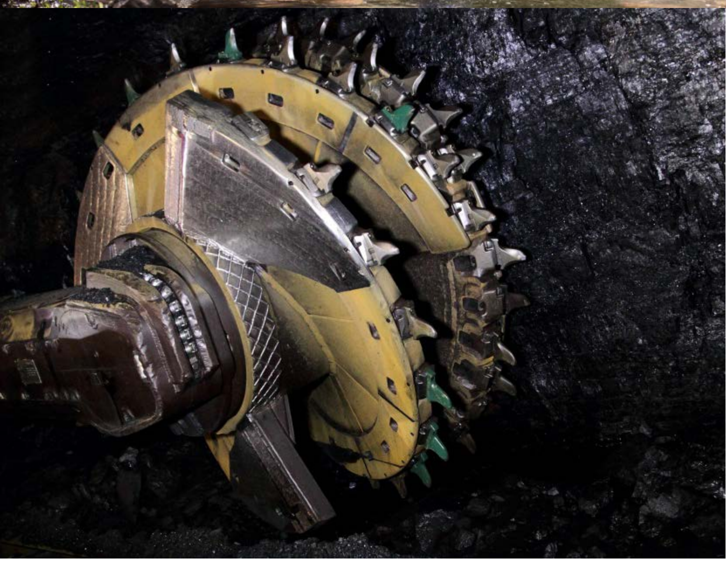
SOUTH32

DENDROBIUM
AREA 3C

NOVEMBER 2019



LONGWALLS 20 AND 21 SUBSIDENCE MANAGEMENT PLAN

EXECUTIVE SUMMARY

Illawarra Metallurgical Coal (IMC), a wholly owned subsidiary of South32 Pty Ltd (South32), operates underground coal mining operations at Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam have been mined in Areas 1, 2, 3A. Longwalls in Area 3B have been previously mined and are currently being extracted.

The socio-economic benefits to New South Wales and the region from underground mining at IMC's Dendrobium and other operations is significant. IMC operations:

- Employ 1,800 people, with 92% of wages paid to workers residing in the Illawarra region.
- Result in expenditure of $400 million a year in the Illawarra region, of which 40% ($161 million) is spent with locally based suppliers.
- Purchase from more than 400 local businesses.
- Contribute approximately $95 million in royalties each year (with approximately $45 million from the Dendrobium Mine).

IMC is the most significant metallurgical coal producer in the region, providing local access to a product essential to the BlueScope steel works.

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project 20 November 2001. Longwalls from the Wongawilli Seam have been mined in Areas 1, 2, 3A. Longwalls in Area 3B have been previously mined and are currently being extracted. Further approval is required from the Secretary prior to the development or extraction of Longwalls 20 and 21 in Dendrobium Area 3C.

The Independent Expert Panel for Mining in the Catchment Initial Report (IEP) (2018) recommended that any Subsidence Management Plan application consider the potential implications for water quantity of faulting, basal shear planes and lineaments and that a Risk Assessment be included in applications to extract coal within Catchment Special Areas.

A Risk Assessment (**Attachment E**) has been completed to identify existing controls associated with mining operations in the Special Areas and to make recommendations for further controls where appropriate. The Longwall 20 and 21 Subsidence Management Plan and Risk Assessment address key catchment values (groundwater, Avon and Cordeaux Reservoirs, Wongawilli Creek, Donalds Castle Creek, swamps and tributaries) in relation to the following concerns (where relevant):

- Surface subsidence and sub surface ground movements;
- Valley closure;
- Lineaments, faults and dykes; and
- Groundwater drawdown.

The following statements from the Initial Report identify that there has been no observed material impacts to Sydney's drinking water supplies due to mining in the catchment:

> *"Reservoir leakage rates – there is no measured evidence of significant long-term leakage from reservoirs due to mining in the Special Areas."*
>
> *"Watercourse bed leakage (at catchment scale) – from material presented to the Panel, there remains no strong evidence that cracking of watercourse beds leads to significant losses of water at catchment scales relevant for water supplies."*

While the potential for mining to cause impacts within the Special Areas requires special attention, the localised impacts that have been observed need to be considered objectively and in the context of the broader catchment.

The Independent Panel's estimate of average surface water diversion of 3 ML/day at the Dendrobium Mine equates to 0.2% of the 1.5 billion litres of drinking water provided to customers each day by Sydney Water.

Table of Contents

Tables

Figures

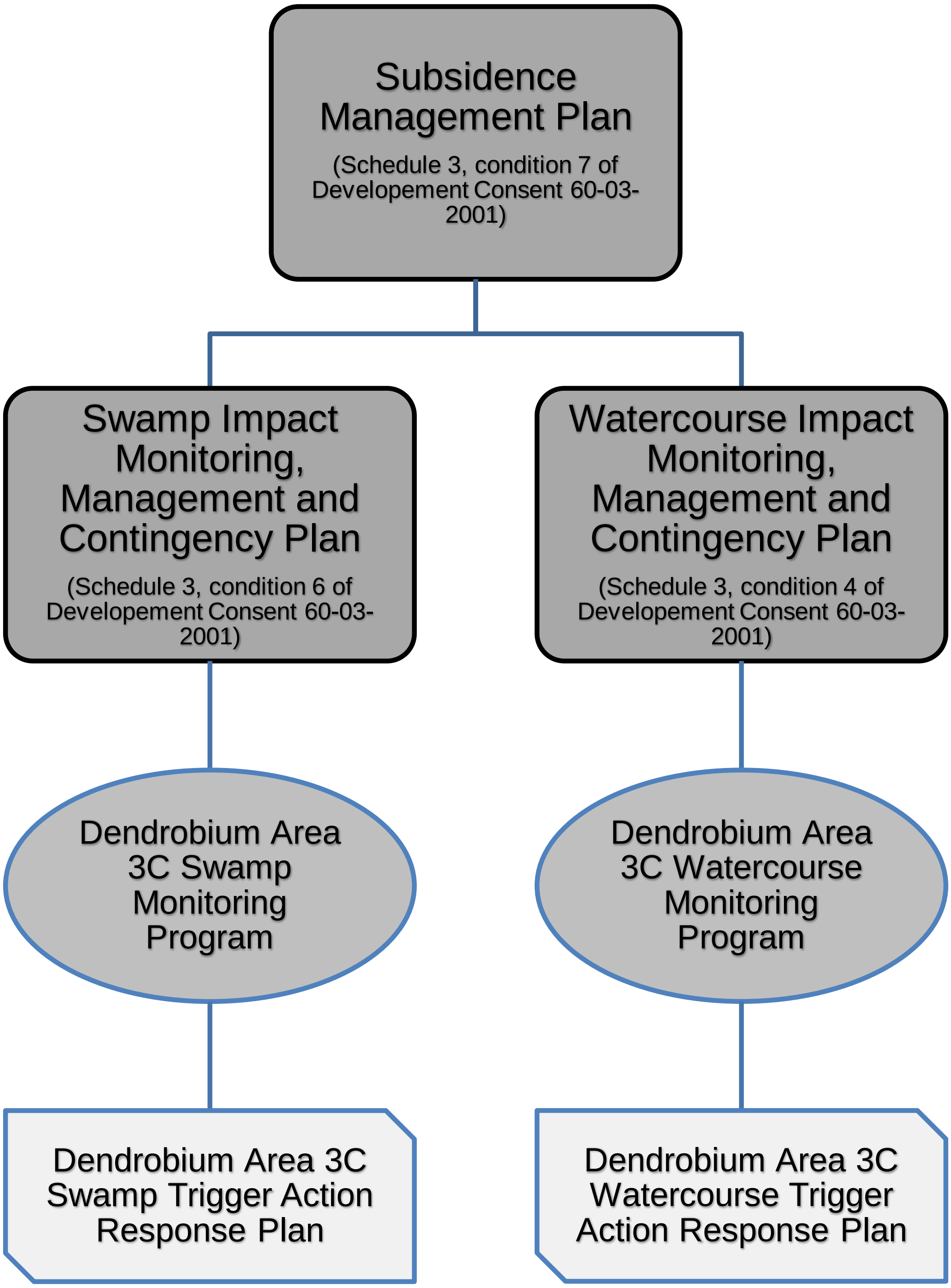
Appendices

Attachments

Review History

Revision	Description of Changes	Date	Approved
1	New Document	May 2019	GB
2	Minor updates	September 2019	GB
3	Figure updates and adding SIMMCP and WIMMCP as appendices	November 2019	GB

Flowchart 1 – SMP, SIMMCP and WIMMCP interactions



1 INTRODUCTION

1.1 Project Background

Illawarra Metallurgical Coal (IMC), a wholly owned subsidiary of South32 Pty Ltd (South32), operates underground coal mining operations at Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam have been mined in Areas 1, 2, 3A. Longwalls in Area 3B have been previously mined and are currently being extracted.

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007, IMC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of s75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

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

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

1.2 Scope

This SMP has been prepared for Dendrobium Area 3C Longwalls 20 and 21, and complies with the Dendrobium Mine revised Consent *Schedule 3, Condition 7* as provided below.

7. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, 3B or 3C, the Applicant must prepare a Subsidence Management Plan (SMP) to the satisfaction of the Secretary and the DRG. Each such SMP must:

(a) integrate ongoing management of Areas 1 and 2;

(b) integrate the Watercourse and Swamp Impact Monitoring, Management and Contingency Plans required under conditions 4 and 6;

(c) include monitoring of subsidence effects;

(d) include a WaterNSW Assets Protection Plan;

(e) include monitoring, management, and contingency plans for all other significant natural features and all significant man made features which may be impacted by subsidence, including:

- landscape (including cliffs and steep slopes);
- groundwater (see condition 13);
- terrestrial flora and fauna and ecology (including all threatened species assessed as being likely to be significantly affected by the development and their habitats);
- Aboriginal and other cultural heritage (see condition 12); and
- electrical, communications and other infrastructure;

(f) be prepared in consultation with OEH, WaterNSW and DRG;

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

(h) be implemented to the satisfaction of the Secretary and the DRG.

1.3 Study Area

The Study Area is defined as the surface area that could be affected by the mining of the proposed Longwalls 20 and 21. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- The 35° angle of draw line from the extents of the proposed Longwalls 20 and 21;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed longwalls; and
- The natural features located within 600 m of the extent of the longwall mining area, in accordance with Condition 8(d) of the Development Consent.

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

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method (IPM), which is described in MSEC (2019).

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

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

1.4 Objectives

The objective of this SMP and associated documents is to:

- Describe a system to adequately manage subsidence risks in a timely manner and to demonstrate IMC's capability to manage subsidence.
- Clearly state the objective of what is to be achieved for both systems and individual plans.
- Outline the systems used to establish monitoring mechanisms.
- Outline the systems to ensure ongoing analysis of monitoring information is used to implement management actions in a timely manner.
- Clearly define the necessary trigger levels and response actions.
- Assess the likelihood and scale of impact and any requirements for statutory approvals.
- Demonstrate preparedness for impacts outside of predictions.
- Carry out remediation works in a manner that protects to the greatest practicable extent the ecological values of the area and re-establishes the ecological values of an area to a similar state to that existing before mining.
- Monitor and report on the effectiveness of the SMP.

The mine plan has been optimised to maximise the extraction of the resource and minimise subsidence impacts to sensitive features. This SMP is to comply with the Dendrobium Conditions of Consent.

1.5 Specialist Assessments

The following specialist assessments have been prepared to support the Area 3C SMP:

Attachment	Addressed in Document
Attachment A	Aboriginal Cultural Heritage Assessment Report – September 2019 (Niche 2019a)
Attachment B	Aquatic Flora and Fauna Assessment – May 2019 (Cardno 2019)
Attachment C	Longwalls 20 and 21 Groundwater Assessment - May 2019 (HydroSimulations 2019)
Attachment D	Subsidence Predictions and Impact Assessments – August 2019 (MSEC 2019)
Attachment E	Risk Assessment Report – May 2019 (Axys 2019)

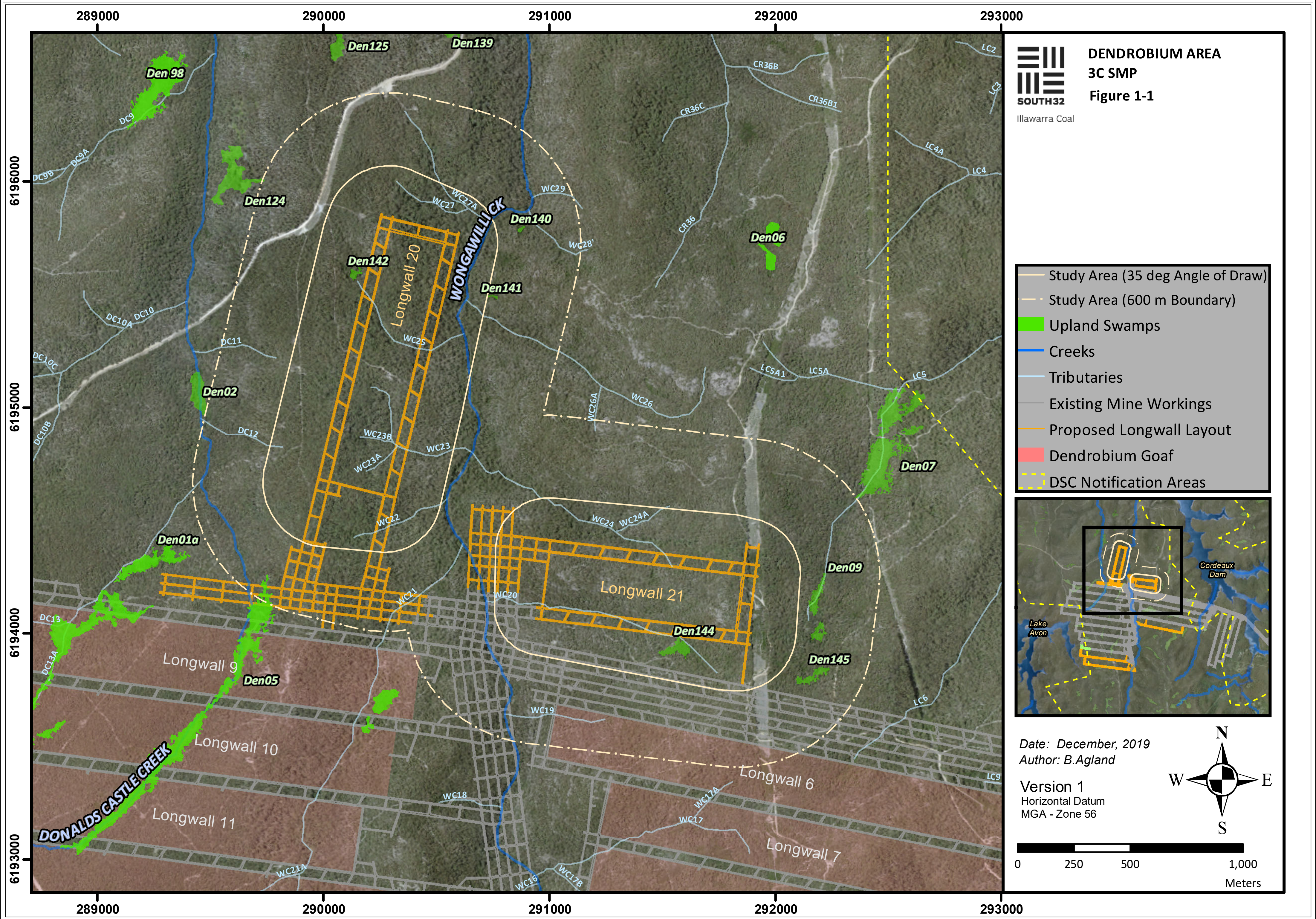
Attachment F	Assessment of Surface Water Flow and Quality Effects of Proposed Dendrobium Longwalls 20 and 21 – May 2019 (HGEO 2019)
Attachment G	Terrestrial Ecology Assessment – August 2019 (Niche 2019b)

1.6 Consultation

The Dendrobium Longwalls 20 and 21 SMP was developed by IMC in consultation with:

- Department of Planning, Infrastructure and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]);
- Biodiversity Conservation Division (BCD) within DPIE (formerly the Office of Environment and Heritage [OEH]); and
- Water NSW.

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



DENDROBIUM AREA
3C SMP
Figure 1-1
SOUTH32
Illawarra Coal
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Cordeaux Dam
Lake Avon
Date: December, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
WONGAWILLI CK
DONALDS CASTLE CREEK
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
Den 98
Den125
Den139
Den124
Den140
Den06
Den142
Den141
Den02
Den07
Den01a
Den09
Den144
Den145
Den05
DC9
DC9A
DC9B
DC10
DC10A
DC10C
DC10B
DC11
DC12
DC13
DC13A
WC27
WC27A
WC29
WC28'
WC25
WC26
WC26A
WC23
WC23A
WC23B
WC22
WC24
WC24A
WC21
WC21A
WC20
WC19
WC18
WC17
WC17A
WC17B
WC16
CR36
CR36B
CR36B1
CR36C
LC2
LC3
LC4
LC4A
LC5
LC5A
LC5A1
LC6
LC9

2 PLAN REQUIREMENTS

Extraction of coal from Longwalls 20 and 21 will be in accordance with the conditions set out in the Dendrobium Area 3 Modified Development Consent and conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence from the extraction of Longwalls 20 and 21. The monitoring in these areas will be based on the Before After Control Impact (BACI) design criteria.

The Area 3C monitoring and assessment programs will provide ongoing data for the areas and features potentially affected by the mining of Longwalls 20 and 21.

2.1 Dendrobium Modified DA60-03-2001 Approval

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under Section 75W of the *EP&A Act 1979* on 8 December 2008. **Table 2-1** lists the Conditions of Consent relevant to the Area 3C SMP.

Table 2-1 Dendrobium Modified DA-60-03-2001 Approval Conditions relevant to Area 3C.

Project Approval Condition
Schedule 3 - Condition 2 The Applicant shall ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than “minor impacts” (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.
Schedule 3 - Condition 3 The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.
Schedule 3 - Condition 4 (a) to (i) 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 Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary.
Schedule 3 – Condition 6 (a) to (i) 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 Director-General. Swamp Impact, Monitoring, Management and Contingency Plan
Schedule 3 - Condition 7 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, 3B or 3C, the Applicant shall prepare a Subsidence Management Plan (SMP) to the satisfaction of the Secretary and the DRE. Each such SMP must: (a) integrate ongoing management of Areas 1 and 2; (b) integrate the Watercourse Impact, Monitoring, Management, and Contingency Plan (WIMMCP) and Swamp Impact, Monitoring, Management, and Contingency Plan (SIMMCP) required under conditions 4 and 6; (c) include monitoring of subsidence effects; (d) include a SCA Assets Protection Plan; (e) include monitoring, management, and contingency plans for all other significant natural features and all significant man-made features which may be impacted by subsidence, including: (f) landscape (including cliffs and steep slopes); (g) groundwater (see condition 13);

(h) terrestrial flora and fauna and ecology (including all threatened species assessed as being likely to be significantly affected by the development and their habitats); (i) Aboriginal and other cultural heritage (see condition 12); and (j) electrical, communications and other infrastructure; (k) be prepared in consultation with OEH, SCA and DRE; (l) be approved prior to the carrying out of any underground mining operations that could cause subsidence in the relevant Area; and (m) be implemented to the satisfaction of the Secretary and the DRE.
Schedule 3 - Condition 8 The SMPs prepared under condition 7 for Areas 3B and 3C must: (a) include a mine plan for the relevant Area; (b) include a detailed subsidence impact assessment, clearly setting out all predicted subsidence effects, subsidence impacts and environmental consequences; (c) include a minimum of 2 years of baseline data, collected at appropriate frequency and scale, for all significant natural features; (d) identify and assess the significance of all natural features located within 600 m of the edge of secondary extraction; (e) distinguish between, clearly describe and adequately quantify all subsidence effects, subsidence impacts and environmental consequences; (f) propose limits on subsidence impacts and environmental consequences to be applied within the relevant Area; (g) be otherwise prepared in accordance with any guidelines for SMPs developed by the Department and/or DRE; (h) be approved prior to the carrying out of any underground mining operations that could cause subsidence in the relevant Area; and (i) be implemented to the satisfaction of the Secretary and the DRE.

2.2 Leases and Licences

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

- Dendrobium Mining Lease CCL 768;
- 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 Approval.

3 MONITORING

3.1 Surface Water Quality

Monitoring undertaken by IMC since 2003 (see Area 3C WIMMCP and SIMMCP) includes water quality monitoring of parameters such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO_4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si).

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3C will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining are monitored to allow for a comparison against sites not influenced by mining.

Pools within streams will be measured monthly before and following mining, weekly during active subsidence and in response to any observed impacts.

The water chemistry, algae and level of water in Avon Reservoir will be monitored as a basis for comparison to the mine water. The locations of the samples and the testing procedure have been developed in consultation with the Dams Safety Committee (DSC) and Water NSW.

3.2 Surface Water Level and Flow

Pool water levels in swamps and streams are measured using installed benchmarks in impact sites and reference sites (see Area 3C WIMMCP and SIMMCP). Water level/flow gauges and data loggers are installed at key stream flow monitoring sites; any proposed sites will be installed 2 years prior to the extraction of the proposed longwalls. Data has been collected since 2003 and has been compiled within monitoring and field inspection reports, End of Panel Reports and Annual Environmental Management Reports.

Pool water levels are measured monthly before and after mining, on a weekly basis during active subsidence and in response to any identified impacts. Water level measurements will be undertaken relative to benchmarks installed on rocks or other stable features on the edge of the pools.

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

3.3 Upland Swamp Near-Surface Groundwater and Soil Moisture

Near-surface groundwater piezometers have been installed within and around several swamps and associated watercourses in Area 3 (see Area 3C WIMMCP and SIMMCP). This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at near-surface groundwater levels is supplemented with monitoring of soil moisture profiles.

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).

3.4 Groundwater

A specialist Groundwater Assessment (HydroSimulations 2019) is provided in **Attachment C**. An existing groundwater monitoring program is in place for Dendrobium, which includes Area 3C. Additional sites will be added to if required under *Schedule 3, Condition 13.*

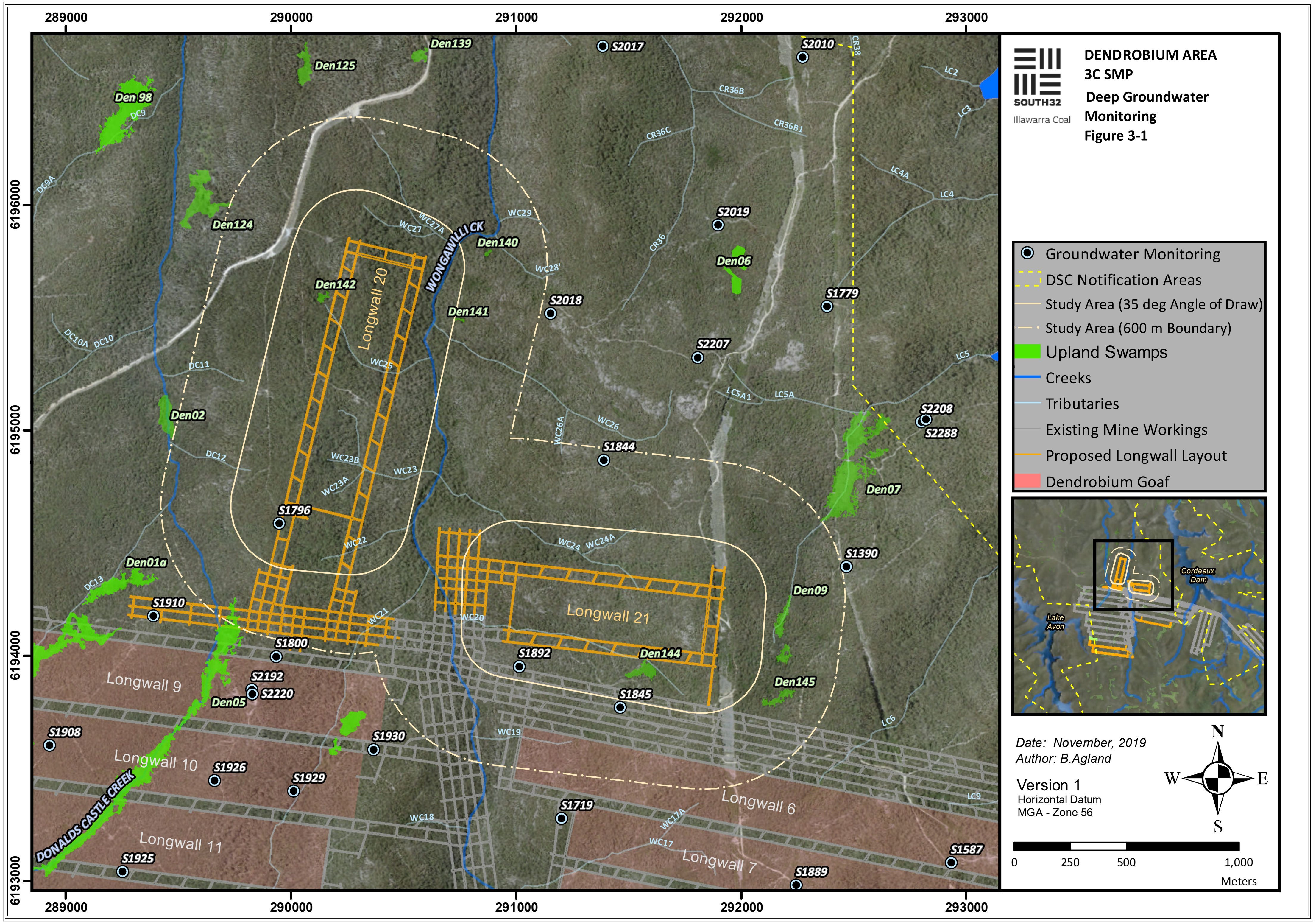
Groundwater monitoring is undertaken in:

- 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 2018). Before and after mining piezometers are routinely installed along the centreline of longwall panels to identify the maximum groundwater effects and the height of free drainage within the subsidence zone.

To investigate groundwater-surface water dynamics in Wongawilli Creek, two monitoring bores are proposed to be installed between the creek and the proposed longwalls, preferably within the Wongawilli Creek valley (contingent on access and approvals). The boreholes would be installed in the Hawkesbury Sandstone and upper Bulgo Sandstone and the data would be paired with surface water flow data from Wongawilli Creek monitoring sites.



DENDROBIUM AREA
3C SMP
Deep Groundwater
Monitoring
Figure 3-1
SOUTH32
Illawarra Coal
Groundwater Monitoring
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
S
W
E
0
250
500
1,000
Meters
Cordeaux Dam
Lake Avon
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den06
Den02
Den01a
Den05
Den07
Den09
Den144
Den145
S2017
S2010
S2019
S2018
S1779
S2207
S2208
S2288
S1844
S1796
S1390
S1910
S1800
S1892
S2192
S2220
S1845
S1908
S1930
S1926
S1929
S1719
S1925
S1587
S1889

3.5 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; and
- The Eckersley Formation.

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (see Area 3C WIMMCP and SIMMCP).

The largest watercourse within the Study Area is Wongawilli Creek, 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.

3.6 Landscape and Photo Point Monitoring

IMC has conducted ongoing observational and photo point monitoring in the Dendrobium area since 2001 (see Area 3C WIMMCP and SIMMCP).

The IMC Environmental Field Team is continuing to undertake a structured monitoring assessment, including:

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

Observations of any surface water and vegetation health for prominent species are conducted. 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. 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.

3.7 Slopes and Gradients

Slopes within Area 3C have been mapped and are identified on Drawing 8 in MSEC (2019) (**Attachment D**). Monitoring of landscape features such as cliffs, slopes and rock outcrop is undertaken in Area 3C (see Area 3C WIMMCP).

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 includes:

- 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.

Steep slopes are 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. The monitoring is undertaken at six monthly intervals for two years following completion of mining.

3.8 Erodibility

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

An extensive survey network has been 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 Area 3C will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

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

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 **Attachment G,** the Area 3C Terrestrial Ecology Assessment (Niche 2019). Aquatic flora and fauna in the Study Area are described in **Attachment B,** the Area 3C Aquatic Ecology Assessment (Cardno 2019).

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence will be implemented for Area 3C (see Area 3C WIMMCP and SIMMCP). 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.

Sufficient baseline data will be collected for Area 3C 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).

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.

3.10 Cultural Heritage

There are no Aboriginal heritage sites that have been identified within the Study Area based on the 35° angle of draw. There are eight Aboriginal heritage sites that are located within the Study Area based on the 600 m boundary and one additional site located just outside this boundary.

The sites within the Study Area comprise six rock shelters with art, one rock shelter with artefacts, and two grinding groove sites. These sites are all located at distances between 210 m and 590 m outside the proposed longwalls (Niche 2019a).

The Aboriginal heritage sites are predicted to experience less than 20 mm vertical subsidence due to the extraction of Longwalls 20 and 21 (MSEC 2019). The sites are not expected to experience measurable upsidence or compressive strain due to valley closure effects as they are located on the sides of the ridgelines away from the valley bases (MSEC 2019).

It is unlikely, therefore, that the Aboriginal heritage sites located within the Study Area would experience adverse impacts due to the extraction of Longwalls 20 and 21 (Niche 2019a).

Further detail on the monitoring and assessment of cultural heritage sites is located in **Attachment A** (Niche 2019a)**.**

3.11 Built Features

Unsealed roads and tracks are located across the Study Area. It is likely that cracking and heaving of the unsealed road surfaces would occur where they are located directly above the proposed longwalls. Routine monitoring will be conducted along road and tracks, during periods of active subsidence, to identify any potential impacts. Based on experience in Areas 1, 2, 3A and 3B, it is expected that these features can be maintained in safe and serviceable conditions using normal road maintenance techniques.

The Cordeaux and Avon Reservoirs are located at minimum distances of 1.6 km and 2.8 km, respectively, from the proposed Longwall 20 and Longwall 21. The Cordeaux Dam Wall and Avon Dam Wall are located at distances of more than 3 km and 7 km, respectively, from the proposed longwalls.

The predicted vertical and horizontal movements at the Cordeaux and Avon Reservoirs and their associated dam walls are very small and are unlikely to be measurable. Previous experience of mining in Areas 1, 2, 3A and 3B has not resulted in adverse impacts on these structures. It is unlikely, therefore, that the reservoirs and dam walls would experience adverse impacts due to the extraction of the proposed Longwall 20 and Longwall 21.

Further detail on built features within the study area is located in **Attachment D** (MSEC 2019).

3.12 Reporting

End of Panel Reports are prepared in accordance with *Schedule 3, Condition 9* of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the End of Panel 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 that response.

Monitoring results are included in the Annual Reporting requirement under *Schedule 8, Condition 5* in accordance with the Dendrobium Area 3 Modification Approval and are made publicly available in accordance with *Schedule 8, Condition 11.*

4 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium modified Consent. These performance measures are presented in **Table 4-1** and will be applied to the Dendrobium Area 3C mining area.

Table 4-1 Subsidence Impact Performance Measures

Dendrobium Modified Development Consent
• Operations shall not cause subsidence impacts at Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality); • Operations will not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.
Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145
Minor environmental consequences including: • negligible erosion of the surface of the swamps; • minor changes in the size of the swamps; • minor changes in the ecosystem functionality of the swamp; • no significant change to the composition or distribution of species within the swamp; and • maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.

A detailed list of performance measures and triggers is included in the Trigger Action Response Plans (TARP) (see attached Area 3C WIMMCP and SIMMCP).

4.1 Impact Mechanisms

Subsidence is a direct consequence of longwall mining, which involves 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.

There are two broad mechanisms by which subsidence could cause changes in hydrology and water quality:

- The bedrock below the watercourse or groundwater dependent community fractures as a consequence of strains and water drains into the fracture zone. The extent and permanence of these changes relate to the size of the fracture zone (increase in porosity/storage) and whether the fractures are connected to a deeper aquifer, the mine workings, conductive geological features/lineaments or bedding shear pathway to the surface lower in the catchment. Surface water diverted through freshly fractured sandstone and/or groundwater that returns to the surface through the fracture network may contain increases in iron concentrations and other minerals.

- Tilting, cracking, desiccation and/or changes in vegetation health result in concentration of runoff and erosion which alters water distribution in the watercourse or groundwater dependent community.

Changes to 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 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 and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates;
- Reduced inflows into Lake Avon and Cordeaux River;
- Increased rates or frequency of erosion events; and
- Increased extent or frequency of fire events resulting in the organic components of the swamp soil profile to burn during intense bushfires.

The impact mechanisms and environmental consequences relevant to the performance measures are detailed in the WIMMCP and SIMMCP.

5 MANAGEMENT AND CONTINGENCY PLAN

This section describes the potential impacts of mine subsidence in Area 3C, together with a summary of the avoidance, minimising, mitigation and remediation measures proposed.

5.1 Objectives

The aims and objectives of the Plan include:

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

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

5.2 Trigger Action Response Plan

The TARPs relate to identifying, assessing and responding to potential impacts to watercourses (including impacts greater than predicted) from subsidence in Dendrobium Area 3C. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3C are included in the SIMMCP and WIMMCP.

the TARPs represent reporting and/or other actions to be taken upon reaching each defined trigger level. A Corrective Management Action (CMA) is developed in consultation with stakeholders in order to manage an observed impact in accordance with relevant approvals. The SIMMCP and WIMMCP provide a basis for the design and implementation of any mitigation and remediation.

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

Level 2 and 3 TARPs result in further investigations and reporting by appropriately qualified people. Impact assessment reports will include:

Study scope and objectives;

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

The Level 2 and 3 TARPs may require the development of site-specific CMAs which include:

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

- Reporting, consultation and communication.

5.3 Avoiding and Minimising

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

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

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

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

Area 3C is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2, 3A and 3B to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of Area 3C including major surface water features such as Lake Cordeaux, Wongawilli Creek, Donalds Castle 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 north-west of the proposed Longwall 20. The process of developing the layout for Area 3C has considered predicted impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

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 3C mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPE and OEH during the consultation process. Mine plan changes result in significant business and economic impact, including:

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

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;
- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;
- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;
- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and

- Requires specialised equipment and skilled personnel with limited availability.

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

5.4 Mitigation and Rehabilitation

If the performance measures in the Development Consent are not met, then following consultation with BCD, Water NSW and T&I, 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 (Minister for Planning 2008), 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 TSC Act is required in respect of those activities.

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

5.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within Wongawilli Creek or Donalds Castle Creeks 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 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 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.

5.4.2 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 profile. 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 by 1 m to 2 m by 2 m. The most efficient way to drill the holes in consideration of potential environmental impacts 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 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 pools were sealed with two to three grout passes.

If flow diversion through a large rockbar occurs it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via traditional or 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 5-1** 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 5-1 Rockbar Grouting in the Georges River

5.4.3 Erosion Control

Erosion can occur along preferred flow paths where subsidence induced tilts increase a catchment area. To arrest this type of erosion, ‘coir log dams’ are installed at knick points in the channelised flow paths or at the inception of tunnel/void spaces (**Figure 5-2**).

Figure 5-2 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. The coir logs are held in place by 50 mm x 50 mm wooden stakes and bound together with wire (**Figure 5-3**).

The coir log dam slows the flows in the eroding drainage line such that the drainage line will silt up.

Figure 5-3 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 soil so the first layer sits on the underlying substrate or so the top of the first coir log is at ground level (**Figure 5-4**).

Figure 5-4 Trenching and Positioning of the First Layer of Coir Logs and Construction of a Small Dam in a Channel

The coir log dams are constructed at intervals down the eroding flow line, 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. Where increased filtering of flows is required the coir logs are wrapped in fibre matting (**Figure 5-5**).

Figure 5-5 Small Coir Log Dams with Fibre Matting

5.4.4 Surface Treatments and Water Spreading

Where cracking develops in significant areas and natural infilling is not occurring, the cracks may require forking over and compacting to prevent erosion. Larger cracks may require more work to repair them, for example, mulch or other protection to prevent the development of erosion channels. Surface protection will remain in place until revegetation covers the disturbed area. In some cases, if the cracks are wider they may require gravel or sand filling up to surface level and revegetation using brush matting. Maintenance of moisture in rehabilitation areas can be enhanced by additional 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 5-6**).

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 5-6 Round Coir Logs Installed to Spread Water

Erosion control and water spreading involves soft-engineering materials that are biodegradable and become integrated into the soil profile. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the soil. This also removes the requirement for any post-rehabilitation removal of structures or materials. However, rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Relevant approvals will be obtained to ensure the protection of the environment as works are implemented.

5.4.5 Gas Release

A typical driver of gas release at the surface is pressure changes, dilation and/or fracturing of the rock mass and associated release to the surface, with or without groundwater flows. Grouting techniques discussed above can reduce these associated gas flows at specific sites. In all identified circumstances in the Southern Coalfield the gas releases have diminished over time. Typically this time is a number of months but it can be a number of years. Long running gas releases significantly reduce in quantity over time. Where vegetation is impacted by gas releases the areas affected will be revegetated once monitoring determines the gas releases have ceased or reduced to an extent that vegetation is no longer affected.

Very few gas releases have been observed within the Dendrobium mining area.

5.4.6 Water Quality

In Appendix A of Attachment B (see Area 3B SMP, Vol.1), Ecoengineers (2012) outline mitigation measures that would be considered if unpredicted water quality impacts were detected. Any works on Water NSW land requires prior approval from Water NSW to access the land and there is a requirement for compliance with the Access Agreement between Water NSW and IMC. These requirements ensure strict limits are placed on any impacts associated with undertaking rehabilitation works on Water NSW land.

5.4.7 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. Should rehabilitation be necessary in Dendrobium Area 3C, 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.

5.4.8 Monitoring Remediation Success

Baseline studies have been completed within the Study Area in order to record biophysical characteristics of the mining area. Monitoring is conducted in the area potentially affected by subsidence from the Area 3C 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.

The monitoring program would remain in place prior to, during and following the implementation of any remediation measures in Area 3C. The monitoring program is based on the BACI design with sampling undertaken at impact and control locations prior to the commencement of remediation, during remediation and after the completion of the remediation actions. The monitoring locations/points for watercourses within Dendrobium Area 3C 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 remediation 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 remediation or natural reduction of mining impacts over time.

Observation data will 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.

5.5 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 Water NSW 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 Water NSW;

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

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

A biodiversity offset strategy has been developed in consultation with OEH and Water NSW for the approval of the Secretary of DPE. The Secretary DPE 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.

5.6 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 will be directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps. The Swamp Rehabilitation Research Program (SRRP) is currently being undertaken in Swamp 1B.

5.7 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 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.
- Updates from specialists on investigation process.
- Inform relevant government agencies of investigation results.
- Develop site CMA in consultation with key stakeholders and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Review the WIMMCP and/or SIMMCP in consultation with key government agencies and seek approval for any modifications.
- 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 degradation that exceeds the trigger levels specified in the TARPS.

The site-specific rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. Authority to access the land to conduct works and implement environmental controls will be approved by Water NSW.

The WIMMCP and SIMMCP describes the avoidance, mitigation and contingency measures proposed to manage impacts where predicted impacts are exceeded.

6 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

6.1 Incidents

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

6.2 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.
    - Area where complaint relates to.
    - Details of any response where appropriate.
    - Details of any corrective actions.

6.3 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 (*Condition 6 Schedule 8*) 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.

7 PLAN ADMINISTRATION

This SMP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Area 3 Approval Conditions. A summary of the administrative requirements is provided below.

7.1 Roles and Responsibilities

Statutory obligations applicable to Dendrobium 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 the SMP resides with the Manager Approvals who shall be the SMP's authorising officer.

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

Manager Approvals

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

Principal Approvals

- Authorise the SMP and any amendments thereto.
- To document any approved changes to the SMP.
- Provide regular updates to IMC on the results of the SMP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the SMP.
- 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 SMP.
- Organise audits and reviews of the SMP.
- 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 SMP 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 SMP.
- Participate in assessment meetings to review subsidence impacts.
- Bring to the attention of the Superintendent Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Superintendent Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the SMP.

Survey Team Lead

- Collate survey data and present in an acceptable form for review at assessment meetings.
- Bring to the attention of the Superintendent Approvals any findings indicating an immediate response may be warranted.

- Bring to the attention of the Superintendent Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the SMP.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Superintendent Approvals 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 SMP.
- Conduct inspections in a safe manner.

7.2 Resources Required

The Manager Approvals provides resources sufficient to implement this SMP.

Equipment will be needed for the TARP provisions of the SIMMCP and WIMMCP. 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.

7.3 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; and
- On-going job specific training and re-training (where required).

It is the responsibility of the Superintendent Approvals to ensure that all persons and organisations having responsibilities under this SMP 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.

7.4 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; and
- The SMP and other relevant documentation will be made available on the IMC website.

7.5 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 IMC 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 SMP 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.*; and
- Any modification to the conditions of this approval.

If deficiencies in the EMS and/or SMP 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.

8 REFERENCES AND SUPPORTING DOCUMENTATION

ACARP, 2009. Damage Criteria and Practical Solutions for Protecting River Channels. Project Number C12016. Ken Mills SCT May 2009.

Axys, 2019. Review of Dendrobium Longwalls 20 and 21 Subsidence Management Plan – Risk Assessment Report. 26 April 2019.

BHP Billiton Illawarra Coal, 2006. Georges River Report: Assessment of Georges River Remediation Longwalls 5A1-4. November 2006.

BHP Billiton Illawarra Coal, 2011. Understanding Swamp Conditions - Field Inspection Report - September 2010 to November 2010. BHP Billiton Illawarra Coal, April 2011.

Biosis Research 2007. Dendrobium Area 3 Species Impact Statement, Prepared for BHP Billiton Illawarra Coal, Biosis Research Pty Ltd.

Biosis Research 2007. Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006, Biosis Research Pty Ltd.

Biosis Research, 2009. Revision of the Dendrobium Coal Mine Flora and Fauna Monitoring Program. February 2009.

Biosis Research, 2012. Elouera and Dendrobium Ecological Monitoring Program. Annual Monitoring Report Financial Year 2010/2011. August 2012.

Biosis Research, 2012. Swamp 15b TARP Assessment – Ecology. Ref:15462, 10 October 2012.

Biosis, 2014. Dendrobium Ecological Monitoring Program, Annual Report for 2012/2013 Financial Year. February 2014. Prepared for Illawarra Coal.

Biosis, 2015. Dendrobium Terrestrial Ecology Monitoring Program, Annual Report for 2014. September 2015. Prepared for Illawarra Coal.

Boughton W, 2004. The Australian water balance model. Environ Model Softw 19:943–956. doi: doi:10.1016/j.envsoft.2003.10.007.

Cardno, 2019. Aquatic Flora and Fauna Assessment. Illawarra Coal Holdings Pty Ltd, 29 May 2019

Cardno Ecology Lab, 2012. Aquatic Flora and Fauna Assessment. Prepared for BHPBIC, February 2012.

Cardno Ecology Lab, 2012. Swamp 15b and SC10C Aquatic Flora and Fauna Review. Ref: NA49913032, 5 October 2012.

Cardno Ecology Lab, 2013. Dendrobium Area 3A Aquatic Ecology Monitoring 2008-2012. Job Number: EL1112073 Prepared for BHP Billiton – Illawarra Coal, February 2013.

Cardno Ecology Lab, 2013. Review of Sandy Creek Pools Aquatic Flora and Fauna. 25 February 2013.

Cardno Ecology Lab, 2013. SC10C Level 3 Aquatic Ecology Trigger Assessment. 11 June 2013.

Cardno Ecology Lab, 2015. Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014. 30 March 2015.

Cardno Forbes Rigby, 2007. Landscape Impact Assessment and Monitoring Site Optimisation. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Area 3A Subsidence Management Plan Longwalls 6 to 10. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Dendrobium Area 3 Environmental Assessment. Prepared for BHPBIC.

Chafer, C., Noonan, M and Macnaught, E. 2004. The Post-Fire Measurement of Fire Severity and Intensity in the Christmas 2001 Sydney Wildfires. International Journal of Wildland Fire Vol. 13; pp. 227-240.

Chiew, F, Wang, Q. J., McConachy, F., James, R., Wright, W, and deHoedt, G. 2002. Evapotranspiration Maps for Australia. Hydrology and Water Resources Symposium, Melbourne, 20-23 May 2002, Institution of Engineers, Australia.

Coffey, 2012. Groundwater Study Area 3B Dendrobium Coal Mine: Numerical Modelling. GEOTLCOV24507AA-AB2 2 October 2012.

Ditton, S., and Merrick, N.P. 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle, NSW.

Doherty, J. 2010. PEST: Model-Independent Parameter Estimation User Manual (5th ed.): Watermark Numerical Computing, Brisbane, Queensland, Australia.

EarthTech Engineering Pty Ltd, 2005. Thresholds for Swamp Stability. Prepared for BHPBIC, January 2005.

The Ecology Lab, 2007. Dendrobium Area 3 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. October 2007.

Ecoengineers, 2006. Assessment of Surface Water Chemical Effects of Mining by Elouera Colliery. January - December 2005. February 2006.

Ecoengineers, 2006. Assessment of Catchment Hydrological Effects by Mining by Elouera Colliery Stage 1: Establishment of a Practical and Theoretical Framework. August 2006.

Ecoengineers, 2007. Surface Water Quality and Hydrology Assessment to Support SMP Application for Dendrobium Area 3.

Ecoengineers, 2010. End of Panel Surface and Shallow Groundwater Impacts Assessment Dendrobium Area 2 Longwall 5. Document Reference No. 2010/01A. April 2010.

Ecoengineers, 2012. Surface Water Quality and Hydrological Assessment: Dendrobium Area 3B Subsidence Management Plan Surface and Shallow Groundwater Assessment.

Ecoengineers, 2012. Level 2 TARP Independent Review and Recommendations Swamp 15b Dendrobium Area 3A. 25 September 2012.

Ecoengineers, 2013. Level 3 TARP Independent Review and Recommendations Sandy Creek Catchment Pool 7 (Dendrobium Area 3A). 12 February 2013.

Ecoengineers, 2013. Level 2 TARP Specialist Review and Recommendations Donalds Castle Creek. 22 May 2013.

Ecoengineers, 2014. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 9. June 2014.

Ecoengineers, 2015. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 10. February 2015.

Eco Logical Australia, 2004. The Impacts of Longwall Mining on the Upper Georges River Catchment: Report to Total Environment Centre, 2004.

Forster, 1995. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

GHD, 2007. Dendrobium Area 3A Predicted Hydrogeologic Performance. Report for BHP Billiton, Illawarra Coal. November 2007.

GSS Environmental, 2013. Baseline and Pre-Mining Land Capability Survey. Dendrobium Mine, Area 3B. February 2013.

Hazelton P.A. and Tille P.J., 1990. Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney.

Hebblewhite, 2010. BHP Billiton Illawarra Coal: Bulli Seam Operations Project – Independent Review. 31 March 2010.

Helensburgh Coal Pty Ltd, 2007. Submission to: Independent Expert Panel - Inquiry into NSW Southern Coalfield July 2007, Helensburgh Coal Pty Ltd.

Heritage Computing, 2009. Dendrobium Colliery Groundwater Assessment: Mine Inflow Review, Conceptualisation and Preliminary Groundwater Modelling. Merrick, N.P., Heritage Computing Report HC2009/2, February 2009.

Heritage Computing, October 2011. Recalibration of the Dendrobium Local Area Groundwater Model after Completion of Longwall 6 (Area 3A). Report prepared for Illawarra Coal. Report HC2011/13.

HGEO, 2019. Assessment of surface water flow and quality effects of proposed Dendrobium Longwalls 20 and 21. Report: D18301. May 2019.

HydroSimulations, 2014. Dendrobium Area 3B Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Sata. Report: HC2014/4 March 2014.

HydroSimulations, 2019. Dendrobium Mine Longwalls 20 and 21 Groundwater Assessment. Prepared for Illawarra Coal Pty Ltd. May 2019.

Illawarra Coal, 2014. Longwall 9 End of Panel Report.

Illawarra Coal, 2015. Longwall 10 End of Panel Report.

Kirchner, J. W. 2009. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modelling, and doing hydrology backwards. Res., W02429.

Manly Hydraulics Laboratory, 2006. BHP Billiton Dendrobium Mine Area 2 Subsidence Environmental Management Plan Water Monitoring and Management Program. Prepared for BHPBIC. Version 1.4 January 2006.

McMahon, 2014. Dendrobium Community Consultative Committee Report: Review of Surface Water Study. An independent review of surface water hydrological modelling associated with Illawarra Coal's Dendrobium Area 3, conducted by Emeritus Professor Thomas McMahon, University of Melbourne. 4 June 2014.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

MSEC, 2019. Dendrobium mine – Area 3C. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 20 and 21 in Area 3C at Dendrobium Mine. MSEC978 August 2019.

Niche Environment and Heritage, 2019a. Aboriginal Cultural Heritage Assessment Report. Prepared for South 32 Illawarra Coal Operations. September 2019.

Niche Environment and Heritage, 2019b. Dendrobium Longwalls 20-21 Terrestrial Ecological Assessment. South 32 Illawarra Coal. 20 August 2019.

OEC, 2001. Environmental Impact Statement Dendrobium Coal Project. Olsen Environmental Consulting, Figtree, N.S.W.

Parkhurst. D.L., and Appelo, C.A.J. 2012. Description of Input and Examples for PHREEQC Version 3 – A Computer Program for Speciation, Batch-Reaction, One- Dimensional Transport and Inverse Geochemical Calculations. US Department of Interior/US Geological Survey.

Parson Brinckerhoff, 2012. Independent Review of Dendrobium Area 2 and 3A Hydrochemical Data. August 20012.

Parsons Brinckerhoff, 2015. Connected fracturing above longwall mining operations, Part 2: Post-longwall investigation. For BHP Billiton Illawarra Coal. Document number 2172268F-WAT-REP-002 RevB. 6 March 2015.

Petersen, 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology Vol 27, Issue 2, April 1992.

Resource Strategies, 2009. Bulli Seam Operations Environmental Assessment. Report in support of an application for the continued operations of the Appin and West Cliff Mines.

Singh & Kendorski, 1981. Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments, Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Tammetta, P. (2013). Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater, 51(5), 723-734.

Tomkins, K.M. and Humphries, G.S. 2006. Technical report 2: Upland Swamp development and erosion on the Woronora Plateau during the Holocene. January 2006. Sydney Catchment Authority – Macquarie Collaborative Research Project.

Waddington, A.A. and Kay, D.R. 2001. Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs. Gorges and River Systems. Final Report on ACARP Research Project C8005, March 2001.

Waddington, A.A. and Kay, D.R. 2002. Management Information handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Zhang, L. Dawes, W.R. and Walker, G.R. 1999. Predicting the effect of Vegetation Changes on Catchment Average Water Balance. Technical Report No. 99/12, Cooperative Research Centre for Catchment Hydrology.

Appendix 1 – Longwalls 20 and 21 -Approved Mine Plan DEN-01-7114.

	MGA E	MGA N
A	290233.220	6195895.014
B	290638.325	6195797.956
C	290285.000	6194323.228
D	290608.720	6194245.669
E	290629.125	6194602.738
F	290874.546	6194585.863
G	290866.026	6194461.955
H	291833.905	6194346.257
I	291844.587	6194435.621
J	291963.109	6194421.453
K	291881.457	6193738.389
L	291817.320	6193751.168
M	291838.240	6193926.173
N	290619.137	6194070.641
O	290603.246	6193929.989
P	289230.917	6194094.513
Q	289230.917	6194302.201
R	289712.542	6194245.090
S	289896.778	6194490.756

LEGEND

EXISTING WORKINGS

PROPOSED WORKINGS FOR THIS APPLICATION

PROPOSED EXTRACTION APPLICATION AREA

PREVIOUS EXTRACTION APPROVALS

I hereby certify the accuracy of the plan.

....
Registered Mining Surveyor Date

I hereby accept the information on the plan.

....
Manager of Mining Engineering Date

SCALE IN METRES

0 100 200 300 400 500 600 700 800 900 1000

Dendrobium Mine
Illawarra Coal
Cordeaux Rd, Mt Kembla, NSW, 2526, Australia
ABN 85 098 744 088

SOUTH32

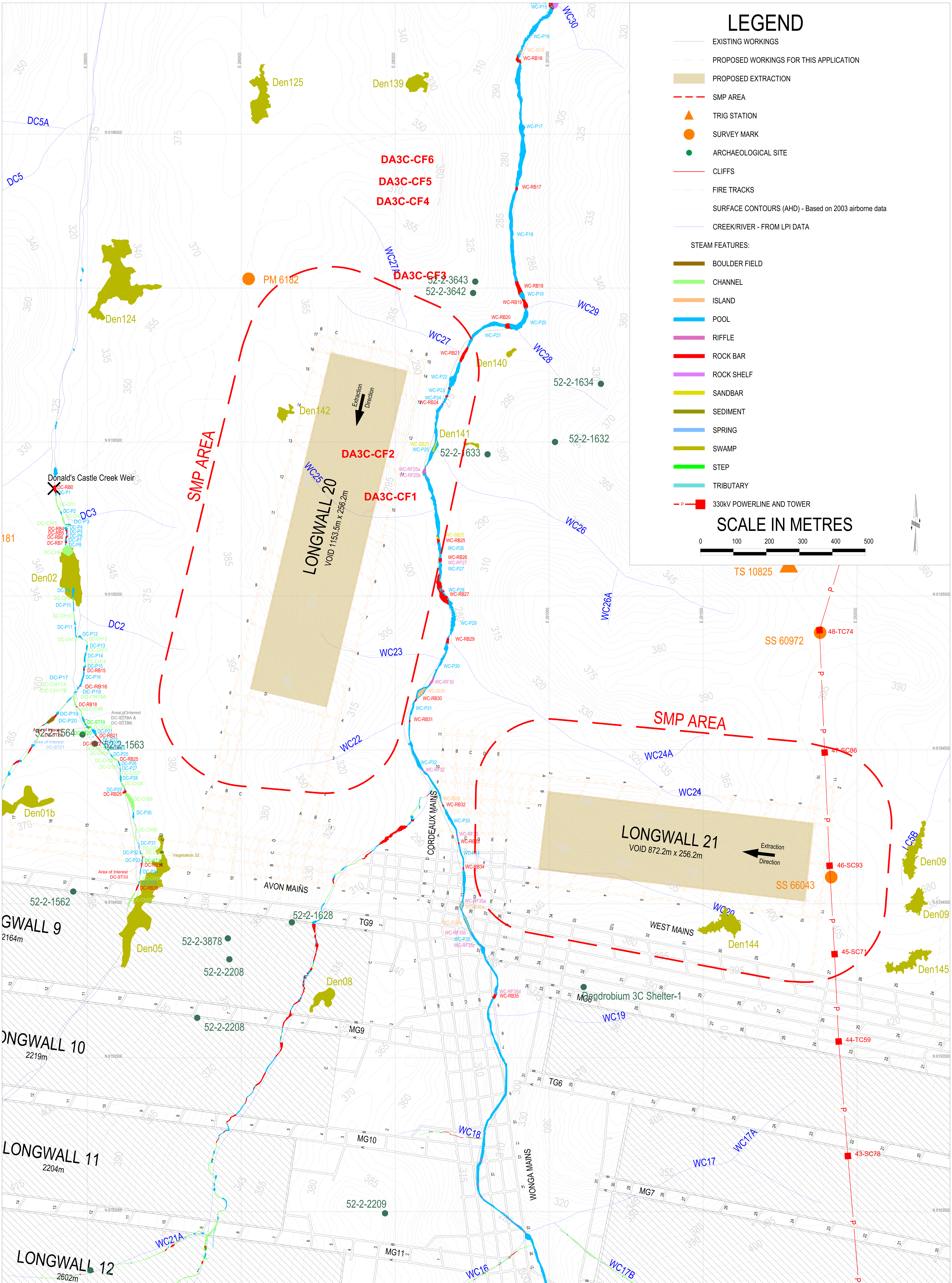
	Name	Date
DRN	P.Naughton	22/08/2019
REV		
APP		
SCALE	1:3750 @ A0	

Title: Dendrobium Mine Longwalls 20 & 21 Subsidence Managment Plan Approved Plan

DRAWING NUMBER DEN-01-7114

REV 2

Appendix 2 – Longwalls 20 and 21 - Surface Features DEN-01-7116.



Dendrobium Mine
Illawarra Coal
Cordeaux Rd, Mt Kembla, NSW, 2526, Australia
ABN 85 098 744 088
SOUTH32

	Name	Date
DRN	P.Naughton	05/09/2019
REV		
APP		
SCALE	1:3750 A0	

Title: Dendrobium Mine Longwalls 20 & 21
Subsidence Management Plan
Plan 2 - Surface Features

DRAWING NUMBER: DEN-01-7116

REV: 2

Appendix 3 – Swamp Impact Management, Monitoring and Contingency Plan

SOUTH32

DENDROBIUM
AREA 3C

NOVEMBER 2019

AREA 3C

SWAMP IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

Table of Contents

Tables

Figures

Attachments

Review History

Revision	Description of Changes	Date	Approved
A	New Document	September 2019	GB
B	Minor updates	September 2019	GB
C	Figure updates	November 2019	GB

Persons involved in the development of this document

Name	Title	Company
Josh Carlon	Environmental Coordinator	Illawarra Metallurgical Coal
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Gary Brassington	Manager Approvals	Illawarra Metallurgical Coal

1 INTRODUCTION

1.1 Project Background

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

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007, IMC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of s75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

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

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

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

1.2 Scope

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

> 6. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:
>
> (a) demonstrate how the subsidence impact limits in condition 5 are to be met;
>
> (b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) of each Area 3A Longwall on Swamp 15a;
>
> (c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;
>
> (d) include a management plan for avoiding, minimising, mitigating and remediating impacts on swamps, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;
>
> (e) address headwater and valley infill swamps separately and address each swamp individually;
>
> (f) be prepared in consultation with DECC, SCA and DPI;
>
> (g) incorporate means of updating the plan based on experience gained as mining progresses;
>
> (h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on swamps in the relevant Area; and
>
> (i) be implemented to the satisfaction of the Secretary.

1.3 Study Area

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

- The 35° angle of draw line from the extents of the proposed Longwalls 20 and 21;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed longwalls; and
- The natural features located within 600 m of the extent of the longwall mining area, in accordance with *Condition 8(d)* of the Development Consent.

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

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method (IPM), which is described in MSEC (2019).

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

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

The swamps located outside the extent of longwall mining which could experience far-field or valley related movements, and could be sensitive to these movements, have been identified and included in the assessments provided in this report.

This SIMMCP applies to Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 within the Dendrobium Area 3C mining domain. Swamp 15a, as defined in the Dendrobium Area 3 Modified Approval (*Schedule 3, Conditions 5, 6a and 6b*), is not within the defined area of study relative to the proposed extents of Longwalls 20 and 21.

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

1.4 Objectives

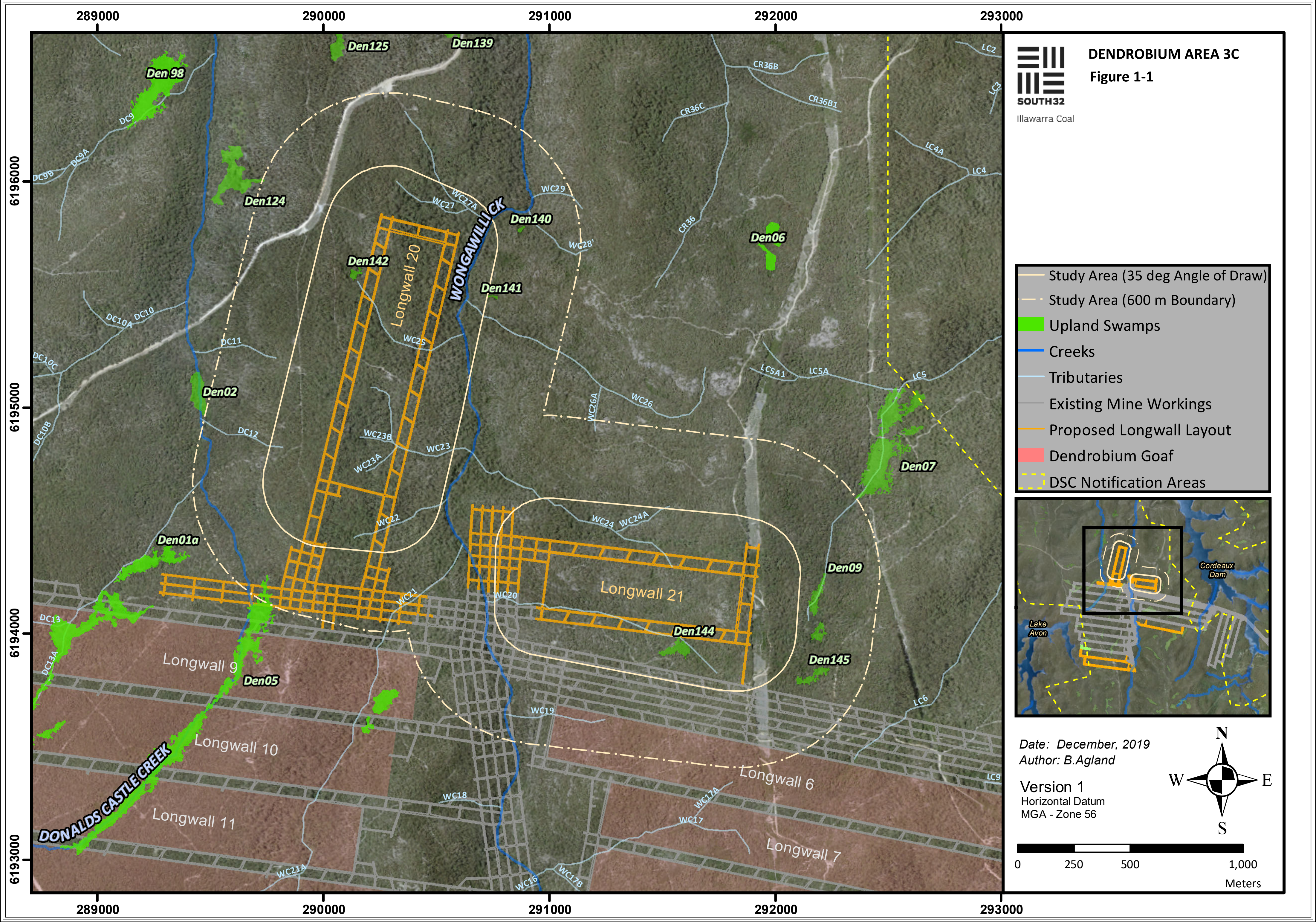
The objectives of this SIMMCP are to identify swamp features and characteristics within the Dendrobium Longwalls 20 and 21 Study Area (**Figure 1-1**:) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on swamps.

1.5 Consultation

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

- Department of Planning, Infrastructure and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]);
- Biodiversity Conservation Division (BCD) within DPIE (formerly the Office of Environment and Heritage [OEH]); and
- Water NSW.

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


DENDROBIUM AREA 3C
Figure 1-1
SOUTH32
Illawarra Coal
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Date: December, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
Cordeaux Dam
Lake Avon
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den06
Den02
Den07
Den01a
Den09
Den144
Den145
Den05
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000

2 PLAN REQUIREMENTS

Extraction of coal from Longwalls 20 and 21 will be in accordance with the conditions set out in the Dendrobium Development Consent as well as conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence from the extraction of Longwalls 20 and 21. The baseline studies have identified monitoring sites in these areas based on the Before After Control Impact (BACI) design criteria.

A comprehensive monitoring program for swamps is outlined in this SIMMCP (**Attachment 1: Table 1.1**).

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

2.1 Dendrobium Modified DA60-03-2001 Approval

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 Modified DA-60-03-2001 Approval Conditions

Project Approval Condition	Relevant SIMMCP Section
Condition 5 – Schedule 3 The Applicant shall ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rock-bar is maintained or restored, to the satisfaction of the Secretary.	Not Applicable to Area 3C
Condition 6 – Schedule 3 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in condition 5 are to be met;	Not Applicable to Area 3C
(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and DPI of the subsidence effects and impacts (individual and cumulative) of each Area 3A Longwall on Swamp 15a;	Not Applicable to Area 3C
(c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;	Section 5 and Attachment 1
(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 5 and Attachment 1
(e) address headwater and valley infill swamps separately and address each swamp individually;	Section 4
(f) be prepared in consultation with DECC, SCA and DPI;	Section 1.5
(g) incorporate means of updating the plan based on experience gained as mining progresses;	Section 8.5 Section 1.4

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

2.2 Leases and Licences

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

- Dendrobium Mining Lease as shown in **Table 2-2**;
- 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 Approval.

Table 2-2 Dendrobium Leases

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

3 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium modified Consent (2008). These performance measures will be applied to the extraction of Longwalls 20 and 21.

Table 3-1 Subsidence Impact Performance Measures

Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145
Minor environmental consequences including: • negligible erosion of the surface of the swamps; • minor changes in the size of the swamps; • minor changes in the ecosystem functionality of the swamp; • no significant change to the composition or distribution of species within the swamp; and • maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.

A detailed list of performance measures and triggers is included in the TARPs in **Attachment 1**.

3.1 Impact Mechanisms

Subsidence is a direct consequence of longwall mining, which involves vertical and horizontal movement of the land surface. Further detail on subsidence movements and mechanisms can be found in MSEC 2019. Subsidence effects include surface and sub-surface cracking, buckling, dilation and tilting. The level of subsidence movements and effects are sensitive to:

- the depth of cover of the strata over the mining area;
- the geology and landform of the mining area;
- the width of the longwall panel;

- the height of the seam extracted; and
- the proximity of the longwall mining to any area of interest.

Subsidence effects can result in changes to the hydrology of streams and groundwater dependent ecosystems such as upland swamps. There are two broad mechanisms by which subsidence could cause changes in swamp hydrology:

- Subsidence-induced cracking in the bedrock beneath the swamp results in water drainage into the fracture zone. The extent and permanence of these changes relate to the size of the fracture zone (increase in porosity/storage) and whether the fractures are connected to a deeper aquifer, the mine workings or bedding shear pathway to the surface lower in the catchment.
- Tilting, cracking, desiccation and/or changes in vegetation health result in concentration of runoff and erosion which alters water distribution in the swamp.

Changes to swamp hydrology can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The environmental consequences which could relate to changes in hydrology include:

- Increased rates or frequency of erosion events.
- Increased extent or frequency of fire events resulting in the organic components of the swamp soil profile to burn during intense bushfires.
- Increased rates of species composition change and/or changes in vegetation communities.

3.2 Potential for Connectivity to the Mine Workings

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

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

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

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

The results of water analysis and the interpretation of the height of connective fracturing was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux". Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield. On the basis of the available data and the Parson Brinckerhoff (2012) review it is considered that the height of desaturation used by Heritage Computing (2009 & 2011) is conservative.

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

- Assess the level of detail, quality of science, depth and technical appropriateness of the water chemistry data.

- Evaluate associated interpretations in relation to underground operations of Dendrobium Mine, with specific focus on how these address the question of hydraulic connectivity between the mined areas and the reservoirs.

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

As reported in Coffey (2012) most of the change in aquifer properties occurs within the collapsed zone. Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storativity. Groundwater drawdown due to sudden storativity increases will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow.

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

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

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

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

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

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

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

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

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

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

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

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

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

- The effects of longwall mining and subsidence on overburden strata;
- A summary of previous research in relation to estimating the extent of the deformed strata above longwall mining, both in general and at Dendrobium;

- Revised estimates of the height of connected fracturing for Dendrobium longwalls using the Ditton ‘Geology Model’ (Ditton and Merrick, 2014) and the Tammetta (2013) method.

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

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

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

The PSM report appears to be limited by the fact that they may not have had access to all data or may simply have lacked time to check all available data and literature. Importantly, the analysis of mine water chemistry (water fingerprinting) is not given due regard. Scientific method should always consider multiple lines of evidence where these are available.

HydroSimulations believe there is a flaw in PSM’s hydrogeological conceptual model, which leads to some errors in their conclusions about the extent of connective fracturing. PSM seems to have assumed vertical connected fracturing on the strength of pressure reductions at piezometers, when pressure reductions could occur due to several factors, including increased horizontal permeability, increased porosity or increasing downward hydraulic gradient due to depressurisation in the goaf.

The IEP (2018) undertook an independent analysis and concluded: *notwithstanding that uncertainty is associated with both the Tammetta and the Ditton height of complete drainage equations, it is recommended to err on the side of caution and defer to the Tammetta equation until field investigations quantify the height of complete drainage at the Dendrobium Mine*.

The Regional Groundwater Model for Dendrobium Mine has been revised to consider the findings of the PSM report and IEP (2018), 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.

3.3 Potential for Fracturing Beneath the Swamps

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2012, 2015 and 2019) the bedrock below the swamps and any significant permanent pools within the swamps are likely to fracture as a consequence of subsidence induced strains.

Surface flows captured by the surface subsidence fracture network resulting from valley related movements which do not connect to a deeper aquifer or the mine workings will re-emerge further downstream (see Section 3.2). This prediction is based on an assessment of the depth of valley closure induced vertical fracturing from the surface and measurements of water balance during the modelled periods of recessional, baseflow and small storm unit hydrograph periods downstream of mining areas.

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

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

- Calliper logging;
- Straddle packer permeability testing;
- Overcore stress measurements;
- Core logging and geotechnical testing;

- Geophysical testing;
- Water level monitoring;
- Borehole cameras;
- Subsidence, extensometer monitoring and shear deformation monitoring;
- Stress change and fracture logging;
- Permeability testing and falling head tests; and
- Mapping of pressured air drilling fines.

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

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

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

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

The effects of mining on surface water flow following the completion of Longwall 13 was modelled and assessed in the Longwall 13 End of Panel Report. This assessment has identified that mining-related effects on the flow regime have occurred in tributaries to Donalds Castle Creek (DCS2, DC13S1), and in Lake Avon tributary LA4. There is also a possible change to runoff characteristics at the downstream gauge of Donalds castle Creek (DCU) and Wongawilli Creek (WWL). Surface fracturing was noted in the channel of tributary WC15 during Longwall 13; however, flow characteristics at the downstream gauge (WC15S1) are not significantly different from baseline.

This suggests that, within the limitations of the monitoring, a high proportion of diverted flow in Wongawilli Creek headwater catchments is returned downgradient. Modelling also suggests that high flows in the mined under catchments are less affected than the lower, recession-limb flows.

3.4 Potential for Erosion Within the Swamps

Tilting, cracking, desiccation and/or changes in vegetation health could result in concentration of runoff and erosion which intern could alter water distribution in the swamp. Changes to swamp hydrology can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The environmental consequences which could relate to changes in hydrology include:

- Increased rates or frequency of erosion events;
- Increased potential for the organic components of the swamp soil to burn during intense bushfires; and
- Increased rates of species composition change and/or changes in vegetation communities.

Subsidence predictions were carried out to assess the potential impacts of longwall mining in Area 3B. The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the swamps is provided in Table 4-2.

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

Changes in gradients predicted to occur following mining are discussed in Section 4.3.1. These changes have been considered in relation to the likelihood of change in drainage line alignment by MSEC (2012, 2015 and 2017). The assessment takes into account the nature of the drainage channel and whether the predicted tilt is significant when compared to the existing slopes.

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

The observed impacts on natural features above Longwalls 1 – 13 have been generally consistent with those predicted in the assessments undertaken prior to mining.

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

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

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

3.5 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.

4 PREDICTED IMPACTS TO UPLAND SWAMPS

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

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

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

Non-conventional movements can also occur, and have occurred, in the NSW Coalfields as a result of, amongst other things, anomalous movements, valley closure and downslope movements. Many of the swamps are located in the bases of drainage lines and, therefore, could experience valley and slope related movements. The predicted valley related movements are provided in MSEC978 (2019). The maximum valley related movements are predicted to occur in the bases of the streams within the extents of the Valley Fill Swamps. The Headwater Swamps are located partly up the valley sides and, therefore, in these cases the predicted valley related movements (upsidence and closure) for these swamps are less than the maxima provided in MSEC978 (2019).

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

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

In accordance with the findings of the Southern Coalfield Inquiry and the IEP (2018):

- **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.

4.1 Description of Upland Swamps Within the Study Area

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

The northern end of Swamp 144 is located above the tailgate (i.e. southern) edge of Longwall 21. The remaining swamps are located outside the extents of the proposed longwalls. A summary of the swamps that are located within the Study Area, based on the 600 m boundary, is provided in . 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 4-1: Swamps located within the Study Area based on the 600 m boundary

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

4.2 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 . The values are the maxima within 20 m of the mapped extents of each of the swamps within the Study Area due to the extraction of the existing longwalls in Area 3B and the proposed Longwalls 20 and 21. The section of Swamp 5 that is located above the previously extracted Longwall 9 in Area 3B has not been included in this table as it is located outside the Study Area.

Table 4-2: Maximum predicted total vertical subsidence, tilt and curvatures for the swamps

Reference	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Swamp 2	< 20	< 0.5	< 0.01	< 0.01
Swamp 5	< 20	< 0.5	< 0.01	< 0.01
Swamp 7	< 20	< 0.5	< 0.01	< 0.01
Swamp 9	< 20	< 0.5	< 0.01	< 0.01
Swamp 124	< 20	< 0.5	< 0.01	< 0.01
Swamp 140	< 20	< 0.5	< 0.01	< 0.01
Swamp 141	< 20	< 0.5	< 0.01	< 0.01
Swamp 142	30	1.0	0.05	< 0.01
Swamp 144	30	1.0	0.05	< 0.01
Swamp 145	< 20	< 0.5	< 0.01	< 0.01

Swamps 142 and 144 are predicted to experience 30 mm vertical subsidence due to the extraction of Longwalls 20 and 21. The maximum predicted tilt is 1 mm/m (i.e. 0.1 % or 1 in 1000). The maximum predicted curvature is

0.05 km^{-1} hogging, which represents a minimum radius of curvature of 20 km. The maximum predicted conventional strains for this swamp, based on applying a factor of 15 to the maximum predicted curvatures, are 1 mm/m tensile and less than 0.5 mm/m compressive.

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

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

Swamps 2 and 5 are located near the base of the valley for Donalds Castle Creek; Swamps 7 and 9 are located along Stream LC5B; Swamp Den142 is located at the upper reaches of Stream WC25; and Swamp 144 is located along Stream WC20. These swamps could experience valley-related effects due to the extraction of the proposed longwalls. The remaining swamps within the Study Area are located further up the valley sides and, therefore, are unlikely to experience upsidence or compressive strain due to valley closure effects.

A summary of the maximum predicted total upsidence and closure for the swamps within the Study Area is provided in . The values are the maxima within 20 m of the mapped extents of each of the swamps within the Study Area due to the extraction of the existing longwalls in Areas 3A and 3B and the proposed Longwalls 20 and 21.

Table 4-3: Maximum predicted total upsidence and closure for the swamps

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

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

4.3 Impact Assessment

4.3.1 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.

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

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

The remaining swamps within the Study Area are located on or outside the Study Area based on the 35° angle of draw. These swamps are predicted to experience tilts of less than 0.5 mm/m (i.e. less than 0.5 %, or 1 in 2000). It is unlikely, therefore, that these swamps would experience adverse changes in the levels of ponding or scouring based on the predicted vertical subsidence and tilt.

4.3.2 Potential for cracking in Upland Swamps and fracturing of bedrock

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

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

The estimated fracture widths in the bedrock beneath the Swamps 142 and 144, based on the maximum predicted conventional tensile strain of 1 mm/m and a typical joint spacing of 10 m, is in the order of 10 mm. Wider fractures could develop if the compressive strains due to the valley closure effects result in localised failure of the bedrock. Fracture widths in the order of 20 mm to 50 mm have been observed due to valley closure effects at similar distances from previous longwall mining. It is possible that a series of smaller fractures, rather than one single fracture, could develop in the bedrock. Fracturing would only be visible at the surface where the bedrock is exposed, or where the thickness of the overlying soil is relatively shallow.

Swamps 142 and 144 are predicted to experience upsidence movements of 40 mm and 50 mm, respectively. These valley related upsidence movements could result in the dilation of the strata beneath these swamps. It has been previously observed that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, is generally in the order of 10 m to 15 m (Mills 2003, Mills 2007, and Mills and Huuskes 2004).

The dilated strata beneath the drainage lines, upstream of Swamps 142 and 144, could result in the diversion of some surface water flows beneath parts of these swamps. The drainage lines upstream of these swamps flow during and shortly after rainfall events. On the basis that there is no connective fracturing to any deeper storage, it is likely that surface water flows will re-emerge at the limits of fracturing and dilation.

The remaining swamps are located outside the proposed longwalls at minimum distances ranging between 230 m and 600 m. These swamps are predicted to experience additional movements, due to Longwalls 20 and 21, of less than 20 mm vertical subsidence, less than 20 mm upsidence and up to 20 mm closure. These swamps are predicted to experience tensile strains less than 0.5 mm/m and compressive strains less than 2 mm/m due to the extraction of the proposed Longwalls 20 and 21. It is unlikely, therefore, that the bedrock beneath these swamps would experience significant fracturing.

Fracturing has been observed in streams located outside the extents of previously extracted longwalls in the NSW coalfields. Fracturing has been observed in the drainage lines at the Mine at distances of up to 290 m from the previously extracted longwalls in Area 3B. Minor and isolated fracturing has also been observed up to 400 m outside of longwalls extracted elsewhere in the Southern Coalfield.

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

4.3.3 Potential changes to Upland Swamp Hydrology

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

- A decrease in the average shallow groundwater elevation;
- A decrease in the duration of saturation of the swamp sediments following a significant rainfall event; or
- A change in the shape of saturation peak and recession curves in response to significant rainfall events (HGEO 2019).

Analyses from the Longwall 13 End of Panel Report indicate that almost all piezometers that are directly mined under by longwalls extracted in Dendrobium Area 3A and 3B showed responses to mining. Swamps located within the zone of influence of mine subsidence (< 400 m) may display hydrological change but are less likely to be affected with increasing distance from the longwall (HGEO 2019). A recent assessment at Dendrobium Mine concluded that hydrological change in Upland Swamps is not evident in shallow groundwater piezometers located more than 60 m from the extracted longwall margin (Watershed Hydrogeo, 2019).

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

Swamp	Area (Ha)	Vegetation communities	Distance from LW20/LW21 goaf (m)	Likelihood of shallow groundwater effects
Swamp 2	0.96	Banksia thicket, Tea-tree thicket	600	Unlikely
Swamp 5	1.71	Banksia thicket, Tea-tree thicket, Restioid Heath	550	Unlikely (previously impacted by LW9)
Swamp 7	5.67	Banksia thicket, Tea-tree thicket	595	Unlikely
Swamp 9	0.80	Banksia thicket, Tea-tree thicket	300	Possible
Swamp 124	2.10	Sedge-Heath Complex, Restioid Heath, Tea-tree thicket	590	Unlikely
Swamp 140	0.05	Banksia thicket	330	Possible
Swamp 141	0.04	Banksia thicket	230	Possible
Swamp 142	0.16	Banksia thicket	70	Possible
Swamp 144	0.54	Banksia thicket	50	Likely
Swamp 145	0.45	Banksia thicket	336	Possible

4.3.4 Potential impacts on Upland Swamp Ecology

Vegetation communities which are not dependent on groundwater are unlikely to be impacted by subsidence due to underground mining (Niche 2019).

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

Riparian vegetation may be 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 2019).

An assessment of the potential ecological impacts of subsidence on Upland Swamps was completed by Niche (2019), summarised below (**Table 4-5)**.

Table 4-5: Ecological impact predictions for upland swamps within and adjacent to the study area (Niche 2019); subsidence predictions from MSEC (2019)

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2019)	Conclusion (Niche 2019)
Swamp 2	Moderate size and complexity.	Edge of swamp within 600 m. Very minor parts of inflow tributaries within angle of draw.	Low likelihood of subsidence impacts given distance from longwalls of the swamp and its tributaries.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
Swamp 5	Large complex swamp.	Small section of swamp within 600 m. Previous direct	Low likelihood of additional subsidence impacts given distance from longwalls of the	Unlikely to be measurable additional impacts to this swamp or associated species

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2019)	Conclusion (Niche 2019)
		undermining (LW9 to 11).	swamp and its tributaries. Previous longwall mining directly below this swamp impacted the swamp (Biosis 2016).	including threatened species from the current proposal. Monitoring of impacts likely to be confounded from previous direct undermining (LW 9 to 11).
Swamp 7	Large complex swamp with pools observed within or on edges of swamp.	Small section of swamp within 600 m. No part of mapped predominant inflow tributary within angle of draw.	Low likelihood of subsidence impacts given distance from longwalls of the swamp and minor proportion of tributaries within angle of draw. The predicted post-mining grades within the swamps are similar to the natural grades and, therefore, it is not expected that there would be adverse changes in ponding or scouring within the Swamps due to tilt (MSEC 2019). It is noted that a track passes through a section of the swamp.	Unlikely to be measurable impacts to this swamp or associated species including threatened species from the current proposal. The swamp will be monitored for potential impacts.
Swamp 9	Small swamp in two sections – moderately complex. Northern section is along or adjacent to ephemeral watercourse.	Between angle of draw and 600 m study area.	Significant fracturing of the bedrock is not expected to occur nor dilation of strata within a predominant upstream tributary. Possibility of some minor subsidence impacts.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
Swamp 124	Large complex swamp. Offline from major watercourse of Donalds Castle Creek.	Small section of swamp within 600 m. Feeding tributaries within 600 m or previously mined areas.	Low likelihood of subsidence impacts given distance from longwalls of the swamp and its position offline of streams.	Unlikely to be measurable impacts to this swamp or associated species including threatened species.
Swamp 140	Small simple swamp, no noticeable pools or watercourses adjacent.	Between angle of draw and 600 m study area.	Possibility of some minor subsidence impacts. Fracturing of the bedrock is not expected to occur nor dilation of strata within a predominant upstream tributary.	While some subsidence impacts are possible, these may not be measurable. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.
Swamp 141	Small simple swamp, no noticeable pools or watercourses adjacent.	Small section of swamp within angle of draw.	Possibility of some subsidence impacts. Fracturing of the bedrock may occur along with dilation of strata.	While some subsidence impacts are possible, these are unlikely to be significant. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values

Swamp	Swamp characteristics	Position	Subsidence predictions (MSEC 2019)	Conclusion (Niche 2019)
				given its size, complexity and lack of pooling habitat.
Swamp 142	Small simple swamp at headwater of WC25.	Within angle of draw.	Fracturing of the bedrock is expected to occur along with dilation of strata within an upstream tributary. This may lead to groundwater changes within the swamp.	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog). Areas may trend towards Fringing Eucalypt Forest if changes are long-term. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.
Swamp 144	Small simple swamp along ephemeral watercourse (WC20)	Swamp within angle of draw.	Fracturing of the bedrock is expected to occur along with dilation of strata within an upstream tributary. This may lead to groundwater changes within the swamp.	Possible ecological impacts including changes in vegetation and threatened species habitat (predominantly for Littlejohn's Tree Frog). Areas may trend towards Fringing Eucalypt Forest if changes are long-term. Swamp is small and simple, however is likely to contribute to Littlejohn's Tree Frog population downstream and or within the swamp.
Swamp 145	Small simple swamp at headwater of watercourse.	Between angle of draw and 600 m study area.	Possibility of some minor subsidence impacts. Fracturing of the bedrock is not expected to occur nor dilation of strata within a predominant upstream tributary.	While some subsidence impacts are possible, these may not be measurable. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.

4.3.4.1 Potential Impacts to Threatened Flora

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

Four species (*Epacris purpurascens var. purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius*) are considered to have habitat within the study area that may be 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.

4.3.4.2 Potential Impacts to Fauna

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

Woodland and forest habitat types make up the majority of the study area. These habitat types which are not dependent on groundwater are unlikely to be impacted by subsidence. Microhabitat features such as tree hollows and exfoliating bark are also unlikely to be impacted (Niche 2019).

4.3.4.3 Potential Impacts to Threatened Fauna

Fifty-four threatened fauna were considered during likelihood of occurrence assessment. Thirty-seven of these species were determined to have a moderate or high likelihood of occurrence within the study area. Subsidence impacts from the proposed longwalls are likely to be negligible for the majority of these species (Niche 2019). Nine threatened species are considered to be potentially impacted by subsidence impacts resulting from the proposal (Niche 2019).

An assessment of potential impacts from the current proposal, for each of the identified threatened species likely to be impacted, is provided in the Area 3C Terrestrial Ecology Assessment (Niche 2019).

5 MONITORING

5.1 Subsidence Monitoring

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

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

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

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

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

5.2 Area 3C Swamps

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

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

Table 5-1: Summary of Swamps within the Area 3C Study Area.

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

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

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

5.3 Observational and Photo Point Monitoring

IMC has conducted ongoing monitoring of upland swamps in the Dendrobium area since 2003. This monitoring builds upon the understanding of processes within the swamps, along with identifying and assessing any episodic or temporal changes. This monitoring (along with other monitoring programs described in the SIMMCP) is consistent with (in part) *Schedule 3, Condition 6* of the Modified Development Consent "*include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function*".

The IMC Environmental Field Team 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 **Attachment 1: Table 1.1**. Additional monitoring within Dendrobium Area 3C will be installed ahead of longwall mining to achieve 2 years baseline data (subject to timing and approval timeframes of any request to install additional monitoring).

Sites are monitored before and after mining and sites that will not be mined under are also monitored for the same parameters to provide a comparison of sites mined under and sites not mined under during different climatic conditions.

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

- Impact sites;
    - Swamps 2 and 7 (previously reference sites for Area 3B);
    - Swamps 5, 9, 124, 140, 141, 142, 144 and 145;
- Reference sites:
    - Swamps 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88.

5.4 Water Quality

Monitoring undertaken by IMC since 2003 includes water quality monitoring of parameters such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si).

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3C will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from the Area 3C mining are monitored to allow for a comparison to sites not influenced by mining.

Water quality monitoring is covered in detail in the WIMMCP.

5.5 Groundwater

A specialist Groundwater Assessment is provided in **Attachment B** (HydroSimulations 2019). An existing groundwater monitoring program is in place for Dendrobium, which includes Area 3C (**Figure 5-3**).

Groundwater monitoring is undertaken in:

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

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

Monitoring pore pressures at Dendrobium Mine uses vibrating wire piezometers installed at different depths within the same borehole, thereby creating a vertical array which can be used for 3D mapping and analysis of the pore pressure regime (IEP 2018). Before and after mining piezometers are routinely installed along the centreline of longwall panels to identify the maximum groundwater effects and the height of free drainage within the subsidence zone.

To investigate groundwater-surface water dynamics in Wongawilli Creek, two monitoring bores are proposed to be installed between the creek and the proposed longwalls, preferably within the Wongawilli Creek valley (contingent on access and approvals). The boreholes would be installed in the Hawkesbury Sandstone and upper Bulgo Sandstone and the data would be paired with surface water flow data from Wongawilli Creek monitoring sites.

5.6 Surface Water Levels and Flows

Pool water levels in swamps and associated streams are measured using installed benchmarks in impact sites and reference sites. Not all swamps have pool features within their boundary. Within the Longwalls 20 and 21 study area, pool water levels are measured within or adjacent to the following swamps:

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

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

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

5.7 Near-Surface Groundwater and Soil Moisture

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

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers are proposed to be installed within several swamps in Area 3C (**Figure 5-1**). Within Area 3C long-term piezometer records are available for Swamp 2 (Donalds Castle Creek) and Swamp 7 (LC5 – Lake Cordeaux tributary). Swamps 15a (SC10), 22, 24, 25, 33 (WC11), 84 (SC9A), 85 (DC10), 86, 87 and 88 (Gallahers Creek) are established reference monitoring sites and will continue to be monitored. This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Reference sites are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles up to a maximum depth of 1.2 m. Key monitoring sites will be installed with loggers to provide a continuous soil moisture record (**Figure 5-1**).

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

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

5.8 Pools and Controlling Rockbars

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

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

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

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

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (**Figure 5-4**).

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

The largest watercourse within the Study Area is Wongawilli Creek, which is located between Areas 3A and 3B; and between Longwalls 20 and 21. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west.

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

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

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

Rockbars and pools in Donalds Castle and Wongawilli Creeks have been mapped (**Figure 5-4**). All mapped rockbar controlled pools in Wongawilli Creek are significant permanent pools.

5.9 Slopes and Gradients

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

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

The inspections and monitoring includes the following monitoring sites:

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

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

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

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

- Slope;
- Morphological type;

- Dimensions;
- Mode of geomorphological activity; and
- Geomorphological agent.

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

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

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

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

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

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

5.10 Erodibility

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

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

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

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

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

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

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

5.11 Flora, Fauna and Ecosystem Function

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

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

Annual Reporting (Biosis 2016, Biosis 2017 and Biosis 2018) documents the ecological monitoring program undertaken within Dendrobium Areas 2 (11 years), 3A (8-14 years) and 3B (4 years). Subsidence related impacts following mining in these areas include lowering of shallow groundwater in uplands swamps and loss or alteration in the quality of pool water for first and second order streams.

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence will be implemented in the Area 3C Study Area. The monitoring program will be based on a BACI design, as implemented in Area 3B, with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction (**Figure 5-1**).

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

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

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

5.11.1 Ecosystem Function

The upland swamps in the Study Area fit the description of Coastal Upland Swamps in the Sydney Basin Bioregion, which has been listed as an EEC under the TSC Act (Niche 2012). 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.

The term 'ecosystem functionality' is included in Table 1 of *Condition 9* of the SMP Approval. The term is not included in the definitions of the Approval. It is proposed that the 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 5-2**).

Table 5-2: Upland Swamps and associated sub-communities within the Study Area (Niche 2019)

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

Mapping will be replicated prior to mining (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.

5.11.2 Swamp Size

Detailed mapping of the boundaries of the swamps and vegetation sub-communities has been undertaken for Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145 (Terrestrial Ecological Assessment, Niche 2019). Three reference swamps have been mapped previously: Swamp DC10 (Swamp 85), Swamp 15a (1) and 33. These swamps were selected based on size, similar vegetation sub-communities, geographic proximity and a lack of previous mining near them.

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

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

Any change in the total area of a swamp will be compared to its pre-mining area and any change in area of reference swamps (**Figure 5-2**).

5.11.3 Flora - Composition and Distribution of Species

5.11.3.1 Quantitative flora monitoring

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 longwalls. 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 400 m 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, Restioid Heath and finally Banksia Thicket.

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

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

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.

5.11.4 Fauna

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

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

Standardised transects in potential breeding habitat for the threatened frog species Littlejohn's tree frog and Giant burrowing frog have been established in Dendrobium Area 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.

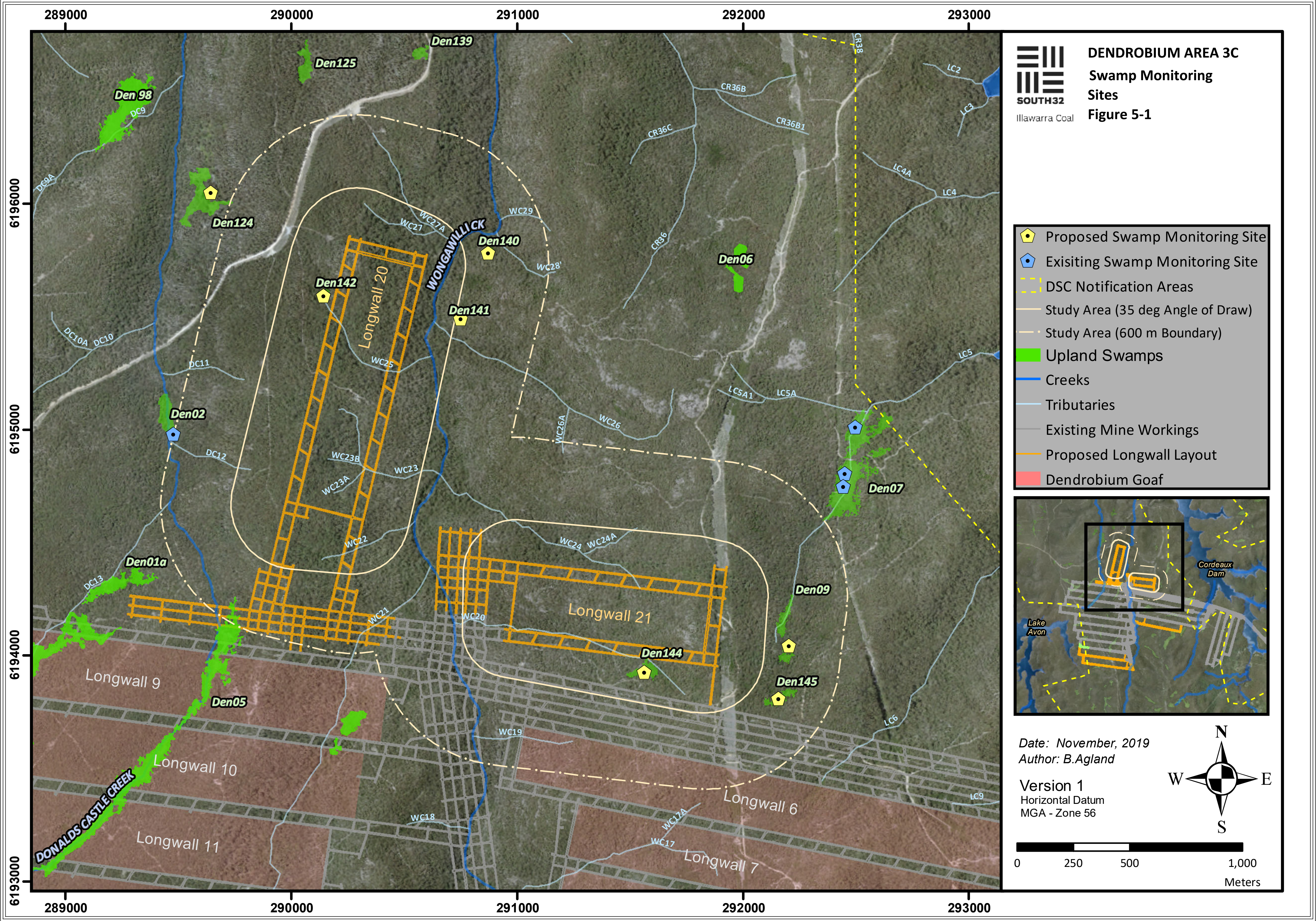
Observations of the sites, photo points and pool water level data will also be collected as part of the frog and observational monitoring programs. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

5.12 Reporting

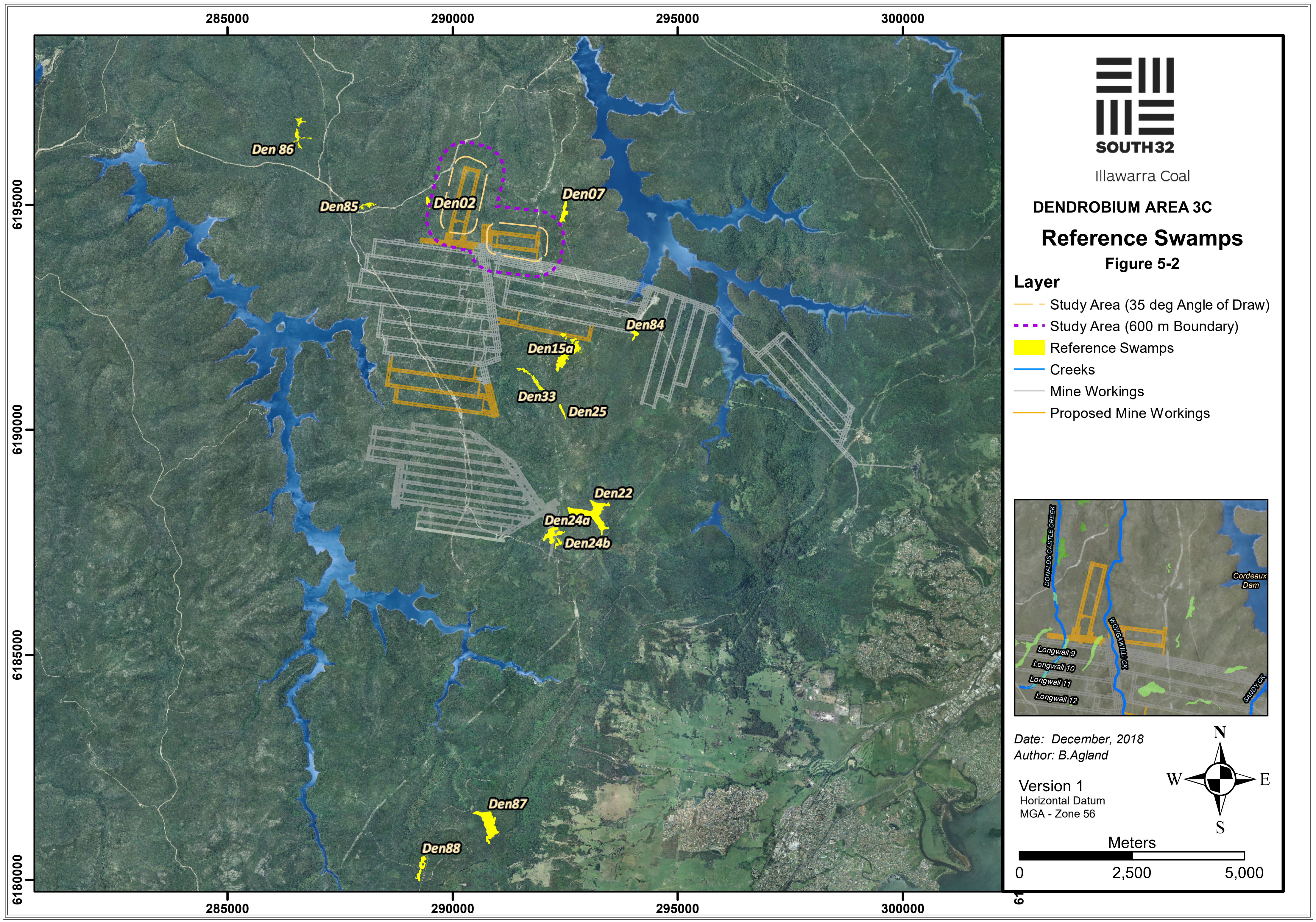
End of Panel Reports are prepared in accordance with *Schedule 3, Condition 9* of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the End of Panel Report and in the Annual Environmental Management Report (AEMR). These reports detail the outcomes of monitoring 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 Superintendent Approvals will initiate the requirements of the Trigger Action Response Plans (TARPs) shown as **Attachment 1: Table 1.2**.

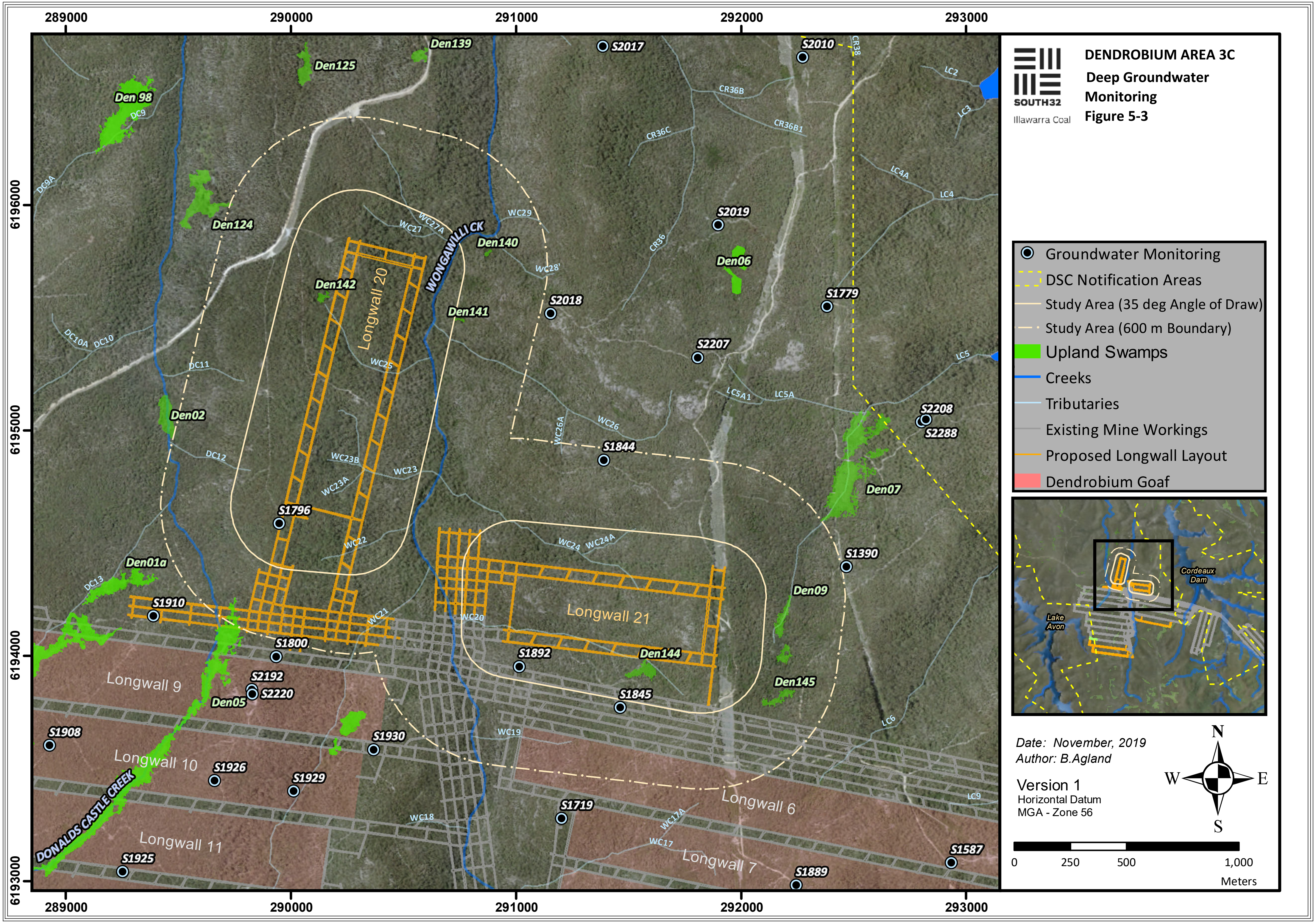
Monitoring results are included in the Annual Reporting requirement under *Schedule 8, Condition 5* in accordance with the Dendrobium Area 3 Modification Approval and are made publicly available in accordance with *Schedule 8, Condition 11.*



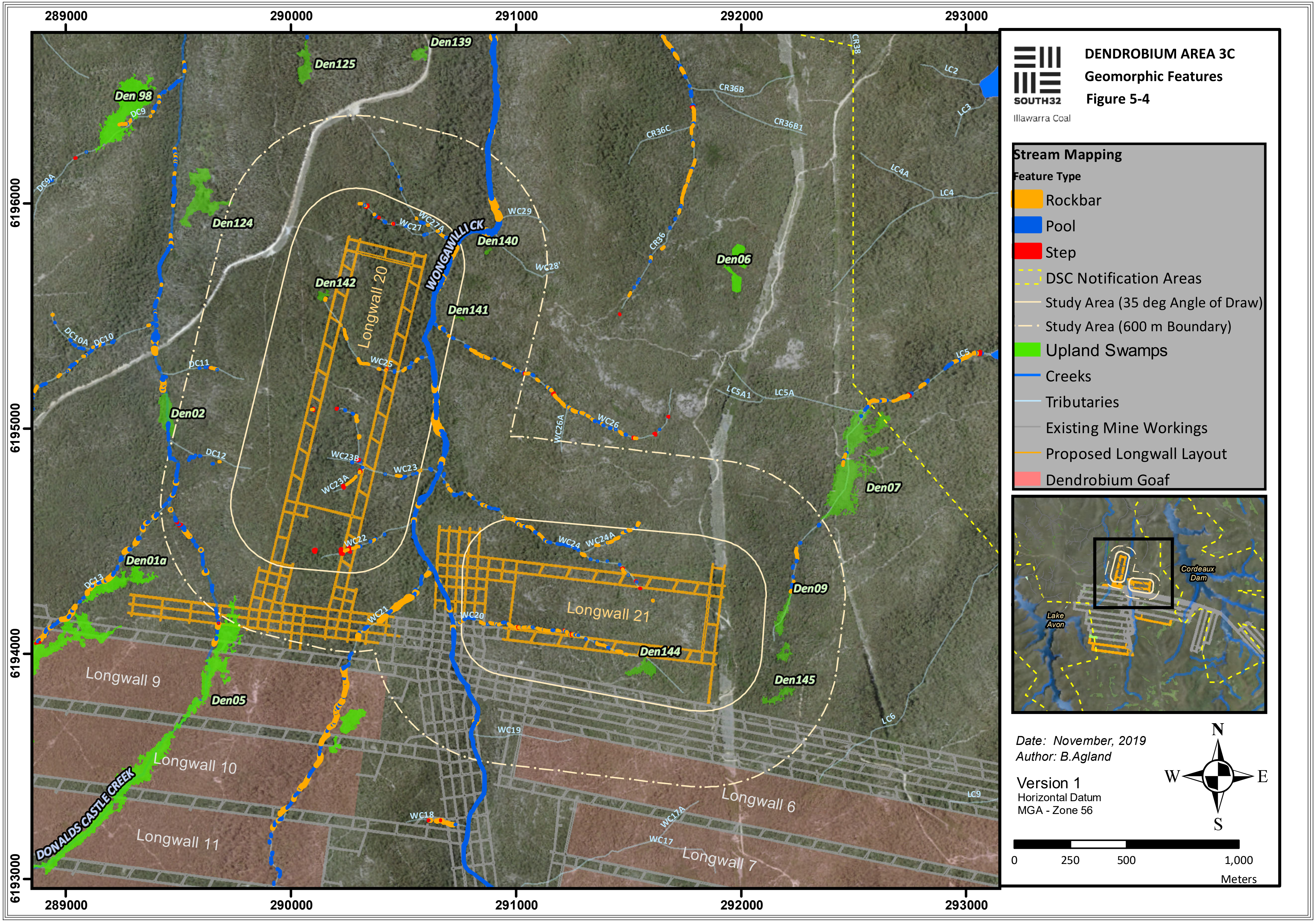
DENDROBIUM AREA 3C
Swamp Monitoring Sites
Figure 5-1
SOUTH32
Illawarra Coal
Proposed Swamp Monitoring Site
Exisiting Swamp Monitoring Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Cordeaux Dam
Lake Avon
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Den139
Den125
Den 98
Den124
Den140
Den142
Den141
Den06
Den02
Den07
Den01a
Den09
Den144
Den145
Den05
WONGAWILLI CK
DONALDS CASTLE CREEK
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7



DENDROBIUM AREA 3C
Reference Swamps
Figure 5-2
SOUTH32
Illawarra Coal
Layer
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Reference Swamps
Creeks
Mine Workings
Proposed Mine Workings
Den 86
Den85
Den02
Den07
Den84
Den15a
Den33
Den25
Den22
Den24a
Den24b
Den87
Den88
DONALDS CASTLE CREEK
WONGAWILLI CK
SANDY CK
Cordeaux Dam
Longwall 9
Longwall 10
Longwall 11
Longwall 12
285000
290000
295000
300000
6195000
6190000
6185000
6180000
Date: December, 2018
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
S
E
W
Meters
0
2,500
5,000



DENDROBIUM AREA 3C
Deep Groundwater Monitoring
Figure 5-3
SOUTH32
Illawarra Coal
Groundwater Monitoring
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
0
250
500
1,000
Meters
N
S
E
W
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Cordeaux Dam
Lake Avon
289000
290000
291000
292000
293000
6193000
6194000
6195000
6196000



DENDROBIUM AREA 3C
Geomorphic Features
Figure 5-4
SOUTH32
Illawarra Coal
Stream Mapping
Feature Type
Rockbar
Pool
Step
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Cordeaux Dam
Lake Avon
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den06
Den02
Den01a
Den05
Den07
Den09
Den144
Den145
DC9
DC9A
DC10A
DC10
DC11
DC12
DC13
WC29
WC27A
WC27
WC28'
WC26A
WC26
WC25
WC23B
WC23A
WC23
WC22
WC24
WC24A
WC21
WC20
WC19
WC18
WC17A
WC17
CR36B
CR36B1
CR36C
CR36
CR38
LC2
LC3
LC4A
LC4
LC5
LC5A1
LC5A
LC6
LC9

6 MANAGEMENT AND CONTINGENCY PLAN

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

6.1 Objectives

The aims and objectives of this Plan include:

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

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

6.2 Trigger Action Response Plan

The TARPs relate to identifying, assessing and responding to potential impacts to swamps (including impacts greater than predicted) from subsidence in Dendrobium Area 3C including Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3C swamps are included in **Attachment 1: Table 1.2**.

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

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

Level 2 and 3 TARPs result in further investigations and reporting by appropriately qualified people. Impact assessment reports will include:

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

The Level 2 and 3 TARPs may require the development of site specific CMAs which include:

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

6.3 Avoiding and Minimising

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

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

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

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

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

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

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

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

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;

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

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

6.4 Mitigation and Rehabilitation

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

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

At the time of grant of the Dendrobium Development Consent there was no requirement for concurrence in respect of threatened species or ecological communities. The requirement for concurrence was, at that time, governed by section 79B of the EPA Act. At the time of grant of the Dendrobium Consent there was a requirement for consultation with the Minister administering the 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 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 Polyurethane Resin (PUR) and other grouting materials. IMC is consulting with Metropolitan Colliery in relation to these new and emerging technologies. Should rehabilitation be necessary in Dendrobium Area 3B, the best option available at the time of the rehabilitation work will be identified and with appropriate approval, implemented by IMC.

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

6.4.6 Monitoring Remediation Success

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

A comprehensive swamp monitoring program is in place for swamps identified in this Plan. A summary of swamp monitoring within Dendrobium Area 3B is provided in Section 2. In the event that monitoring reveals impacts greater than what is authorised by the approval, modifications to the project, mitigation measures and environmental offsets would be considered to minimise impacts.

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

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

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

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

6.5 Biodiversity Offset Strategy

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

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

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

6.6 Research

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

The program of research will continue through the mining of Area 3 and be adaptive to results as the program is implemented. The research will be conducted as provided by a Swamp Rehabilitation Research Program. This Program will:

- be prepared in consultation with BCD, Water NSW and T&I;
- 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 Area 3B, including Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145.

This would involve the following actions:

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

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

The site-specific swamp rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. All works and environmental controls will be approved by Water NSW prior to implementation.

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

Table 6-1 Performance Measures, Potential Impacts, Mitigation and Contingent Measures for Swamps

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145	**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	a) upfront mine planning b) erosion monitoring (i.e. ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase >5% of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (i.e. increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is >5%).	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective. This period can be extended to 5 years, with the agreement of the Secretary.
		Subsidence impacts (i.e. cracking) on bedrock base or controlling rockbar	• Observation of swamps, streams and pools • Measurements of pool water level	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting	Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, i.e. pool water level within the swamp after CMAs continues to be >20% lower than baseline for >20% of the time over a period of 1 year.	Offset required immediately, if no remediation considered practicable. Offset required 2 years following remediation, if it is ineffective. This period can be extended to 5 years, with the

Swamp	Performance Measure	Potential Impacts	Monitoring Method	Management Strategies	Exceeding Prediction	Offsets
				h) investigation and review i) update future predictions		agreement of the Secretary.

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

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

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

7.2 Complaints Handling

IMC will:

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

7.3 Non-Conformance Protocol

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

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

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

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

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

8 PLAN ADMINISTRATION

This SIMMCP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Area 3 Approval 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 Superintendent Approvals who shall be the SIMMCP's authorising officer.

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

General Manager Mine Services

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

Manager Approvals

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

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 Superintendent Approvals any findings indicating an immediate response that may be warranted.
- Bring to the attention of the Superintendent Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the SIMMCP.

Survey Team Lead

- Collate survey data and present in an acceptable form for review at assessment meetings.

- Bring to the attention of the Superintendent Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Superintendent 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 Superintendent Approvals 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 General Manager Mine Services 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 Superintendent Approvals 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 Superintendent Approvals to ensure that all persons and organisations having responsibilities under this SIMMCP are trained and understand their responsibilities.

The person(s) performing regular inspections shall be under the supervision of the 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 *Schedule* 8, *Condition 5*. More specifically this SIMMCP will be subject to review (and revision if necessary, to the satisfaction of the Secretary) following:

- The submission of an annual review under *Schedule 8, Condition 5;*
- The submission of an incident report under *Schedule 8, Condition 3;*
- The submission of an audit report under *Schedule 8, Condition 6; and*
- Any modification to the conditions of this approval.

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

9 REFERENCES AND SUPPORTING DOCUMENTATION

ACARP, 2009. Damage Criteria and Practical Solutions for Protecting River Channels. Project Number C12016. Ken Mills SCT May 2009.

BHP Billiton Illawarra Coal, 2006. Georges River Report: Assessment of Georges River Remediation Longwalls 5A1-4. November 2006.

BHP Billiton Illawarra Coal, 2011. Understanding Swamp Conditions - Field Inspection Report - September 2010 to November 2010. BHP Billiton Illawarra Coal, April 2011.

Biosis Research 2007. Dendrobium Area 3 Species Impact Statement, Prepared for BHP Billiton Illawarra Coal, Biosis Research Pty Ltd.

Biosis Research 2007. Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006, Biosis Research Pty Ltd.

Biosis Research, 2009. Revision of the Dendrobium Coal Mine Flora and Fauna Monitoring Program. February 2009.

Biosis Research, 2012(a). Elouera and Dendrobium Ecological Monitoring Program. Annual Monitoring Report Financial Year 2010/2011. August 2012.

Biosis Research, 2012(b). Swamp 15b TARP Assessment – Ecology. Ref:15462, 10 October 2012.

Biosis, 2014. Dendrobium Ecological Monitoring Program, Annual Report for 2012/2013 Financial Year. February 2014. Prepared for Illawarra Coal.

Biosis, 2015. Dendrobium Terrestrial Ecology Monitoring Program, Annual Report for 2014. September 2015. Prepared for Illawarra Coal.

Boughton W, 2004. The Australian water balance model. Environ Model Softw 19:943–956. doi: doi:10.1016/j.envsoft.2003.10.007.

Cardno, 2019. Aquatic Flora and Fauna Assessment. Illawarra Coal Holdings Pty Ltd, 29 May 2019.

Cardno Ecology Lab, 2012. Aquatic Flora and Fauna Assessment. Prepared for BHPBIC, February 2012.

Cardno Ecology Lab, 2012. Swamp 15b and SC10C Aquatic Flora and Fauna Review. Ref: NA49913032, 5 October 2012.

Cardno Ecology Lab, 2013. Dendrobium Area 3A Aquatic Ecology Monitoring 2008-2012. Job Number: EL1112073 Prepared for BHP Billiton – Illawarra Coal, February 2013.

Cardno Ecology Lab, 2013. Review of Sandy Creek Pools Aquatic Flora and Fauna. 25 February 2013.

Cardno Ecology Lab, 2013. SC10C Level 3 Aquatic Ecology Trigger Assessment. 11 June 2013.

Cardno Ecology Lab, 2015. Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014. 30 March 2015.

Cardno Forbes Rigby, 2007. Landscape Impact Assessment and Monitoring Site Optimisation. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Area 3A Subsidence Management Plan Longwalls 6 to 10. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Dendrobium Area 3 Environmental Assessment. Prepared for BHPBIC.

Chafer, C., Noonan, M and Macnaught, E. 2004. The Post-Fire Measurement of Fire Severity and Intensity in the Christmas 2001 Sydney Wildfires. International Journal of Wildland Fire Vol. 13; pp. 227-240.

Chiew, F, Wang, Q. J., McConachy, F., James, R., Wright, W, and deHoedt, G. 2002. Evapotranspiration Maps for Australia. Hydrology and Water Resources Symposium, Melbourne, 20-23 May, 2002, Institution of Engineers, Australia.

Coffey, 2012. Groundwater Study Area 3B Dendrobium Coal Mine: Numerical Modelling. GEOTLCOV24507AA-AB2 2 October 2012.

Ditton, S., and Merrick, N.P. 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle, NSW.

Doherty, J. 2010. PEST: Model-Independent Parameter Estimation User Manual (5th ed.): Watermark Numerical Computing, Brisbane, Queensland, Australia.

EarthTech Engineering Pty Ltd, 2005. Thresholds for Swamp Stability. Prepared for BHPBIC, January 2005.

The Ecology Lab, 2007. Dendrobium Area 3 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. October 2007.

Ecoengineers, 2006. Assessment of Surface Water Chemical Effects of Mining by Elouera Colliery. January - December 2005. February 2006.

Ecoengineers, 2006. Assessment of Catchment Hydrological Effects by Mining by Elouera Colliery Stage 1: Establishment of a Practical and Theoretical Framework. August 2006.

Ecoengineers, 2007. Surface Water Quality and Hydrology Assessment to Support SMP Application for Dendrobium Area 3.

Ecoengineers, 2010. End of Panel Surface and Shallow Groundwater Impacts Assessment Dendrobium Area 2 Longwall 5. Document Reference No. 2010/01A. April 2010.

Ecoengineers, 2012. Surface Water Quality and Hydrological Assessment: Dendrobium Area 3B Subsidence Management Plan Surface and Shallow Groundwater Assessment.

Ecoengineers, 2012. Level 2 TARP Independent Review and Recommendations Swamp 15b Dendrobium Area 3A. 25 September 2012.

Ecoengineers, 2013. Level 3 TARP Independent Review and Recommendations Sandy Creek Catchment Pool 7 (Dendrobium Area 3A). 12 February 2013.

Ecoengineers, 2013. Level 2 TARP Specialist Review and Recommendations Donalds Castle Creek. 22 May 2013.

Ecoengineers, 2014. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 9. June 2014.

Ecoengineers, 2015. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 10. February 2015.

Eco Logical Australia, 2004. The Impacts of Longwall Mining on the Upper Georges River Catchment: Report to Total Environment Centre, 2004.

Forster, 1995. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

GHD, 2007. Dendrobium Area 3A Predicted Hydrogeologic Performance. Report for BHP Billiton, Illawarra Coal. November 2007.

GSS Environmental, 2013. Baseline and Pre-Mining Land Capability Survey. Dendrobium Mine, Area 3B. February 2013.

Hazelton P.A. and Tille P.J. 1990. Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney.

Hebblewhite, 2010. BHP Billiton Illawarra Coal: Bulli Seam Operations Project – Independent Review. 31 March 2010.

Helensburgh Coal Pty Ltd, 2007. Submission to: Independent Expert Panel - Inquiry into NSW Southern Coalfield July 2007, Helensburgh Coal Pty Ltd.

Heritage Computing, 2009. Dendrobium Colliery Groundwater Assessment: Mine Inflow Review, Conceptualisation and Preliminary Groundwater Modelling. Merrick, N.P., Heritage Computing Report HC2009/2, February 2009.

Heritage Computing, October 2011. Recalibration of the Dendrobium Local Area Groundwater Model after Completion of Longwall 6 (Area 3A). Report prepared for Illawarra Coal. Report HC2011/13.

HydroSimulations, 2014. Dendrobium Area 3B Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Sata. Report: HC2014/4 March 2014.

HydroSimulations, 2019. Dendrobium Mine Longwalls 20 and 21 Groundwater Assessment. Prepared for Illawarra Coal Pty Ltd. May 2019.

Illawarra Coal, 2014. Longwall 9 End of Panel Report.

Illawarra Coal, 2015. Longwall 10 End of Panel Report.

Kirchner, J. W. 2009. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modelling, and doing hydrology backwards. Res., W02429.

Manly Hydraulics Laboratory, 2006. BHP Billiton Dendrobium Mine Area 2 Subsidence Environmental Management Plan Water Monitoring and Management Program. Prepared for BHPBIC. Version 1.4 January 2006.

McMahon, 2014. Dendrobium Community Consultative Committee Report: Review of Surface Water Study. An independent review of surface water hydrological modelling associated with Illawarra Coal's Dendrobium Area 3, conducted by Emeritus Professor Thomas McMahon, University of Melbourne. 4 June 2014.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

MSEC, 2019. Dendrobium mine – Area 3C. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 20 and 21 in Area 3C at Dendrobium Mine. MSEC978 August 2019.

Niche Environment and Heritage, 2012. Terrestrial Ecological Assessment. Prepared for BHP Billiton Illawarra Coal. February, 2012.

Niche Environment and Heritage, 2019a. Aboriginal Cultural Heritage Assessment Report. Prepared for South 32 Illawarra Coal Operations. September 2019.

Niche Environment and Heritage, 2019b. Dendrobium Longwalls 20-21 Terrestrial Ecological Assessment. South 32 Illawarra Coal. 20 August 2019.

NPWS, 2003. The Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments. Central Conservation Programs and Planning Division NSW National Parks and Wildlife Service; August 2003.

OEC, 2001. Environmental Impact Statement Dendrobium Coal Project. Olsen Environmental Consulting, Figtree, N.S.W.

Parkhurst. D.L., and Appelo, C.A.J. 2012. Description of Input and Examples for PHREEQC Version 3 – A Computer Program for Speciation, Batch-Reaction, One- Dimensional Transport and Inverse Geochemical Calculations. US Department of Interior/US Geological Survey.

Parson Brinckerhoff, 2012. Independent Review of Dendrobium Area 2 and 3A Hydrochemical Data. August 20012.

Parsons Brinckerhoff, 2015. Connected fracturing above longwall mining operations, Part 2: Post-longwall investigation. For BHP Billiton Illawarra Coal. Document number 2172268F-WAT-REP-002 RevB. 6 March 2015.

Petersen, 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology Vol 27, Issue 2, April 1992.

Resource Strategies, 2009. Bulli Seam Operations Environmental Assessment. Report in support of an application for the continued operations of the Appin and West Cliff Mines.

Singh & Kendorski, 1981. Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments, Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Tammetta, P. (2013). Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater, 51(5), 723-734.

Tomkins, K.M. and Humphries, G.S. 2006. Technical report 2: Upland Swamp development and erosion on the Woronora Plateau during the Holocene. January 2006. Sydney Catchment Authority – Macquarie Collaborative Research Project.

Tozer, M. et el 2002. Native Vegetation Maps of the Cumberland Plain Western Sydney. NSW National Parks and Wildlife Service 2002.

Waddington, A.A. and Kay, D.R. 2001. Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs. Gorges and River Systems. Final Report on ACARP Research Project C8005, March 2001.

Waddington, A.A. and Kay, D.R. 2002. Management Information handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Zhang, L. Dawes, W.R. and Walker, G.R. 1999. Predicting the effect of Vegetation Changes on Catchment Average Water Balance. Technical Report No. 99/12, Cooperative Research Centre for Catchment Hydrology.

Attachment 1 – Swamp Monitoring and TARP

Attachment 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	Swamps 15A, 15B, 12 and 16	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	*Impact Sites* Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A and 35B *Reference Sites* Swamps 2[1], 7[1], 15A, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	*Impact Sites* 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 15A, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
EROSION MONITORING				
AREA 3B	*Impact Sites* Swamps 01A, 01B, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35A and 35B *Reference Sites* Swamps 2[1], 7[1], 15A, 22, 24, 25, 33, 84, 85, 86, 87 and 88	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 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145			

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

SHALLOW GROUNDWATER LEVEL				
AREA 3A	Approximately 50 piezometers in and around swamps in Area 3A (Swamp 15A, 15B, 12 and 16)	Monitoring bore drilled into the soil profile	For open hole sites: Monthly monitoring pre, during and post mining for two years to be reviewed annually Reference sites 6 monthly For instrumented sites: Automatic groundwater level monitoring pre, during and post mining (1-hour interval or similar) Monitoring post mining for five years to be reviewed annually	Piezometric and dip meter monitoring of shallow groundwater level
AREA 3B	*Impact Sites* Swamp 01A: 01a_01, 01a_02, 01a_03, 01a_04, 01a_04i, 01a_04ii, 01a_04iii, 01a_04iv, 01a_04v Swamp 01B: 01b_01, 01b_02, 01b_02i, 01b_02ii, 01b_02iii, 01b_02iv, 01b_03 Swamp 03: 03_01 Swamp 04: (thin soil profile) Swamp 05: 05_01, 05_02, 05_03, 05_03i, 05_03ii, 05_03iii, 05_04, 05_05, 05_06 Swamp 08: 08_01, 08_02, 08_03, 08_04, 08_05, 08_06 Swamp 10: 10_01 Swamp 11: S11-HI, S11-H2, S11-H3 Swamp 13: 13_01 Swamp 14: 14_01, 14_02 Swamp 23: 23_01, 23_02 Swamp 35A: 35A_01 Swamp 35B: 35B_01 Note: Swamp 4 is too shallow for a piezometer to be installed. *Reference Sites* Swamp 2*(1)*: 02_01 Swamp 7*(1)*: 07_05, 07_06 Swamp 15A: 15a_02, 15a_03, 15a_04, 15a_06, 15a_07, 15a_08, 15a_09, 15a_11, 15a_12, 15a_15 Swamp 22: 22_01, 22_02 Swamp 24: 24_01 Swamp 25: 25_01 Swamp 33: 33_01, 33_03 Swamp 84: 84_02 Swamp 85: 85_01, 85_02 Swamp 86: 86_01, 86_02 Swamp 87: 87_01, 87_02 Swamp 88: 88_01, 88_02			
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

<table>
<tr><th colspan="5">SOIL MOISTURE</th></tr>
<tr><td>AREA 3B</td><td>Impact Sites
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 15A: S15a_S01, S15a_Piezo, S15a_S04, S15a_S06
Swamp 22: 22_01, 22_02
Swamp 24: S24_S01
Swamp 25: S25_S01
Swamp 33: S033_S01, S033_S03
Swamp 84: S84_S02
Swamp 85: S85_S01, S85_S02
Swamp 86: S86_S01, S86_S02
Swamp 87: S87_S01, S87_S02
Swamp 88: S88_S01, S88_S02</td><td rowspan="2">Monitoring bore drilled into the soil profile</td><td rowspan="2">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</td><td rowspan="2">Installed dielectric soil moisture sites down to 1.5 m to measure deep soil moisture</td></tr>
<tr><td>AREA 3C</td><td>Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145
Soil moisture sites will be paired with sites with piezometers</td></tr>
</table>

[(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(2)	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	*Impact Sites* 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 3B	*Impact Sites* Swamps 01A, 01B, 05, 8, 11, 13, 14 and 23 *Reference Sites* Swamps DC10 (Swamp 85), 15A(1), 15A(2) and 33	Size of the groundwater dependent communities (Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex) and the total size of the swamps	Baseline mapping prior to mining with repeat mapping after each longwall or as determined by observational monitoring i.e. if dieback or invasion of non-swamp species is observed	Detailed mapping including the use of LiDAR data to indicate the location and extent of upland swamp boundaries. Ground-truthing of these boundaries and the vegetation sub-communities will be undertaken if subsequent Lidar data shows swamp boundary movements
AREA 3C	Swamps 2, 5, 7, 9, 124, 140, 141, 142, 144 and 145			
TERRESTRIAL FAUNA – THREATENED FROG SPECIES				
AREA 3A	Swamps 15B and 15A(2)	Frog monitoring	Surveys are undertaken in winter each year to target active breeding periods (these can be variable depending on prevailing conditions) To address recommendation from Niche (2019), rainfall or hydrometric trigger values for surveys will be developed for surveys to allow for greater consistency between years which would aid in comparison of results (pre- versus post- mining and impact versus control). To address recommendation from Niche (2019), a baseline survey focussed on tadpole survey for Littlejohn's Tree Frog and aural detection of Red-crowned Toadlet is proposed to be conducted after sufficient rainfall and within the appropriate season.	For swamps frog surveys are conducted along associated creeks with a focus on features susceptible to impacts e.g. breeding pools. Potential breeding habitat for Littlejohn's Tree Frog and Giant Burrowing Frog will be targeted. Standardised transects have been established to record numbers of individuals recorded at each site from one year to the next. Tadpole counts will also be undertaken as part of the breeding habitat monitoring transects. These transects are surveyed by walking down the creekline and counting all amphibians seen or heard on either side of the line
AREA 3B	*Impact Sites* 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)			

AQUATIC ECOLOGY				
AREAS 3A, 3B and 3C	**Sandy Creek Catchment** *Impact Sites* Sites 8, 9, 10, 11, 12 and 13 (Sandy Creek) *Reference Sites* Site 7 (Sandy Creek) **Wongawilli Creek Catchment** *Impact Sites* 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** *Impact Sites* 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 Area 3 Swamp TARP

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

		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. *<u>Level 2:</u>* 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.. *<u>Level 3:</u>* 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.. *<u>Exceeding Prediction:</u>* 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** *<u>Level 1:</u>* 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 *<u>Level 2:</u>* 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. *<u>Level 3:</u>* 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. *<u>Exceeding Prediction:</u>* Mining results in a **>10%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **five** consecutive years.	k) update future predictions		
Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	Subsidence impacts (ie cracking) on bedrock base or controlling rockbar	*<u>Level 1:</u>* 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). *<u>Level 2:</u>* 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). *<u>Level 3:</u>* 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	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective.	

		any decrease in reference pools). *<u>Exceeding Prediction</u>* 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.	rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting h) investigation and review i) update future predictions	This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the ecosystem functionality of the swamps	Falls in surface or near-surface groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*<u>Level 1:</u>* Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *<u>Level 2:</u>* Groundwater level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a **50%** of monitoring sites (within 400m of mining) within the swamp. *<u>Level 3:</u>* Groundwater level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **>80%** of monitoring sites (within 400 m of mining) within the swamp.	a) upfront mine planning b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*<u>Level 1:</u>* Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps). *<u>Level 2:</u>* Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). *<u>Level 3:</u>* Soil moisture level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps).	a) upfront mine planning b) soil moisture monitoring c) water spreading d) weeding e) fire management f) reporting g) update future predictions		Triggers of soil moisture decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars

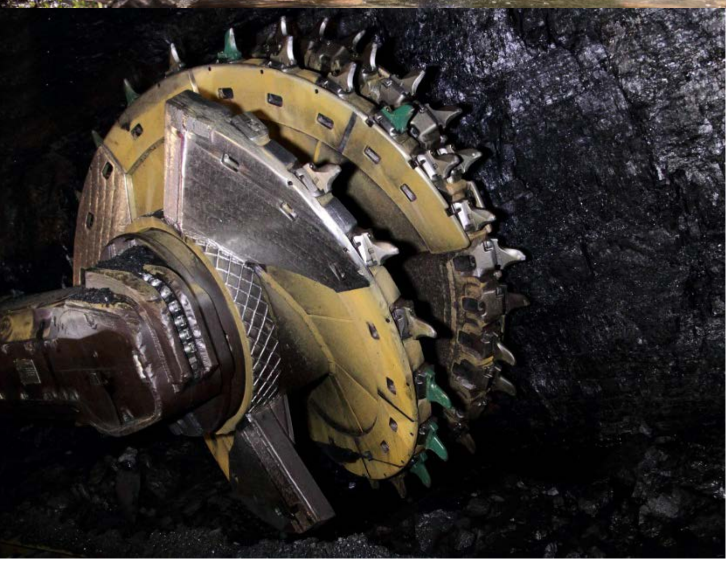
Appendix 4 – Watercourse Impact Management, Monitoring and Contingency Plan

SOUTH32

DENDROBIUM
AREA 3C

NOVEMBER 2019






AREA 3C

WATERCOURSE IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

Table of Contents

Tables

Figures

Attachments

Review History

Revision	Description of Changes	Date	Approved
A	New Document	May 2019	GB
B	Minor updates	September 2019	GB
C	Figure updates	November 2019	GB

Persons involved in the development of this document

Name	Title	Company
Josh Carlon	Environmental Coordinator	Illawarra Metallurgical Coal
Cody Brady	Principal Approvals	Illawarra Metallurgical Coal
Gary Brassington	Manager Approvals	Illawarra Metallurgical Coal

1 INTRODUCTION

1.1 Project Background

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

IMC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007, IMC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of s75W of the Environmental Planning and Assessment Act 1979 (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from cracking and diversion of surface water as a result of the proposed mining. These impacts included diversion of flow, lowering of aquifers, changes to habitat for threatened species as well as other impacts and environmental consequences.

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

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

This document satisfies *Schedule 3, Condition 4* of the Development Consent, which requires the development of a Watercourse Impact Monitoring, Management and Contingency Plan (WIMMCP) for approval prior to carrying out mining operations in Area 3C.

1.2 Scope

The Dendrobium Mine revised Consent requires a WIMMCP subject to *Schedule 3, Condition 4* as provided below.

4. 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 Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:

(a) demonstrate how the subsidence impact limits in conditions 1 - 3 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) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;

(c) 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;

(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses, 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 third and higher order streams individually but address first and second order streams collectively;

(f) be prepared in consultation with DECC, Water NSW 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 watercourses in the relevant Area; and

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

1.3 Study Area

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

- The 35° angle of draw line from the extents of the proposed Longwalls 20 and 21;

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

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

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the calibrated Incremental Profile Method (IPM), which is described in MSEC (2019).

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

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

1.4 Objectives

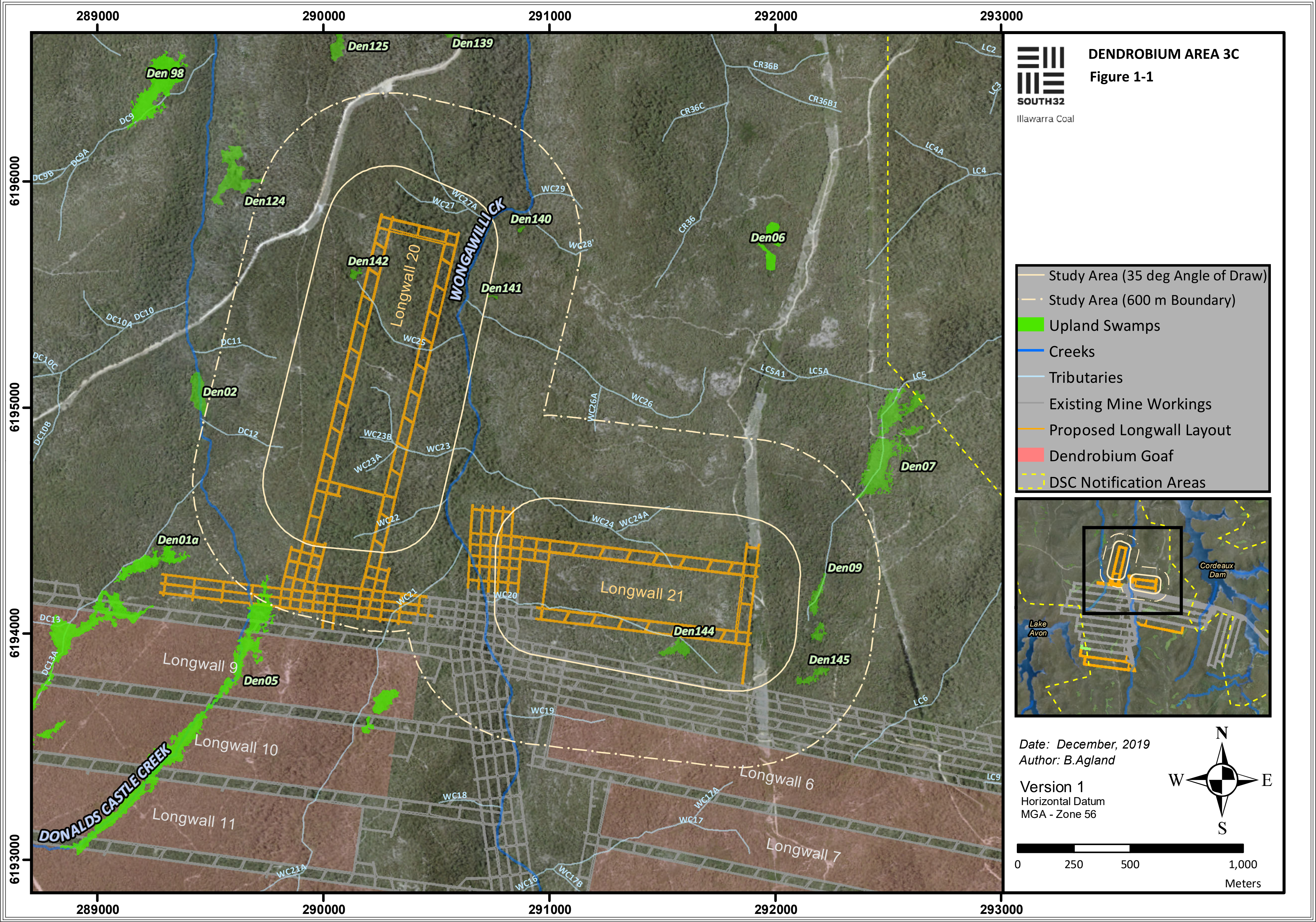
The objectives of this WIMMCP are to identify watercourse features and characteristics within the Dendrobium Longwalls 20 and 21 Study Area (**Figure 1-1**) and to monitor and manage potential impacts and/or environmental consequences of the proposed workings on watercourses.

1.5 Consultation

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

- Department of Planning, Industry and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]);
- Biodiversity Conservation Division within DPIE (formerly the Office of Environment and Heritage [OEH]; and
- Water NSW.

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


DENDROBIUM AREA 3C
Figure 1-1
SOUTH32
Illawarra Coal
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
DSC Notification Areas
Date: December, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
S
E
W
0
250
500
1,000
Meters
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den06
Den02
Den07
Den01a
Den09
Den144
Den145
Den05
Cordeaux Dam
Lake Avon
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000

2 PLAN REQUIREMENTS

Extraction of coal from Longwalls 20 and 21 will be in accordance with the conditions set out in the Dendrobium Development Consent as well as conditions attached to relevant mining leases.

Baseline studies have been completed within the Study Area and surrounds to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence from Longwall 20 and 21 extraction. The baseline studies have identified monitoring sites in these areas based on the Before After Control Impact (BACI) design criteria.

Details of surface water monitoring incorporating water quality and hydrographic monitoring and the interpretation of data are provided in Attachment A of the Surface Water Quality and Hydrology Assessment (HGEO 2019). The monitoring program is incorporated into this plan and the Longwall 20 and 21 SMP.

The monitoring and assessment programs will provide ongoing water-related monitoring of the streams and sub-catchments potentially affected by the mining of Dendrobium Area 3C and allow assessment of the magnitude of any developing trends in overland and subsurface flow and water quality effects resulting from mining. The Dendrobium Area 3C watercourse monitoring is summarised as **Attachment 1: Table 1.1**.

The Strahler stream classification system is commonly used to define the class of a watercourse and was used in the Southern Coalfield Inquiry (IEP, 2018). Streams are classified based on the number of contributing tributaries, with headwater streams classed as first and second order streams and third and higher order streams being given the classification as ‘streams of significance’. The Southern Coalfield Inquiry recommends that assessments should focus on these higher order streams. Within Area 3C, Wongawilli Creek is classed as a third order stream and Donalds Castle Creek is classed as a second order stream. Other unnamed drainage lines within Area 3C are first or second order streams.

The monitoring locations for watercourses within Dendrobium Area 3C will be reviewed as required and can be modified (with agreement) accordingly.

Should monitoring reveal impacts greater than what is authorised by the approval, modifications to the project and mitigation measures would be considered to minimise impacts.

2.1 Dendrobium Modified DA60-03-2001 Approval

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under *Section 75W* of the *EP&A Act 1979* on 8 December 2008. **Table 2-1** lists the Conditions of Consent relevant to the WIMMCP and where the conditions are addressed.

Table 2-1 Dendrobium Modified DA-60-03-2001 Approval Conditions

Project Approval Condition	Relevant WIMMCP Section
Condition 2 – Schedule 3 The Applicant shall ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than “minor impacts” (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	Sections 3, 4 and 5 (Sandy Creek not within the Study Area)
Condition 3 – Schedule 3 The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.	Sections 3, 4 and 5

Project Approval Condition	Relevant WIMMCP Section
Condition 4 – 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 Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:	
(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;	Sections 3, 4 and 5
(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) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;	Section 2 and Attachment 1 (Sandy Creek and Sandy Creek Waterfall not within the Study Area)
(c) 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;	Section 3 and Attachment 1
(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses; include a tabular contingency plan (based on the Trigger Action Response Plan structure) which focuses on measures for remediating both predicted and unpredicted impacts on watercourses;	Section 6 and Attachment 1
(e) address third and higher order streams individually but address first and second order streams collectively;	Sections 5
(f) be prepared in consultation with DECC, Water NSW and DPI;	Section 1.5
(g) incorporate means of updating the plan based on experience gained as mining progresses;	Section 8.5
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and	Section 1.4
(i) be implemented to the satisfaction of the Secretary.	

2.2 Leases and Licences

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

- Dendrobium Mining Lease as shown in **Table 2-2**;
- 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 Approval.

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

3.1 Subsidence Monitoring

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

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

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

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

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

3.2 Area 3C Watercourses

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of significant features in the watercourses (**Figure 1-1**). In line with recommendations of IEP (2018) and the 2016 Catchment Audit (Alluvium Consulting Australia 2017a) the locations and timing of monitoring for ecological aspects, water quality and stream flow is integrated and uses a BACI design. Baseline monitoring will be initiated at least 2 years prior to mining. Monitoring of streams in Area 3C is outlined in Table 3-1.

Table 3-1 Summary of Watercourses to be monitored within the Study Area

Watercourse	Catchment	Monitoring
Donalds Castle Creek	Donalds Castle Creek	Water Quality, Observations, Photo, Water Level, Flow, Aquatic Ecology
DC13	Donalds Castle Creek	Water Quality, Observations, Photo, Water Level, Flow
Wongawilli Creek	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow, Aquatic Ecology
WC20	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow
WC21	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow, Aquatic Ecology
WC22	Wongawilli Creek	Water Quality, Observations, Photo, Water Level
WC23	Wongawilli Creek	Observations, Photo, Water Level
WC24	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow
WC25	Wongawilli Creek	Observations, Photo, Water Level
WC26	Wongawilli Creek	Water Quality, Observations, Photo, Water Level, Flow
WC27	Wongawilli Creek	Observations, Photo, Water Level
WC29	Wongawilli Creek	Observations, Photo, Water Level

Watercourse	Catchment	Monitoring
LC5	Lake Cordeaux	Water Quality, Observations, Photo, Water Level, Flow

3.3 Observational and Photo Point Monitoring

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

Monitoring by IMC (along with other monitoring programs described in the WIMMCP) is consistent with (in part) *Schedule 3, Condition 4*: "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 IMC 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 **Attachment 1: Table 1.1**. Additional monitoring within Dendrobium Area 3C will be installed ahead of longwall mining to achieve at least 2 years of baseline data (subject to timing and approval timeframes of any request to install additional monitoring).

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. Observations of any surface flow are also made during monitoring.

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

The following Area 3C impact sites are included in the observational and photo point monitoring program:

- Impact sites:
    - WC21, Wongawilli and Donalds Castle Creeks, DC13 (commenced 2001);
    - WC20, WC22, WC23, WC24, WC25, WC26, WC27, WC29 (proposed sites);
    - LC5 (previously used as a reference site for Area 3B; additional proposed sites);
    - Swamp 5 (commenced March 2005);
    - Swamps 2 and 7 (previously used as reference sites for Area 3B);
    - Swamps 9, 124, 140, 141, 142, 144 and 145 (proposed sites).
- Reference sites:
    - Swamps 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88.
    - Wongawilli Creek, Sandy Creek, WC11 (Swamp 33), SC9A (Swamp 84), SC10A, NDC1, DC10 (Swamp 85), D10 and Gallahers Creek (Swamp 88).

3.4 Water Quality

Water quality monitoring at watercourse sites includes the collection of in-field parameters pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si) (**Figure 3-2**).

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3C will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining are monitored to allow for a comparison against sites not influenced by mining.

Over time, some water quality-specific site names have changed. These changes have been implemented to align monitoring site's names with mapped stream features. These changes are shown in **Table 3-2** below.

Table 3-2 Changes to Water Quality monitoring site names

Previous Site Name	Current Site Name	Watercourse
SCL	SCk_Rockbar 5	Sandy Creek
WWL2	Wongawilli Ck (FR6)	Wongawilli Creek
WWM1	WC_Pool 46	Wongawilli Creek
WWM3	WC_Pool 43b	Wongawilli Creek
DC_S2	DC_Pool 22	Donalds Castle Creek
DCU3	Donalds Castle Ck (FR6)	Donalds Castle Creek
WC15_S1	WC15_Pool 9	WC15
WC21_S1	WC21_Pool 5	WC21
DC13_S1	DC13_Pool 2b	DC13

Trigger values are proposed for water quality parameters in the TARP (**Attachment 1: Table 1.2**). The TARPs are based on the field parameters pH, EC and DO due to the ability of these parameters to indicate potential mining impacts on water quality, the rapid and in situ nature in which they are determined, and the quantity of baseline data available, which for Wongawilli and Donalds Castle Creeks is greater than 15 years (since August 2001).

A change of three standard deviations (enclosing approximately 99.7% of the baseline data assuming a normal distribution) from the respective parameter means resulting from mining will be used for determining potential exceedances of water quality performance measures.

Statistical analysis of baseline and impact period data will be provided in End of Panel (EoP) Reports, including clearly specifying the duration of the baseline monitoring period. Any historical mining outside the project area (e.g. Wongawilli Creek mined beneath by Elouera) will be acknowledged and if required reflected in the baseline monitoring assessment.

Exceedances of these levels have occurred occasionally in the baseline period. This is to be expected assuming a normal statistical distribution of the data, in addition to random natural environmental effects on water quality such as storms (effects of decomposition of detrital organic matter), wildfires (ash wash off and dissolution effects), prolonged dry weather and drought (evaporative concentration effects).

As such, exceedance of the water quality performance measures will be quantitatively defined by "mining resulting in exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events".

3.5 Groundwater

A specialist Groundwater Assessment is provided in **Attachment B** (HydroSimulations 2019). An existing groundwater monitoring program is in place for Dendrobium, which includes Area 3C (**Figure 3-5**).

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 2018).

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

To investigate groundwater-surface water dynamics in Wongawilli Creek, two monitoring bores are proposed to be installed between the creek and the proposed longwalls, preferably within the Wongawilli Creek valley (contingent on access and approvals). The boreholes would be installed in the Hawkesbury Sandstone and upper Bulgo Sandstone and the data would be paired with surface water flow data from Wongawilli Creek monitoring sites.

3.6 Stream Flows and Pool Water Levels

Water level/flow gauges and data loggers are installed at key stream flow monitoring sites; additional sites will be installed to effectively monitor Area 3C (**Figure 3-3**). Data has been collected since 2003 and has been compiled within monitoring and field inspection reports (Illawarra Coal 2011), End of Panel Reports and regular impact update reports. Pool water level and flow monitoring sites have been established in Dendrobium Area 3 for monitoring before, during and after mining. Additional flow and pool water level monitoring within Dendrobium Area 3C will be installed ahead of mining to achieve at least 2 years of baseline data (subject to timing and approval timeframes of any request to install additional monitoring).

Pool water levels in swamps and streams are measured using installed benchmarks in impact sites and reference sites (**Figure 3-1)**.Pool water levels will be measured monthly before and after mining, on a weekly basis during active subsidence and in response to any identified impacts. Water level measurements will be undertaken relative to benchmarks installed on rocks or other stable features on the edge of the pools.

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

This monitoring provides key data to assess the Wongawilli and Donalds Castle Creek Performance Measures; “Minor environmental consequences including”:

- Minor fracturing; and
- Minor impacts on flows and pool water levels.

Performance against this measure will be based on comparing pool water levels before mining with after mining. Pool water level data would also be used to determine the success of any pool/rockbar mitigation or rehabilitation.

The flow monitoring sites are installed downstream of the mining area to assess any changes in surface flow from a catchment resulting from the mining. Sites have previously been installed using natural flow control features such as rockbars. However, in line with the recommendations of the IEP (2018), IMC has installed low-flow weirs, in order to gain high quality low-flow data. Flow monitoring sites are not installed directly over the longwalls as mining induced surface fracture networks typically result in receding flows being entirely diverted below the surface. The downstream monitoring sites are installed to measure catchment flow reductions downstream of the mining area.

Flow gauges have been installed on Sandy Creek (Area 3A); Wongawilli Creek (Areas 3A, 3B and 3C) and its tributaries WC21 and WC15 (DA3B); Donalds Castle Creek and its tributary DC13 (DA3B) and Lake Avon tributary LA4 (Area 3B). The historical flow record has been plotted alongside the record from a nearby ‘control’ gauge i.e. a gauge that was not mined under, either at all, or not during the period of interest. Additional flow gauge sites for Area 3C are proposed at Wongawilli Creek tributaries WC20, WC24, WC26; Lake Cordeaux tributary LC5; and in line with the recommendations of the IEP (2018) a stream flow reference site at Cordeaux River tributary CR36.

An Australian Water Balance Model (AWBM; Boughton 2004) was constructed and calibrated for each of the sites, focussing on ‘history-matching’ of observed and modelled flows during the pre-mining period at each monitoring site. The flow during the ‘post-mining’ periods are then predicted while holding all parameters constant.

The predicted post-mining flows are compared against observed flows. Differences in the pre- and post-mining periods are highlighted and in consideration of reference sites, used to infer and quantify any effects of mining.

IMC commissioned the development of a regional-scale numerical groundwater flow model in support of mining at Dendrobium (Coffey Geotechnics 2012). IMC commissioned HydroSimulations (2014) to review and enhance the Model.

One of the enhancements to the Model was to interchange the MODFLOW Drain boundary condition, which was previously used to simulate creeks and rivers, for the Stream Flow Routing (SFR1; Prudic et al., 2004) boundary condition.

The Dendrobium Regional Groundwater Model has been updated by HydroSimulations (2019) as required by *Schedule 3, Condition 13* of the Area 3B SMP Approval (2018). This model has been used for the assessment of Longwalls 20 and 21.

3.7 Near-Surface Groundwater and Soil Moisture

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

Monitoring of shallow groundwater levels allows for the indirect measurement of water storage and transmission parameters within the saturated part of hill-slope/upland swamp complexes. Shallow groundwater piezometers are proposed to be installed within several swamps in Area 3C (**Figure 3-4**). Within Area 3C long-term piezometer records are available for Swamp 2 (Donalds Castle Creek) and Swamp 7 (LC5 – Lake Cordeaux tributary). Swamps 15a (SC10), 22, 24, 25, 33 (WC11), 84 (SC9A), 85 (DC10), 86, 87 and 88 (Gallahers Creek) are established reference monitoring sites and will continue to be monitored. This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Reference sites are monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles up to a maximum depth of 1.2 m (**Figure 3-4**). Key monitoring sites will be 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 3C with the most appropriate data used, taking into account proximity, length of record and data quality.

3.8 Pools and Controlling Rockbars

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

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

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

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

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (**Figure 3-6**).

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

The largest watercourse within the Study Area is Wongawilli Creek, which is located between Areas 3A and 3B; and between Longwalls 20 and 21. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west.

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

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

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

Rockbars and pools in Donalds Castle and Wongawilli Creeks have been mapped (**Figure 3-6**). All mapped rockbar controlled pools in Wongawilli Creek are significant permanent pools.

3.9 Slopes and Gradients

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

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.

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

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

For each watercourse monitoring site, 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.

3.10 Erodibility

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

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 Area 3C will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

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

The nominal accuracy of ALS derived subsidence contours are 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.

3.11 Flora, Fauna and Ecosystem Function

Terrestrial flora and vegetation communities in the Study Area are described in the SMP Terrestrial Ecology Assessment (Niche 2019b). Aquatic flora and fauna in the Study Area are described in **Attachment B**, the Area 3C Aquatic Ecology Assessment (Cardno 2019).

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

A monitoring program designed to detect potential impacts to terrestrial ecology and ecosystem function from subsidence has been implemented for Area 3. 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 (**Figure 3-1**).

Monitoring in Area 3 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 3. 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 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 Area 3C are shown in the Aquatic Ecology Assessment (Cardno 2019) (**Attachment B**). 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 **Attachment 1: Table 1** and in **Attachment B** (Cardno 2019)**.**

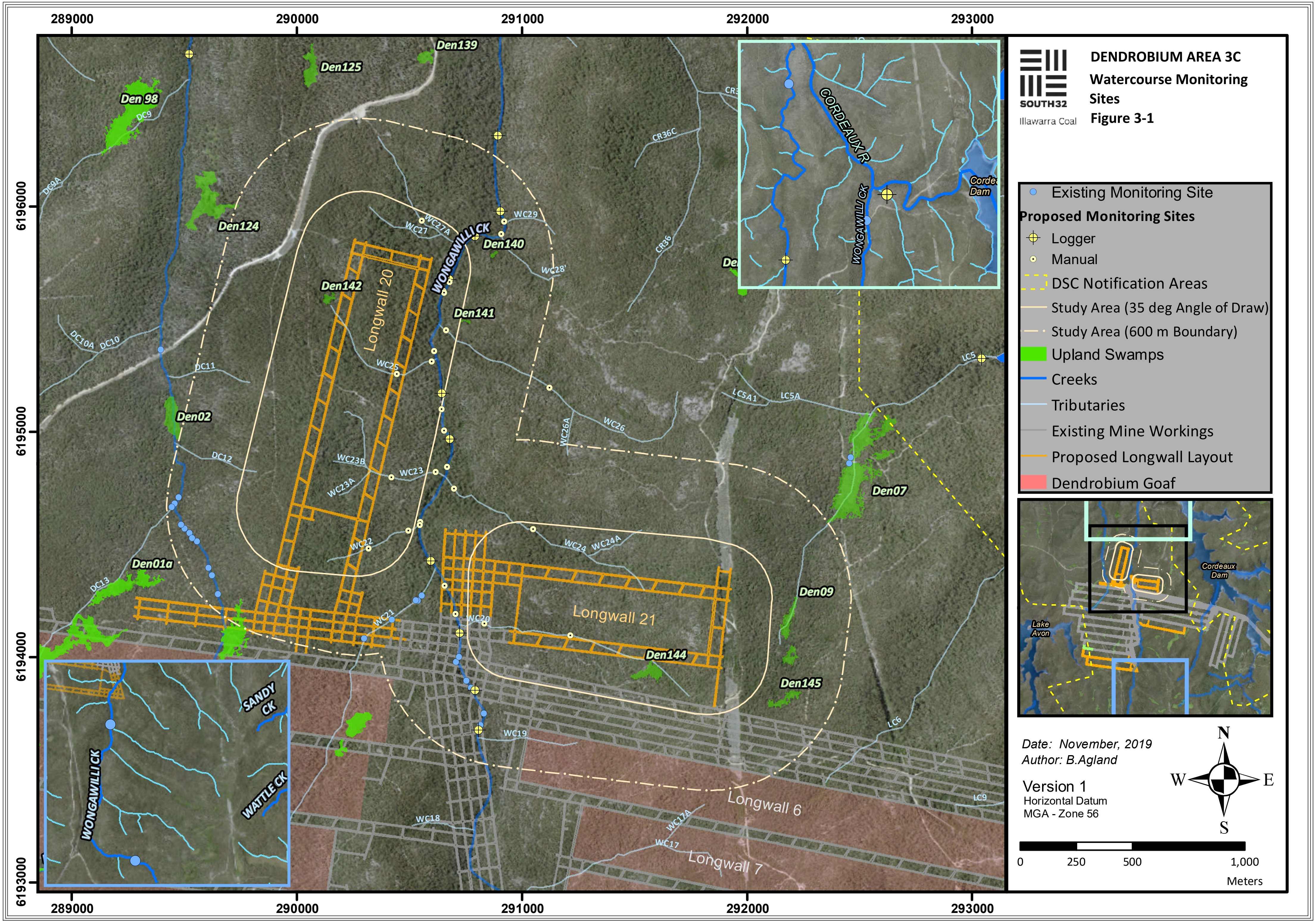
Observation data will also be collected as part of the monitoring program. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

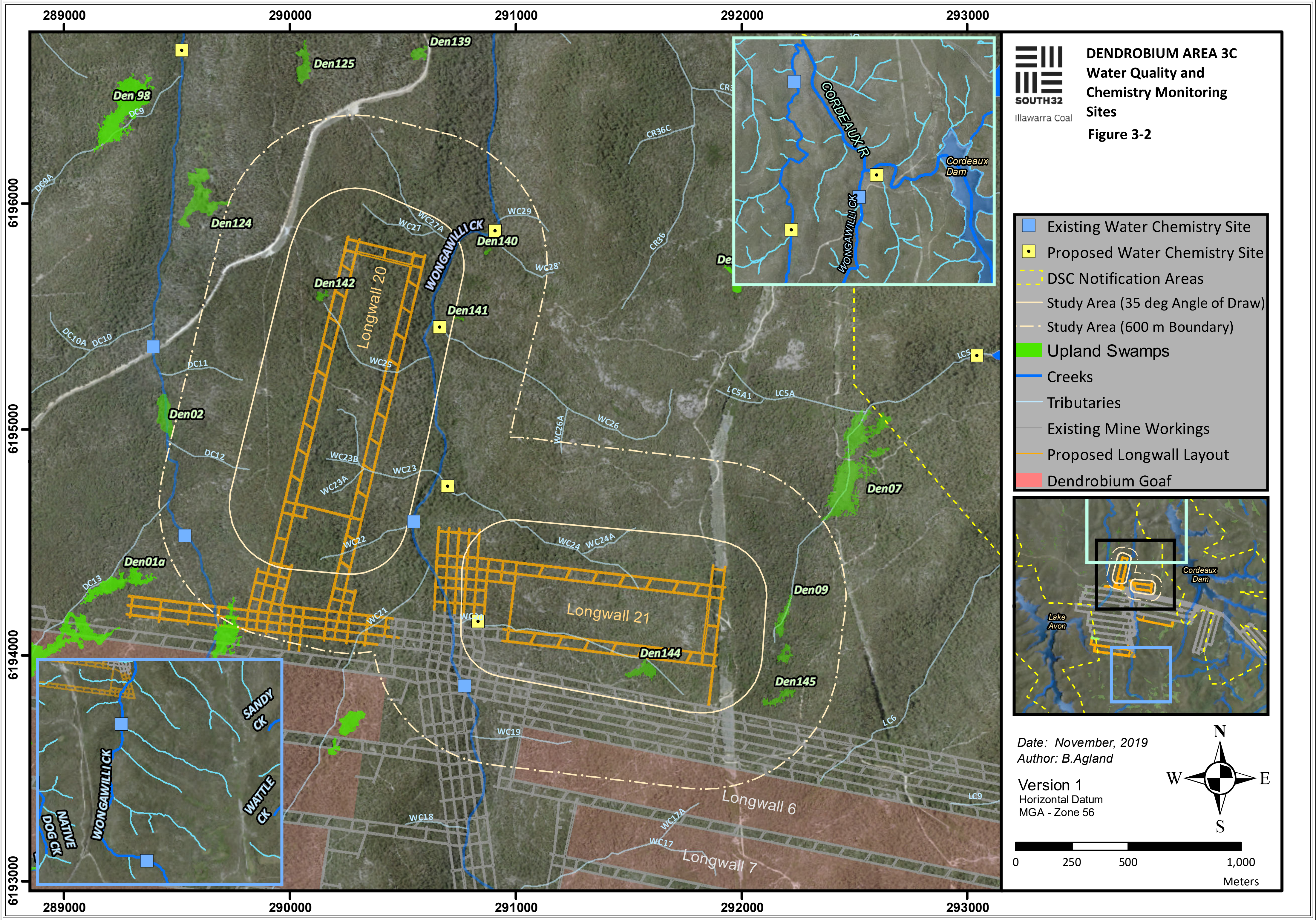
3.12 Reporting

End of Panel Reports are prepared in accordance with *Condition 9, Schedule 3* of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the End of Panel Report and in the Annual Environmental Management Report (AEMR). These reports detail the outcomes of monitoring undertaken; provide results of visual inspections and determine whether performance indicators have been exceeded.

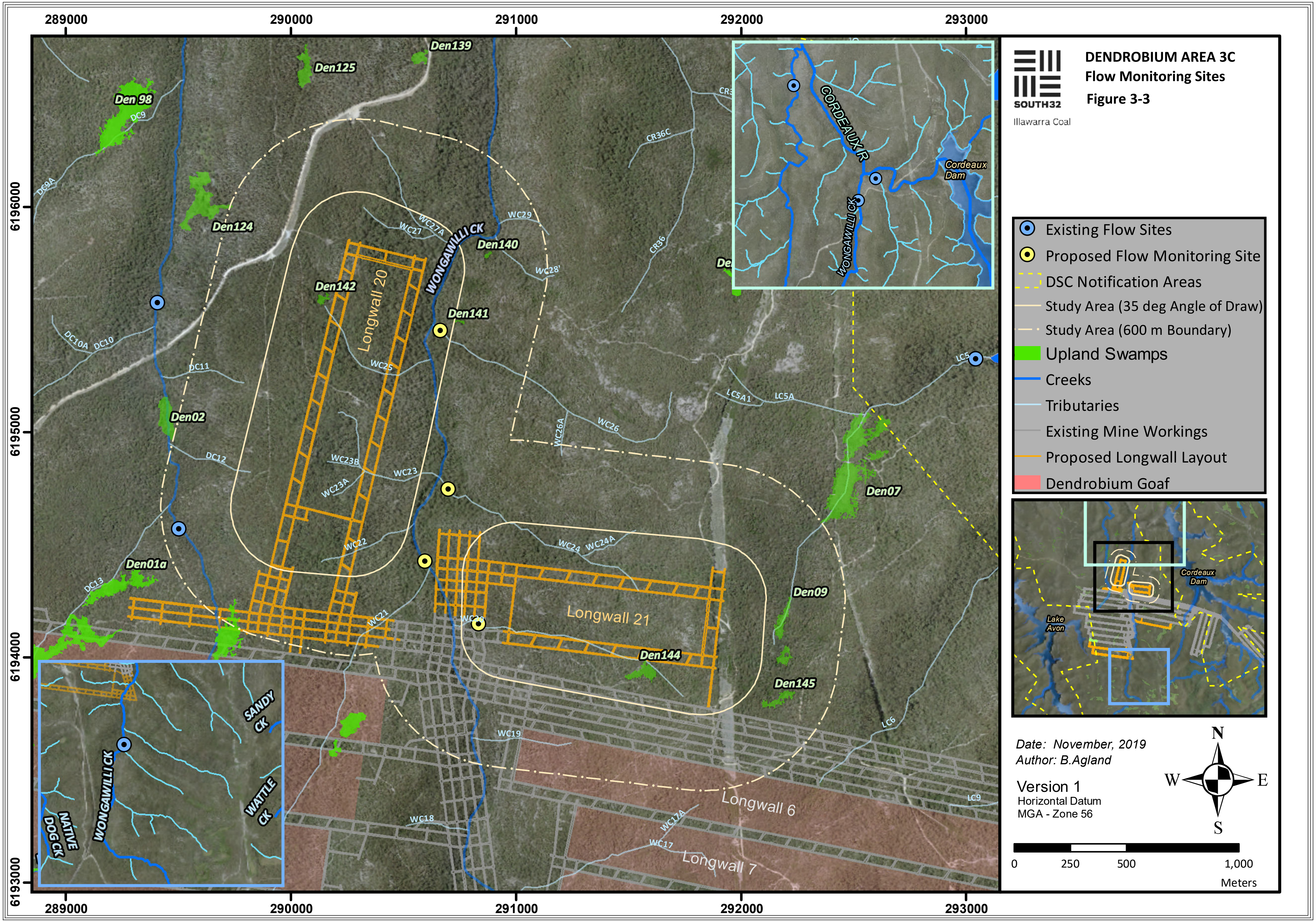
Monitoring results will be reviewed monthly by the IC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Superintendent Approvals will initiate the requirements of the TARPs (**Attachment 1: Table 2**).

Monitoring results are included in the Annual Reporting requirement under *Condition 5, Schedule 8* in accordance with the Dendrobium Area 3 Modification Approval and are made publicly available in accordance with *Condition 11, Schedule 8.*

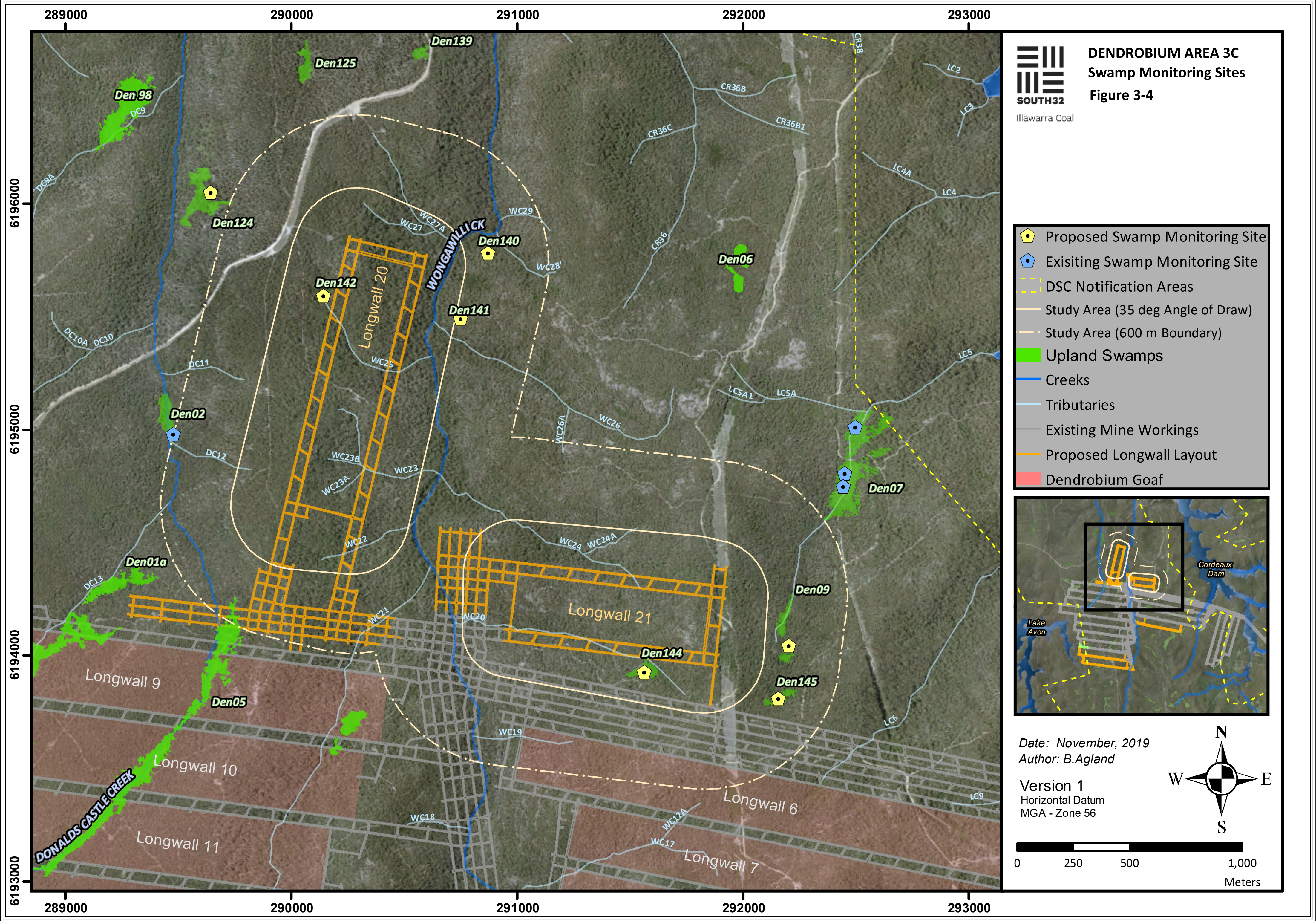

DENDROBIUM AREA 3C
Watercourse Monitoring Sites
Figure 3-1
SOUTH32
Illawarra Coal
Existing Monitoring Site
Proposed Monitoring Sites
Logger
Manual
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6193000
6194000
6195000
6196000
Longwall 20
Longwall 21
Longwall 6
Longwall 7
WONGAWILLI CK
CORDEAUX R
Cordeaux Dam
Lake Avon
SANDY CK
WATTLE CK
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den02
Den01a
Den07
Den09
Den144
Den145
DC9
DC9A
DC10A
DC10
DC11
DC12
DC13
WC29
WC27A
WC27
WC28'
WC26
WC26A
WC25
WC23B
WC23
WC23A
WC22
WC24
WC24A
WC21
WC20
WC19
WC18
WC17A
WC17
CR36C
CR36
LC5
LC5A1
LC5A
LC6
LC9

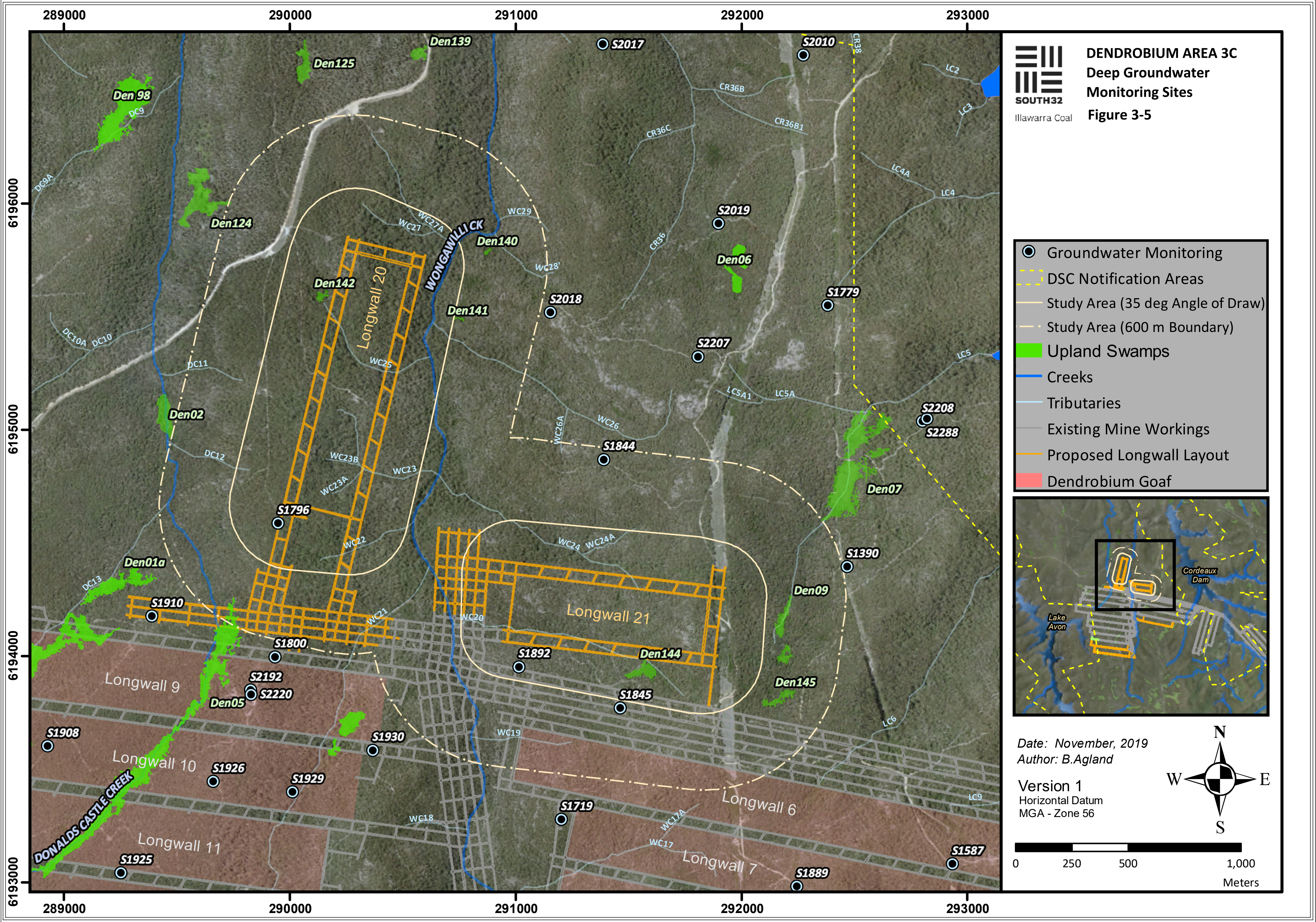


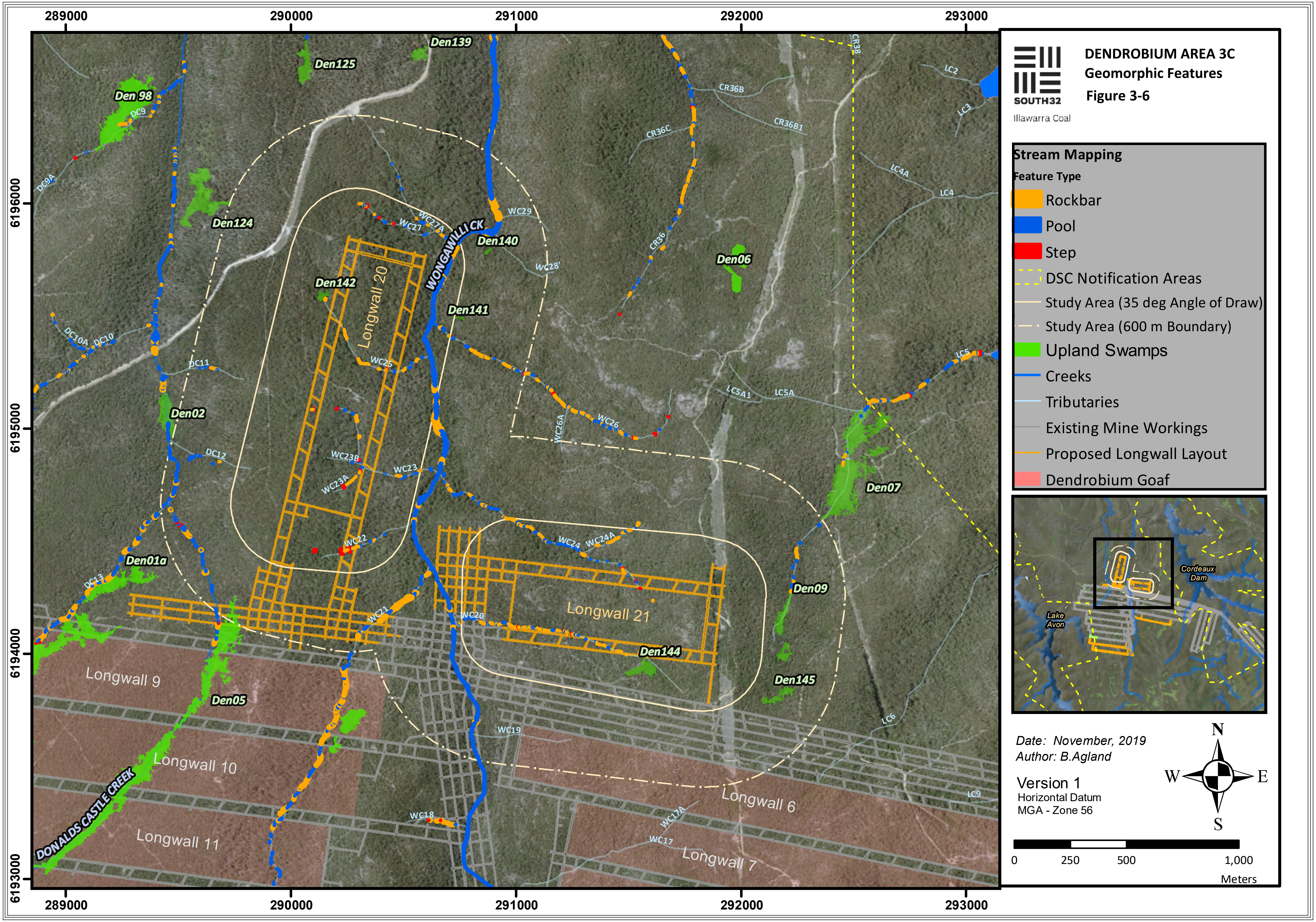
DENDROBIUM AREA 3C
Water Quality and Chemistry Monitoring Sites
Figure 3-2
SOUTH32
Illawarra Coal
Existing Water Chemistry Site
Proposed Water Chemistry Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
S
E
W
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Longwall 20
Longwall 21
Longwall 6
Longwall 7
WONGAWILLI CK
CORDEAUX R
Cordeaux Dam
Lake Avon
SANDY CK
WATTLE CK
NATIVE DOG CK
Den139
Den125
Den 98
Den124
Den140
Den142
Den141
Den02
Den07
Den01a
Den09
Den144
Den145
DC9
DC9A
DC10A
DC10
DC11
DC12
DC13
CR36C
CR36
WC29
WC27A
WC27
WC28'
WC26A
WC26
WC25
WC23B
WC23
WC23A
WC22
WC24
WC24A
WC21
WC19
WC18
WC17A
WC17
LC5A1
LC5A
LC6
LC9



DENDROBIUM AREA 3C
Flow Monitoring Sites
Figure 3-3
SOUTH32
Illawarra Coal
Existing Flow Sites
Proposed Flow Monitoring Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Longwall 20
Longwall 21
Longwall 6
Longwall 7
WONGAWILLI CK
CORDEAUX R
Cordeaux Dam
Lake Avon
SANDY CK
WATTLE CK
NATIVE DOG CK
Den139
Den125
Den 98
Den124
Den140
Den142
Den141
Den02
Den01a
Den07
Den09
Den144
Den145


DENDROBIUM AREA 3C
Swamp Monitoring Sites
Figure 3-4
SOUTH32
Illawarra Coal
Proposed Swamp Monitoring Site
Exisiting Swamp Monitoring Site
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
Cordeaux Dam
Lake Avon
289000
290000
291000
292000
293000
6196000
6195000
6194000
6193000
Den 98
Den125
Den139
Den124
Den140
Den142
Den141
Den06
Den02
Den07
Den01a
Den09
Den144
Den145
Den05
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
DC9
DC9A
DC10A
DC10
DC11
DC12
DC13
WC17
WC17A
WC18
WC19
WC20
WC21
WC22
WC23
WC23A
WC23B
WC24
WC24A
WC25
WC26
WC26A
WC27
WC27A
WC28'
WC29
CR36
CR36B
CR36B1
CR36C
CR38
LC2
LC3
LC4
LC4A
LC5
LC5A
LC5A1
LC6
LC9


DENDROBIUM AREA 3C
Deep Groundwater
Monitoring Sites
Figure 3-5
SOUTH32
Illawarra Coal
Groundwater Monitoring
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
0 250 500 1,000
Meters
N S W E
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Cordeaux Dam
Lake Avon
S2017 S2010 S2019 S2018 S2207 S1779 S2208 S2288 S1844 S1796 S1390 S1910 S1800 S1892 S1845 S2192 S2220 S1908 S1930 S1926 S1929 S1719 S1925 S1587 S1889
Den139 Den125 Den 98 Den124 Den140 Den142 Den141 Den06 Den02 Den07 Den01a Den09 Den144 Den145 Den05
289000 290000 291000 292000 293000
6196000 6195000 6194000 6193000



DENDROBIUM AREA 3C
Geomorphic Features
Figure 3-6
SOUTH32
Illawarra Coal
Stream Mapping
Feature Type
Rockbar
Pool
Step
DSC Notification Areas
Study Area (35 deg Angle of Draw)
Study Area (600 m Boundary)
Upland Swamps
Creeks
Tributaries
Existing Mine Workings
Proposed Longwall Layout
Dendrobium Goaf
Cordeaux Dam
Lake Avon
Date: November, 2019
Author: B.Agland
Version 1
Horizontal Datum
MGA - Zone 56
N
W
E
S
0
250
500
1,000
Meters
289000
290000
291000
292000
293000
6193000
6194000
6195000
6196000
Longwall 20
Longwall 21
Longwall 9
Longwall 10
Longwall 11
Longwall 6
Longwall 7
WONGAWILLI CK
DONALDS CASTLE CREEK
Den139
Den125
Den 98
Den124
Den140
Den142
Den141
Den06
Den02
Den01a
Den05
Den07
Den09
Den144
Den145

4 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium modified Consent. These performance measures are presented in **Table 4-1** and will be applied to the Dendrobium Area 3C mining area.

Table 4-1 Subsidence Impact Performance Measures

Dendrobium Modified Development Consent
• Operations shall not cause subsidence impacts at Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality); • Operations will not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

A detailed list of performance measures and triggers is included in the TARPs in **Attachment 1: 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.

There are two broad mechanisms by which subsidence could cause changes in watercourse hydrology and water quality:

- The bedrock below the watercourse fractures as a consequence of strains and water drains into the fracture zone. The extent and permanence of these changes relate to the size of the fracture zone (increase in porosity/storage) and whether the fractures are connected to a deeper aquifer, the mine workings, conductive geological features/lineaments or bedding shear pathway to the surface lower in the catchment. Surface water diverted through freshly fractured sandstone and/or groundwater that returns to the surface through the fracture network may contain increases in iron concentrations and other minerals.
- Tilting, cracking, desiccation and/or changes in vegetation health result in concentration of runoff and erosion which alters water distribution in the watercourse.

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 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 and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates.
- Reduced inflows into Lake Avon and Cordeaux River.

4.2 Potential for Connectivity to the Mine Workings

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

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

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

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

The results of water analysis and the interpretation of the height of connective fracturing was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux". Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield.

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

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

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

As reported in Coffey (2012) most of the change in aquifer properties occurs within the collapsed zone. Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storativity. Groundwater drawdown due to sudden storativity increases will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow.

Predictions of fracture zone dimensions for Dendrobium (MSEC 2012 and Coffey 2012) refer to geotechnical fracturing behaviour and are not necessarily directly related to 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.

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

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

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

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

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

HysroSimulations believe there is a flaw in PSM's hydrogeological conceptual model, which leads to some errors in their conclusions about the extent of connective fracturing. PSM seems to have assumed vertical connected fracturing on the strength of pressure reductions at piezometers, when pressure reductions could occur due to several factors, including increased horizontal permeability, increased porosity or increasing downward hydraulic gradient due to depressurisation in the goaf.

The IEP (2018) undertook an independent analysis and concluded: *notwithstanding that uncertainty is associated with both the Tammetta and the Ditton height of complete drainage equations, it is recommended to err on the side of caution and defer to the Tammetta equation until field investigations quantify the height of complete drainage at the Dendrobium Mine*.

The Regional Groundwater Model for Dendrobium Mine has been revised to consider the findings of the PSM report and IEP (2018), 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.

4.3 Potential for Fracturing Beneath the Watercourses

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2019) the bedrock below the watercourses 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 storage, aquifer or the mine workings will re-emerge further downstream (see **Section 4.2**). This prediction is based on an assessment of the depth of valley closure induced vertical fracturing from the surface and measurements of water balance 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 (IEP 2018). In this instance the diversion of surface flow to deep strata storage or the mine relates to vertical permeability increases associated with this fracturing.

Prior to any remediation works within Area 3C 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 conductivity 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 13 was modelled and assessed in the Longwall 13 End of Panel Report. This assessment has identified that mining-related effects on the flow regime have occurred in tributaries to Donalds Castle Creek (DCS2, DC13S1), and in Lake Avon tributary LA4. There is also a possible change to runoff characteristics at the downstream gauge of Donalds castle Creek (DCU) and Wongawilli Creek (WWL). Surface fracturing was noted in the channel of tributary WC15 during Longwall 13; however, flow characteristics at the downstream gauge (WC15S1) are not significantly different from baseline.

The water level in Pool 43a on Wongawilli Creek has declined since 2012, and water levels dropped below baseline on 20 November 2017. Assessment of the declining water levels in Pool 43 was hindered by the unusually dry conditions during the extraction of Longwall 13 which has affected pools outside the influence of mining. However, the steady decline in water levels at Pool 43a since 2012 appears independent of the rainfall trends and, combined with observations of drawdown in groundwater pressures in the sandstone substrate, suggests that water level trends at Pool 43a may be due to induced baseflow reduction. Rainfall-runoff modelling of flows at the downstream gauge (WWL) indicates that baseflow reduction is less than predicted by numerical modelling.

An additional Wongawilli Creek downstream flow monitoring site to WWL has been installed at a flume and rockbar site, just upstream of the fire road crossing, Site WWL_A. This will improve the flow monitoring accuracy for Wongawilli Creek.

4.4 Potential for Erosion Within the Watercourses

Tilting, cracking, desiccation and/or changes in vegetation health could result in erosion within the watercourses. The likelihood and timing of these consequences relate to the size and duration of the effect.

Subsidence predictions were carried out to assess the potential impacts of longwall mining in Area 3C (MSEC 2019). The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the watercourses is provided in **Section 5**.

Tilting of sufficient magnitude could change the catchment area of a watercourse or re-concentrate runoff leading to scour and erosion.

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 (2019). 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 watercourses 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 and the condition of rockbars.

The observed impacts on natural features above Area 3B to date are generally consistent with those predicted in the assessments undertaken prior to mining.

4.5 Potential for Aquatic Ecology Changes Within the Watercourses

Where there are changes to watercourse hydrology that are large and persistent there is likely to be an aquatic ecology response. Aquatic species which do not have life-cycles adapted to temporary loss of aquatic habitat are likely to be relatively susceptible to changes in pool water level. In comparison, riparian vegetation is likely to be relatively resilient to short term changes in groundwater level and soil moisture, demonstrated by the persistence of these vegetation communities during extended periods of drought.

Cardno Ecology Lab undertakes a monitoring program designed to detect mining-related subsidence impacts to indicate the condition of aquatic ecology. The monitoring program is based on a BACI design that provides a measure of natural spatial and temporal variability in key aquatic ecology indicators at potential impact and control sites before, during and after mining. This enables changes in the mining area to be distinguished from changes due to natural variability.

The monitoring program focuses on the following key indicators:

- RCE Inventory method and by establishing a photographic record through time;
- Aquatic macroinvertebrates sampled in accordance with AUSRIVAS;
- Aquatic macroinvertebrates sampled quantitatively using artificial collectors;
- Sampling of fish using bait traps and backpack electrofishing; and
- Limited in situ water quality sampling is undertaken to assist with interpretation of trends in the above indicators.

Monitoring is undertaken within Wongawilli Creek, WC21 (a tributary of Wongawilli Creek) and Donalds Castle Creek, and at comparable Control sites established on Wongawilli, Sandy, Donalds Castle and Kentish creeks. Univariate and multivariate statistical analyses have been conducted on the AUSRIVAS sampling and artificial collectors.

Physical impacts in Lake Avon tributary LA4B, including fracturing and flow diversion has resulted in a reduction in aquatic habitat. Fracturing of bedrock and diversion of flows in Lake Avon tributaries is likely to have resulted in some minor reduction in quantity and connectivity of aquatic habitat.

WC21 has been mined beneath by Longwalls 9 to 14 with fracturing of bedrock, flow diversions and associated reductions in pool water levels and flow. Following the extraction of Longwall 14, these impacts have been observed in 1.7 km (over 50 %) of the total length of the watercourse.

4.6 Potential for Raw Water Quality Changes

From several years of monitoring there has been no evidence of short or long-term impacts to water quality or drinking water quality in Lake Avon, despite tributaries of the lake being directly undermined by Elouera Colliery and Dendrobium Mine longwalls, causing bedrock fracturing.

Due to the setbacks from Wongawilli and Donalds Castle Creeks of the Area 3C longwalls, it is not expected any significant fracturing and sub-bed flow diversions in the creeks would alter flows or water quality other than minor impacts. Due to the substantial distance downstream, it is predicted there will be no reduction (other than negligible reduction) in the quality or quantity of surface water inflow to the Cordeaux River at its confluences with Wongawilli and Donalds Castle Creeks.

Based on past experience from Wongawilli and Native Dog Creeks, which were directly mined under by Elouera Colliery longwalls, it is also considered highly unlikely that there would be any adverse effect on bulk drinking water supply quality in the Lake Avon or Cordeaux River (into which Donalds Castle and Wongawilli Creeks discharge) systems.

Any water-borne inputs to Lake Cordeaux and Cordeaux River would likely be restricted to a possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor tributaries designated LC5, WC20, WC21, WC22. WC23, WC24, WC25, WC26, WC27 and WC28, during mining of Area 3C. It is predicted that these water-borne inputs will result in negligible environmental consequences.

These tributaries are all remote from respective dam off-takes and outflows. Such zones would be localised around the point of input to the Lake and would be unlikely to have any detrimental effect on local freshwater ecology and unable to affect bulk water supply quality.

4.7 Achievement of Performance Measures

Longwall mining can result in surface cracking, heaving, buckling and stepping at the surface. Surface deformations can also develop as the result of downslope movements where longwalls are extracted beneath steep slopes. In these cases, the downslope movements can result in the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes. Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley closure movements. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, geomorphology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

A number of large surface cracks were observed at the commencing end of Longwall 3 in Area 2 at Dendrobium Mine. The depth of cover at the commencing end of Longwall 3 was as shallow as 145 m, which is less than that above Longwalls 20 and 21. It is expected, therefore, that the widths of surface cracking resulting from the extraction in Area 3C would be generally less than that observed above the commencing end of Longwall 3.

The experience gained from mining in Dendrobium Areas 1, 2, 3A and 3B indicate that mining-induced fracturing in bedrock and rockbars are commonly found in sections of streams that are located directly above extracted longwalls. However, minor fracturing has also been observed in some locations beyond extracted longwall goaf edges, the majority of which have been within the limit of conventional subsidence or associated with valley closure or bedding plane shear.

An empirical database has been developed of pool and rockbar sites in the Southern Coalfield that have experienced mining induced valley related movements. The upsidence and closure movements at these sites have been predicted, using the ACARP Method of predicting valley closure, at the time when the first pool impact occurred, or after this time, when pool water loss was first recorded.

An analysis of impact rates has been undertaken using the currently available database of pools and rockbar case studies. This database is being continually developed and, to date, research has mainly concentrated on collating knowledge on the known pool and rockbar impact sites, whilst less data has been included for sites that had no impacts as a result of mining. The current reference to the 200 mm predicted total closure value should therefore be viewed as an indication of low probability of impact (i.e. around 10 %).

It has been assessed, therefore, that it is unlikely that significant fracturing or surface water flow diversions would occur along Wongawilli or Donalds Castle Creeks as a result of the extraction. This assessment has been based on limiting the predicted additional closure at the mapped rockbars and riffles to 200 mm.

During the Longwall 13 extraction period, low water levels in Pool 43a were observed.

Additionally, approximately 1.5 km reach of Wongawilli Creek, extending from Pool 43a, was observed to be dry (Longwall 13 End of Panel Report). Although the fracture in the base of Pool 43a was caused by mine subsidence, water levels in the pool were declining prior to the fracture occurring, with no significant changes in pool water-level recession (Watershed HydroGeo 2018). Investigation and analyses showed that reductions in baseflow to Wongawilli Creek, in-line with predictions, had occurred due to mining in Areas 3A and 3B and subsequent reductions in groundwater levels in the Upper Bulgo Sandstone and Lower Hawkesbury Sandstone (Watershed HydroGeo 2018). However, the dominant process contributing to the low pool water-levels was the severe rainfall deficit and depressed groundwater levels (Watershed HydroGeo 2018).

IEP (2018) reviewed the valley closure impact model and made the following recommendation: *the concept of restricting predicted valley closure to a maximum of 200 mm to avoid significant environmental consequences should be revised for watercourses*.

As described above, the closure impact model has been successfully used at Dendrobium Mine to date, with the target value of 200 mm predicted closure resulting in a low-likelihood of impact (consistent with the model predictions). The valley closure impact model undergoes continuous review as part of the EoP Reporting process to determine the applicability of the predicted valley closure target for each stream.

IMC has adopted a 200 mm predicted closure as a key design constraint for the setback of longwall panels from named watercourses at Dendrobium Mine, where a setback is provided to reduce impacts to that stream. The empirical data used to develop the 200mm closure target includes only streams with a setback from mining. An alternative target would need to be developed for streams directly mined under.

When applied on a case-by-case basis, the closure impact model can be refined and continue to be used to achieve a specified level of impact likelihood. While ongoing review of data to refine the closure impact model and closure target is supported, monitoring data to date does not indicate that the target of 200 mm predicted closure for named streams at Dendrobium Mine requires significant change at this time.

5 PREDICTED IMPACTS FOR NATURAL FEATURES

Subsidence has the potential to affect watercourses overlying and adjacent to the proposed longwalls due to either transient or relatively permanent changes in porosity and permeability of the soil matrix and bedrock. Sandstone is likely to fracture as a result of the differential subsidence movements predicted.

If a watercourse overlies a longwall panel it is likely to 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 at any one location.

In addition, where a watercourse overlies a longwall, it is likely to 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.

Predicted impacts were assessed for Wongawilli Creek (third order) and all other drainage lines (first and second order) within Area 3C in **Attachment D** (MSEC 2019).

In accordance with the findings of the Southern Coalfield Inquiry and the IEP (2018):

- **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.

Impact predictions have been completed within the Study Area in order to record potential and likely impacts from the proposed mining. The predictions are based on mathematical and empirical models and utilise the best available information for the Southern Coalfield and in particular Dendrobium Mine conditions. The impact predictions have been compared with previous predictions for Dendrobium Mine and the Conditions of Consent to ensure compliance of the proposed mining.

Monitoring is conducted in the area potentially affected by subsidence and in reference areas. Data collected in the impact zone will be compared to baseline and reference sites to determine any impacts from subsidence.

5.1 Subsidence Effects

The maximum predicted subsidence parameters resulting from the extraction of Longwalls 20 and 21 are provided in MSEC (2019). The predicted subsidence parameters including; vertical subsidence, tilt and curvature have been used in the impact assessment for Dendrobium Area 3C.

The predicted strains were determined by analysing the strains measured at Dendrobium Mine and other NSW Collieries, where the longwall width-to depth ratios and extraction heights were similar to the proposed longwalls. The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of joints in bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains resulting from the extraction of proposed Longwalls 20 and 21, based on applying a factor of 15 to the maximum predicted curvatures, are 8 mm/m tensile and 11 mm/m compressive. These strains represent typical values when the ground subsides regularly with no localised or elevated strains due to near-surface geological structures or valley closure effects. The maximum strains can be much greater than these typical values, especially in the locations of near-surface geological structures and in the bases of valleys.

5.2 Wongawilli Creek

5.2.1 Description

Wongawilli Creek is a third order perennial stream with a small base flow and increased flows for short periods of time after significant rain events. The creek generally flows in a northerly direction and drains into the Cordeaux River approximately 2.3 km to the north of the proposed longwalls. Pools in the creek naturally develop behind the rockbars and at the sediment and debris accumulations.

Wongawilli Creek is located between the proposed Longwalls 20 and 21. The thalweg (i.e. base or centreline) of the creek is 125 m east of the tailgate of Longwall 20 and 240 m west of the finishing end of Longwall 21, at the closest points to the proposed longwalls. Further upstream, the creek is located between the completed longwalls in Areas 3A and 3B. The minimum distances between the thalweg of the creek and the completed longwalls are 110 m for Area 3A and 260 m for Area 3B.

The total length of Wongawilli Creek located within the Study Area based on the 35° angle of draw line is approximately 0.8 km. The length of the creek located within the Study Area based on the 600 m boundary is approximately 3.0 km.

5.2.2 Subsidence Predictions

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for Wongawilli Creek is provided in **Table 5-1**. The values are the maxima anywhere along the section of the creek located within the Study Area based on the 600 m boundary.

Table 5-1: Maximum predicted total vertical subsidence, upsidence and closure for Wongawilli Creek

Location	Area or Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Wongawilli Creek	Areas 3A and 3B	< 20	140	200
	LW20	< 20	140	200
	LW21	< 20	150	210

The section of Wongawilli Creek located within the Study Area is predicted to experience less than 20 mm vertical subsidence. Whilst the creek could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains.

The maximum predicted total valley related movements for the section of creek located within the Study Area are 150 mm upsidence and 210 mm closure. The maximum predicted valley related effects within the Study Area occur adjacent to the completed Longwalls 9 and 10 in Area 3B.

The maximum predicted additional valley related effects due to the extraction of the proposed Longwalls 20 and 21 are 60 mm upsidence and 150 mm closure. The maximum additional valley related effects occur where Wongawilli Creek is located closest to the proposed Longwall 20.

Wongawilli Creek could experience compressive strains due to the valley closure movements. The predicted strains have been determined based on the analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for Wongawilli Creek. The maximum predicted compressive strain for Wongawilli Creek due to the extraction of the proposed Longwalls 20 and 21 is 8 mm/m based on the 95 % confidence level.

5.2.3 Impact Predictions/Environmental Consequences

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

The average natural grade of the section of Wongawilli Creek within the Study Area is approximately 3.7 mm/m (i.e. 0.37 %, or 1 in 270). The predicted changes in grade due to the extraction of Longwalls 20 and 21 (less than 0.5 mm/m), therefore, are considerably less than the average natural grade. It is unlikely, therefore, that there would be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilt.

However, it is possible that there could be some localised changes in the levels of ponding or flooding where the maximum changes in grade coincide with existing pools, steps or cascades along the creek. It is not anticipated that these changes would result in adverse impacts on the creek, due to the mining-induced tilt, since the predicted changes in grade are less than 0.05 %.

Potential for fracturing of bedrock and surface water flow diversions

Diversions of surface water flows also occur naturally from erosion and weathering processes and from natural valley bulging movements. Mining-induced surface water flow diversions into the strata occur where there is an upwards thrust of bedrock, resulting in a redirection of some water flows into the dilated strata beneath the creek beds. At higher depths of cover, where a constrained zone exists or where the creek is not directly mined beneath, the water generally reappears further downstream of the fractured zone as the surface flow is only redirected below the creek bed where the fractured zone exists.

Fracturing in bedrock has been observed due to previous longwall mining where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. Therefore, it is possible that fracturing could occur along Wongawilli Creek due to the valley-related compressive strains. Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield. Fracturing has been observed at distances up to 300 m from the completed longwalls in Area 3B.

The maximum predicted total closure along Wongawilli Creek within the Study Area, following the extraction of the proposed Longwalls 20 and 21, is 210 mm. The predicted rate of impact for the rockbars along this creek after the extraction of the proposed longwalls, therefore, is in the order of 7 % based on the maximum predicted closure.

It has been assessed that the likelihood of fracturing resulting in surface water flow diversions along Wongawilli Creek, due to the extraction of the proposed Longwalls 20 and 21, is low, i.e. affecting less than 10 % of rockbars located within the Study Area. However, minor fracturing could still occur along the creek, at distances up to approximately 400 m from the proposed longwalls.

Baseflow Depletion

Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), mining-induced subsidence and depressurisation can result in a reduction in the baseflow component and subsequent reductions in low-flows and increases in the duration of cease-to-flow conditions (HGEO 2019).

Baseflow contribution for Wongawilli Creek has been estimated as 10-16 % (1.22 – 1.95 ML/day) of average daily yield (HydroSimulations 2019 and HGEO 2019).

Baseflow reductions in Wongwawilli Creek have been estimated at 0.2 ML/day (after 2 years of Longwall 21 extraction) and 0.18 ML/day (after 10 years of Longwall 21 extraction) (HGEO 2019).

Basal Shear Planes

Basal shear planes are lateral planar features that can extend laterally in strata (e.g. Bald Hill and Stanwell Park Claystones) at an elevation of, or just beneath, the base of incised valleys. The presence of basal shear planes has a potential role in connecting features to the goaf. The shorter distance from the proposed longwalls to Wongawilli Creek means that shear planes may increase connection to these features (HydroSimulations 2019).

5.3 Donalds Castle Creek

5.3.1 Description

The section of Donalds Castle Creek located within the Study Area is a second order perennial stream with a small base flow and increased flows for short periods after significant rain events. The creek generally flows in a northerly direction and drains into the Cordeaux River more than 4 km to the north of the proposed longwalls. The bed of the creek comprises exposed bedrock containing rockbars with standing pools. There are also other controlling features including channels, steps and debris accumulations.

Donalds Castle Creek is located to the west of the proposed longwalls. The thalweg of the creek is 470 m from the maingate and finishing end of Longwall 20, at its closest point. Donalds Castle Creek is located outside the Study Area based on the 35° angle of draw. The total length of the creek located within the Study Area based on the 600 m boundary is approximately 0.8 km.

Donalds Castle Creek crosses directly above the completed Longwalls 9 to 12 in Area 3B upstream of the proposed longwalls. The total length of creek that has been directly mined beneath in Area 3B is approximately 1.5 km.

5.3.2 Subsidence Predictions

A summary of the maximum predicted values of total vertical subsidence, upsidence and closure for Donalds Castle Creek is provided in (**Table 5-2**). The values are the maxima anywhere along the section of the creek located within the Study Area based on the 600 m boundary and include the predicted movements due to the previously extracted longwalls in Area 3B.

Table 5-2: Maximum predicted total vertical subsidence, upsidence and closure for Donalds Castle Creek

Location	Area or Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total upsidence (mm)	Maximum predicted total closure (mm)
Donalds Castle Creek	Area 3B	< 20	90	170
	LW20	< 20	90	180
	LW21	< 20	90	180

The section of Donalds Castle Creek located within the Study Area is predicted to experience less than 20 mm vertical subsidence after the extraction of the proposed Longwalls 20 and 21. Whilst the creek could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional tilts, curvatures or strains.

The maximum predicted upsidence (**Table 5-2**) and closure occur adjacent to the existing longwalls in Area 3B. Only very small additional movements are predicted to occur in this location due to the extraction of the proposed Longwalls 20 and 21.

The section of Donalds Castle Creek located downstream of the previously extracted longwalls in Area 3B could experience additional valley-related effects, where it is located closest to the proposed Longwall 20. The maximum predicted additional valley related movements for the section of creek located within the Study Area are less than 20 mm upsidence and less than 20 mm closure. Only low-levels of additional valley related effects are predicted due to the distance of Donalds Castle Creek from the proposed longwalls.

Donalds Castle Creek could experience compressive strains due to the low-level valley closure movements. The predicted strains have been determined based on the analysis of ground monitoring lines for valleys with similar heights located at similar distances from previously extracted longwalls in the Southern Coalfield, as for Donalds Castle Creek. The maximum predicted compressive strain for Donalds Castle Creek due to the extraction of the proposed Longwalls 20 and 21 is 1 mm/m based on the 95 % confidence level.

5.3.3 Impact Assessment

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

Donalds Castle Creek is predicted to experience less than 20 mm additional vertical subsidence due to the extraction of the proposed Longwalls 20 and 21. Whilst the creek could experience very low-levels of additional vertical subsidence, it is not expected to experience measurable conventional tilts. That is, the predicted changes in grade along the creek due to the conventional movements are less than 0.5 mm/m (i.e. less than 0.05 %, or 1 in 2000).

The average natural grade of the section of Donalds Castle Creek within the Study Area is approximately 35 mm/m (i.e. 3.5 %, or 1 in 30). The predicted changes in grade due to the extraction of the proposed Longwalls 20 and 21, therefore, are considerably less than the average natural grade. Therefore, it is unlikely that there would be adverse changes in the potential for ponding, flooding or scouring of the banks along the creek due to the mining-induced tilts.

Potential for fracturing of bedrock and surface water flow diversions

Fracturing occurred in Rockbar DC-RB33 along Donalds Castle Creek, due to the extraction of Longwall 9, which resulted in the diversion of surface water flows in that location (i.e. Type 3 impact). This rock bar is located outside the Study Area at a distance of 660 m south-west of the finishing end of the proposed Longwall 20.

At this distance, Rockbar DC-RB33 is not predicted to experience measurable additional upsidence or closure movements due to the extraction of Longwalls 20 and 21. It is unlikely that additional fracturing would occur at this rockbar due to these proposed longwalls.

The remaining rockbars along Donalds Castle Creek downstream of Rockbar DC-RB33 are predicted to experience additional closure movements of less than 20 mm. The maximum predicted compressive strain for the creek due to the valley closure effects is 1 mm/m based on the 95 % confidence level.

Fracturing has been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield. Donalds Castle Creek is located 470 m from the maingate and finishing end of Longwall 20, at its closest point to the proposed longwalls.

It is considered unlikely, therefore, that fracturing would occur along Donalds Castle Creek due to the extraction of Longwalls 20 and 21 due to the low-levels of predicted movements and its distance from the proposed longwalls.

Baseflow Depletion

Where stream flow is partly sustained by the discharge of groundwater from adjacent aquifers (baseflow), mining-induced subsidence and depressurisation can result in a reduction in the baseflow component and subsequent reductions in low-flows and increases in the duration of cease-to-flow conditions (HGEO 2019).

Baseflow contribution for Donalds Castle Creek has been estimated as 1 - 6 % (0.017 – 0.099 ML/day) of average daily yield (HydroSimulations 2019 and HGEO 2019). Baseflow reductions in Donalds Castle Creek have been estimated at 0.14 ML/day (after 2 years of Longwall 21 extraction) and 0.008 ML/day (after 10 years of Longwall 21 extraction) (HGEO 2019).

5.4 Drainage Lines

5.4.1 Description

The unnamed drainage lines are located above and adjacent to Longwalls 20 and 21. These drainage lines are first and second order streams that form tributaries to Wongawilli Creek. The beds of the drainage lines generally comprise exposed bedrock containing rockbars with some standing pools. There are also steps and cascades along the steeper sections. Debris accumulations have formed along the flatter sections that include loose rocks and tree branches.

The natural gradients of the drainage lines vary between 20 mm/m (i.e. 2.0 %, or 1 in 50) and 500 mm/m (i.e. 50 %, or 1 in 2), with average natural gradients typically ranging between 100 mm/m (i.e. 10 %, or 1 in 10) and 200 mm/m (i.e. 20 %, or 1 in 5). The drainage lines have localised areas with natural grades greater than 500 mm/m where there are steps and cascades.

5.4.2 Subsidence Predictions

The drainage lines are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the drainage lines is provided in **Table 5-3**. The total parameters represent the accumulated movements within the Study Area due to the extraction of the existing and proposed longwalls.

Table 5-3: Maximum predicted total subsidence, tilt and curvature for the drainage lines

Location	After longwall	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})
Drainage Lines	LW20 and LW21	2050	30	0.50	0.75

The maximum predicted total tilt for the drainage lines is 30 mm/m (i.e. 3.0 %, or 1 in 33). The maximum predicted total conventional curvatures are 0.50 km^{-1} hogging and 0.75 km^{-1} sagging, which represent minimum radii of curvatures of 2 km and 1.3 km, respectively.

The drainage lines have shallow incisions into the natural surface. The predicted valley related movements, therefore, are small and not considered significant when compared with the predicted conventional movements provided in the above table.

The maximum predicted conventional strains for the drainage lines, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8 mm/m tensile and 11 mm/m compressive. The predicted strains directly above the proposed longwalls are 6 mm/m tensile and compressive based on the 95 % confidence level.

5.4.3 Impact Assessment

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

Mining can result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural drainage line gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the banks in the locations where the mining induced tilts considerably increase the natural drainage line gradients that exist before mining.

The maximum predicted tilt for the drainage lines within the Study Area is 30 mm/m (i.e. 3.0 % or 1 in 33). The predicted mining-induced tilts are less than the natural gradients of the drainage lines that typically vary between 100 mm/m and 200 mm/m (i.e. 10 % to 20 %).

It is unlikely, therefore, that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along these drainage lines due to the mining-induced tilt. It is possible that localised increased ponding could develop in some isolated locations, where the natural grades are small and where the drainage lines exit the mining area.

The potential impacts of increased ponding and scouring of the drainage lines, therefore, are expected to be minor and localised. The impacts resulting from the changes in surface water flows are expected to be small in comparison with those which occur during natural flooding conditions.

Potential for cracking in the creek bed and fracturing of bedrock

Impacts have been observed along the drainage lines above and adjacent to the previously extracted Longwalls 9 to 14 in Area 3B, including fracturing in the rockbars and exposed bedrock, dilation and uplift of the bedrock, iron staining, surface water flow diversions and reduction in pool water levels. These impacts predominately occurred directly above the extracted longwalls. However, fracturing was also observed up to 290 m from the extracted longwalls.

The predicted subsidence parameters for the proposed longwalls are less than the maxima predicted for the existing and approved longwalls due to their narrower longwall void widths.

It is expected that fracturing of the bedrock would occur along the sections of the drainage lines that are located directly above the proposed Longwalls 20 and 21. Fracturing can also occur outside the extents of the proposed longwalls, with minor and isolated fracturing occurring at distances up to approximately 400 m.

The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the topmost bedrock, as it is less confined.

This valley closure related dilation is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

Surface water flow diversions are likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls.

6 MANAGEMENT AND CONTINGENCY PLAN

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

6.1 Objectives

The aims and objectives of the Plan include:

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

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

6.2 Trigger Action Response Plan

The TARPs relate to identifying, assessing and responding to potential impacts to watercourses (including impacts greater than predicted) from subsidence in Dendrobium Area 3C. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3C watercourses are included in **Attachment 1: Table 1.2**.

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

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

Level 2 and 3 TARPs result in further investigations and reporting by appropriately qualified specialists. 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 objectives for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;
- Roles and responsibilities;

- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

6.3 Avoiding and Minimising

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

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

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

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

Area 3C is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2, 3A and 3B to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of Area 3C including major surface water features such as Lake Cordeaux, Wongawilli Creek, Donalds Castle 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 north-west of the proposed Longwall 20. The process of developing the layout for Area 3C has considered predicted impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

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 3C mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPE and OEH during the consultation process. Mine plan changes result in significant business and economic impact, including:

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

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;
- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;
- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;

- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and
- Requires specialised equipment and skilled personnel with limited availability.

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

6.4 Mitigation and Rehabilitation

If the performance measures in the Development Consent are not met, then following consultation with BCD, Water NSW and T&I, 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 (Minister for Planning 2008), 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 TSC Act is required in respect of those activities.

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

6.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within Wongawilli Creek or Donalds Castle Creeks 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 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 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 profile. 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 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 large rockbar occurs it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via traditional or 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

Erosion can occur along preferred flow paths where subsidence induced tilts increase a catchment area. To arrest this type of erosion, ‘coir log dams’ are installed at knick points in the channelised flow paths or at the inception of tunnel/void spaces (**Figure 6-2**).

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. The coir logs are held in place by 50mm x 50mm wooden 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.

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 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 and Positioning of the First Layer of Coir Logs and Construction of a Small Dam in a Channel

The coir log dams are constructed at intervals down the eroding flow line, 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. 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 Surface Treatments

Where cracking develops in significant areas and natural infilling is not occurring, the cracks may require forking over and compacting to prevent erosion. Larger cracks may require more work to repair them, for example, mulch or other protection to prevent the development of erosion channels. Surface protection will remain in place until revegetation covers the disturbed area. In some cases, if the cracks are wider they may require gravel or sand filling up to surface level and revegetation using brush matting. Maintenance of moisture in rehabilitation areas can be enhanced by additional 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**).

Figure 6-6 Round Coir Logs Installed to Spread Water

Erosion control and water spreading involves soft-engineering materials that are biodegradable and become integrated into the soil profile. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the soil. This also removes the requirement for any post-rehabilitation removal of structures or materials. However, rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Relevant approvals will be obtained to ensure the protection of the environment as works are implemented.

6.4.5 Gas Release

A typical driver of gas release at the surface is pressure changes, dilation and/or fracturing of the rock mass and associated release to the surface, with or without groundwater flows. Grouting techniques discussed above can reduce these associated gas flows at specific sites. In all identified circumstances in the Southern Coalfield the gas releases have diminished over time. Typically, this time is a number of months but it can be a number of years. Long running gas releases significantly reduce in quantity over time. Where vegetation is impacted by gas releases the areas affected will be revegetated once monitoring determines the gas releases have ceased or reduced to an extent that vegetation is no longer affected.

Very few gas releases have been observed within the Dendrobium mining area.

6.4.6 Water Quality

Ecoengineers (2012) outline mitigation measures that would be considered if unpredicted water quality impacts were detected. Any works on Water NSW land requires prior approval from Water NSW to access the land and there is a requirement for compliance with the Access Agreement between Water NSW and IMC. These requirements ensure strict limits are placed on any impacts associated with undertaking rehabilitation works on Water NSW land.

6.4.7 Alternative Remediation Approaches

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

6.4.8 Monitoring Remediation Success

Baseline studies have been completed within the Study Area in order to record biophysical characteristics of the mining area. Monitoring is conducted in the area potentially affected by subsidence from the Area 3C 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.

The monitoring program would remain in place prior to, during and following the implementation of any remediation measures in Area 3C. The monitoring program is based on the BACI design with sampling undertaken at impact and control locations prior to the commencement of remediation, during remediation and after the completion of the remediation actions. The monitoring locations/points for watercourses within Dendrobium Area 3C 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 remediation 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 remediation or natural reduction of mining impacts over time.

Observation data will 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.

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, Schedule 3* of the Development Consent:

The Applicant shall provide suitable offsets for loss of water quality or loss of water flows to Water NSW 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 Water NSW; and

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

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

A biodiversity offset strategy has been developed in consultation with OEH and Water NSW for the approval of the Secretary of DPE. The Secretary DPE approved the Strategic Biodiversity Offset in accordance with *Condition 15 of Schedule 2* of the Development Consent for the Dendrobium Coal Mine 16th December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of Condition 9 of the SMP for Area 3 (2016).

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 will be directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps. The Swamp Rehabilitation Research Program (SRRP) is currently being undertaken in Swamp 1B.

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 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.
- Updates from specialists on investigation process.
- Inform relevant government agencies of investigation results.
- Develop site CMA in consultation with key stakeholders and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Review the WIMMCP in consultation with key government agencies and seek approval for any modifications.
- 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 degradation that exceeds the trigger levels specified in the TARPS.

The site-specific rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. Authority to access the land to conduct works and implement environmental controls will be approved by Water NSW.

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

Table 6-1 Performance Measures, Predicted Impacts, Mitigation and Contingent Measures for Watercourses

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
Wongawilli Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on water flows, water levels and water quality	• Observation of Wongawilli Creek for fracturing, gas release and iron staining • Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback 125 m and 240 m from Wongawilli Creek Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	Mining results in more than minor environmental consequences in Wongawilli Creek, including: • fracturing within Wongawilli Creek resulting in diversion of surface flow such that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River that is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site Wongawilli Ck (FR6) • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events that cannot be attributed to natural variation	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by *Condition 14 Schedule 3* of the Development Consent
Donalds Castle Creek	**Minor environmental consequences** including: minor fracturing, gas release and iron staining; and minor impacts on water	Minor environmental consequences including: minor fracturing, gas release and iron staining; and minor impacts on	• Observation of Donalds Castle Creek for fracturing, gas release and iron staining	The Longwall 20 has been setback 470 m from Donalds Castle Creek. Longwall 21 has been setback so that Donalds	Mining results in more than minor environmental consequences in Donalds Castle Creek, including: • fracturing within Donalds Castle Creek resulting in diversion of surface flow such	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
	flows, water levels and water quality	water flows, water levels and water quality	• Measurement of pool water levels • Measurement of surface water flow • Measurement of surface water quality	Castle Creek lies outside the 35º angle of draw. Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period	that >10% of the pools have water levels lower than baseline period • measured surface water flow reduction in Donalds Castle Creek at its confluence with Cordeaux River that is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation • gas release results in vegetation dieback that does not revegetate • gas release results in mortality of threatened species or ongoing loss of aquatic habitat • iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Ck (FR6) • ±3 standard deviation change (positive for EC, negative for pH and DO) from the baseline mean, for a minimum of two consecutive monitoring events that cannot be attributed to natural variation	water level lower than baseline period Provide residual environmental offset for any mining impact as required by *Condition 14 Schedule 3* of the Development Consent
Cordeaux River	Operations do not result in reduction (other than **negligible reduction**) in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	Negligible reduction in the quality and quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	• Observation of Wongawilli Creek for iron staining • Measurement of surface water flow • Measurement of surface water quality	The longwalls have been setback 125 m and 240 m from Wongawilli Creek	Mining results in more than negligible reduction in the quality or quantity of surface water inflows to the Cordeaux River at its confluence with Wongawilli Creek, including: • measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation • ±3 standard deviation change (positive for EC, negative for pH and DO) from the	Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period Provide residual environmental offset for any mining impact as required by *Condition 14*

Feature	Performance Measure	Predicted Impacts	How Monitored	How Managed	Exceeding Prediction	Contingent Measures
					baseline mean of Wongawilli Creek at its confluence with Cordeaux River, for a minimum of two consecutive monitoring events that cannot be attributed to natural variation	*Schedule 3* of the Development Consent

Note: The mitigation measures will be assessed for appropriateness (in consultation with key stakeholders), as the need arises, on the individual watercourses being impacted to ensure significant additional impacts to the watercourses 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.

7 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

7.1 Incidents

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

7.2 Complaints Handling

IMC will:

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

7.3 Non-Conformance Protocol

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

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

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

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

An independent environmental audit will also be undertaken (*Condition 6 Schedule 8*) 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 WIMMCP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Area 3 Approval Conditions. A summary of the administrative requirements is provided below.

8.1 Roles and Responsibilities

Statutory obligations applicable to Dendrobium 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 WIMMCP resides with the Superintendent Approvals who shall be the WIMMCP's authorising officer.

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

Manager Approvals

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

Principal Approvals

- Authorise the WIMMCP and any amendments thereto.
- To document any approved changes to the WIMMCP.
- Provide regular updates to IMC on the results of the WIMMCP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the WIMMCP.
- 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 WIMMCP.
- Organise audits and reviews of the WIMMCP.
- 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 WIMMCP 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 WIMMCP.
- Participate in assessment meetings to review subsidence impacts.
- Bring to the attention of the Superintendent Approvals any findings indicating an immediate response that may be warranted.
- Bring to the attention of the Superintendent Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the WIMMCP.

Survey Team Lead

- Collate survey data and present in an acceptable form for review at assessment meetings.

- Bring to the attention of the Superintendent Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Superintendent Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the WIMMCP.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Superintendent Approvals 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 WIMMCP.
- Conduct inspections in a safe manner.

8.2 Resources Required

The Manager Approvals provides resources sufficient to implement this WIMMCP.

Equipment will be needed for the TARP provisions of this WIMMCP. 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 Superintendent Approvals 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 Superintendent Approvals to ensure that all persons and organisations having responsibilities under this WIMMCP 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 WIMMCP and other relevant documentation will be made available on the IMC website.

8.5 Management Plan Review

A review of the objectives and targets associated with the Dendrobium Area 3 operations is undertaken on an annual basis via the IMC planning process. These reviews, which include involvement from senior management 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 WIMMCP 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 this approval.

If deficiencies in the EMS and/or WIMMCP 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.

9 REFERENCES AND SUPPORTING DOCUMENTATION

ACARP, 2009. Damage Criteria and Practical Solutions for Protecting River Channels. Project Number C12016. Ken Mills SCT May 2009.

BHP Billiton Illawarra Coal, 2006. Georges River Report: Assessment of Georges River Remediation Longwalls 5A1-4. November 2006.

BHP Billiton Illawarra Coal, 2011. Understanding Swamp Conditions - Field Inspection Report - September 2010 to November 2010. BHP Billiton Illawarra Coal, April 2011.

Biosis Research 2007. Dendrobium Area 3 Species Impact Statement, Prepared for BHP Billiton Illawarra Coal, Biosis Research Pty Ltd.

Biosis Research 2007. Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006, Biosis Research Pty Ltd.

Biosis Research, 2009. Revision of the Dendrobium Coal Mine Flora and Fauna Monitoring Program. February 2009.

Biosis Research, 2012. Elouera and Dendrobium Ecological Monitoring Program. Annual Monitoring Report Financial Year 2010/2011. August 2012.

Biosis Research, 2012. Swamp 15b TARP Assessment – Ecology. Ref:15462, 10 October 2012.

Biosis, 2014. Dendrobium Ecological Monitoring Program, Annual Report for 2012/2013 Financial Year. February 2014. Prepared for Illawarra Coal.

Biosis, 2015. Dendrobium Terrestrial Ecology Monitoring Program, Annual Report for 2014. September 2015. Prepared for Illawarra Coal.

Boughton W, 2004. The Australian water balance model. Environ Model Softw 19:943–956. doi: doi:10.1016/j.envsoft.2003.10.007.

Cardno 2019. Aquatic Flora and Fauna Assessment. Illawarra Coal Holdings Pty Ltd, 29 May 2019.

Cardno Ecology Lab, 2012. Aquatic Flora and Fauna Assessment. Prepared for BHPBIC, February 2012.

Cardno Ecology Lab, 2012. Swamp 15b and SC10C Aquatic Flora and Fauna Review. Ref: NA49913032, 5 October 2012.

Cardno Ecology Lab, 2013. Dendrobium Area 3A Aquatic Ecology Monitoring 2008-2012. Job Number: EL1112073 Prepared for BHP Billiton – Illawarra Coal, February 2013.

Cardno Ecology Lab, 2013. Review of Sandy Creek Pools Aquatic Flora and Fauna. 25 February 2013.

Cardno Ecology Lab, 2013. SC10C Level 3 Aquatic Ecology Trigger Assessment. 11 June 2013.

Cardno Ecology Lab, 2015. Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014. 30 March 2015.

Cardno Forbes Rigby, 2007. Landscape Impact Assessment and Monitoring Site Optimisation. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Area 3A Subsidence Management Plan Longwalls 6 to 10. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Dendrobium Area 3 Environmental Assessment. Prepared for BHPBIC.

Chafer, C., Noonan, M and Macnaught, E. 2004. The Post-Fire Measurement of Fire Severity and Intensity in the Christmas 2001 Sydney Wildfires. International Journal of Wildland Fire Vol. 13; pp. 227-240.

Chiew, F, Wang, Q. J., McConachy, F., James, R., Wright, W, and deHoedt, G. 2002. Evapotranspiration Maps for Australia. Hydrology and Water Resources Symposium, Melbourne, 20-23 May 2002, Institution of Engineers, Australia.

Coffey, 2012. Groundwater Study Area 3B Dendrobium Coal Mine: Numerical Modelling. GEOTLCOV24507AA-AB2 2 October 2012.

Ditton, S., and Merrick, N.P. 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle, NSW.

Doherty, J. 2010. PEST: Model-Independent Parameter Estimation User Manual (5th ed.): Watermark Numerical Computing, Brisbane, Queensland, Australia.

EarthTech Engineering Pty Ltd, 2005. Thresholds for Swamp Stability. Prepared for BHPBIC, January 2005.

The Ecology Lab, 2007. Dendrobium Area 3 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. October 2007.

Ecoengineers, 2006. Assessment of Surface Water Chemical Effects of Mining by Elouera Colliery. January - December 2005. February 2006.

Ecoengineers, 2006. Assessment of Catchment Hydrological Effects by Mining by Elouera Colliery Stage 1: Establishment of a Practical and Theoretical Framework. August 2006.

Ecoengineers, 2007. Surface Water Quality and Hydrology Assessment to Support SMP Application for Dendrobium Area 3.

Ecoengineers, 2010. End of Panel Surface and Shallow Groundwater Impacts Assessment Dendrobium Area 2 Longwall 5. Document Reference No. 2010/01A. April 2010.

Ecoengineers, 2012. Surface Water Quality and Hydrological Assessment: Dendrobium Area 3B Subsidence Management Plan Surface and Shallow Groundwater Assessment.

Ecoengineers, 2012. Level 2 TARP Independent Review and Recommendations Swamp 15b Dendrobium Area 3A. 25 September 2012.

Ecoengineers, 2013. Level 3 TARP Independent Review and Recommendations Sandy Creek Catchment Pool 7 (Dendrobium Area 3A). 12 February 2013.

Ecoengineers, 2013. Level 2 TARP Specialist Review and Recommendations Donalds Castle Creek. 22 May 2013.

Ecoengineers, 2014. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 9. June 2014.

Ecoengineers, 2015. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 10. February 2015.

Eco Logical Australia, 2004. The Impacts of Longwall Mining on the Upper Georges River Catchment: Report to Total Environment Centre, 2004.

Forster, 1995. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

GHD, 2007. Dendrobium Area 3A Predicted Hydrogeologic Performance. Report for BHP Billiton, Illawarra Coal. November 2007.

GSS Environmental, 2013. Baseline and Pre-Mining Land Capability Survey. Dendrobium Mine, Area 3B. February 2013.

Hazelton P.A. and Tille P.J., 1990. Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney.

Hebblewhite, 2010. BHP Billiton Illawarra Coal: Bulli Seam Operations Project – Independent Review. 31 March 2010.

Helensburgh Coal Pty Ltd, 2007. Submission to: Independent Expert Panel - Inquiry into NSW Southern Coalfield July 2007, Helensburgh Coal Pty Ltd.

Heritage Computing, 2009. Dendrobium Colliery Groundwater Assessment: Mine Inflow Review, Conceptualisation and Preliminary Groundwater Modelling. Merrick, N.P., Heritage Computing Report HC2009/2, February 2009.

Heritage Computing, October 2011. Recalibration of the Dendrobium Local Area Groundwater Model after Completion of Longwall 6 (Area 3A). Report prepared for Illawarra Coal. Report HC2011/13.

HGEO, 2019. Dendrobium Mine Assessment of surface water flow and quality effects of proposed Dendrobium Longwalls 20 and 21. Report: D18301 May 2019.

HydroSimulations, 2014. Dendrobium Area 3B Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Sata. Report: HC2014/4 March 2014.

HydroSimulations, 2019. Dendrobium Mine Longwalls 20 and 21 Groundwater Assessment. Prepared for Illawarra Coal Pty Ltd. May 2019.

Illawarra Coal, 2014. Longwall 9 End of Panel Report.

Illawarra Coal, 2015. Longwall 10 End of Panel Report.

Kirchner, J. W. 2009. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modelling, and doing hydrology backwards. Res., W02429.

Manly Hydraulics Laboratory, 2006. BHP Billiton Dendrobium Mine Area 2 Subsidence Environmental Management Plan Water Monitoring and Management Program. Prepared for BHPBIC. Version 1.4 January 2006.

McMahon, 2014. Dendrobium Community Consultative Committee Report: Review of Surface Water Study. An independent review of surface water hydrological modelling associated with Illawarra Coal's Dendrobium Area 3, conducted by Emeritus Professor Thomas McMahon, University of Melbourne. 4 June 2014.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

MSEC, 2019. Dendrobium mine – Area 3C. Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 20 and 21 in Area 3C at Dendrobium Mine. MSEC978 August 2019.

Niche Environment and Heritage, 2012. Terrestrial Ecological Assessment. Prepared for BHP Billiton Illawarra Coal. February 2012.

Niche Environment and Heritage, 2019a. Aboriginal Cultural Heritage Assessment Report. Prepared for South 32 Illawarra Coal Operations. September 2019.

Niche Environment and Heritage, 2019b. Dendrobium Longwalls 20-21 Terrestrial Ecological Assessment. South 32 Illawarra Coal. 20 August 2019.

OEC, 2001. Environmental Impact Statement Dendrobium Coal Project. Olsen Environmental Consulting, Figtree, N.S.W.

Parkhurst. D.L., and Appelo, C.A.J. 2012. Description of Input and Examples for PHREEQC Version 3 – A Computer Program for Speciation, Batch-Reaction, One- Dimensional Transport and Inverse Geochemical Calculations. US Department of Interior/US Geological Survey.

Parson Brinckerhoff, 2012. Independent Review of Dendrobium Area 2 and 3A Hydrochemical Data. August 20012.

Parsons Brinckerhoff, 2015. Connected fracturing above longwall mining operations, Part 2: Post-longwall investigation. For BHP Billiton Illawarra Coal. Document number 2172268F-WAT-REP-002 RevB. 6 March 2015.

Petersen, 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology Vol 27, Issue 2, April 1992.

Resource Strategies, 2009. Bulli Seam Operations Environmental Assessment. Report in support of an application for the continued operations of the Appin and West Cliff Mines.

Singh & Kendorski, 1981. Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments, Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Tammetta, P. (2013). Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater, 51(5), 723-734.

Tomkins, K.M. and Humphries, G.S. 2006. Technical report 2: Upland Swamp development and erosion on the Woronora Plateau during the Holocene. January 2006. Sydney Catchment Authority – Macquarie Collaborative Research Project.

Waddington, A.A. and Kay, D.R. 2001. Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs. Gorges and River Systems. Final Report on ACARP Research Project C8005, March 2001.

Waddington, A.A. and Kay, D.R. 2002. Management Information handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Zhang, L. Dawes, W.R. and Walker, G.R. 1999. Predicting the effect of Vegetation Changes on Catchment Average Water Balance. Technical Report No. 99/12, Cooperative Research Centre for Catchment Hydrology.

Attachment 1 – Watercourse Monitoring and TARP

Attachment 1

Watercourse monitoring within Dendrobium Area 3 will be installed ahead of mining to achieve 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 Watercourse Monitoring

	MONITORING SITE	SITE TYPE	MONITORING FREQUENCY	PARAMETERS
OBSERVATIONAL, PHOTO POINT AND WATER QUALITY PARAMETER MONITORING				
AREA 3A	Sandy Creek and tributaries (including SC7 and SC10)	Observation and photo point monitoring: • Sites based on an assessment of risk • Streams and swamps • Pools and rockbars • Previously observed impacts that warrant follow-up inspection	• Monthly 2 years pre- and post-mining, weekly when longwall is within 400 m of monitoring site • Reference sites 6 monthly	Visual signs of impacts to creeks 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 Manual Field Testing: Key water quality parameters in pools analysed to identify any changes resulting from mining including pH, Temp, EC, DO and ORP Pool water levels to identify any changes resulting from mining. At suitable sites, pool water levels will be measured with a pressure transducer and continuous logger. A benchmark for manual readings will be installed at sites that are not suitable for a logger
AREA 3B	**Impact Sites** Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC18, WC16, WC15, WC12, WC9, WC8, WC7, WC6, LA5, LA4, LA3, LA2, ND1 and DC13 Swamps 5, 10, 11, 13, 14, 23, 35a, 35b, 1a, 1b, 8, 3 and 4 **Reference Sites** Wongawilli Creek, Sandy Creek, LC5(1), LC7B, WC11, SC9A, SC10A, NDC1, DC10 and D10 Swamps 2(1), 7(1), 15a, 22, 24, 25, 33, 84, 85, 86, 87 and 88			
AREA 3C	**Impact Sites** (2, 3) Wongawilli Creek, Donalds Castle Creek, DC13, WC20, WC21, WC22, WC23, WC24, WC25, WC26, WC27, WC29, LC5(1) Swamps 2(1), 5, 7(1), 9, 124, 140, 141, 142, 144 and 145 **Reference Sites** CR36 (Cordeaux River tributary)			
WATER CHEMISTRY				
AREA 3A	**Wongawilli Creek** WWU1, WWU4, WC_Pool 46, WWM2, WC_Pool 43b and Wongawilli Ck (FR6) **Sandy Creek** SCk_Rockbar 5 (Sandy Creek adjacent to LW7)	• Collect sample • Field water quality	• Monthly monitoring pre, during and post mining for two years	Lab. Analytes: • (incl. lab check of pH, lab. check of EC, DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si)

AREA 3B	**Wongawilli Creek** WWU1 (Wongawilli Creek headwaters) WWU4 (Wongawilli Creek upstream) WC_Pool 51 (Wongawilli Creek downstream of WC7) WC Pool 49 (Wongawilli Creek adjacent to LW15) WC_Pool 46 (Wongawilli Creek adjacent to LW12) WWM2 (Wongawilli Creek adjacent to LW11) WC_Pool 43b (Wongawilli Creek downstream of LW9) Wongawilli Ck (FR6) (Wongawilli Creek downstream) WC21_Pool 5 (Wongawilli Creek tributary downstream of mining) WC21 Pools 30 and 53 (Wongawilli Creek tributaries over mining) WC15_Pool 28 (Wongawilli Creek tributary downstream of mining) WC15_Pool 9 (Wongawilli Creek tributary downstream of mining) WC15_Pool 2 (Wongawilli Creek tributary downstream of mining) **Lake Avon** LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA3_Pool 4, LA2_Pool 5 and LA_1 (Lake Avon tributaries and lake sites downstream of mining) NDC4 (Native Dog Creek downstream of mining) NDC1 (Native Dog Creek upstream of Area 3B) **Donalds Castle Creek** Donalds Castle Ck (FR6) (Donalds Castle Creek downstream) DCL3 (Donalds Castle Creek towards Cordeaux River) DC_Pool 22 (Donalds Castle Creek downstream of mining) DC13_Pool 2b (Donalds Castle Creek tributary downstream of mining)			

AREA 3C	**Wongawilli Creek** WWU1 (headwaters; upstream of Area 3C) WWU4 (upstream of Area 3C) Wongawilli Ck (FR6) (Wongawilli Creek downstream) WC_Pool 43b (adjacent to Longwall 20) WC_S1 (downstream of Longwall 21) WC_Pool 20 (downstream of Longwalls 20 and 21) (4) WC20_S1 (downstream of Longwall 20) (4) WC24_S1 (downstream of Longwall 20) (4) WC26_S1 (downstream of Longwall 20) (4) **Donalds Castle Creek** Donalds Castle Ck (FR6) (Donalds Castle Creek lower) DCL3 (Donalds Castle Creek upstream of Cordeaux River confluence) **Lake Avon** NDC1 (Native Dog Creek upstream of Area 3B) **Lake Cordeaux** LC5_S1 (downstream of Longwall 20) **Cordeaux River** CR36_S1 (Reference site northeast of Area 3C)			
STREAM FLOW				
AREA 3A	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) * WWL (Wongawilli Creek downstream) * **Sandy Creek** SCL2 (Sandy Creek at downstream) SC10S1 and SC10CS1 (Sandy Creek tributary)	• Pressure transducer with data logger • Flow gauging site (volumetric or flow meter). Low-profile weir or suitable natural rockbar control	• Continuous 1-hour logging intervals • Monthly flow gauging, manual water level measurements and site maintenance	Automatic pool water level measurements which are converted to flows by calculation of rating curves using measured creek cross-sections/measured flows at the monitoring point
AREA 3B	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) * WWL (Wongawilli Creek downstream) WC21S1 (Wongawilli Creek tributary downstream of mining) WC15S1 (Wongawilli Creek tributary downstream of mining) WC12S1 (Wongawilli Creek tributary downstream of mining) **Donalds Castle Creek** DCU (Donalds Castle Creek @ FR6) DC13S1 (Donalds Castle Creek tributary downstream of mining) DCS2 (Donalds Castle Creek downstream of mining) **Lake Avon** LA4S1 (Lake Avon tributary downstream of mining)			

	LA3S1 (Lake Avon tributary downstream of mining) LA2S1 (Lake Avon tributary downstream of mining) NDTS1 (Lake Avon Tributary downstream of mining)			
AREA 3C	**Wongawilli Creek** WWU (Wongawilli Creek upstream) WWL_A (Wongawilli Creek downstream) [5] WWL (Wongawilli Creek downstream) [5] WW_Proposed (Wongawilli Creek downstream of Area 3B) [6] WC20S1 (Wongawilli Creek tributary downstream of mining) WC24S1 (Wongawilli Creek tributary downstream of mining) WC26S1 (Wongawilli Creek tributary downstream of mining) **Lake Cordeaux** LC5S1 (Lake Cordeaux tributary downstream of mining) **Cordeaux River** CR36S1 (Cordeaux River tributary reference site northeast of Area 3C)			

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

[2] *The proposed sites are designed to monitor each mapped pool/rockbar complex within the Study Area reach of Wongawilli Creek. Based on site inspections (August 2019), continuous monitoring will be implemented at suitable sites. A benchmark for manual readings will be installed at sites that are not suitable for continuous monitoring.*

[3] *Proposed sites within the Wongawilli Creek tributaries are subject to change based on further field inspections. The sites will target pool/rockbar complexes and steps.*

[4] *The proposed water chemistry monitoring sites are designed to detect changes to water quality, due to mining in Area 3C, within Wongawilli Creek. The proposed tributary sites (WC26, WC24 and WC20) aim to detect surface water inputs into Wongawilli Creek. Based on field observations, the Wongawilli Creek tributaries WC29, WC28, WC27, WC25, WC23 and WC22 were deemed as unsuitable for water chemistry sites due to morphology.*

[5] *The WWL site has recently been relocated upstream and upgraded to include a low-profile weir (WWL_A). These changes will improve the accuracy of flow measurements and analyses for Wongawilli Creek. The redundant WWL site will be measured concurrently with WWL_A, in order to establish a relationship between the two sites. Monitoring at WWL will cease once there is sufficient data to relate WWL_A with the historic data.*

[6] *An additional Wongawilli Creek flow site is proposed (immediately downstream of WC21 confluence). The site is subject to additional inspections and approval.*

.

<table>
<tr><th></th><th>MONITORING SITE</th><th>SITE TYPE</th><th>MONITORING FREQUENCY</th><th>PARAMETERS</th></tr>
<tr><td colspan="5">AQUATIC ECOLOGY</td></tr>
<tr><td>AREAS 3A, 3B and 3C</td><td>Impact Sites:
Sites 2, 3, 4, X4, X5 and X6 (Wongawilli Creek)
Sites X2 and X3 (WC21)
Site X1 (Donalds Castle Creek)
Sites 8, 9, 10, 11, 12 and 13 (Sandy Creek Catchment)

Reference Sites:
Site 1 (Wongawilli Creek – until LW15)
Site 5 (Wongawilli Creek)
Site 14 (Donalds Castle Creek)
Site 6 (WC21)
Site 7 (Sandy Creek)
Sites 15 and 16 (Kentish Creek)
Sites established in Wongawilli Creek as mentioned above.</td><td>• Quantitative and observational monitoring</td><td>• 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</td><td>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</td></tr>
<tr><td colspan="5">TERRESTRIAL ECOLOGY</td></tr>
<tr><td>AREAS 3A, 3B and 3C</td><td>Impact Sites:
DC13 (Donalds Castle Creek tributary)
DC(1) (Donalds Castle Creek)
WC15 and 21 (Wongawilli Creek tributaries)
LA4A (Lake Avon tributary)
ND1 (Native Dog Creek tributary)

Reference Sites:
WC10 and 11 (Wongawilli Creek tributaries)
SC6, SC7-1, SC7-2, SC7A and SC8 (Sandy Creek tributaries)
DC8 (Donalds Castle Creek tributary)
NDC (Native Dog Creek)</td><td>• Standardised transects in potential breeding habitat for two threatened frog species, Littlejohn's Tree Frog and Giant Burrowing Frog</td><td>• Surveys are undertaken in optimal periods over the season (i.e. when frogs are calling and/or active at known sites)</td><td>Frog surveys are conducted along 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</td></tr>
</table>

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
OBSERVATIONAL, PHOTO POINT AND WATER MONITORING		
Native Dog, Wongawilli and Donalds Castle Creeks; WC21, WC15, LA4, DC13, LA5, ND1, WC6, WC7, WC8, WC9, WC12, WC15, WC16, WC18, WC20, WC21, WC22, WC23, WC24, WC25, WC26, WC27, WC29 and LC5 General observation of streams in active mining areas when longwall is within 400m Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences • Waterfall WC-WF54 – negligible environmental consequences	***Level 1 **** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • 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 • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area	• Continue monitoring program • Submit an Impact Report to DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with DPIE, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key stakeholders
	Exceeding Prediction • Structural integrity of the bedrock base of any significant pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • Gas release results in vegetation dieback that does not revegetate • Gas release results in mortality of threatened species or ongoing	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
	loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site WONGAWILLI CK (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Ck (FR6) • Rock fall at WC-WF54 or its overhang • Impacts on the structural integrity of WC-WF54, its overhang or its pool	
WATER QUALITY		
Wongawilli Creek Wongawilli Ck (FR6) Baseline means: • pH 5.98 • EC 98.8 uS/cm • DO 89.5% Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Donalds Castle Creek Donalds Castle Ck (FR6) Baseline means: • pH 5.41 • EC 116.0 uS/cm • DO 85.6%	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
Relevant Performance Measure(s): • Donalds Castle Creek - minor environmental consequences	***Level 2*** * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Avon Lake Avon tributary (LA4_S1) Baseline means: • pH 5.38 • EC 90.8 uS/cm • DO 89.9% (24 months of baseline data available - to be updated with additional baseline data) Relevant Performance Measure(s): • Lake Avon - negligible reduction in the quality of surface water inflows to Lake Avon	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• Continue monitoring program • Submit an Impact Report to DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two consecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean of the Lake Avon inflows during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
POOL WATER LEVEL		
Mapped pools in the mining area: • Wongawilli Creek • Donalds Castle Creek	***Level 1*** * • Fracturing not resulting in diversion of flow	• Continue monitoring program • Submit an Impact Report DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences	***Level 2*** * • Fracturing resulting in diversion of flow	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with DPIE, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
Waterfall WC-WF54 Relevant Performance Measure(s): • Waterfall WC-WF54 – negligible environmental consequences	***Exceeding Prediction*** • Fracturing in Wongawilli Creek within 30m of the waterfall which results in observable flow diversion • Fracturing in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
MODELLED PERIODS OF RECESSIONAL, BASEFLOW AND SMALL STORM UNIT HYDROGRAPH PERIODS		
Subcatchments of Wongawilli and Donalds Castle Creeks; and Lakes Avon and Cordeaux tributaries **	***Level 1 **** • 6-12% reduction in average Q (ML/d) ***	• Continue monitoring program • Submit an Impact Report to DPIE and Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • 12-18% reduction in average Q (ML/d) ***	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • >18% reduction in average Q (ML/d) ***	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with DPIE, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key stakeholders
Inflows to Lake Avon and Cordeaux River ** Relevant Performance Measure(s): • Lake Avon - negligible reduction in the quantity of surface water inflows to Lake Avon • Cordeaux River - negligible reduction in the quantity of surface water flows from Wongawilli Creek to Cordeaux River	***Exceeding Prediction*** • Measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River that is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation • Surface water flow reduction into Lake Avon is greater than predicted by modelling (to the satisfaction of the Secretary) that cannot be attributed to natural variation	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
AQUATIC ECOLOGY		

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 8 sites • Donalds Castle Creek catchment – 1 site	***Level 1 **** • Reduction in aquatic habitat for 1 year	• Continue monitoring program • Submit an Impact Report to DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Reduction in aquatic habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with DPIE, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 2 sites • Donalds Castle Creek catchment – 2 sites • Lake Avon tributary – 1 site • Native Dog tributary – 1 site	***Level 1 **** • Reduction in habitat for 1 year	• Continue monitoring program • Submit an Impact Report to DPIE, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Reduction in habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Reduction in habitat for > 2 years or complete loss of habitat following the active subsidence period	• *Actions as stated for Level 2* • Site visit with DPIE, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders

Table 1.2 – Dendrobium Watercourse Impacts, Triggers and Response

Monitoring	Trigger	Action
		• Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with DPIE, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between S32, DPIE and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

* These may be revised in consultation with DPIE and other key stakeholders following analysis of natural variability within the pre-mining baseline data. These TARPs relate to Dendrobium Areas 3B and have been updated to address proposed mining in Area 3C; impacts resulting from mining in Areas 1, 2 and 3A were managed under previous TARPs.

** Water budgets during recessional, baseflow and small storm unit hydrograph periods would be determined by hydrologic modelling of pre- and post-mining hydrographic data.

*** Hydrologic modelling conducted in the manner described above for the baseline period routinely produces mean estimated water budgets lying within about ±6% of average annual precipitation at the one standard deviation level and within about ±12% at the two standard deviation level.

Department of Planning, Industry and Environment (DPIE) includes the following clusters:

- Biodiversity Conservation Division (BCD);
- NSW Resources and Geoscience; and
- Resources Regulator.

Water NSW (formally SCA)