proposal, for each of the identified threatened species likely to be impacted, is provided in the Longwall 19 Terrestrial Ecology Assessment (Niche 2020).

Table 5-5 Ecological impact predictions for upland swamps within 600 m Study Area boundary (Niche 2020)

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2020)	Conclusion
12	Medium sized simple swamp. Northern tip of swamp adjacent to WC17.	Within the angle of draw. Directly above Longwalls 7 and 8, 180 m north of Longwall 19 at closest point	Swamp 12 is located above the previously extracted Longwalls 7 and 8. There are small reductions in stream grade within or near to Swamp 12. There is potential for subsidence induced tilt to result in minor and localised increased ponding upstream of this location. However, this swamp is located above the existing Longwalls 7 and 8 and, therefore, the potential for increased ponding occurs due to these existing longwalls rather than the proposed Longwall 19. Fracturing of the bedrock could occur beneath Swamp 12. The swamp has layers of organic soil and, in most cases, cracking would not be visible at the surface within the swamp, except where the depths of bedrock are shallow or exposed. The dilated strata beneath the drainage lines could result in the diversion of some surface water flows beneath parts of the swamp where they are located above and adjacent to the proposed longwall. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation.	Monitoring of the impacts of Longwall 7 in DA3A, which was extracted directly beneath Swamp 12, revealed one fracture in a rock outcrop after mining beneath this swamp. Regular monitoring has been undertaken and, to date, no erosion or other changes have been observed (MSEC 2020). Unlikely to be measurable additional impacts (after impacts from Longwalls 7 and 8) to this swamp or associated species including threatened species from the current proposal. Monitoring of impacts likely to be confounded from previous direct undermining (Longwalls 7 and 8). A known population of Littlejohn's Tree Frog occurs along WC17 downstream, of swamp 12.
15A	Large complex swamp with pools observed within or on edges of swamp. Swamp follows alignment of watercourse SC10	Partially above the maingate of Longwall 19, within angle of draw. Feeding tributary (SC10) within angle of draw.	Fracturing could occur beneath swamp 15A near the valley base and where it is located closest to the proposed longwall. It is possible that a series of smaller fractures, rather than one single fracture could develop in the bedrock. Predicted upsidence could result in the dilation of the strata beneath this swamp (where it occurs above Longwall 19). The dilated strata beneath the drainage lines could result in the diversion of some surface water flows beneath parts of the swamp where they are located above or adjacent to the proposed longwall. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Swamp 15A, is located near the base of drainage lines SC10. This swamp could experience valley related effects due to the extraction of the longwalls in DA3A. The potential for fracturing of the downstream controlling rockbar for Swamp 15A due to the mining	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog) for the area of swamp directly above and adjacent the proposed longwall. A large population of Littlejohn's Tree Frog is known to occur within areas of this swamp and associated drainage lines and pools. Breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing. Areas may trend towards Fringing Eucalypt Forest if changes are long-term. Swamp is large and complex and contributes significantly to biodiversity values given its size, complexity and available pooling habitat, which is known to support a population of Littlejohn's Tree Frog.

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2020)	Conclusion
			of the proposed Longwall 19, resulting in reduction in standing water level based on current rainfall and surface water flow, is in the order of 13 %. Given their proximity to the proposed longwall panel, it is likely that shallow groundwater levels will be affected at Swamp 15A (7% of the mapped area of Swamp 15A is within 60 m of the goaf footprint) HGEO (2020).	
15B	Large complex swamp with pools observed within or on edges of swamp. Swamp follows alignment of watercourse SC10C.	Within angle of draw. Previously mined beneath by Longwall 8. Directly above Longwalls 7 and 8, partially above Longwall 19 tailgate.	Fracturing could occur in the bedrock beneath this swamp where it is located above and adjacent to the proposed longwall. There are no predicted reversals of stream grade along drainage lines nor within the extents of the swamp as a result of subsidence induced tilt. Predicted upsidence could result in the dilation of the strata beneath this swamp. The dilated strata beneath the drainage lines could result in the diversion of some surface water flows beneath parts of the swamp where they are located above or adjacent to the proposed longwall. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. Swamp 15B is located near the bases of drainage line SC10C. This swamp could experience valley related effects due to the extraction of the longwalls in DA3A. These impacts 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). A population of Littlejohn's Tree Frog is known to occur within areas of this swamp and associated drainage lines and pools. Breeding habitat for this population may be impacted through reductions in water retention from pools after fracturing. Areas may trend towards Fringing Eucalypt Forest if changes are long-term. Swamp is large and complex and contributes significantly to biodiversity values given its size, complexity and available pooling habitat. Monitoring of impacts from Longwall 19 are likely to be confounded from previous direct undermining (Longwalls 7 and 8).
34	Small simple swamp occurring along WC13.	Within 600 m boundary. Feeding tributary (WC13) within 600 m boundary. Outside the mining area, 310 m south of Longwall 19 at closest point.	It is unlikely that fracturing would occur in the bedrock beneath this swamp. Unlikely to experience upsidence or compressive strain due to valley closure effects. Swamp 34 is located along WC13. There are no predicted reversals of stream grade along the drainage line nor within the extents of the swamp due to subsidence induced tilt. This swamp could experience valley related effects due to the extraction of the longwalls in DA3A.	Unlikely to be measurable impacts to this swamp or associated species, including threatened species. Swamp is small and simple. Observations of Littlejohn's Tree Frog were made approximately 200 m downstream of the swamp and the species may occur within the swamp and downstream pools.
95	Small simple swamp along watercourse SC10.	Within 600 m boundary. Feeding tributary (SC10) within angle of draw. Outside the mining area, 230 m east of Longwall 19.	It is unlikely that fracturing would occur in the bedrock beneath this swamp. Unlikely to experience upsidence or compressive strain due to valley closure effects.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2020)	Conclusion
		Located partially above Longwall 8.		
96	Small simple swamp, no mapped pools or watercourses adjacent.	Partially within 600 m boundary. Outside the mining area, 210 m south of Longwall 19.	It is unlikely that fracturing would occur in the bedrock beneath this swamp. Unlikely to experience upsidence or compressive strain due to valley closure effects.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
146	Small simple swamp, no mapped pools or watercourses adjacent.	Partially within 600 m boundary. Directly above Longwall 7, 580 m north of Longwall 19.	It is unlikely that fracturing would occur in the bedrock beneath this swamp as a result of Longwall 19. Unlikely to experience upsidence or compressive strain due to valley closure effects as a result of Longwall 19.	Unlikely to be measurable additional impacts (after impacts from Longwalls 7 and 8) to this swamp or associated species including threatened species from the current proposal. Monitoring of impacts from Longwall 19 likely to be confounded from previous direct undermining (Longwalls 7 and 8).
147	Small simple swamp, Adjacent to tributary of Sandy Creek.	Within 600 m boundary. Outside the mining area, 490 m south-east of Longwall 19.	It is unlikely that fracturing would occur in the bedrock beneath this swamp. Unlikely to experience upsidence or compressive strain due to valley closure effects.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
148	Small simple swamp, Adjacent to WC14.	Partially above Longwall 19	Fracturing of the bedrock could occur beneath Swamp 148 where it is located above and adjacent to the proposed longwall. The swamp has layers of organic soil and, in most cases, cracking would not be visible at the surface within the swamp, except where the bedrock is shallow or exposed. The dilated strata beneath the drainage lines could result in the diversion of some surface water flows beneath parts of the swamp where they are located above and adjacent to the proposed longwall. Where there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation. There are no predicted reversals of stream grade along drainage lines nor within the extent of the swamp due to subsidence induced tilt.	Possible ecological impacts including changes in vegetation and threatened species habitat. Areas may trend towards Fringing Eucalypt Forest if changes are long-term.

6 MANAGEMENT AND CONTINGENCY PLAN

The potential impacts of mine subsidence to upland swamps in the Longwall 19 Study Area 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 and reporting 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.
- Implementing environmental offsets where applicable.
- Monitoring and reporting effectiveness of the SIMMCP.

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

6.2 Trigger Action Response Plan

The TARPs relate to identifying, reporting, assessing and responding to potential impacts to swamps (including impacts greater than predicted) from impacts due to the mining of Longwall 19; including Swamps 15A (bottom section), 34, 96 and 147. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for any Longwall 19 impacts within the Study Area swamps are included in **Appendix A**. For impacts due to mining Longwalls 6 to 8 on Swamps 12, 15B and 95 which are within the Longwall 19 Study Area, the Dendrobium Area 3A SIMMCP TARPs (approved 28 June 2010) will be applied. Swamps 146 and 148 were mapped by Niche in the 2020 surveys but may have been impacted by Longwalls 6 – 8, Swamps 146 and 148 will be monitored and assessed against the impact predictions described in the Longwall 19 specialist assessments.

The TARPs represent actions (including reporting) to be taken upon reaching each defined trigger level. If required, 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 a CMA, including 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. Any changes to the triggers would require approval of DPIE.

Level 1 TARPs typically relate to the routine impacts from mining and/or natural (non-mining) variability in the monitoring data. TARP level 1 impacts are reported to key stakeholders via a variety or mechanisms, including an Impact Update Report provided to Government Agencies.

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;
- Environmental offsetting;
- 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 3A including Longwall 19 have been developed using IMC's Integrated Mine Planning Process (IMPP). This process considers mining and surface impacts when designing mine layouts.

IMC has assessed mining layout options for Dendrobium Area 3A 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 3A were 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 surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3A was achieved.

SMP Approval for the area of Longwall 19 was granted 9 July 2010, along with Longwalls 6 – 8. The width of the proposed Longwall 19 was set at 305 m in April of 2014 when the mains headings were established to allow for the gateroads of the longwall. Subsequent Area 3B Approval conditions required that Longwall 19 be further considered by DPIE. Due to these circumstances, consideration of a reduction in longwall width cannot be assessed as part of this SMP application.

Area 3A is part of the overall mining schedule for Dendrobium Mine and has previously been mined, with Longwall 8 the most recently extracted in December 2012. A return to Area 3A to extract Longwall 19 has been designed to flow on from Areas 3B and 3C to provide a continuous mining operation.

There are a number of surface and subsurface constraints within the vicinity of Area 3A including major surface water features such as Cordeaux Reservoir, Sandy Creek, Wongawilli Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion, which has intruded into the Wongawilli Seam to the east of Longwall 19. The process of developing the layout for Area 3A has considered predicted impacts on 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 to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3A mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPIE and BCD. 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.

The mining layout of the proposed longwall is designed to avoid Wongawilli Creek and the Nepheline Syenite Intrusion. A summary of the geology of Longwall 19 is available in Attachment H of the SMP.

Wongawilli Creek is located to the east of the proposed Longwall 19. The thalweg (i.e. base or centreline) of Wongawilli Creek is located at a minimum distance of 175 m south-west of the finishing end of Longwall 19, at its closest point. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Longwall 6 in Area 3A and 290 m for Longwall 9 in Area 3B.

6.4 Mitigation and Rehabilitation

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

As indicated in Schedule 2, Conditions 1 and 14 of the Development Consent, 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 licence under the then *Threatened Species Conservation Act 1995* (TSC Act) (repealed by the *Biodiversity Conservation Act 2016*) 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 cementitious (or alternative) 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 including cement and Poly-urethane Resin (PUR), with various additives. These grouts 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 PUR and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these technologies. Should rehabilitation be necessary in the Longwall 19 Study Area, 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 Longwall 19 extraction as well as areas away from mining to act as control sites. The studies in these areas are based on the BACI design criteria.

A comprehensive swamp monitoring program is in place for swamps identified in this SIMMCP. A summary of swamp monitoring within the Longwall 19 Study Area 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 the Longwall 19 Study Area.

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 the Longwall 19 Study Area 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

Where impacts are greater than predicted or not within approved levels, compensatory measures will be considered. Any compensatory measure will consider the level of impact requiring compensation, the compensatory measures available and the practicality and cost of implementing the measure.

Subject to Condition 14 of Schedule 3 of the Development Consent:

- The Applicant shall provide suitable offsets for loss of water quality or loss of water flows to WaterNSW storages, clearing and other ground disturbance (including cliff falls) caused by its mining operations and/or surface activities within the mining area, unless otherwise addressed by the conditions of this consent, to the satisfaction of the Secretary. These offsets must:

  (a) be submitted to the Secretary for approval by 30 April 2009;

(b) be prepared in consultation with WaterNSW;

(c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of WaterNSW's Special Areas or water catchments.

IMC transferred 33 ha of land adjacent to the Cataract River to WaterNSW to meet the above condition.

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 16 December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of the SMP for Area 3B and 3C. IMC has sought concurrence from the Secretary that the Strategy also satisfies the requirements of the SMP for Area 3A.

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 Longwall 19 and be adaptive to results as the program is implemented. The research will be conducted as provided by a Swamp Rehabilitation Research Program. This Program will:

- be prepared in consultation with BCD, WaterNSW and DRG;
- be submitted by 31 October 2013 to the Secretary for approval;
- investigate methods to rehabilitate swamps subject to subsidence impacts and environmental consequences within Area 3A and 3B, with the aim of restoring groundwater levels and groundwater recharge response behaviour to pre-mining levels;
- establish a field trial (for a 5 year duration or longer) for rehabilitation techniques at a swamp or swamps that have been impacted by subsidence;
- provide for the expenditure of at least $3.5 million over this period; and
- include a schedule of subsequent trials, development of work plans and ongoing reporting.

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 Longwall 19 Study Area, including Swamps 15A, 34, 96 and 147.

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.
- Provide any environmental offset required by the Consent.
- 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 rehabilitation action plan will be developed in consultation with relevant stakeholders. Authority to access the land to conduct works and implement environmental controls requires approval of WaterNSW.

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
Swamp 15A	**Negligible** erosion of the surface of the swamp	Gully erosion or similar	• Observation of swamps for new erosion or changes to existing erosion • Identification and measurements of erosion via airborne laser scanning (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.
	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	• Repeat mapping of swamp boundaries • Repeat mapping of groundwater dependent community boundaries • Statistical analyses of species richness and diversity	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	• 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 standard error of the Control Group. • 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	Offset required immediately, if no remediation considered practicable. Offset required 5 years following remediation, if it is ineffective.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
				base and/or use of other remediation techniques i) reporting j) investigation and review k) update future predictions	exceeding the standard error of the Control Group. • 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.	This period can be extended to 10 years, with the agreement of the Secretary.
	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	• 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 h) investigation and review i) update future predictions	Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, i.e. pool water level within the swamp after CMAs continues to be >20% lower than baseline for >20% of the time over a period of 1 year.	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective. This period can be extended to 5 years, with the agreement of the Secretary.

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
Swamps 12,15B, 34, 95, 96, 146, 147 and 148	**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	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
				other remediation techniques o) CMAs p) reporting q) investigation and review r) update future predictions		This period can be extended to 5 years, with the agreement of the Secretary.

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 3A 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 in accordance with 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 Approvals Manager who shall be the SIMMCP's authorising officer.

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

Approvals Manager

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

Principal Approvals

- 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.

Environmental Field Team Lead

- 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 Plan 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 Approvals Manager and provide expert opinion.

Person(s) Performing Inspections

- Inform the Environmental Field Team Lead 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 Approvals Manager 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 Environmental Field Team Lead and be trained in observation, measurement and reporting. The Environmental Field Team Lead 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 IMC website.

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

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 sites 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.

Table 1.1 – Dendrobium Area 3 Swamp Monitoring Program

	Monitoring Site	Site Type	Monitoring Frequency	Parameters
OBSERVATIONAL, PHOTO POINT AND WATER MONITORING				
Area 3A	Longwall 19 Study Area Swamps 15A, 34, 95 and 147 Area 3A Swamps 12, 15A, 15B and 96 Swamps 146 and 148 *Reference Sites* Swamps, 22, 24, 25, 33, 84, 85, 86, 87 and 88	Observation and photo point monitoring: Sites based on risk Swamps Pools and rockbars Steep slopes and rock outcrops Previously observed impacts that warrant follow-up inspection Mining areas	Pre and post mining for 2 years, monthly when longwall is within 400 m of monitoring site Weekly inspection and pool water levels when longwall is within 400 m of monitoring site Reference sites 6-monthly	Visual signs of impacts to swamps and drainage lines (i.e. cracking, vegetation changes, increased erosion, changes in water colour, soil moisture etc.) determined by comparing baseline photos with photos during the mining period Key water quality parameters in pools within and downstream of swamps analysed to identify any changes resulting from mining
AREA 3B	Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A and 35B *Reference Sites* Swamps 2[1], 7[1], 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 General observation of swamps in active mining areas when longwall is within 400 m of swamp *Reference Sites* Swamps, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
EROSION MONITORING				
Area 3A	Longwall 19 Study Area Swamps 15A, 34, 95 and 147 Area 3A Swamps 12, 15A 15B, 34, 95, 96 and 96 Swamps 146 and 148	Airborne Laser Scanning Surveyed cross-sections, areas and lengths	ALS base surveys were completed in December 2005, with a verification base survey performed in 2013, immediately prior to the commencement of Longwall 9 extraction Ground based surveys to be completed for each longwall after each longwall or to define any new erosions identified by ALS survey	Raw ground strike ALS data will be contoured with a 0.2 m interval after the completion of subsidence at each longwall to provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to assess for new or increases in existing erosion. The maximum area/length and depth of any erosion identified by ALS will be measured by standard survey methods

AREA 3B	Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A and 35B *Reference Sites* Swamps 2[1], 7, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145			
SHALLOW GROUNDWATER LEVEL				
AREA 3A	Longwall 19 Study Area Swamps 15A: 15a_03, 15a_04, 15a_07, 15a_15, 34, 96 and 147 Area 3A Swamp 15a_12, 15a_18, 15b_H1, 15b_H2, 15b_H3, 12_01, 12_03, 12_04 Swamp 146: DA2A_01 and 148 At least one piezometer site per swamp if sediment depth is appropriate.	Monitoring bore drilled into the soil profile	For open hole sites: Monthly monitoring pre, during and post mining for two years to be reviewed annually Reference sites 6 monthly For instrumented sites: Automatic groundwater level monitoring pre, during and post mining (1-hour interval or similar)	Piezometric and dip meter monitoring of shallow groundwater level

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

AREA 3B	Swamp 01A: 01a_04ii, 01a_04iii Swamp 01B: 01b_02iii, 01b_02iv Swamp 03: 03_01 Swamp 04: (thin soil profile) Swamp 05: 05_01, 05_04 Swamp 08: 08_01, 08_04 Swamp 10: 10_01 Swamp 11: 11-HI, 11-H2, 11-H3 Swamp 13: 13_01 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35A_01 Swamp 35B: 35B_01 Note: Swamp 4 is too shallow for a piezometer to be installed. *Reference Sites* Swamp 2[(1)]: 02_01 Swamp 7[(1)]: 07_05, 07_06 Swamp 22: 22_01, 22_02 Swamp 24: 24_01 Swamp 25: 25_01 Swamp 33: 33_01, 33_03 Swamp 84: 84_02 Swamp 85: 85_01, 85_02, 85_03 Swamp 86: 86_01, 86_02, 86_03 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02		Monitoring post mining for five years to be reviewed annually	
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 At least one piezometer site per swamp if sediment depth is appropriate.			

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

SOIL MOISTURE				
Area 3A	Install soil moisture at existing shallow groundwater sites Longwall 19 Study Area Swamp 15A: 15a_03, 15a_04, 15a_07 and_15a_15, At least one Soil Moisture site per swamp if sediment depth is appropriate at Swamp 34, 96 and 147 Area 3A Swamp 15a_12, 15a_18, 15b_H1, 15b_H2, 15b_H3, 12_01, 12_03, 12_04 Swamp 146: DA2A_01 and 148			

AREA 3B	Swamp 03: (thin soil profile) Swamp 04: (thin soil profile) Swamp 05: S05_S01, S05_S02, S05_S05, S05_S08 Swamp 08: S08_S05 Swamp 11: S11_S01, S11_S02, S11_S05 Swamp 13: S13_S01, S13_S02, S13_S03 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35a_01 Swamp 35B: 35b_01 *Reference Sites* Swamp 2[1]: S02_S01 Swamp 7[1]: 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, S85_03 Swamp 86: S86_S01, S86_S02, S86_03 Swamp 87: S87_S01, S87_S02 Swamp 88: S88_S01, S88_S02	Monitoring bore drilled into the soil profile	For manually measured sites: Monthly monitoring for 2 years baseline and post mining and 6-monthly reference sites Weekly monitoring when longwall is within 400 m of monitoring site For instrumented sites: Automatic soil moisture monitoring pre, during and post Monitoring post mining for five years to be reviewed annually	Installed dielectric soil moisture sites down to 1.5 m to measure deep soil moisture
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 Soil moisture sites will be paired with sites with piezometers			

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

TERRESTRIAL FLORA – COMPOSITION AND DISTRIBUTION OF SPECIES				
AREA 3A	Swamps 15B and 15A	Swamp vegetation transects	Two baseline monitoring campaigns 1 year prior to mining during autumn and spring (Autumn - Photo points; spring - Photo points & 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; and • Photo point monitoring at each transect
AREA 3B	Swamps 01A, 01B, 05, 11 *Reference Sites* Gallahers Swamp (Swamp 88), Fire Trail 15e Swamp (Swamp 87), Fire Trail 6x Swamp (Swamp 86), Swamp 15A(1), Swamp 22 and Swamp 33			
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 (Sites yet to be determined)			
TERRESTRIAL FLORA – SWAMP SIZE AND ECOSYSTEM FUNCTION				
Area 3A	Swamp 15A, 15B	Size of the groundwater dependent communities (Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex) and the total size of the swamps	Baseline mapping prior to mining with repeat mapping after each longwall or as determined by observational monitoring i.e. if dieback or invasion of non-swamp species is observed	Detailed mapping including the use of LiDAR data to indicate the location and extent of upland swamp boundaries. Ground-truthing of these boundaries and the vegetation sub-communities will be undertaken if subsequent Lidar data shows swamp boundary movements
AREA 3B	Swamps 01A, 01B, 05, 8, 11, 13, 15A, 15B 14 and 23 *Reference Sites* Swamps DC10 (Swamp 85) and 33			
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3A	Swamps 15B and 15A	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).	For swamps frog surveys are conducted along associated creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals recorded at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line
AREA 3B	DC13, DC1, WC21, LA4A, ND1 and WC15 *Reference Sites* WC10, WC11, SC6, SC7(1), SC7(2), SC7A, SC8, DC8 and NDC			

AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 (Sites yet to be determined)		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.	
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[(1)], 19[(1)], 20[(1)], 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) **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 Monitoring during mining in autumn and spring Monitoring post mining for two years or as otherwise required Monitoring targets sites as mining progresses through the domain	Macroinvertebrate sampling and assessment using the AUSRIVAS protocol and quantitative sampling using artificial collectors. In consideration of Adams Emerald Dragonfly and Sydney Hawk Dragonfly, individuals of the genus *Austrocorduliidae* and *Gomphomacromiidae* are identified to species level if possible. Fish are sampled by visual observations and dip netting in Area 3A and sampled using a back-pack electrofisher and baited traps in Area 3B.

[(1)]Reference site for Area 3B; impact site when mining commences in Area 3C

Table 1.2 - Dendrobium Longwall 19 Study Area 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	<u>Level 1:</u> 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. <u>Level 2</u>: 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. <u>Level 3:</u> 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. *<u>Exceeding Prediction</u>* Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase **>5%** of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (ie increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is **>5%**).	a) upfront mine planning b) erosion monitoring (ie ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the size of the swamps **Minor changes** in the ecosystem functionality of the swamps **No significant change** to the composition or distribution of species within the swamps	Swamp vegetation changes: - Swamp size - Species richness, distribution, composition and diversity - Vegetation sub-communities	**Swamp Size** <u>Level 1:</u> 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. <u>Level 2:</u> 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. <u>Level 3:</u> 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. *<u>Exceeding Prediction:</u>* 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** <u>Level 1:</u> A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.	a) upfront mine planning b) vegetation monitoring c) water spreading d) seeding/planting e) weeding f) fauna monitoring g) fire management h) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques i) reporting j) investigation and review k) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **5 years** following remediation, if it is ineffective. This period can be extended to **10 years**, with the agreement of the Secretary.	Monitoring period for swamp size is related to capture of Lidar data at the end of each longwall ~ 1 year Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring

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

functionality of the swamps	groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *<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.	b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*<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