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DENDROBIUM LONGWALLS 20-21 TERRESTRIAL ECOLOGICAL ASSESSMENT

ACCOMPANYING DOCUMENT TO DENDROBIUM LONGWALLS 20-21 SUBSIDENCE MANAGEMENT PLAN

Prepared for SOUTH 32 ILLAWARRA COAL | 20 May 2019

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Document control

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Executive Summary

Project outline

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by South 32 Illawarra Coal (South 32) to prepare a Terrestrial Ecological Assessment for the extraction of Longwalls 20 and 21 within Dendrobium Area 3C (DA3C). Initial approval to mine Dendrobium Area 3 was granted in 2001 (DA 60-03-2001) and a modification to the consent was granted in 2008. Development consent was granted following the completion of a number of assessments specific to DA3 including a Species Impact Statement (SIS), which was completed in 2007 (Biosis 2007) as part of the modification.

Further to the 2008 approval, a Subsidence Management Plan (SMP), specific to Longwalls 20 and 21 within DA3C is required to be approved by the New South Wales Department of Planning and Environment (DPE) prior to mining. The SMP must be accompanied by a revised terrestrial ecological assessment to address any recent legislative changes, guidelines and research regarding subsidence associated with longwall mining. This report constitutes the revised terrestrial ecological assessment and is specific to Longwalls 20 and 21 having regard to the proposed mine design and longwall layout as defined by the Mine Subsidence Engineering Consultants (MSEC) subsidence impact assessment (MSEC 2018).

The SMP involved flora and fauna survey within DA3C and focused on landscape features and associated biodiversity which may be sensitive to the impacts of subsidence from longwall extraction. The study area was defined by the limit of subsidence associated with proposed Longwalls 20 and 21.

Natural areas sensitive to subsidence within the DA3C study area include: Wongawilli Creek, Donalds Castle Creek, watercourses, cliffs, rock outcrops, steep slopes and upland swamps. Significant conclusions from the MSEC (2018) report, relevant to this study include the following:

- Fracturing of the surface will occur above the mining area, including fracturing and flow diversion in streams. Fracturing could also occur along sections of creeks (including Wongawilli and Donalds Castle Creek) that are located within a distance of approximately 400 metres from the proposed longwalls. The rate of Type 3 impacts (i.e. fracturing resulting in surface water flow diversions) for the rockbars of Wongawilli Creek located within the study area has been assessed as low, i.e. less than 10 %. It is considered unlikely that fracturing would occur along Donalds Castle Creek due to the extraction of LW20 and LW21 due to the low-levels of predicted movements and its distance from the proposed longwalls. Lake Cordeaux is not predicted to experience any significant mine subsidence movements.
- Fracturing of the bedrock beneath the upland swamps may occur. It is possible that the resulting changes in surface and groundwater level within the swamps could impact on the distribution of local vegetation within the swamps. The surfaces of the swamps are largely free draining, and it is not anticipated that significant changes in surface water levels would occur as a result of subsidence induced tilt.
- Isolated rockfalls are possible, and may occur along the cliffs, overhangs, rock outcrops and areas of steep slopes.
- Subsidence impacts for Longwalls 20 and 21 (subject to this assessment) are predicted to be less than predicted impacts for DA3A and DA3B, due to narrower longwall void widths and lesser extraction heights (MSEC 2018).

Literature Review

The findings from the MSEC (2018) report form the basis to which the impact assessments for threatened flora, fauna and ecological communities have been assessed in this report.

A significant body of other work relating to previous approvals and monitoring for underground mining within DA3A and DA3B was reviewed as part of this report with major reports listed below:

- SIS completed for the 2008 modification (Biosis 2007)
- Dendrobium Area 3B Terrestrial Ecology Assessment (Niche 2012)
- Monitoring as part of previous SMPs for longwalls within Areas 3A and 3B including annual and end of panel reporting (e.g. Biosis 2016; HGeo 2017)
- Statutory reviews and policy guidelines including
    - Southern Coalfields Inquiry (DOP 2008)
    - Upland Swamps Environmental Assessment Guidelines – Draft (OEH 2012).

Summary of Methods

Literature review was supplemented with field survey concentrating on landscape features and associated biodiversity which may be sensitive to impacts of subsidence from longwall extraction such as swamps, watercourses and rocky areas. Survey was conducted between July 2017 and December 2018.

Survey activities included vegetation validation of upland swamps, diurnal and nocturnal frog and tadpole searches, frog acoustic recording and active reptile searches. A likelihood of occurrence and impact analysis was conducted for threatened species after considering the literature review and survey results.

Summary of Results and Impact Assessment

Ground-truthing of upland swamp community mapping resulted in changes to upland swamp sub-community patterns, swamp boundaries and changes in vegetation communities. Ten upland swamps occur within the wider study area with complexity of swamps generally increasing with overall size. None of the complex larger swamps are within the predicted area of subsidence impacts (35 degree angle of draw study area). Based on previous subsidence monitoring, a maximum impact area for swamps was calculated at 0.70 hectares constituting all five upland swamps within the 35 degree angle of draw study area.

Habitats such as pools, along a combined length of between 2 – 7.5 kilometres of watercourses within 600 metres of the proposed longwalls, are likely to experience some level of subsidence impacts (comprising both direct and indirect impacts). Subsidence impacts to features such as cliffs, overhangs and rocky outcrops have the potential to occur but are likely to have limited impacts on threatened biodiversity within the study area due to the small area of predicted impacts.

Four threatened plant species (*Epacris purpurascens var. purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius)* were deemed to have habitat in the study area that may be potentially impacted by subsidence, however impacts for these species are likely to be minimal.

Nine threatened fauna species are considered to be potentially impacted by subsidence impacts resulting from the proposal comprising:

- Frogs: Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet.
- Reptiles: Broad-headed Snake, Rosenberg's Goanna.
- Mammals: Eastern Bentwing Bat, Little Bentwing Bat, Southern Myotis.

- Invertebrates: Giant Dragonfly.

From the above species, it is considered that potentially significant impacts could occur for the three frog species and the Giant Dragonfly.

Ongoing monitoring requirements for biodiversity are provided within the recommendations section of the report. Recommendations are focussed around swamp and frog monitoring along watercourses in concert with established programs for measuring physical impacts of subsidence.

Glossary and list of abbreviations

Term or abbreviation	Definition
BC Act	NSW *Biodiversity Conservation Act 2016*
DA3C	Dendrobium Area 3C
DEE	Commonwealth Department of Environment and Energy
DPE	NSW Department of Planning and Environment
EEC	Endangered Ecological Community
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
ESSGW	Exposed Sandstone Scribbly Gum Woodland
ha	hectares
KTP	Key Threatening Process
Locality	The area within a 10 kilometre radius of the study area
LW	Longwall
MNES	Matters of National Environmental Significance listed on the EPBC Act
NPWS	National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage
Proposal	the development, activity or proposed action
SCA	Sydney Catchment Authority
SGPF	Sandstone Gully Peppermint Forest
SIS	Species Impact Statement
SMP	Subsidence Management Plan
South 32	South 32 Illawarra Coal
Study area	Area potentially directly or indirectly impacted by the proposal
THPS	Temperate Highland Peat Swamps
TSC Act	NSW *Threatened Species Conservation Act 1995*
USBT	Upland Swamp: Banksia Thicket
USTTT	Upland Swamp: Tea Tree Thicket
USSHC	Upland Swamp: Sedgeland Heath Complex
USFEW	Upland Swamp: Fringing Eucalypt Woodland

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1 Introduction

1.1 Background and need for the project

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by South 32 Illawarra Coal (South 32) to prepare a Terrestrial Ecological Assessment for the extraction of Longwalls 20 and 21 within Dendrobium Area 3C (DA3C) (Figure 1). Initial approval to mine Dendrobium Area 3 was granted in 2001 (DA 60-03-2001) and a modification to the consent was granted in 2008 (Figure 2). Development consent was granted following the completion of a number of assessments specific to DA3 including a Species Impact Statement (SIS), which was completed in 2007 (Biosis 2007) as part of the modification.

Further to the 2008 approval, a Subsidence Management Plan (SMP) for Longwalls 20 and 21 within DA3C (Figure 1 and Figure 2) is required to be approved by the New South Wales (NSW) Department of Planning and Environment (DPE) prior to mining. The SMP must be accompanied by a revised terrestrial ecological assessment to address any recent legislative changes, guidelines and research regarding subsidence associated with longwall mining. This report constitutes the revised terrestrial ecological assessment and is specific to the proposed Longwalls 20 and 21 in DA3C having regard to the proposed mine design as defined by the Mine Subsidence Engineering Consultants (MSEC) subsidence impact assessment (MSEC 2018).

This ecological report has been prepared to meet the relevant sections of the *NSW Department of Primary Industries Guideline for Applications for Subsidence Management Approvals December 2003*.

1.2 Statutory and other approvals

1.2.1 Landscape approval

Approval to mine Dendrobium Area 3 was granted by the Department of Planning in 2001. In 2007, South 32 applied to modify the approval for Dendrobium Mine pursuant to section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act). A SIS was conducted, and an environmental assessment completed to support the proposal to modify the footprint of Area 3.

Since the Dendrobium mine was approved by the Commonwealth of Australia as a controlled action under the *Environmental Protection and Biodiversity Act 1999* (EPBC Act) in December 2001, approval within this assessment is not required under the EPBC Act. Threatened species and Endangered Ecological Communities (EECs) listed under the EPBC Act have been considered within this report, however revised impact assessments for species listed under the EPBC Act are not required.

1.3 Consultation

South 32 have consulted with key Government Agencies (e.g. DPE and WaterNSW) during the development of the SMP.

2 Description of the Study Area and Subsidence Predictions

2.1 Study Area

Two Longwalls (LW20 and LW21) (hereafter referred to as the proposal) have been proposed in the study area. The study area (Figure 2) is consistent with the area described in MSEC 2018 as the surface area that could be affected by the mining of the proposed LW20 and LW21 (combined area of longwalls approximately 50 hectares [ha]) consisting of:

- The 35° angle of draw line from the extents of the proposed LW20 and LW21.
- The predicted limit of vertical subsidence, taken as the 20 millimetres (mm) subsidence contour, resulting from the extraction of the proposed longwalls.
- The natural features located within 600 metres (m) of the extent of the longwall mining area, in accordance with Condition 8(d) of the Development Consent DA 60-03-2001.

The study area at its largest (Figure 2) constitutes approximately 550 ha of largely undisturbed bushland and watercourses of the Cordeaux River Catchment inside the WaterNSW Metropolitan Special Area. The Cordeaux River is part of the Hawkesbury-Nepean Catchment.

Fire roads and active and rehabilitating trails as well as exploration drilling sites occur within the study area and are the chief sources of disturbance. The SCA study area is contiguous with a large reserve system which includes the Upper Nepean State Conservation Area to the west and the Illawarra Escarpment Area to the east (Figure 1).

2.1.1 Creeks and Waterways

The major permanent waterway within the study area, Wongawilli Creek, flows northwards through the centre of the study area and joins the Cordeaux River approximately 3 km to the north (Figure 2). Pools and riffle zones in Wongawilli Creek are permanent and naturally develop upstream of rockbars and at areas of sediment and debris accumulations.

Donalds Castle Creek runs parallel to Wongawilli Creek to its east and passes through the south-western corner of the study area (Figure 3). Smaller tributary streams occur throughout the study area flowing into Wongawilli Creek, Donalds Castle Creek and Lake Cordeaux to the west (outside of the study area). Lake Cordeaux or Cordeaux Dam is one of several large artificial waterbodies in the locality used for drinking water catchment.

A number of waterways throughout the study area have upland swamps at their headwaters or along other sections. Swamps within the study area act as a buffer for surface flow allowing for more continuous and even water flows along streams after rain events.

2.2 Predicted mine subsidence for natural features

Subsidence predictions for Longwalls 20 and 21 within DA3C were investigated and reported by MSEC (2018). Subsidence impacts for natural features prone to subsidence impacts were examined including:

- Major creeks and associated drainage features
- Swamps
- Cliffs, rock outcrops and steep slopes.

The natural features may provide important habitat for threatened species or constitute threatened ecological communities and are the focus of this assessment. A summary of the predicted impacts that the proposal will have on these features is described below (Table 1), as documented in MSEC 2018.

Table 1: Predicted subsidence impacts to natural features and potential biodiversity impacts for Longwalls 20 and 21 (MSEC 2018; HydroGeo 2018)

Feature	Description of natural feature	Predicted subsidence or surface water impact LW20 and 21	Previously observed impacts in other areas
Wongawilli Creek	Wongawilli Creek is a third order perennial stream with a small base flow and increased flows for short periods of time after each significant rain event. Pools in the creek are permanent (based on monitoring to date) and naturally develop behind the rockbars and at sediment and debris accumulations. Wongawilli Creek is situated between the proposed longwalls in Area 3C. The creek is 125 m east of the tailgate of LW20 and 215 m west of the finishing end of LW21, at the closest points to the proposed longwalls.	Wongawilli Creek is predicted to experience less than 20 mm vertical subsidence and less than or equal to 60 mm upsidence and 210mm closure due to the extraction of the proposed longwalls. 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 LW20 and LW21, 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.	Maximum predicted upsidence of 150 mm adjacent to LW 9 & 10 (Area 3B) Type 3 impact of fracturing in one pool (pool 43a between LW6 and LW9) within Wongawilli Creek has previously been recorded upstream from mining activity within 110 m of the creek.
Donalds Castle Creek	Donalds Castle Creek 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 is located to the west of the proposed longwall, 490 m from the main-gate and finishing end of LW20, at its closest point. Donalds Castle Creek crosses directly above the completed LW9 to LW12 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.	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 LW20. 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. It is considered unlikely that fracturing would occur along Donalds Castle Creek due to the extraction of LW20 and LW21 due to the low-levels of predicted movements and its distance from the proposed longwalls.	Fracturing occurred in Rockbar DC-RB33 along Donalds Castle Creek, due to the extraction of LW9, which resulted in the diversion of surface water flows in that location (i.e. Type 3 impact). There was no observable fracturing along the creek due to the extraction of LW10, as Swamp 5 overlays the creek above the extent of this longwall. There were increased rates of water level recession compared to baseline conditions within this swamp. There were no observable impacts to Donalds Castle Creek due to the subsequent extraction of LW11 to LW13. LW20 occurs approximately 600 m east of Donalds Castle Creek, compared with LW11

			and LW12 which occur directly beneath a section of Donalds Castle Creek.
Drainage Lines	There are a number of smaller drainage lines that are located above and adjacent to LW20 and LW21. These drainage lines are first and second order streams that form tributaries to Wongawilli Creek, Donalds Castle Creek and Lake Cordeaux.	It is expected that fracturing of the bedrock would occur along the sections of the drainage lines that are located directly above the proposed LW20 and LW21. 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.	A variety of impacts have been observed in previous longwalls, particularly due to extraction along LW9 and LW13. This ranges from exposed bedrock and rockbars approximately 1 mm fractures to 50 mm in some locations and up to 5.5 meters in length and a variety of surface water flow diversions and orange precipitate (iron staining) in the water or on the bedrock.
Cliffs "Continuous rock face, including overhangs, having a minimum length of 20 m, a minimum height of 10 m	There are three cliffs that have been identified within the study area. There is also one additional cliff located within the study area based on the 600 m boundary. The minor cliffs within the study area are located within the valleys of Wongawilli Creek, Donalds Castle Creek and their tributaries. The lengths of each of the minor cliffs typically range between 20 m and 50 m and have heights up to 10 m.	These cliffs are predicted to experience only low-levels of tilt, curvature and strain. Isolated rock falls could occur at some of the cliffs located outside the extents of the proposed longwalls. This is based on the extensive experience of mining near to but not directly beneath cliffs in the NSW coalfields, where no large cliff falls have occurred when the cliffs are located completely outside the angle of draw from mining. It is still possible, but unlikely, that isolated rock falls could occur due to mining, natural processes, or both.	Based on impacts experienced in Area 1 at the Mine, it has been assessed that Cliff DA3C-CF1 could be impacted due to the extraction of LW20 directly beneath it. Cliffs DA3C-CF2 and DA3C-CF3 are located outside the extents of the proposed longwalls and are predicted to experience vertical subsidence of 50 mm or less. It is unlikely that other cliffs located outside the 35° angle of draw would experience adverse impacts due to their distances outside of the mining areas.

and a minimum slope of 2 to 1 (>63.4º)"			
Rock outcrops/ steep slopes	There are many rock outcrops and rock platforms that are located across the study area. The rock outcrops are generally less than 5 m in height.	The rock outcrops and steep slopes are located across the study area and, therefore, are expected to experience the full range of predicted subsidence movements. It is likely that fracturing and cracking would occur where these features are located directly above the proposed longwalls. The crack widths could be similar to those previously observed in Area 3B.	Cracks up to approximately 400 mm in width, but typically in the order of 100 mm to 150 mm in width.
Swamps, wetlands and water related ecosystems	Within the study areas, there have been five swamps identified wholly or partially within the study area 35 degree angle of draw. An additional five swamps are located wholly or partially within the study area based on the 600 m boundary.	It is expected that fracturing would occur in the bedrock beneath swamp Den144. The estimated fracture widths in the bedrock beneath Swamp Den144 is in the order of 30 mm. It is possible that a series of smaller fractures, rather than one single fracture, would develop in the bedrock. Swamps Den09 and Den142 are located along the upper reaches of Streams LC5B and WC25, respectively, near the proposed longwalls. Fracturing could also occur in the bedrock beneath these swamps. The remaining swamps are located outside the extents of the proposed longwalls at minimum distances between 110 m and 600 m. It is unlikely, therefore, that the bedrock beneath these swamps would experience significant fracturing.	The soil crack and rock fracture widths at Swamps Den09, Den142 and Den144 due to the extraction of the proposed LW20 and LW21 are expected to be less, on average, than those previously measured at the Mine due to the lower predicted mine subsidence parameters. The dilated strata beneath the drainage lines, upstream of Swamps Den09, Den142 and Den144, 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.
Water quality and surface water	• Donalds Castle Creek • Wongawilli Creek	The baseflow components of Donalds Castle Creek and Wongawilli Creek may decline by up to 0.14 ML/day and 0.20 ML/day following longwall extraction, equating to approximately 8.5% and 1.6%	Watercourses that have been affected by subsidence (e.g. WC21 during mining of Longwalls 9, 10 and 11) have shown temporary increases in dissolved Fe and Mn, and an increase in pH to near neutral (pH 7)

	• Tributaries	of mean annual streamflow at the downstream gauging sites. Water quality influence due to mining is expected to be minor in stream reaches within subsidence affected areas. Effects are likely to include temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide.	at sampling locations immediately down-gradient of the affected area. The overall salinity of stream waters (as estimated from EC) is controlled largely by rainfall patterns, with EC tending to increase during periods of low rainfall. This reflects evaporative concentration of salts and the relative increase in contribution from groundwater discharge (baseflow). There is no discernible change in EC as a result of mining subsidence.

2.3 Approach

The approach to this assessment has been shaped by previous ecological survey work and impact assessment for the study area and surrounds, current knowledge of subsidence impacts on the landscape, legislative guidelines and consultation.

While impact assessment for the entire DA3 area has already been completed in the form of a SIS (Biosis 2007), the current assessment is required to ensure that the findings of the SIS remain relevant to Longwalls 20 and 21 within DA3C, given the following:

- Updates to schedules of relevant legislation concerning threatened species (which may confer a different conservation status for certain species or community).
- New information regarding predicted subsidence impacts, the accuracy of previous subsidence predictions and results from monitoring of impacts to ecological features and threatened species.

The SIS of Dendrobium Area 3, which incorporated the current study area, was completed in 2007 (Biosis 2007). Some data gaps within the SIS have been identified in this study, and appropriate surveys completed to fill these gaps.

The target of the current survey and assessment has been to focus on the ecological values sensitive to the effects of subsidence, as identified in MSEC (2018) and Section 2.2.

3 Literature Review

A significant body of work has been conducted within the DA3 study area for previous approvals for underground mining and to satisfy consent conditions in regard to monitoring. The main relevant documentation was reviewed as part of this SMP as listed below and details provided in proceeding sections of this report:

- SIS completed for the 2008 modification (Biosis 2007)
- Dendrobium Area 3B Terrestrial Ecology Assessment (Niche 2012)
- Monitoring as part of previous SMPs for longwalls within areas 3A and 3B (Figure 2), including annual and end of panel reporting
- Statutory reviews and policy guidelines including
    - Southern Coalfields Inquiry
    - Upland Swamps Environmental Assessment Guidelines (Draft).

3.1 Dendrobium Area 3 Species Impact Statement

Biosis prepared a SIS in 2007, to support the application to modify the Dendrobium Mine consent (DA-60-03-2001) to incorporate a revised Area 3 footprint and longwall layout. The SIS involved an extensive survey and impact assessment of Areas 3A, 3B and 3C.

To assess the impacts of mining in Dendrobium Area 3, the maximum subsidence parameters determined from MSEC (2007) for DA3A were extrapolated to the entire Dendrobium Area 3 footprint.

As such, the consent required that once the mine plans for these areas were finalised any impacts in areas DA3B and DA3C greater than those specified in the SIS, would require a review of the SIS outcomes. The SIS therefore provides the basis against which the proposal should be assessed.

A comparison of the relevant DA3C subsidence parameters used in the SIS (MSEC, 2007), against the current MSEC (2018) report is provided below in Table 2. Both MSEC reports concluded similar potential subsidence impacts, with the latest report providing greater detail, particularly in relation to Donalds Castle Creek. The impact assessments for threatened species in the SIS are similar to those within this report.

Table 2: Subsidence predictions from the Area 3 SIS (2007) compared to MSEC (2018) report for current study area.

Subsidence Parameters	MSEC (2007) report for Dendrobium Area 3 used in the SIS	MSEC (2018) report for Dendrobium Area 3C
Wongawilli Creek	Longwalls set back from Wongawilli Creek. Wongawilli Creek is unlikely to incur any significant impacts as a result of the extraction of the proposed longwalls. Some minor fracturing and localised ponding changes may occur due to subsidence induced tilt.	Longwalls set back from Wongawilli Creek. It is possible that there could be some localised changes in the levels of ponding or flooding where the maximum changes in grade due to subsidence induced tilt 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. 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 LW20 and LW21, 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.
Cordeaux River (downstream of study area)	The Cordeaux River is not predicted to experience any significant mine subsidence movements.	The Cordeaux River is not predicted to experience any significant mine subsidence movements.
Donalds Castle Creek and drainage lines	Predicted impacts to Donalds Castle Creek from DA3 longwalls were regarded similar to the impacts to Longwalls 6-10 in DA3A due to similar void widths, chain pillar widths and extraction heights. Valley related movements would result in fracturing, bulking and dilation of the topmost bedrock along the creek with could result in surface water flow diversions.	It is considered unlikely that fracturing would occur along Donalds Castle Creek as a result of the extraction of LW20 and LW21 due to the low-levels of predicted movements and its distance from the proposed longwalls. Fracturing would occur along the sections of the drainage lines that are located directly above the proposed LW20 and LW21. Fracturing can also occur outside the extents of the proposed longwalls at distances up to approximately 400 m. Surface water flow diversions are also likely to occur along the sections of drainage lines that are located directly above and adjacent to the proposed longwalls.

Subsidence Parameters	MSEC (2007) report for Dendrobium Area 3 used in the SIS	MSEC (2018) report for Dendrobium Area 3C
Cliffs	Predicted to be some impact to between 7% and 10% of the cliff lines that will be directly mined beneath. Cliff lines that will not be directly mined beneath are unlikely to exhibit any significant impacts.	The cliff located directly above LW20 could experience adverse impacts including rockfalls and cliff instabilities. Only low-levels of vertical subsidence (50 mm or less) are predicted for the other two cliffs within the study area. It is possible that isolated rock falls could occur at two cliffs located outside the extents of the proposed longwalls.
Rock outcrops	Percentage of rock outcrops that are likely to be impacted by mining is small – much less than 7% to 10% of the total length of rock outcrops directly mined beneath.	It is likely that fracturing and cracking would occur where rock outcrops are located directly above the proposed longwalls.
Steep slopes	Potential DA3 steep slopes are expected to result in cracking of the surface soils and possible downhill movements, similar to Dendrobium Areas 1 and 2. The greatest surface cracking and downhill movements are expected to occur along the steep slopes directly mined beneath and adjacent to ridgelines.	It is likely that fracturing and cracking would occur where steep slopes are located directly above the proposed longwalls.
Upland swamps	Swamps directly mined beneath are expected to experience the full range of predicted subsidence and valley related movements. It is unlikely that mine subsidence induced scour effects would affect the swamps in Area 3. Based on longwalls in Area 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A and 3B, the maximum predicted systematic subsidence parameters resulting from the extraction of longwalls are expected to be similar to those predicted for Longwalls 6 to10. It is possible that the changes in water level within the swamps could impact on the distribution of local vegetation within the swamps. The surfaces of the swamps are free draining, and it is	It is not expected that there would be adverse changes in ponding or scouring within the swamps due to subsidence induced tilt. Fracturing of the bedrock is expected to occur beneath Swamps Den09, Den142 and Den144. These swamps have layers of organic soil and, in most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The dilated strata beneath the drainage lines, upstream of Swamps Den09, Den142 and Den144, 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

Subsidence Parameters	MSEC (2007) report for Dendrobium Area 3 used in the SIS	MSEC (2018) report for Dendrobium Area 3C
	not anticipated that significant changes in water levels would occur as a result of subsidence induced tilt.	to any deeper storage, it is likely that the diverted surface water flows will re-emerge at the limits of fracturing and dilation.

The results of the SIS in regard to ecological impacts, specifically threatened species, included the following:

- Fourteen threatened flora species were considered in the SIS. Two threatened flora species, *Acacia bynoeana* and *Pultenaea aristata* were recorded within Area 3. A further nine species were regarded as having potential habitat. Seven-part tests under the TSC Act (equivalent to the current five-part test under the BC Act) concluded that the proposed longwall mining activities in Area 3 were unlikely to have a significant impact on any threatened flora within the study area.
- Sixty three threatened fauna were considered in the SIS. Sixteen species were recorded in the Area 3 study area including:
- Littlejohn's Tree Frog (*Litoria Littlejohni*)
- Giant burrowing Frog (Heleioporus australiacus)
- Red-crowned Toadlet (*Pseudophryne australis*)
- Gang-gang cockatoo (Callocephalon fimbriatum)
- Glossy black cockatoo (*Calyptorhynchus lathami*)
- Olive Whistler (Pachycephala olivacea)
- Barking Owl (Ninox connivens)
- Powerful Owl (*Ninox strenua*)
- Eastern Pygmy-possum (*Cercartetus nanus*)
- Eastern Freetail Bat (Mormopterus norfolkensis)
- Koala (Phascolarctos cinereus)
- Grey-headed Flying-fox (*Pteropus poliocephalus*)
- Eastern Bentwing-bat (Miniopterus schreibersii)
- Large-eared Pied bat (*Chalinolobus dwyeri*)
- Southern Myotis (*Myotis macropus*)
- Rosenberg's Goanna (*Varanus rosenbergi*).

- 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*). 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.
- One EEC: Shale Sandstone Transition Forest, which was listed on the *Threatened Species Conservation Act 1995* (TSC Act) (now the *Biodiversity Conservation Act 2016*) and EPBC Acts was recorded within the study area. However, was considered unlikely to be significantly impacted by the proposal. Shale Sandstone Transition Forest is now listed as a Critically Endangered Ecological Community (CEEC).

It is noted that upland swamps within the study area were not a listed EEC at this time.

The survey effort and outcomes of the SIS have been summarised in Section 4.1.

3.2 Dendrobium Area 3B Terrestrial Ecology Assessment

Niche was commissioned by Illawarra Coal in 2011 to prepare a Terrestrial Ecological Assessment for Dendrobium Area 3B (DA3B) (Niche 2012).

The assessment involved a flora and fauna survey within DA3B which focused on landscape features sensitive to the impacts of subsidence from extraction of proposed Longwalls 9 to 18. Natural areas sensitive to subsidence within the DA3B study area included: Wongawilli Creek, Donalds Castle Creek, drainage lines, cliffs, rock outcrops, steep slopes, and upland swamps.

One threatened flora population of *Pultenaea aristata* was recorded in an upland swamp in the DA3B study area. The population estimate was greater than a thousand individuals. The SIS also identified a population of *Acacia bynoeana* consisting of approximately 30 individuals within the DA3B study area.

Four threatened plant species (*Epacris purpurascens* var*. purpurascens, Pultenaea aristata, Cryptostylis hunteriana* and *Leucopogon exolasius*) were considered to have habitat in the study area that may be potentially impacted by subsidence. Seven-Part Tests were carried out for each of these species which concluded that a significant impact was unlikely. The same conclusion was reached in the 2007 SIS (Biosis 2007).

Threatened fauna recorded during the DA3B survey included Red-crowned Toadlet, Littlejohn's Tree Frog, Gang-gang Cockatoo, and Grey-headed Flying Fox. Fauna impact assessments were conducted for 31 threatened fauna, including:

- Amphibians: Littlejohn's Tree Frog, Giant Burrowing Frog and Red-crowned Toadlet;
- Birds: Barking Owl, Black Bittern (*Ixobrychus flavicollis*), Eastern Bristle Bird (*Dasyornis brachypterus*), Eastern Ground Parrot (*Pezoporus wallicus wallicus*), Grass Owl (*Tyto longimembris*), Gang-gang Cockatoo, Glossy Black Cockatoo, Masked Owl (*Tyto novaehollandiae*), Sooty Owl (*Tyto tenebricosa*), and Powerful Owl;
- Mammals: Brush-tailed Rock Wallaby (*Petrogale penicillata*), Eastern Pygmy Possum, Long nosed Potoroo (*Potorous tridactylus tridactylus*), Southern Brown Bandicoot (*Isoodon obesulus*), Spotted tail Quoll (*Dasyurus maculatus*), Squirrel Glider (*Petaurus norfolcensis*), Eastern Bentwing-bat, Little Bentwing-bat (*Miniopterus australis*), Large-eared Pied Bat, Eastern Cave Bat (*Vespadelus troughtoni*), Eastern False Pipistrelle (*Falsistrellus tasmaniensis*), Golden-tipped Bat (*Kerivoula papuensis*), Southern Myotis, Greater Broad-nosed Bat (*Scoteanax rueppellii*) and Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*).
- Reptiles: Broad-headed Snake (*Hoplocephalus bungaroides*) and Rosenberg's Goanna; and
- Giant Dragonfly.

Seven-Part Tests concluded that the proposed longwalls were likely to have a significant impact on local populations of Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet, and Giant Dragonfly. Subsidence impacts were determined as likely for known and potential habitat for these species, as they are reliant upon Donalds Castle Creek and drainage lines, upland swamps, ridgelines and rock outcrops. The same conclusion was reached in the SIS impact assessments for these species, however the Stuttering Frog was considered to be significantly impacted within the initial SIS whereas it was considered unlikely to occur within the Area 3B Terrestrial Ecological Assessment.

Shale Sandstone Transition Forest (SSTF), which was listed as a CEEC under the EPBC Act and TSC Act, occurs within the DA3B study area. Mining in DA3B was considered unlikely to result in any physical landscape changes which may impact this community. The assessment concluded that SSTF is unlikely to be significantly impacted by the Proposal.

Thirteen large upland swamps were recorded within the DA3B study area. 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 since the 2007 SIS. The potential for DA3B to impact upland swamps was considered to be low. A Seven-Part Test for Coastal Upland Swamps in the Sydney Basin Bioregion was conducted and concluded that a significant impact on this community was unlikely, primarily due to the proportion of swamps likely to be impacted compared with swamps within the locality and the severity of impacts predicted.

A number of recommendations were proposed in relation to terrestrial ecological values, and included the following:

- On-going monitoring which is currently being undertaken within Dendrobium Area 3 should continue. Monitoring of DA3B to follow pre-existing methodology. Monitoring to continue targeted surveys for Littlejohn's Tree Frog, Red-crowned Toadlet and Giant Dragonfly. Upland swamp monitoring transects should continue. Transect and photo point monitoring to be included within upland swamp 35a as this swamp contains a population of *Pultenaea aristata*. In the event that monitoring reveals impacts greater than predicted or authorised by the approval, modifications to the project and mitigation measures should be considered to minimise impacts.
- The implementation of any mitigation measures should include monitoring to confirm the success of any implemented measures.
- All remediation works should include appropriate measures to minimise environmental impacts. This includes avoiding the spread of Chytrid Fungus following the NPWS guidelines.
- Surface cracking within woodland or forested areas where significant fauna entrapment is likely should be mitigated in order to minimise fauna entrapment.

3.3 Dendrobium Terrestrial Ecology Monitoring Program

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.

The following ecological features are monitored as part of the terrestrial ecology program:

- Vegetation within upland swamps in Dendrobium Area 2, Area 3A and Area 3B
- Vegetation along one stream in Dendrobium Area 3A
- Littlejohn's Tree Frog along streams in Dendrobium Area 3A and Area 3B.

The following summarises the findings of the vegetation monitoring program to date (Biosis 2018):

- Swamp size and the extent of groundwater dependent swamp sub-communities showed a global decrease across control and impacted swamps in 2014 and 2015 when compared to 2012 data. The

decrease was found to be greater at impacted sites when compared to control sites suggesting some effect of mining-related impacts. However, ground-truthing of modelled results at several swamps in March 2016 found that, in many cases, the modelled contraction in swamp size was not a true and accurate reflection of swamp vegetation on the ground and the model tended towards over-estimation of the reduction in swamp size and extent of groundwater dependent sub-communities.

- All upland swamps continue to show a trending decline in total species richness, indicating broader landscape scale driven changes.
- Regardless of treatment (impact and control), species composition is changing every year and this change is statistically significant at most sites. This change is within the expected range, as some natural turnover of species occurs at sites each season and across the years monitored.
- There is one post-mining creek site (SC10) within Dendrobium Area 3A where monitoring is conducted. There has been no significant change in the total species richness when comparing pre-mining data and post-mining data for the one post-mining creek being monitored in Dendrobium Area 3A (SC10).

The Littlejohn's Tree Frog Monitoring (Biosis 2016) detailed the following results:

- Monitoring of five streams in 2015 (SC10C, DC (1), DC13, WC17 and WC21) as part of the Littlejohn's Tree Frog program were analysed as post-mining sites. Within Dendrobium Area 3A, adult Littlejohn's Tree Frogs have not been recorded at WC17 for two consecutive years following subsidence related impacts. Following heavy rains during the breeding season Littlejohn's Tree Frog was recorded at SC10C for the first time since 2012. When assessing the presence of Littlejohn's Tree Frog at SC10C over the course of time, it is clear that despite detecting the species in 2015, a local reduction in the available breeding habitat has occurred where mining impacts have occurred. This reduction in habitat has been evident for three consecutive winter monitoring surveys. Similarly for Dendrobium Area 3B, Littlejohn's Tree Frogs were recorded in 2015 at DC13 for the first time since 2012 after subsidence related impacts occurred in 2013. Adult frog abundance was very low (one frog).
- Donalds Castle Creek tributary (DC1): water levels at important breeding pools along this transect do contain water for extended periods of time.
- Donalds Castle Creek tributary (DC13): following the 2015 survey at DC13, pools that were previously utilised by the species to breed were recorded to have minimal to no water for three consecutive years (2013, 2014 and 2015). This represents a reduction in breeding habitat across three monitoring periods and two years following mining impacts.
- Wongawilli Creek tributary (WC21): A reduction in habitat for two monitoring periods (one year) has been recorded at WC21 following the extraction of Longwall 9 and Longwall 10. Approximately 35% of the potential breeding habitat along this stream was experiencing a reduction in water levels including three confirmed breeding pools (observations by Biosis during monitoring in 2015).

3.4 Previous Surveys and Ongoing Monitoring

The DA3C study area has been included within ecological assessments commissioned by Illawarra Coal for over 15 years which have been used to support development applications and exploration activities within the area. The results of select key relevant assessments have been referred to or summarised in

this report. Threatened species previously recorded in previous assessments have generally been supplied to OEH (and its predecessors) for inclusion in the Bionet Atlas of NSW Wildlife threatened species database which has been consulted for this assessment. Relevant assessments conducted within the Dendrobium domain area include:

- Dendrobium Coal Project SIS (Biosis 2001a);
- Dendrobium Coal Project: Terrestrial and Aquatic Habitat Assessment (Biosis 2001b);
- Dendrobium Coal Project: Likely Impacts of Subsidence on Terrestrial Ecology (Biosis 2001c);
- Terrestrial Flora and Fauna Habitat Assessments accompanying coal exploration activities within DA3B (various companies approximately 1996 – 2011);
- Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006 (Biosis 2007a);
- Dendrobium Area 2 Longwalls 3-5a Impacts of Subsidence on Terrestrial Flora and Fauna (Biosis 2007b);
- Dendrobium Area 3B: Terrestrial Ecological Assessment (Niche Environment and Heritage 2012).
- Geographic review of mining effects on Upland Swamps at Dendrobium Mine (Watershed HydroGeo 2019).

Long-term monitoring of vegetation and fauna populations has been undertaken in Dendrobium Areas 1, 2 and 3, which began in 2003. Ecological monitoring has targeted both flora and fauna, and has involved vegetation quadrats and transects, and bird, frog and reptile surveys. Five years of data and records from the monitoring locations were utilised in the SIS (Biosis 2007).

Recently, a review of piezometer data used for detection of impacts to swamps throughout the Dendrobium domain has been conducted (Watershed HydroGeo 2019), which concluded that: "*Based on assessments of water levels and recession rates around past mining in Areas 2, 3A and 3B, hydrographs from swamp piezometers within 60 m are likely to exhibit a mining effect and almost certain to exhibit a mining effect when directly mined under, be that through a reduction in the water table to below pre-mining levels and/or increased recession (drainage) rate. Effects on swamp water tables have not been observed at distances greater than 60 m from a longwall panel.*

When considering piezometers that are lithologically similar, but lying outside of mapped swamp communities, impacts have been observed at 95 and 125 m in two piezometers in Area 3B. Some piezometers within that distance (125 m) have recorded no mining effects."

The above findings are important with regard to assessing the likely extent of impacts to swamp communities.

3.5 Relevant Reviews Considered in this Report

The following reviews have been considered in the current study:

- Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield (Southern Coalfield Inquiry) (DOP 2008); and
- The Draft Upland Swamp Environmental Assessment Guidelines, Guidance for the Underground Mining Industry Operating in the Southern and Western Coalfields (DECCW 2011).

Key findings of the above reviews (as relevant to this assessment) are shown in Table 3.

Table 3: Key findings of relevant reviews

Southern Coalfield Inquiry
Environmental assessments should include a minimum of 2 years of baseline data, collected at an appropriate frequency and scale provided for significant natural features.
Development of improved regional and cumulative data sets for the natural features of the Southern Coalfield.
Before After Control Impact (BACI) study is considered the most appropriate design for many impact studies. Appropriate replication in both impact (directly above the mine) and control (outside direct impact zone) sites is required in monitoring programs so natural variability can be determined.
Environmental assessments should include identification and assessment of significance for all natural features located within 600 m of the edge of secondary extraction.
Risk Management Zones should be identified for all significant natural features, which are sensitive to valley closure and upsidence, including rivers, significant streams (3rd order or above in the Strahler stream classification), significant cliff lines, significant overhangs and valley infill swamps.
Approved mining within identified Risk Management Zones (and particularly in proximity to highly-significant natural features) should be subject to increased monitoring and assessment requirements which address subsidence effects, subsidence impacts and environmental consequences.
The requirements should also address reporting procedures for back analysis and comparison of actual versus predicted effects and impacts, in order to review the accuracy and confidence levels of the prediction techniques used.
Upland Swamps Environmental Assessment Guidelines (Draft)
All underground mining proposals and operations that have the potential to impact on upland swamps demonstrate how they have applied the Upland Swamp Environmental Assessment Guideline.
Impacts to swamps of 'special significance status' are avoided.
Impacts on upland swamps (not of special significance status) are minimised as far as possible.
Monitoring undertaken by the underground mining industry to understand subsidence effects, impacts and environmental consequences is greatly improved.
Adaptive management should be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent further impacts. Active adaptive management usually involves a comparison of management options and a conscious investment in learning by experimentation.
Effective and rigorous monitoring, evaluation, and reporting on management performance and ecological and hydrological impacts are required to inform the adaptive management process and should be integrated into core management systems in a consistent way across industry.
Management measures are to include contingency plans that allow for any unforeseen circumstances, particularly given the uncertainty inherent in the assessment of subsidence impacts, such as non-systematic subsidence (valley closure and upsidence).
Prior to underground mining proponents preparing an environmental assessment there is a need to gather baseline data. Initial steps in the collection of baseline data on upland swamps may include desktop studies to identify the location of the upland swamps (e.g. through vegetation mapping) and the identification of key threatening processes and upland swamps listed under national and state legislation.

The current project is consistent with the recommendations of both reports due to the following proposed actions:

- Subsidence prediction reports and environmental studies have been used to determine potential impacts for DA3C;
- Potential Impacts to upland swamps have been determined;
- Long-term monitoring of natural features including upland swamps in Dendrobium Area 3 is currently undertaken and it is recommended these programs continue and are expanded to DA3C; and
- Additional management and mitigation measures have been recommended in this report and SIS.

3.6 Databases

Databases used in the preparation of this report include:

- OEH Bionet Atlas of NSW Wildlife (OEH 2018) (Accessed November 2018); and
- EPBC Act Protected Matters Search Tool (DoEE 2018) (Accessed November 2018).

Further records of threatened species were obtained from the SIS (Biosis 2007), and from the previous studies listed in Section 3.4.

4 Field Survey

4.1 Previous Survey Effort

This section identifies the extensive surveys which have been conducted within Dendrobium Area 3 and surrounds. The survey effort from the SIS (Biosis 2007) and previous surveys within Dendrobium Area 3 has been summarised in Table 4.

Table 4: Approximate total hours of SIS survey effort and other previous surveys in Area 3

Survey method	Total hours
Vegetation quadrats and transects	44 person hours in SIS, and 373.5 person hours in previous surveys
Vegetation validation and Targeted surveys for threatened plant species	244.5 person hours in SIS and 95 hours in previous surveys
Plot based surveys for *Pultenaea aristata* population count	14 person hours in SIS
Diurnal bird survey	288.5 person hours in previous survey
Nocturnal frog survey	270 person hours in previous survey
Bat Detection	68 Trap nights
Harp Trap	24 Trap nights
Arboreal Elliot Traps (Small)	72 Trap nights
Arboreal Elliot Traps (Large)	72 Trap nights
Arboreal hair tubes	303 Trap nights
Cage traps	360 Trap nights
Diurnal bird surveys	13.88 person hours
Diurnal herpetofauna Search	42.33 person hours
Diurnal call playback	2.05 person hours
Frog habitat search	8.5 person hours
Nocturnal watercourse search	49 person hours
Spotlighting	64 person hours
Nocturnal call playback	52 person hours
Frog call/Song Meter	7 trap nights

Areas previously surveyed within the current study area as part of the SIS, have been identified in Table 5.

Table 5: Previous Survey Effort of Swamps in Area 3C

Site	Swamp characteristics	Position of highest impact area	Previous vegetation survey	Previous fauna survey
Den02	Large complex swamp	Very small section of swamp within 600 m. Feeding	2 x vegetation surveys sites (vegetation	-

		tributaries within angle of draw.	validation and dominant species observations).	
Den05	Large complex swamp	Small section of swamp within 600 m. Previous direct undermining (LW9).	1 x vegetation surveys sites (vegetation validation and dominant species observations).	Diurnal and nocturnal herpetofauna search, scat collection and diurnal bird survey.
Den 07	Large complex swamp	Small section of swamp within 600 m. Feeding tributary within angle of draw.	1 x vegetation surveys sites (vegetation validation and dominant species observations).	Nocturnal call playback (frogs, mammals, owls, Bush-stone Curlew), scat collection, Nocturnal frog habitat search, Spotlighting (mammals, reptiles, birds) on foot and in vehicle and Arboreal Elliots/Hair tubes.
Den 09	Small swamp in two sections – moderately complex	Angle of draw.	-	-
Den 124	Large complex swamp	Small section of swamp within 600m. Feeding tributaries within 600m or previously mined areas.	-	-
Den 140	Small simple swamp	Within 600 m boundary.	-	-
Den 141	Small simple swamp	Small section of swamp within angle of draw.	-	-
Den 142	Small simple swamp	Angle of draw.	1 x vegetation surveys sites (vegetation validation and dominant species observations).	Spotlighting mammals, reptiles and birds on foot.
Den 144	Small simple swamp	Margin of swamp along longwall remainder angle of draw	-	Diurnal herpetofauna search.
Den 145	Small simple swamp	Angle of draw	-	-

Table 6: Previous Survey Effort of Natural Features in Area 3C

Stream	Stream order	Length (m)	Position of highest impact area	Previous vegetation survey	Previous fauna survey
DC11	1	256	600 m boundary	-	-
DC12	1	377	Angle of draw	-	-
DC13	2	48	600 m boundary	Survey adjacent (upstream) of study area (vegetation validation).	-
Donalds Castle Creek	2	784	600 m boundary	Survey adjacent (upstream) of study area (vegetation validation).	Harp trap, diurnal bird survey, nocturnal call playback (owls), diurnal herpetofauna search, nocturnal watercourse search (frogs).
LC5	1	675	Angle of draw	-	Nocturnal call playback (frogs, mammals, owls, Bush-stone Curlew), scat collection, Nocturnal frog habitat search, Spotlighting (mammals, reptiles, birds) on foot and in vehicle and Arboreal Elliots/Hair tubes.
LC6	1	333	600 m boundary	-	Scat collection, Diurnal herpetofauna search, spotlighting mammals, reptiles and birds in vehicle.
WC17A	1	21	600 m boundary		-
WC19	1	451	600 m boundary		-
WC20	1	1124	Longwall		-
WC21	2	507	600 m boundary		Nocturnal call playback frogs, nocturnal watercourse search frogs, diurnal bird survey, scat collection, diurnal herpetofauna search, diurnal frog call playback and habitat search, diurnal bird survey, Habitat assessment, Spotlighting mammals, reptile sand birds in vehicle and on foot.
WC22	1	455	Angle of draw	-	-
WC23	2	681	Longwall	2 x vegetation surveys sites (vegetation validation and	

				dominant species observations).	
WC23A	1	179	Longwall	-	-
WC23B	1	153	Longwall	-	-
WC24	2	1079	Angle of draw	-	-
WC24A	1	275	Angle of draw	-	-
WC25	1	649	Longwall	-	-
WC26	2	481	Angle of draw	-	-
WC26A	1	39	600 m boundary	-	-
WC27	2	484	Angle of draw	-	-
WC27A	1	538	Angle of draw	-	Diurnal frog call playback, diurnal bird survey.
WC28	1	327	600 m boundary	-	-
WC29	1	194	600 m boundary	-	-
Wongawilli Creek	3	3065	Angle of draw	1 x vegetation surveys sites (vegetation validation and dominant species observations) and 3 x 20 x 20 m quadrats (Q1, Q7 and Q8).	Frog surveys and call play back, bird survey, frog searches, habitat assessments, diurnal herpetofauna search, anabat, spotlighting, nocturnal call play back for owls, various other surveys.

Table 7: Previous Survey Effort of Cliffs and Rocky Outcrops in Area 3C

Area	Survey Type	Effort
Southern end of Longwall 20	Diurnal herpetofauna searches	2 people on two occasions in autumn or winter targeting Broad-headed Snake. Minimum of 40 m x 40 m searched.
Eastern end of Longwall 21	Diurnal herpetofauna searches	2 people on two occasions in autumn or winter targeting Broad-headed Snake. Minimum of 40 m x 40 m searched.
Various tracks	Nocturnal spotlighting	Six transects within study area.

4.2 Current Survey

4.2.1 Survey timing

The current project involved flora and fauna survey within the study area and focused on landscape features and associated biodiversity which may be sensitive to the impacts of subsidence from longwall extraction such as swamps, waterways and rocky areas. Survey effort focussed on areas study area which had not been subject to previous survey or had limited survey coverage (Figure 7).

Survey was conducted throughout the study area in two phases in response to changes in the longwall layout:

- 5 days between the 27th of July 2017 to 5th of October 2017; and
- 2 days between the 28th of August and 4th of December 2018.

Field survey activities and detailed in the following sections.

4.2.2 Flora and vegetation survey

Flora survey focused on vegetation validation of upland swamps within the study area (Figure 5). Each swamp mapped within the Woronora vegetation mapping project (NPWS 2003) or identified via aerial photography analysis was visited to confirm the vegetation present including the swamp unit and sub unit as per NPWS 2003. This process was completed by performing Rapid Data Points (RDPs) to record the following:

- Dominant species present at all strata levels; and
- Total projective foliage cover and height at all strata levels.

Species composition and characteristics were then compared with vegetation descriptions. Boundaries between units and sub units were captured in the field by collecting waypoints and tracks along identified boundaries. Where possible, vegetation patterns within swamps were also observed from surrounding vantage points using binoculars to aid with identifying consistency of vegetation or otherwise across the swamp.

Field GPS data was later overlaid onto aerial imagery and boundary mapping was completed with adjustments made if necessary, according to observable colour and texture patterns of vegetation as well as observations of tree canopies, which were used to define the outer-boundaries of the swamps.

Limitations associated with the selected method include reliance on correct positioning of aerial imagery as well as correct interpretation of canopy shadows. Boundaries between swamp communities and sub-communities are frequently not discrete, rather these communities grade into one another. Therefore, there is an element of subjectivity regarding the exact positioning of boundaries dependent upon the observer.

The flora survey included targeted threatened plant species search within upland swamps in the study area.

4.2.3 Fauna survey

Fauna survey effort focused on areas susceptible to subsidence impacts and associated fauna. Areas targeted included upland swamps, creek lines and ridge-top/cliff line environments (Figure 6). Contour mapping and aerial photography was used to identify potential outcrop habitats along ridgelines and were subsequently inspected for the presence of suitable habitat for species such as the Broad Headed Snake.

Listening devices (Wildlife Acoustics Song Meter 2+) targeting threatened frogs were deployed in creeks and upland swamps for different durations to assist with detection of adult frogs if tadpoles could not be detected. A summary of the current survey effort is shown in Table 8.

Table 8: Current Survey Effort

Survey Technique	Habitat	Survey Effort (trap nights/person hours)	Date
Diurnal frog and tadpole searches	Creeks	15.4	27/07/17 02/08/17 04/09/17 04/10/17 05/10/17 28/08/18 04/12/18
Nocturnal frog searches	Creek	4.8	02/08/2017
Frog acoustic recording	Swamps and Creeks	218 nights	28/08/18
Active reptile searches	Ridgelines	1.7	2/08/2017 04/10/17

4.2.4 Survey conditions and limitations

Survey was conducted between July 2017 and December 2018. There were inconsistent rainfall events throughout the 18 month period (Appendix 3) which limited breeding habitat for various frogs including target winter and spring breeding threatened species. This may have limited observations where the Littlejohn's Tree Frog has previously been recorded. For example, the species has been recorded from several sites adjacent to Swamp Den 05, however no pool habitat was observed along the mapped creek line to enable breeding or tadpole observations during August 2018 survey. A revisit to the site in December 2018 after recent significant rain allowed for observations of multiple pools with tadpoles. A similar situation occurred along the western tributary to Wongawilli Creek (WC21) within the south-eastern section of the study area, demonstrating that smaller pools with tadpoles are unlikely to be detected unless survey is conducted soon after rain events.

4.3 Likelihood of Occurrence Assessment for Threatened Species

A list of threatened species within the locality was derived from database searches (OEH Atlas of NSW Wildlife and EPBC Act Protected Matters Search Tool) (Appendix 1). The list of potentially impacted species is determined from consideration of this list. In order to adequately determine the relevant level of assessment for each species, further analysis of the likelihood of those species occurring within the study area was undertaken.

Five categories for 'likelihood of occurrence' (Table 9) were attributed to species after consideration of criteria such as known records, presence or absence of important habitat features on the subject site, results of the field surveys and professional judgement. This process was completed for each individual species.

Species considered further were those in the 'Known' to 'Moderate' categories and where impacts for the species could reasonably occur from the development (Appendix 1).

Table 9: Likelihood of occurrence methodology

Likelihood rating	Threatened Flora/EEC Criteria	Threatened and Migratory Fauna Criteria
Known	The species/EEC was observed within the study area.	The species was observed within the study area.
High	It is likely that a species/EEC inhabits or utilises habitat within the study area.	It is likely that a species inhabits or utilises habitat within the study area.
Moderate	Potential habitat for a species/EEC occurs on the site. Adequate field survey would determine if there is a 'high' or 'low' likelihood of occurrence for the species within the study area.	Potential habitat for a species occurs on the site and the species may occasionally utilise that habitat. Species unlikely to be wholly dependent on the habitat present within the study area.
Low	It is unlikely that the species/EEC inhabits the study area.	It is unlikely that the species inhabits the study area. If present at the site, the species would likely be a transient visitor. The site contains only very common habitat for this species which the species would not rely on for its on-going local existence.
None	The habitat within the study area is unsuitable for the species/EEC.	The habitat within the study area is unsuitable for the species.

5 Results

5.1 Vegetation Communities

Eight vegetation communities or sub-communities have been mapped as occurring within the study area by NPWS (2003) and Niche during the current project, after confirmation of swamp mapping (Table 10).

Ground-truthing of upland swamp community mapping resulted in changes to upland swamp sub-community patterns, swamp boundaries and changes in vegetation communities (Figure 5).

Two small swamps were added to vegetation mapping after field observations. Conversely, two small areas mapped as upland swamps were reclassified as other community types. These areas corresponded with woodland or forest communities with thick understories of banksia thicket. These changes are to be expected since the base mapping of the Upland Swamp Banksia Thicket community unit did not attempt to remove areas of banksia thicket that may occur in other communities such as Exposed Sandstone Scribbly Gum Woodland (see page 200 of NPWS 2003).

Banksia thickets occur moderately frequent throughout the study area in the range of communities present. Often these areas share floristic similarities with simpler swamp types such as areas of banksia thicket (typically dominated by *Banksia marginata*). However, the presence of other diagnostic swamp species that are more reliant on frequently waterlogged soils is lacking or poorly represented in these areas.

Table 10: Area of vegetation communities within the study area (including adjacent swamp areas)

Map Unit (NPWS 2003)	Vegetation Community (NPWS 2003)	Area in study area 600m of Longwalls* (ha)
MU4	Sandstone Riparian Scrub (SRS)	4.0
MU26	Sandstone Gully Peppermint Forest (SGPF)	206.1
MU29	Exposed Sandstone Scribbly Gum Woodland (ESSGW)	316.4
MU42	Upland Swamps: Banksia Thicket (USBT)	5.4
MU43	Upland Swamps: Tea-Tree Thicket (USTTT)	4.2
MU44a	Upland Swamps: Sedgeland-Heath (USSH) Complex	0.9
MU44b	Upland Swamps: Restioid Heath (USRH) Complex	0.9
MU45	Upland Swamps: Fringing Eucalypt Woodland (USFEW)	4.0

*note that figures for swamp communities include areas of swamps beyond the 600 m study area boundary where any part of the swamp occurs within the boundary excluding USFEW.

5.2 Upland swamps within the study area

Ten upland swamps occur within the study area (Table 11) (Figure 4). The majority of swamps are smaller swamps with single sub-communities, which tend to be drier swamp types (Banksia Thicket). Complexity of swamps generally increased with overall size of the swamp complex. This is likely due to larger swamps having more variable groundwater conditions across the swamp from more frequently waterlogged areas with heavy peat development to less frequently waterlogged areas with less peat development.

The larger more complex swamps within the study area have small portions within the margins of the 600 m study area boundary (Figure 5). None of the complex larger swamps are within the predicted area of subsidence impacts (35 degree angle of draw study area).

Table 11: Upland swamps within the study area

Swamp No.	Swamp Community/sub-community	Area (ha) within and adjacent to 600m boundary	Area (ha) within 600 m boundary	Area (ha) within angle of draw	Area (ha) above proposed longwalls
Den02	Upland Swamps: Banksia Thicket	0.62	0.0006	-	-
	Upland Swamps: Tea-tree Thicket	0.32	0.0009	-	-
Den05	Upland Swamps: Banksia Thicket	0.09	-	-	-
	Upland Swamps: Restioid Heath	0.40	-	-	-
	Upland Swamps: Tea-tree Thicket	1.18	0.13	-	-
Den07	Upland Swamps: Banksia Thicket	3.18	0.004	-	-
	Upland Swamps: Tea-tree Thicket	1.69	-	-	-
Den09	Upland Swamps: Banksia Thicket	0.29	0.29	-	-
	Upland Swamps: Tea-tree Thicket	0.50	0.50	-	-
Den124	Upland Swamps: Restioid Heath	0.55	-	-	-
	Upland Swamps: Sedgeland-Heath Complex	0.90	0.002	-	-
	Upland Swamps: Tea-tree Thicket	0.53	0.01	-	-
Den140	Upland Swamps: Banksia Thicket	0.05	0.05	-	-
Den141	Upland Swamps: Banksia Thicket	0.04	0.04	0.003	-
Den142	Upland Swamps: Banksia Thicket	0.16	0.16	0.16	-
Den144	Upland Swamps: Banksia Thicket	0.54	0.54	0.54	-
Den145	Upland Swamps: Banksia Thicket	0.41	0.41	-	-
Total		**11.45**	**2.13**	**0.70**	**0.00**

5.3 Upland Swamp Community Descriptions

5.3.1 MU42: Upland Swamps: Banksia Thicket (BT)

Banksia Thicket occurs as two single small swamps or on the drier edges of larger more complex swamps within the study area. The community typically grades into adjoining areas of the drier MU45: Upland Swamps: Eucalypt Fringing Woodland.

In some swamps, a sparse canopy layer exists. Where this occurs, the canopy has a low projective foliage cover (e.g. 5%). Trees included *Eucalyptus racemosa* or *E. sieberi* with a canopy height to approximately to 15 m.

The shrub layer reached a height of approximately 4 - 5 m, and a high projective foliage cover of 60 to 90 percent. The shrub layer primarily consisted of *Banksia ericifolia* with associate species including *Acacia terminalis, Hakea teretifolia, Leptospermum polygalifolium, L. juniperinum, L. squarrosum, Petrophile pulchella.*

Ground layer species include: *Bauera rubioides, Baeckea imbricata, Epacris microphylla, Empodisma minus, Cyathochaeta diandra, Hibbertia riparia, Lepidosperma limicola, Sprengelia incarnata, Schoenus brevifolius* and *Dillwynia floribunda.*

5.3.2 MU43: Upland Swamps: Tea Tree Thicket (TTT)

Tea Tree Thicket occurs in areas of impeded drainage within swamps in the study area.

The community has been classified as a closed scrub, with a small tree and shrub layer reaching a height of approximately 5 m and project foliage cover of up to 80 percent. Canopy trees include *Eucalyptus piperita and E. racemosa.*

The midstorey and shrub layers include: *Acacia rubida, Banksia robur, Melaleuca linearifolia, Leptospermum juniperinum, L polygalifolium, L lanigerum* and *Petrophile pulchella.*

Ground layer species include: *Gahnia sieberi, Baumea teretifolia, Dillwynia floribunda, Empodisma minus, Leptocarpus tenax* and *Lepidosperma limicola*.

5.3.3 MU44: Upland Swamps: Sedgeland Heath Complex

a) Sedgeland

The sedgeland community was recorded within minor depressions in a number of upland swamps in the study area.

The shrub layer reached a height of approximately 1 m with a project foliage cover of up to 30 percent. Shrubs included: *Baeckea imbricata, Epacris obtusifolia, Sprengelia incarnata, Symphionema paludosum, Boronia parviflora, Hakea teretifolia* and *Banksia ericifolia* subsp*. ericifolia*

The Ground layer has a projected foliage cover of approximately 30 to 60 percent. Species include: *Leptocarpus tenax, Schoenus brevifolius, Schoenus paludosus, Lepyrodia scariosa, Ptilothrix deusta, Dampiera stricta* and *Stylidium graminifolium.*

b) Restioid Heath

The restioid heath, like that of sedgeland, occurs within the minor depressions in a number of upland swamps in the study area.

A low shrub layer of *Banksia oblongifolia*, *Hakea teretifolia* and *Epacris obtusifolia* consistently occur with occasional *B. robur*, *Melaleuca thymifolia* and *M. squarrosa*. The project foliage cover is approximately 40 percent to a height of 1 m.

The ground cover consists of a combination of rushes, herbs and grasses forming a dense ground cover. Species present include *Empodisma minus*, *Lepyrodia scariosa*, *Leptocarpus tenax*, *Lindsaea linearis*, *Xanthorrhoea resinifera*, *Stackhousia nuda*, *Mitrasacme polymorpha* and *Schoenus brevifolius*.

5.4 Upland Swamp – EEC Classification

5.4.1 EPBC Act

The mapped upland swamps in the study area do not comprise any of the swamps referred to within the Scientific Committee determination for the Temperate Highland Peat Swamps on Sandstone EEC (DoEE 2019). The conservation advice for this EEC notes that the ecological community comprises particular swamps in the Blue Mountains, Lithgow, Southern Highlands and Bombala regions. In addition, an accompanying map of likely EEC areas does not show any swamps within the Dendrobium area or surrounds (DEH 2004). Given the above, swamps within the study area are not considered to be part of the Commonwealth EEC.

It should be noted that the determination of THPS within upland swamps on the Woronora Plateau has been discussed in the Planning and Assessment Commission, Bulli Seam Operations PAC Report (2010). The assessment panel, through consultation with OEH is of the view that a number of swamps on the Woronora Plateau, are more likely than not to be classified ultimately as examples of THPS and therefore of National Significance.

5.4.2 BC Act/TSC Act

All upland swamps within the study area are considered to fit the NSW determination description of Coastal Upland Swamps in the Sydney Basin Bioregion, which is listed as an Endangered Ecological Community under the NSW BC Act (formerly TSC Act). Point 7 of the Final Determination (NSW Scientific Committee 2005) states Coastal Upland Swamp in the Sydney Basin bioregion includes mapping units: Upland Swamps Banksia Thicket (MU42), Upland Swamps Tea-tree Thicket (MU43) and Upland Swamps Sedgeland-Heath Complex (MU44) of NPWS (2003). All three of these communities occur within the Upland Swamps in the study area (Figure 5).

The approximate area of Coastal Upland Swamps within the wider study area, which includes the totality of a swamp where any part of the swamp is within 600 m of the proposed longwalls is 11.45 ha (Table 11).

5.5 Threatened Flora

A total of 27 threatened plant species listed on the EPBC Act and or TSC Act have been previously recorded, or have potential habitat within a 5 km radius of the study area (Table 15 and Figure 7). Extensive occurrences of *Leucopogon exolasius* were observed at multiple locations within the study area, within areas where the species has previously been observed and mapped. This species predominantly occurs on ridgetops within the study area and is not dependent on groundwater. Therefore, as this species would not be impacted by subsidence the species was not recorded. No other threatened flora was recorded within the study area.

Of the 23 threatened species obtained in the database searches, 11 species (*Acacia baueri* spp*. aspera, Acacia bynoeana, Cryptostylis hunteriana, Epacris purpurascens* var*. purpurascens, Grevillea parviflora* subsp*. parviflora, Leucopogon exolasius, Melaleuca deanei, Persoonia acerosa, Persoonia bargoensis, Persoonia hirsuta* and *Pultenaea aristata*) were considered to have a Moderate to High likelihood of occurrence in the study area.

Potential impacts to these threatened flora are discussed in Section 6.2.

5.6 Threatened Fauna

A total of 54 threatened fauna species listed on the EPBC Act and or TSC Act have been previously recorded, or have potential habitat within a 5 km radius of the study area (Table 16 and Figure 8).

The previous SIS survey recorded 139 fauna, including 32 threatened fauna within Dendrobium Area 3. Four threatened fauna were recorded during the current survey as detailed below.

Threatened species	Observation details	Date
Red-crowned Toadlet	Single site along 1st order stream WC20, downstream of swamp 144, after significant rain. Frogs responded to call playback: one frog captured, two heard calling.	04/12/2018
Littlejohn's Tree Frog	Five observations of tadpoles were made from four locations: WC 20 (7 pools downstream of swamp 144 with tadpole counts of 150, 25, 30, 20, 25, 6 and 20 respectively). LC 5 (7 pools immediately downstream of Swamp 07 with approximately 200-300 tadpoles present along with some egg masses). WC 26 (4 observations from upstream to downstream: 12 tadpoles observed, 4 adults heard, 5 adults heard and 4 adults heard). WC 21 - outside of study area. 25 tadpoles observed.	04/12/2018 04/12/2018 02/08/2018 04/09/2017
Koala	Wongawilli Creek. Single scat observation during nocturnal frog survey.	02/08/2018
Powerful Owl	Recorded on songmeter at one site.	23/08/2017

5.7 Fauna Habitat

Fauna habitat within the study area considered prone to subsidence impacts is described in Sections 5.7.1 to 5.7.3.

5.7.1 Upland swamps

Upland swamps range in character from relatively dry swamps supporting Banksia Thicket to more permanently inundated swamps with abundant sedges and herbs (see section 5.2). Upland swamps may provide habitat to a wide variety of birds, mammals, amphibians, reptiles and invertebrate species, with particular species performing strong associations with swamps (e.g. the Giant Dragonfly).

Upland swamps within the study area also provide an important role in regulating flows along particular watercourses within the study area.

5.7.2 Creeks and Drainage Lines

Major watercourses within the DA3C study area include: Donalds Castle Creek, Wongawilli Creek and Lake Cordeaux. Various drainage lines and tributaries of these watercourses occur throughout the study area. All creeks and drainage lines within the study area are considered to be generally in good condition, and they provide a range of habitat features including: emergent vegetation, riffles, pools, sandy substrate and rocks. Isolated areas of poorer condition due to cracking from previous longwall mining were observed south of the study area at Donalds Castle Creek.

Creek lines are important to particular frogs and reptiles including threatened species, with water facilitating the breeding cycle and other lifecycle components of most frogs. The character of drainage lines depends on their size, slope and catchment area with small ephemeral streams offering important breeding and sheltering habitat for some species while larger permanent streams are preferred by others. Habitat features along the streams include rock pools, riffle zones, gravel beds, woody debris, boulders and aquatic vegetation.

5.7.3 Sandstone Outcrops, Overhangs and Caves

These habitat feature are typically important to reptile and bat species. Threatened reptiles that may utilise such features include the threatened Broad-headed Snake.

Caves and overhangs within the study area may provide habitat for micro-bats, including threatened species: Eastern Bentwing-bat, Little Bentwing-bat and Southern Myotis. Cave development within the study area is poor however so roosting is likely to occur in crevices.

5.8 Key Threatening Processes

Key-threatening processes (KTP) relevant to the project include:

1. Alteration of habitat following subsidence due to longwall mining; and
2. Alteration of the natural flow regimes of rivers, stream, floodplains and wetlands.

5.8.1 Alteration of habitat following subsidence due to Longwall mining

Alteration of habitat following subsidence due to longwall mining is listed as a KTP under the NSW BC Act. This is the most relevant KTP associated with the Proposal.

Subsidence due to longwall mining has been recognised as causing habitat alteration, with species and ecological communities that depend on aquatic and semi-aquatic habitats being particularly susceptible to the impacts of subsidence. Consequently, alteration of habitat following subsidence due to longwall mining has been determined by the NSW Scientific Committee to constitute a Key Threatening Process (NSW Scientific Committee 2005).

A list of threatened species, populations and EECs potentially impacted by longwall mining is provided in the NSW Scientific Committee Final Determination for this KTP (NSW Scientific Committee 2005). Flora of

relevance to this assessment include: *Acacia baueri* subsp*. aspera, Epacris purpurascens* var. *purpurascens, Leucopogon exolasius, Melaleuca deanei, Persoonia acerosa* and *Pultenaea aristata.* Fauna include: Eastern Pygmy Possum, Southern Brown Bandicoot, Giant Burrowing Frog, Black Bittern, Littlejohn's Tree Frog, Stuttering Frog, Large-footed Myotis (*Myotis adversus*), Red-crowned Toadlet, Grey-headed Flying Fox, Giant Dragonfly, Broad-headed Snake and Rosenberg's Goanna.

5.8.2 Alteration of the natural flow regimes of rivers, stream, floodplains and wetlands

Alteration of the natural flow regimes of rivers, stream, floodplains and wetlands is listed as a KTP under Schedule 3 of the TSC Act. This is a relevant KTP associated with the Proposal, which is caused by subsidence.

Alteration to natural flow regimes can occur through reducing or increasing flows, altering seasonality of flows, changing the frequency, duration, magnitude, timing, predictability and variability of flow events, altering surface and subsurface water levels and changing the rate of rise or fall of water levels.

5.9 Critical Habitat or Areas of Outstanding Biodiversity Value (AOBV)

Areas of Critical Habitat under the NSW TSC Act have been replaced by AOBVs with the introduction of the NSW BC Act. No AOBVs have been declared for any ecological values within the study area. No AOBVs will be impacted by the Proposal.

6 Impact Assessment

Potential Impacts to Vegetation

Vegetation communities which are not dependant on groundwater are unlikely to be impacted by subsidence due to underground mining. This accounts for most of the woodland and forest communities in Table 10.

Groundwater dependant and riparian vegetation may experience some floristic changes in response to changed groundwater conditions, as a result of subsidence.

Riparian vegetation is generally not mapped as discrete vegetation communities, rather these areas display structural and floristic variation within their composite community in response to more frequent contact with shallow groundwater. Riparian vegetation may be potentially impacted by subsidence through water diversion, or cracking of bedrock.

In the Southern Coalfield, observed impacts to riparian vegetation as a result of subsidence are minor in occurrence. Furthermore, limited impacts to riparian vegetation have been observed in Dendrobium Mine to date (Biosis 2016). Previous examples of impacts include: dieback of riparian vegetation as a result of methane releases which occurred nearby Cataract River during the 1990s (Eco Logical Australia 2004), and small localised changes to riparian vegetation along a section of the Waratah Rivulet.

Impacts to riparian vegetation associated with the Proposal are predicted to be minor in occurrence, being localised if they occurred.

Groundwater dependant ecosystems (typically comprising upland swamps within the locality) on the other hand are prone to groundwater changes as a result of subsidence. Potential impacts are discussed below.

6.1 Potential Impacts to upland swamps

The study area contains a mixture of headwater swamps and valley infill swamps, with headwater swamps being closer to the proposed longwalls. If all 10 swamp areas within and adjacent to the 600 m study area boundary are considered, 11.45 ha of upland swamps including complex swamps with wetter sub-units have some potential for impact. However, the areas bounded by 600 m (especially if adjacent swamp areas are included) is considered a conservative approach to determining areas of potential impacts. The majority of impacts will occur above the proposed longwalls, with severity and risk of impacts reducing with distance from longwalls up to the 35° angle of draw study area, which includes the 20 mm subsidence contour. Beyond the 35° angle of draw study area, impacts to features such as swamps and watercourses are expected to be minor or negligible. A recent assessment at Dendrobium Mine concluded that hydrological change in Upland Swamps is not evident in shallow groundwater piezometers located more than 60 m from the extracted longwall margin (Watershed Hydrogeo, 2019).

No swamps occur directly above proposed longwalls, while 0.70 ha of upland swamps from three swamps occur within the 35° angle of draw study area. These areas are likely to be subsidence impacted to some extent (see Table 12). Up to a further 10.75 ha of upland swamps within the wider study area may experience some minor or negligible impact depending on the distance from proposed longwalls.

To assess the potential impacts of subsidence on Upland Swamps, a review of MSEC (2018) subsidence predictions and previous literature on monitoring of swamp subsidence impacts from the locality has been completed, with a summary provided in Table 12.

Table 12: Impact predictions for upland swamps within and adjacent to the study area

Site	Swamp characteristics	Position	Subsidence predictions	Conclusion
Den02	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.
Den05	Large complex swamp.	Small section of swamp within 600m. Previous direct undermining (LW9 to 11).	Low likelihood of additional subsidence impacts given distance from longwalls of the swamp and its tributaries. Previous longwall mining directly below this swamp impacted the swamp (Biosis 2016).	Unlikely to be measurable additional impacts to this swamp or associated species including threatened species from the current proposal. Monitoring of impacts likely to be confounded from previous direct undermining (LW 9 to 11).
Den 07	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 2018). 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.
Den 09	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.	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.

Den 124	Large complex swamp. Offline from major watercourse of Donalds Castle Creek.	Small section of swamp within 600 m. Feeding tributaries within 600m 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.
Den 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.
Den 141	Small simple swamp, no noticeable pools or watercourses adjacent.	Small section of swamp within angle of draw.	Possibility of some subsidence impacts. Fracturing of the bedrock may occur along with dilation of strata.	While some subsidence impacts are possible, these are unlikely to be significant. Swamp is small and simple and is unlikely to contribute significantly to biodiversity values given its size, complexity and lack of pooling habitat.
Den 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.
Den 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.
Den 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.

The MSEC (2018) report has predicted potential subsidence impacts within swamps located within the 35° angle of draw study area constituting three small swamps, with their closest point situated from between 50 m and 230 m away from proposed longwalls. It is expected, at the magnitudes of predicted curvatures and strains, that fracturing of the bedrock beneath these three swamps would occur as the result of the proposed longwalls (MSEC 2012).

Should changes in groundwater levels within the upland swamps occur, this may impact on the distribution of local vegetation within the swamps as well as potential for downstream impacts to associated watercourses.

6.2 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 (Appendix 4). However, a limited number have potential habitat likely to be impacted by subsidence.

Threatened flora likely to be impacted by subsidence (Table 13), include those associated with ground water dependent habitats, such as upland swamps and riparian vegetation. Ridgeline and woodland dependent threatened flora are unlikely to be significantly impacted by subsidence mechanisms.

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.

Impacts from the current proposal on threatened flora have been assessed within the project's SIS and are likely to be minimal from the current proposal.

Table 13: Threatened flora with potential to be impacted within the study area

Botanical Name	Potential Habitat in study area	Potential to be Impacted by Subsidence	Seven-Part Test Undertaken in SIS (Biosis 2007)
Cryptostylis hunteriana	Not previously recorded in study area. Potential habitat includes upland swamps, creek lines and ridge lines.	Yes. Upland swamps and creek line habitat may be impacted by subsidence mechanisms.	Yes. No significant impact concluded.
Epacris purpurascens var. purpurascens	Not previously recorded in study area. Potential habitat includes upland swamps, creek lines and ridge lines.	Yes. Upland swamps and creek line habitat may be impacted by subsidence.	Yes. No significant impact concluded.
Leucopogon exolasius	Not previously recorded in study area. Potential habitat includes creek lines. Vegetation communities include SGPF and SRS.	Yes. Creek line habitat may be impacted by subsidence mechanisms.	Yes. No significant impact concluded.
Pultenaea aristata	Not previously recorded in study area. Potential habitat includes upland swamps and creek lines.	Yes. Upland swamps and creek line habitat may be impacted by subsidence mechanisms.	Yes. No significant impact concluded.

6.3 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. Predicted impacts to these habitats are documented in Table 1.

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.

The proposed longwall layout has been set back from major watercourses within the study area including Wongawilli Creek and Donalds Castle Creek, and as such, subsidence impacts within these areas would be limited (MSEC 2018).

Watercourses that are directly mined beneath and those within the 35° angle of draw, are likely to have bedrock fracturing with associated impacts such as diversion of surface water flows and draining of pooled water. In addition to hydrological impacts, secondary impacts on water quality, such as increased concentrations of iron precipitates are likely to occur as a result of bedrock fracturing and increased groundwater input to the streams. Both such impacts (hydrological and water quality) may extend some distance downstream from the zone of fracturing, with the severity of impacts reducing with distance from the zone of fracturing. Overall, 5.6 km of mapped watercourses occur within the 35 degree angle of

draw study area, which are prone to subsidence impacts (both direct and indirect), however impacts are likely to be confined to features such as standing pools, which make up a small but important proportion of the overall watercourse. A total of 12.8 km of mapped streams occur within 600m from the proposed longwalls.

Within the Dendrobium mining domain, the above-mentioned aquatic impacts are considered the most significant impact to fauna. In regard to terrestrial fauna, such impacts are of particular relevance to frog species including the threatened species Red-crowned Toadlet, Littlejohn's Tree Frog and Giant Burrowing Frog, which are discussed in detail in Section 6.4.

Impacts on cliff lines, rock outcrops and other rocky habitats within the study area are likely to be minor, as observed in previous mining areas. No large scale cliff collapses or slope failures are predicted. Small rock outcrops are expected to experience minor impacts. Such impacts, while having some potential to alter available roosting or sheltering habitat for a range of species, have limited potential to harm or cause widespread mortality to species given the minimal occurrence of rock falls and collapses predicted, as well as the limited importance of any given area of such habitat (i.e. there is no one area considered to be particularly important for the survival of species within the study area such as roosting bats).

6.4 Potential Impacts to Threatened Fauna

Fifty four threatened fauna were considered during likelihood of occurrence assessment (Appendix 1). 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. Nine threatened species are considered to be potentially impacted by subsidence impacts resulting from the proposal (Table 14).

Assessments of significance under the TSC Act were carried out for 30 threatened species during the project SIS, with significant impacts considered to potentiality occur for six species comprising:

- Frogs: Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Stuttering Frog;
- Reptiles: Broad-headed Snake
- Invertebrates: Giant Dragonfly.

The results of the assessments of significance are considered relevant to the current project considering the DA3, with the exception of the Stuttering Frog. The Stuttering Frog is not likely to be present in the study area as it has not been recorded during the present study or during extensive survey programs targeting threatened frog species conducted in adjacent areas with the same habitats (Biosis 2016). The very few recent records of the Stuttering Frog located from the Sydney Basin and southwards have all been associated with large permanent streams lined by wet sclerophyll or rainforest vegetation that tends to form a dense enclosing canopy over the stream area. This habitat is very limited or absent from the study area and surrounds.

An assessment of potential impacts from the current proposal for each of the identified threatened species likely to be impacted is provided below in Table 14.

Table 14: Threatened fauna with moderate to high potential for impacts of study area due to the proposal

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
Amphibians				
Heleioporus australiacus Giant Burrowing Frog	Species has been recorded during SIS and subsequent monitoring surveys in areas 3A and 3B (Biosis 2016; Figure 8). Records are sporadic due to difficulty of detection. Not recorded during current survey but assumed to be present due to difficulty of detection.	Potential impacts include: changes to flow regimes, loss of surface flow and water retention within breeding pools. Changes in Upland swamps are likely to impact the species via influencing downstream pool availability or permanency or through changes in sheltering habitat within swamps.	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS. Habitat has been shown to be impacted during monitoring of subsidence impacts within Areas 3A and 3B as predicted within SIS. Access constraints and detectability make it difficult to judge severity of impacts on population via effective monitoring. Impacts detected for Littlejohn's Tree Frog for permanent pools are likely relevant for Giant Burrowing Frog.
Litoria Littlejohni Littlejohn's Tree Frog	Recorded throughout Areas 3A-3C during SIS. Recorded within current study in several watercourses and downstream of upland swamps (Figure 6). Likely to be present in other watercourses throughout study area where appropriate breeding habitat is present. Within the project area, the species relies upon semi-permanent pools for tadpole development. Maturation times for tadpoles	Potential impacts include: changes to flow regimes, loss of surface flow and water retention within breeding pools. Changes in Upland swamps are likely to impact the species via influencing downstream pool availability or permanency or through changes in sheltering habitat within swamps.	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS. Habitat has been shown to be impacted during monitoring of subsidence impacts within Areas 3A and 3B as predicted within SIS. Monitoring within Area 3B indicates that abundance of species is likely to have declined due to subsidence impacts such as reduced water retention in pools (Biosis 2016).

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
	have been observed to take around 4 months (Anstis 2002), although this is variable in the field depending on factors such as weather. Pools of sufficient depth and hydroperiod within the catchment area were almost exclusively located along second order or higher streams or else first order streams where headwater swamps are positioned upstream. Larger, faster flowing streams such as Wongawilli Creek are less likely to support breeding.			
Pseudophryne australis Red-crowned Toadlet	Recorded during the SIS at five sites in Area 3 including upland swamp 10, and a drainage line near upland swamp 15b. Recorded in area 3B in 2012 surveys (Niche 2012) and during follow-up monitoring (e.g. Biosis 2016). Recorded in Area 3C during current survey along WC20.	Yes, potentially impacted. Given its habitat preferences appear to be largely dependent upon surface water runoff and seepage rather than ground water and requirements for semi-permanent pools, it is considered that this species is less sensitive to impacts from subsidence in comparison with other species such as Littlejohn's Tree Frog. Nonetheless, changes in hydrology related to cracking of bedrock underlying streams providing habitat for the Red-crowned	Yes. Significant impact determined.	Conservation listing status of species has not changed since original SIS. There has been limited monitoring to specifically assess impacts to Red-crowned Toadlet due to subsidence within the Dendrobium area. Monitoring has focussed upon the Littlejohn's Tree Frog which is likely to be more prone to subsidence impacts and more effectively monitored due to a conspicuous, relatively lengthy tadpole phase.

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
		Toadlet have the potential to influence moisture levels and retention of moisture within small pools, soaks and leaf litter environments on which Red-crowned Toadlets rely to complete their lifecycle. While some records of the species in the local area are adjacent to swamps, it is not considered that swamps play a particularly important role in providing appropriate breeding or sheltering habitat.		Impacts detected for Littlejohn's Tree Frog along smaller streams are likely relevant for Red-crowned Toadlet.
Reptiles				
Hoplocephalus bungaroides Broad-headed Snake	Not previously recorded in study area. Potential habitat includes ridgeline and creek lines. Vegetation communities include SGPF and ESSGW.	Yes, potentially impacted. Impacts to any potential habitat is likely to be limited, based on previous observations of subsidence within adjacent mined areas and predictions of subsidence for the current proposal. That is, predictions of subsidence impacts such as rock-falls are limited in their extent (MSEC 2018; Section 5.9.4). This factor, coupled with the requirement that subsidence would need to be coincident with sheltering habitat for the Broad-headed Snake which is quite limited,	Yes. No significant impact determined.	Conservation listing status of species has not changed since original SIS. Limited monitoring has been done for this species. The species is difficult to detect and monitoring which includes lifting of preferred rock plates is potentially harmful to the species. It is not known if this species has been impacted by subsidence from mining within the Dendrobium area, however given the limited extent of reported rock-falls, impacts

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
		and that deleterious impacts would need to then result, leads to a prediction of minimal impacts for this species.		are likely to be minimal and difficult to detect.
Varanus rosenbergi Rosenberg's Goanna	Previously recorded by Biosis (2007) within Area 3. Potential habitat includes upland swamps, ridgelines and creek lines. Vegetation communities include: SGPF and upland swamp communities.	Yes, potentially impacted. Potential impacts include: death or injury resulting from rock fall or collapse. Impacts to any potential habitat is likely to be limited, based on previous observations of subsidence within adjacent mined areas and subsidence predictions for the current proposal. That is, predictions of subsidence impacts such as rock-falls are limited in their extent (MSEC 2018; Section 5.9.4). This factor, coupled with the requirement that subsidence would need to be coincident with sheltering habitat for the Rosenberg's Goanna and that deleterious impacts would need to then result, leads to a prediction of minimal impacts for this species.	Yes. No significant impact determined.	Conservation listing status of species has not changed since original SIS. Limited monitoring has been done for this species. It is not known if this species has been impacted by subsidence from mining within the Dendrobium area, however given the limited extent of reported rock-falls, impacts are likely to be minimal and difficult to detect.
Mammals				
Miniopterus schreibersii	Recorded in Study Area with probable certainty during the SIS.	Yes, potentially impacted.	Yes.	

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
Eastern Bentwing-bat	Potential habitat includes the entire study area, however only specific features likely to be impacted.	Potential impacts include: death or injury resulting from rock fall or collapse, possible changes in availability of breeding and roosting habitat. Maternity caves would not occur within the Study Area. If roosting occurs within the Study Area, it is unlikely to be widespread or significant. Minimal impacts (from subsidence of features such as cliffs and overhangs) are expected to occur given the limited propensity of roosting within the Study Area and the limited area of impact predicted to occur for possible roost habitats.	No significant impact determined.	
Minipoterus australis Little bent-wing bat	Recorded in Study Area with probable certainty during the SIS. Potential habitat includes the entire study area, however only specific features likely to be impacted.	Yes, potentially impacted. Potential impacts include: death or injury as result of rock fall or collapse, possible changes in availability of breeding and roosting habitat.	Yes. No significant impact determined.	
Myotis macropus Southern Myotis	Recorded in Study Area during the SIS. Potential habitat includes larger watercourses with pools and standing water and adjacent vegetation.	Yes, potentially impacted. Potential impacts include: death or injury as result of rock fall or collapse and impacts on prey availability due to drying of pools.	Yes. No significant impact determined.	

Species	Recent records and habitat in study area	Potential impact to species or potential habitat in study area	Assessment of significance undertaken in SIS and result (Biosis 2007)	Current conservation and impact status
Invertebrates				
Petalura gigantea Giant Dragonfly	Not recorded in study area. Potential habitat includes upland swamps.	Yes, potentially impacted. Potential impacts include: loss of upland swamp habitat as a result of subsidence.	Yes. Significant impact determined.	One swamp with preferred foraging habitat (i.e. within 500 m of a swamp with breeding habitat) for this species (Den09) occurs between the angle of draw study area and the 600m study area. Minimal impacts are expected to occur for this foraging habitat. Swamps with preferred breeding habitat for this species (Den07, Den124) occur on the edges of the 600 m study area but are not expected to experience subsidence impacts from the proposal.

7 Monitoring and Recommendations

7.1 Existing Monitoring and Requirements

A terrestrial ecology monitoring program within Dendrobium began in 2003. Details of the current monitoring program for DA3B are contained in Biosis (2016) *Dendrobium Terrestrial Ecological Monitoring Program Annual Report for 2015*. Findings from each year of terrestrial ecology monitoring are reported in Annual Environmental Management Reports and End of Panel Reports.

Related monitoring programs include monitoring of abiotic parameters which are key predictors of biodiversity impacts, such as soil moisture, shallow groundwater levels and recharge rates, rainfall and temperature.

Prior to the proposed mining, a Swamp Impact Monitoring, Management and Contingency Plan and Watercourse Impacts Monitoring Management and Contingency Plan is to be made to the satisfaction of the Secretary as per Schedule 3 Condition 6 of the Notice of Modification. It is to be prepared in consultation with OEH, WaterNSW and DPI.

7.2 Recommendations for Future Monitoring

Terrestrial ecology monitoring for DA3C should continue to be based on existing methodologies within Biosis (2016) to ensure consistency of data capture to allow for ongoing comparisons with monitoring conducted to date. Improvements and additions to these programs are however recommended.

It is recommended the following be continued or included in the terrestrial ecology monitoring program for DA3C:

- Monitoring of upland swamps should continue to follow the methodology outlined in Biosis (2016) which is consistent with Keith *et al.* (2006).
- Visual comparison of photo point monitoring undertaken at each upland swamp site should also continue from marked monitoring points.
- Mapping of upland swamp boundaries within DA3C should be refined prior to baseline surveys. Recent methods including the use of drones is likely to achieve better accuracy and consistency for mapping of swamp boundaries and overcome current identified limitations (see 4.2.2).
- Mapping of microhabitats such as pools along streams, as currently performed by South32 for DA3B, should be extended to DA3C prior to baseline frog surveys.
- It is recommended that frog monitoring in area 3C (and other areas) develop rainfall or hydrometric trigger values for surveys to allow for greater consistency between years which would aid in comparison of results (pre versus post mining and impact versus control).
- A baseline survey focussed on tadpole survey for Littlejohn's Tree Frog and aural detection of Red-crowned Toadlet should be conducted after sufficient rainfall and within the appropriate season.
- Monitoring programs should continue to be based on BACI design.
- Swamp and watercourse monitoring should categorise impact sites based on their distance from longwalls distinguishing between sites above longwalls, sites less than 60 m from longwalls and sites outside the 35° angle of draw.

- All remediation works that are undertaken near waterways, must take appropriate measures to minimise environmental impacts. This includes avoiding the spread of Chytrid Fungus following the NPWS guidelines.
- The implementation of mitigation measures should also be followed by monitoring to confirm the success or otherwise of any implemented measures.
- Methods should seek to identify any significant (e.g. greater than 10 mm) surface cracking within the study area so that monitoring and mitigation measures to minimise fauna entrapment (if identified as occurring) can be undertaken.

8 Conclusion

Impacts on features from subsidence caused by longwall mining within the Dendrobium domain are largely predictable given a particular longwall mine layout. This is evidenced through identification of reasonably consistent patterns during monitoring of subsidence impacts undertaken for Dendrobium Areas 2, 3A and 3B (e.g. MSEC 2018; Watershed HydroGeo 2019). Subsidence predictions for the proposed Longwalls 20 and 21 within DA3C are consistent with previous subsidence predictions for Area 3B in their nature, however are less severe due to the limited number of longwalls proposed and their spatial arrangement (MSEC 2018).

Monitoring of impacts to natural features such as swamps, watercourses and cliffs in Dendrobium Area 3A and 3B (e.g. Biosis 2016; HGEO 2017) supports past subsidence predictions. Monitoring results have highlighted a high likelihood of impacts to watercourses and swamps through a reduced capacity for water recharge and permanency within the shallow groundwater table and within features such as pools along watercourses. Such impacts can be confidently predicted above and in close proximity to longwalls but become less apparent with distance from longwalls. For example, a recent review of monitoring (Watershed HydroGeo 2019) indicates that hydrographs from swamp piezometers within 60 m of longwalls at Dendrobium are likely to exhibit a mining effect and almost certain to exhibit a mining effect when directly mined under, be that through a reduction in the water table to below pre-mining levels and/or increased recession (drainage) rate. Conversely, effects on swamp groundwater have not been observed at distances greater than 60 m from a longwall panel.

Where subsidence impacts do occur, deleterious effects to particular threatened species such as Littlejohn's Tree Frog have been highlighted as highly likely or definitive in some areas. However, clear patterns regarding the significance and severity of impacts to biodiversity values such as swamps and target threatened species have at times been difficult to illustrate confidently due to other impacts such as drought operating concurrently with subsidence impacts (e.g. Biosis 2016).

Review of the SIS predictions with regard to subsidence impacts on threatened biodiversity along with other relevant studies and surveys conducted as part of the current project support the findings of the *Dendrobium Area 3 Species Impact Statement* (Biosis 2007) with few departures. Since the SIS (2007), upland swamps of the study area have been listed as an EEC within NSW under the TSC/BC Acts. In addition, whereas the original SIS highlighted significant impacts for the Stuttering Frog (on a precautionary basis) sufficient data now exists to assess with relatively high confidence that the species does not occur within the study area.

Ten upland swamps occur within the study area and the majority of these are not expected to be impacted by the proposal. A maximum of 0.70 ha of swamps within the study area are likely to be impacted via subsidence from the proposal. In addition, habitats such as pools, along a combined length of between 5.6 km of watercourses within the 35° angle of draw study area, are likely to experience subsidence impacts (comprising both direct and indirect impacts). Subsidence impacts to features such as cliffs, overhangs and rocky outcrops have the potential to occur but are likely to have limited impacts on threatened biodiversity within the study area due to the small area of predicted impacts.

It is recommended that subsidence monitoring programs including biodiversity monitoring continue and, for DA3C, will commence with design of an appropriate monitoring program incorporating a minimum of

two years baseline monitoring data prior to longwall extraction. Recommendations in regard to biodiversity monitoring have been included within this report.

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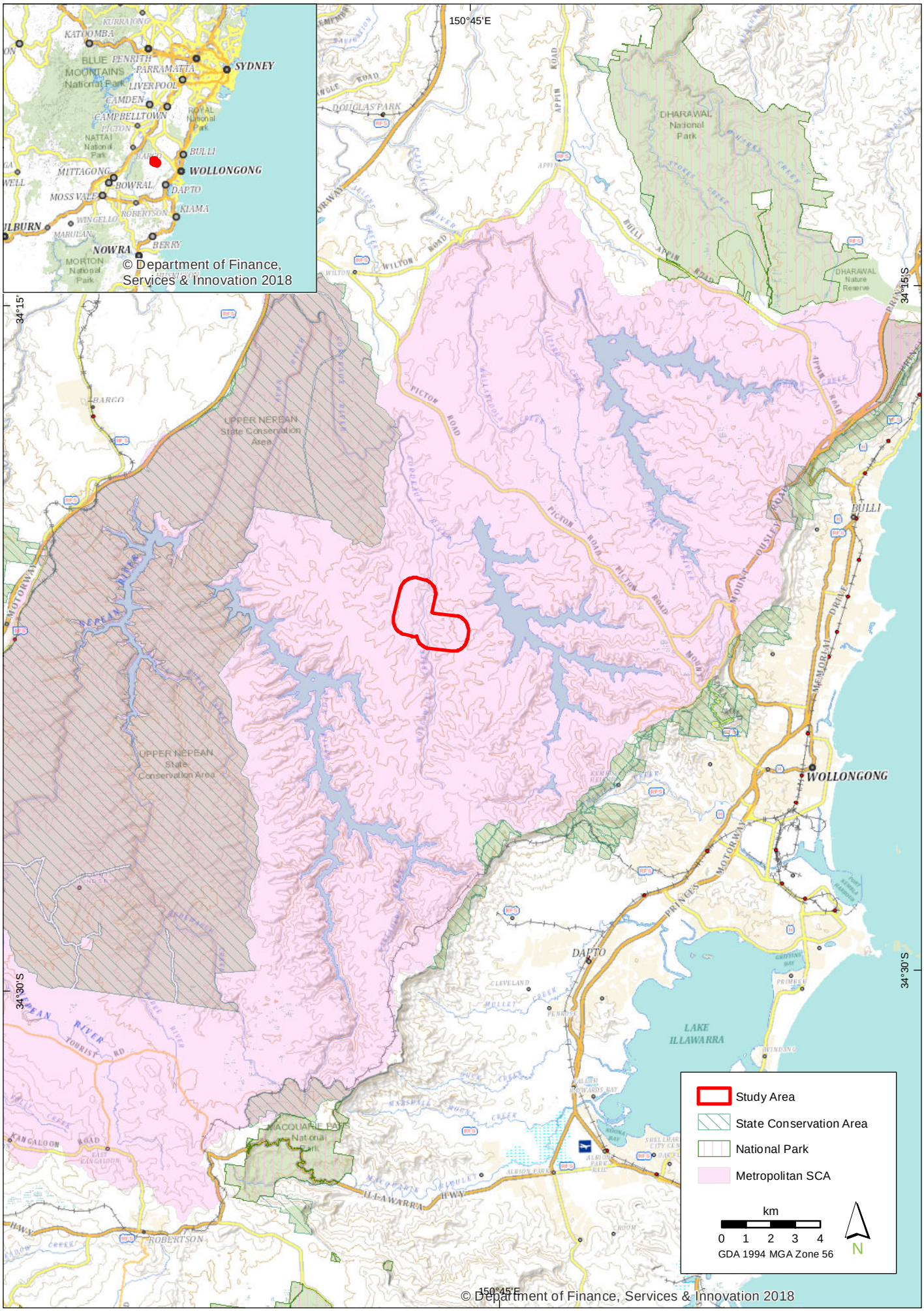
Figures



Location Map

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 1

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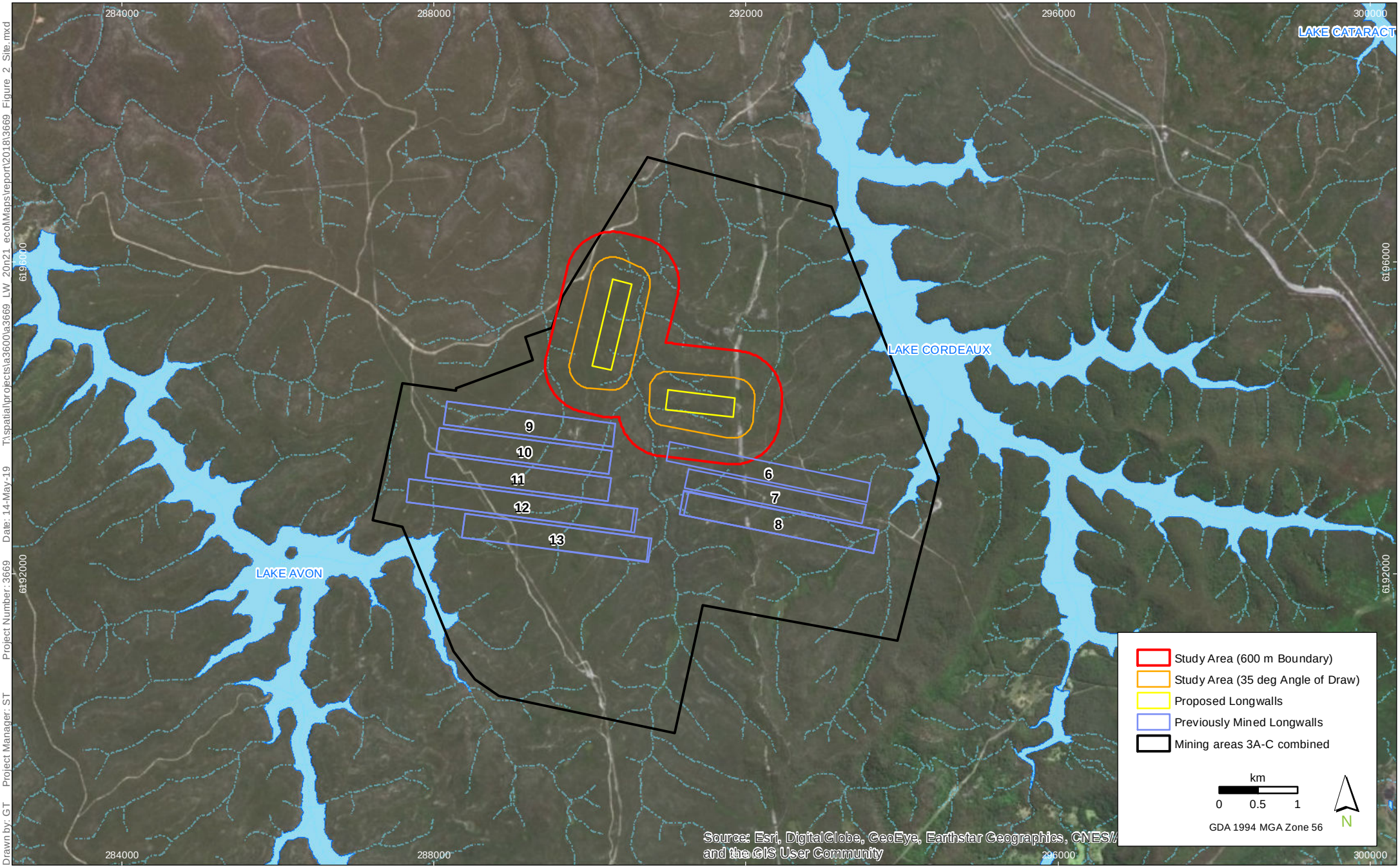

Site Map

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 2

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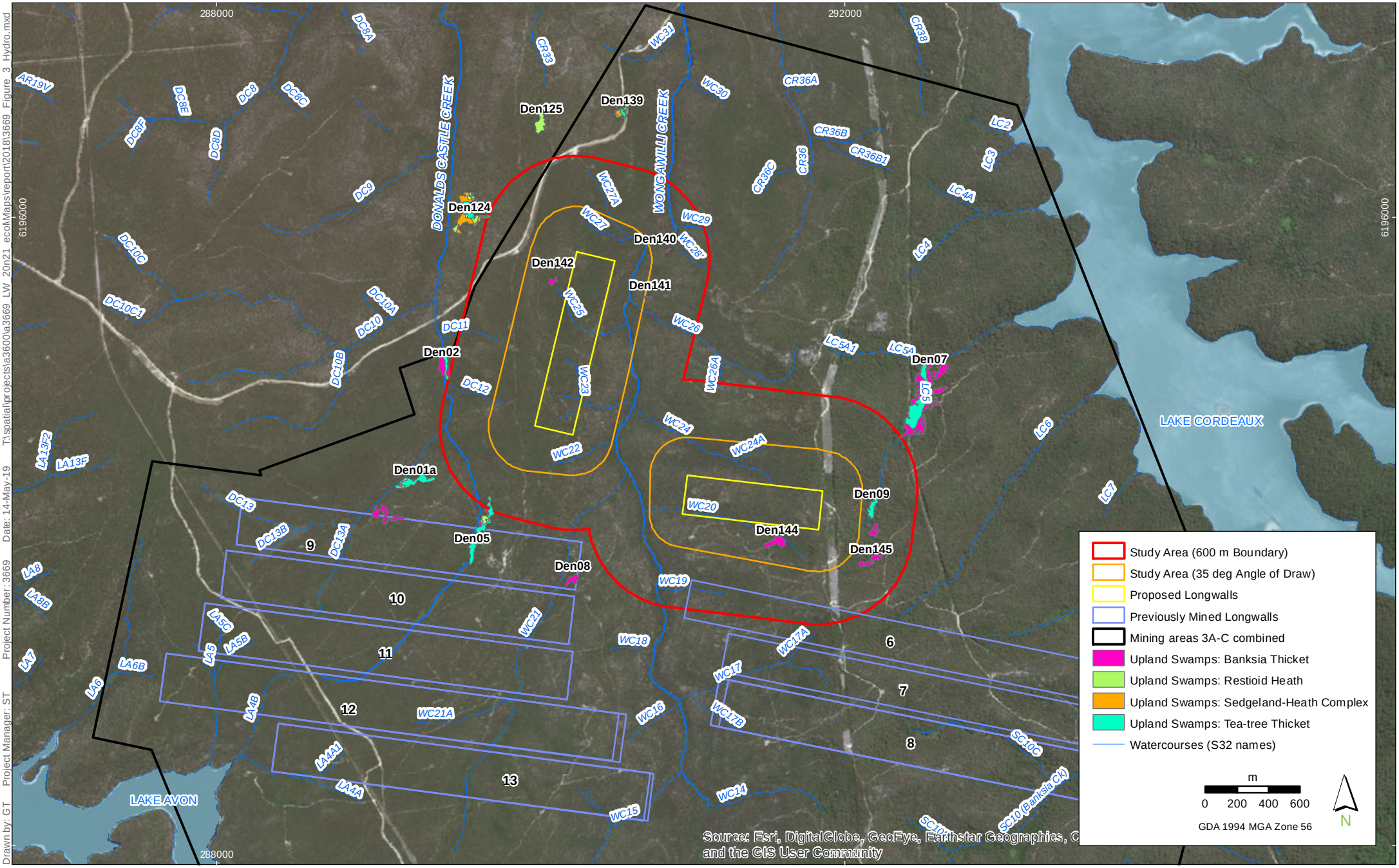

Watercourses and Confirmed Swamps within the Study Area and Surrounds

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 3

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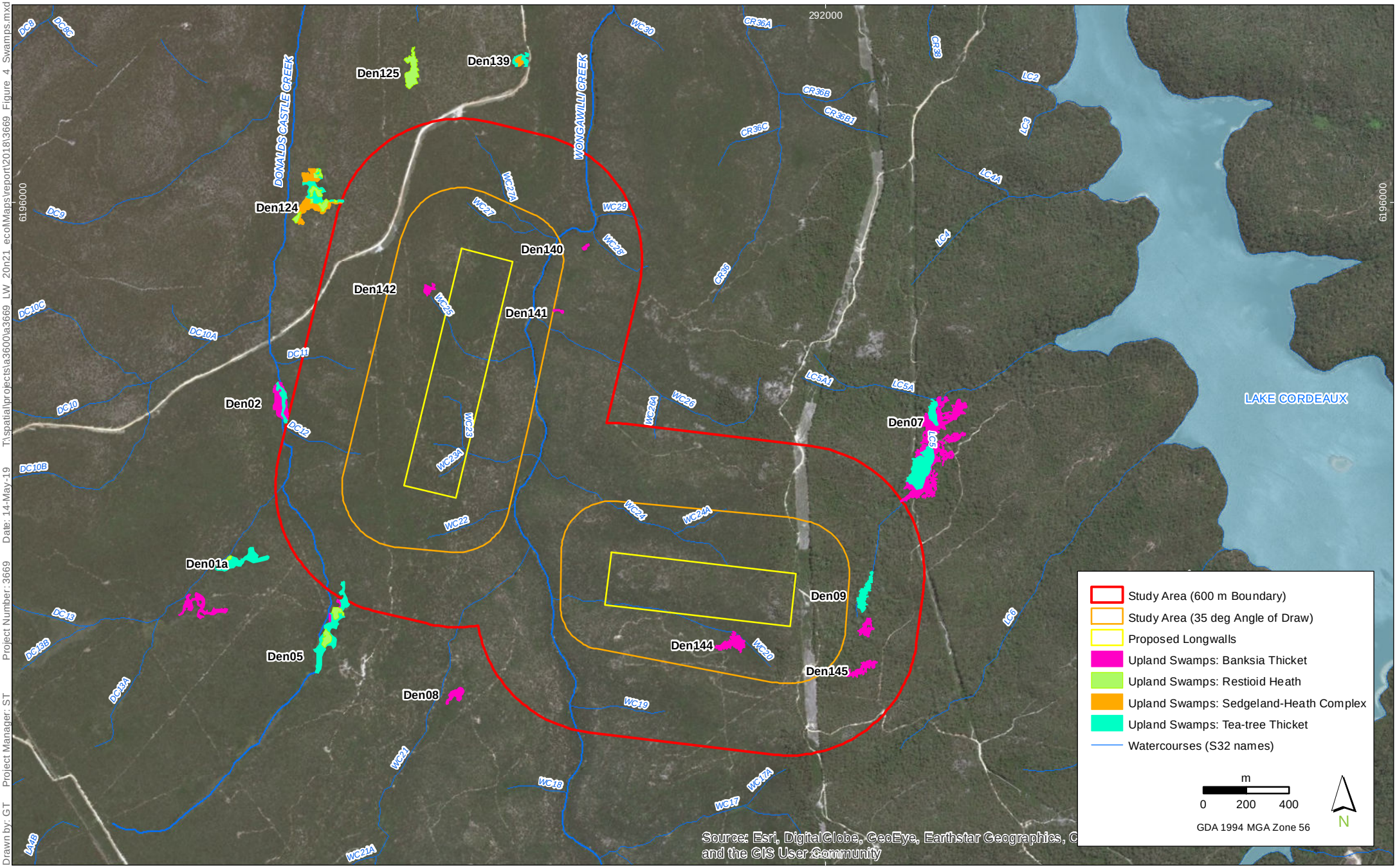

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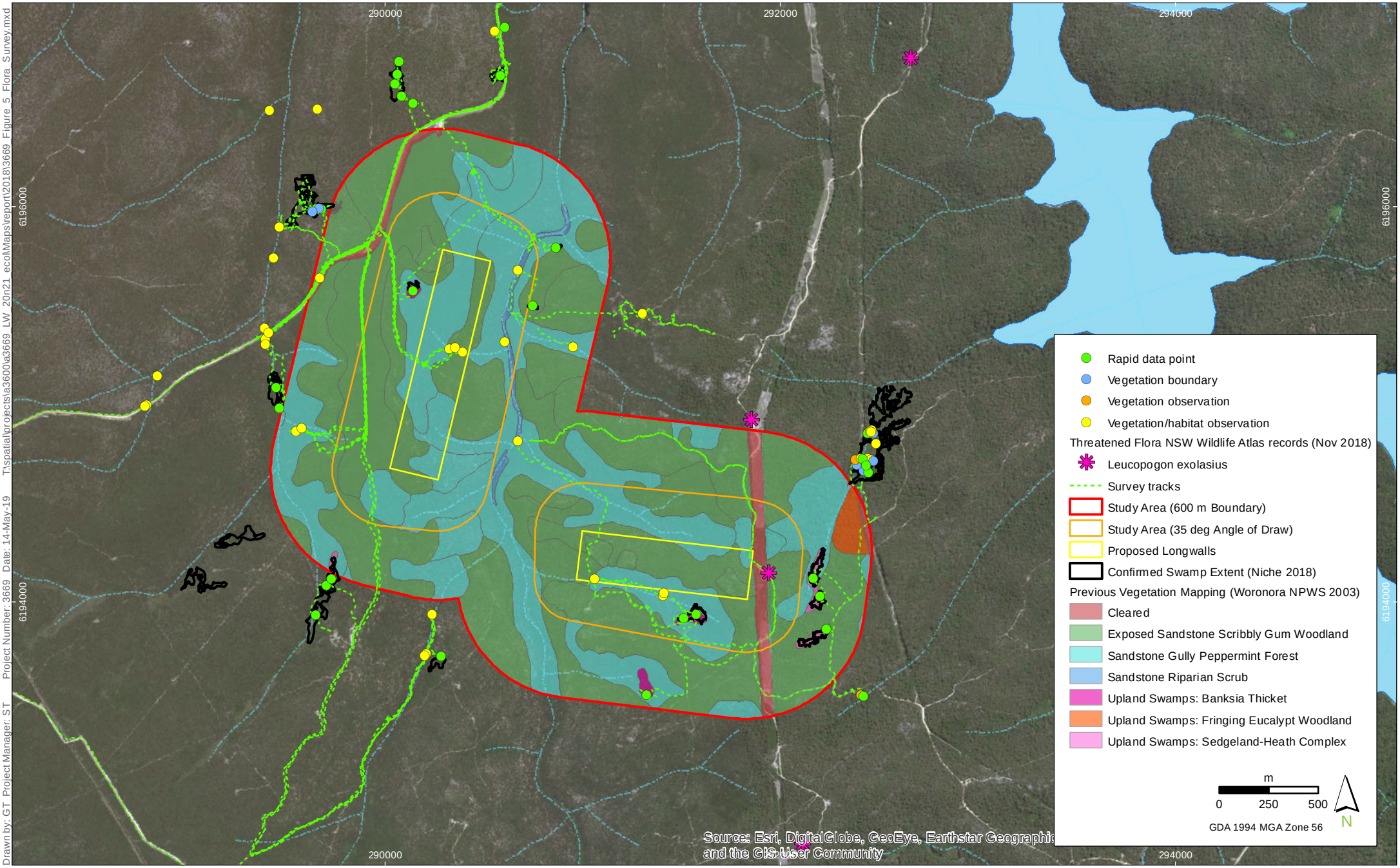
Swamps within and adjacent to the Study Area

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 4

Imagery: (c) DigitalGlobe 2017-11-01



Flora Survey Methods, Vegetation Mapping and Threatened Flora Records

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 5

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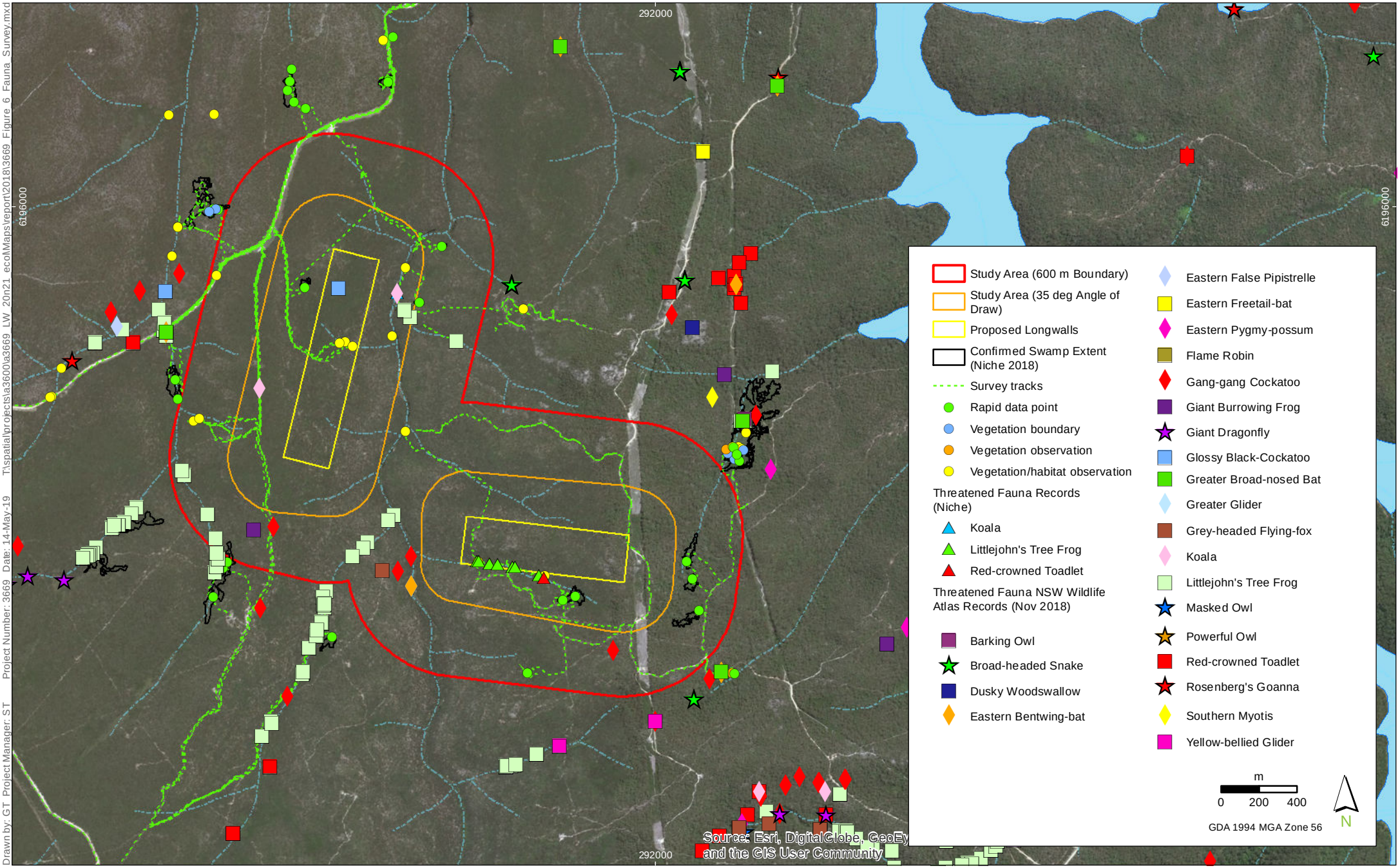

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Fauna Survey Methods, Results and Threatened Fauna Records

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 6

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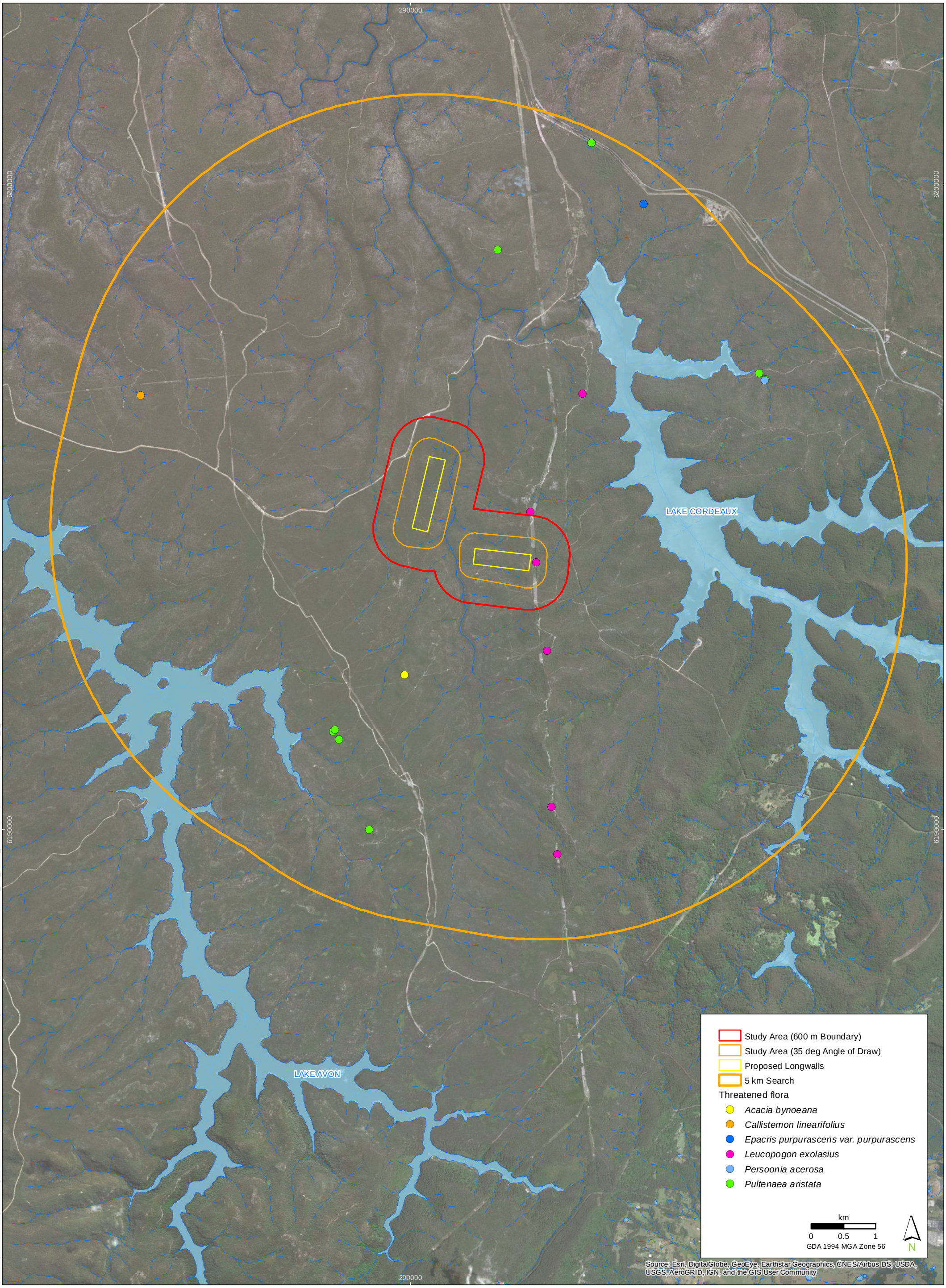

NSW Wildlife Atlas Threatened Species 5km Search - Flora

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 7

Imagery: (c) DigitalGlobe 2017-11-01

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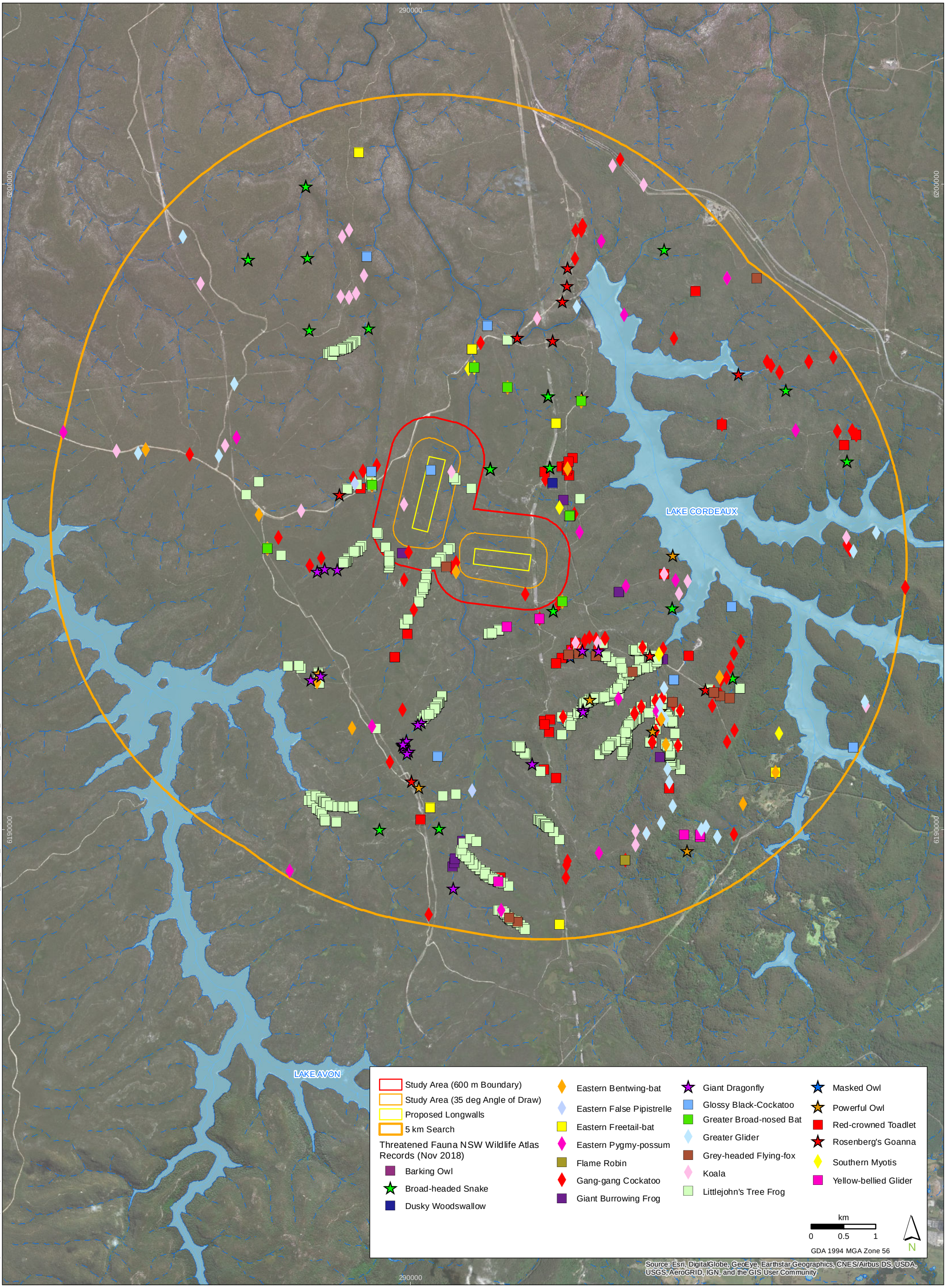

NSW Wildlife Atlas Threatened Species 5km Search - Fauna

Dendrobium Area 3C Longwalls 20-21 Terrestrial Ecological Assessment

FIGURE 8

Imagery: (c) DigitalGlobe 2017-11-01

Appendices

Appendix 1: Threatened Species Likelihood of Occurrence Tables

Table 15. Threatened Flora Likelihood of Occurrence

Species	EPBC Act	BC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Acacia bynoeana Bynoe's Wattle	V	E1	Grows mainly in heath and dry sclerophyll forest in sandy soils. Mainly south of Dora Creek-Morisset area to Berrima and the Illawarra region, west to the Blue Mountains, also recorded from near Kurri Kurri in the Hunter Valley and from Morton National Park. ROTAP: 3VC-	Yes. Previously recorded in Area 3C in the Biosis (2007) SIS along Fire Road 6.	Low
Allocasuarina glareicola	E	E	Primarily restricted to the Richmond (NW Cumberland Plain) district, but with an outlier population found at Voyager Point, Liverpool. Grows in Castlereagh woodland on lateritic soil. Found in open woodland with Parramatta Red Gum, Broad-leaved Ironbark, Narrow-leaved Apple, Scribbly Gum and Paperbarks.	Low	Low
Caladenia tessellata Tessellated Spider Orchid	V	E1	The Tessellated Spider Orchid is found in grassy sclerophyll woodland on clay loam or sandy soils, though the population near Braidwood is in low woodland with stony soil. Known from the Sydney area (old records), Wyong, Ulladulla and Braidwood in NSW. Populations in Kiama and Queanbeyan are presumed extinct. ROTAP: 3V	Low	Low
Callistemon linearifolius	-	V	This shrub is up to 3-4 m tall, grows in dry sclerophyll forest on the coast and adjacent ranges. Recorded from the Georges River to Hawkesbury River in the Sydney area, and north to the Nelson Bay area of NSW. Flowers during spring and summer	Low	Low
Cryptostylis hunteriana Leafless Tongue Orchid	V	V	Grows in swamp-heath on sandy soils, chiefly in coastal districts, south from the Gibraltar Range. ROTAP: 3VC-	High	Moderate
Cynanchum elegans White-flowered Wax Plant	E	E	Recorded from rainforest gullies scrub and steep slopes from the Gloucester district to the Wollongong area and inland to Mt Dangar. ROTAP: 3ECi	Low	Low

Epacris purpurascens var. purpurascens	-	V	Grows in sclerophyll forest, scrubs and swamps on sandstone from Gosford and Sydney districts. ROTAP: 2KC-	High	Moderate
Genoplesium baueri Bauer's Midge Orchid	E	E	Grows in dry sclerophyll forest and moss gardens over sandstone. Flowers February to March. Has been recorded between Ulladulla and Port Stephens. Currently the species is known from just over 200 plants across 13 sites. The species has been recorded in Berowra Valley Regional Park, Royal National Park and Lane Cove National Park and may also occur in the Woronora, O'Hares, Metropolitan and Warragamba Catchments.	Low	Low
Grevillea parviflora ssp. parviflora Small-flower Grevillea	V	V	Grows in heathy associations or shrubby woodland, in sandy or light clay soils usually over shale substrates. Occurs west and south of Sydney from west of Prospect (where now almost certainly extinct), Kemps Creek and lower Georges River south to Camden, Appin and Cordeaux Dam, with disjunct northern populations south of Putty and near Cessnock and Cooranbong, possibly also south of Moss Vale.	High	Low
Haloragis exalata subsp. exalata Square Raspwort	V	V	Occurs in 4 widely scattered localities in eastern NSW. It is disjunctly distributed in the central coast, south coast and north-western slopes botanical subdivisions of NSW. The species appears to require protected and shaded damp situations in riparian habitats.	Low	Low
Leucopogon exolasius Woronora Beard-heath	V	V	Grows in woodland on sandstone. Restricted to the Woronora and Grose Rivers and Stokes Creek, Royal National Park. ROTAP: 2VC-	High	Moderate
Melaleuca biconvexa Biconvex Paperbark	V	V	Biconvex Paperbark generally grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Scattered and dispersed populations found in the Jervis Bay area in the south and the Gosford-Wyong area in the north.	Low	Low
Melaleuca deanei Dean's Low Melaleuca	V	V	Grows in wet heath on sandstone in coastal districts from Berowra to Nowra. ROTAP: 3RC-	Moderate to High	Low
Persoonia acerosa Mossy Geebung	V	V	Occurs in heath or dry sclerophyll forest on sandstone, from central Blue Mountains south to Hill Top. ROTAP: 2VC-	High	Low

Persoonia hirsuta	E	E	The Hairy Geebung is found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone.	Moderate to High	Moderate
Pomaderris brunnea Rufous Pomaderris	V	V	Brown Pomaderris grows in moist woodland or forest on clay and alluvial soils of flood plains and creek lines in association with *Eucalyptus amplifolia*, *Angophora floribunda*, *Acacia parramattensis, Bursaria spinosa* and *Kunzea ambigua*. ROTAP: 2VC-	Low	Low
Pterostylis gibbosa Illawarra Greenhood	E	E	Grows in open forest or woodland, on flat or gently sloping land with poor drainage. Known from a small number of populations in the Hunter region (Milbrodale), the Illawarra region (Albion Park and Yallah) and the Shoalhaven region (near Nowra). ROTAP: 2E	Low	Low
Pterostylis saxicola Sydney Plains Greenhood	E	E	Restricted to western Sydney between Freemans Reach in the north and Picton in the south. Most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. The vegetation communities above the shelves where *Pterostylis saxicola* occurs are sclerophyll forest or woodland on shale/sandstone transition soils or shale soils.	Low	Low
Pultenaea aristata Prickly Bush-pea	V	V	Grows in moist, dry sclerophyll woodland to heath on sandstone, specifically the drier areas of upland swamps. Restricted to the Woronora Plateau, a small area between Helensburgh, south of Sydney, and Mt Keira above Wollongong. ROTAP: 2V	High. Previously recorded in Biosis (2007) SIS in DA3 (but not DA3C)	Low
Pultenaea glabra Smooth Bush-Pea	V	V	Grows in swamp margins, hillslopes, gullies and creekbanks and occurs within dry sclerophyll forest and tall damp heath on sandstone. Restricted to the higher Blue Mountains.	Low	Low
Syzygium paniculatum Magenta Lilly Pilly	E	V	Found only in NSW, in a narrow, linear coastal strip from Bulahdelah to Conjola State forest. On the south coast the species occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral rainforest. On the central coast it occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities.	Low	Low
Thelymitra kangaloonica Kangaloon Sun-orchid	CE	CE	Recorded from shallow black peaty soil in coastal heath on sandstone. *Thelymitra sp. Kangaloon* is a terrestrial orchid endemic to New South Wales, and is known from three locations near Robertson in the Southern Highlands.	Low	Low

Thesium austral Austral Toadflax	V	V	Grows in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia. Occurs in grassland or grassy woodland. Grows on Kangaroo Grass tussocks but has also been recorded within the exotic Coolatai Grass.	Low	Low

Table 16. Threatened Fauna Likelihood of Occurrence

Scientific Name	Common Name	BC Act	EPBC Act	Habitat	Likelihood of Occurrence	Potential for Impact
Amphibians						
Heleioporus australiacus	Giant Burrowing Frog	V	V	Prefers hanging swamps on sandstone shelves adjacent to perennial non-flooding creeks (Daly 1996, Recsei 1996). Can also occur within shale outcrops within sandstone formations. In the southern part of its range can occur in wet and dry forests, montane sclerophyll woodland and montane riparian woodland (Daly 1996). Individuals can be found around sandy creek banks or foraging along ridge-tops during or directly after heavy rain. Males often call from burrows located in sandy banks next to water (Barker 1995).	High	High
Litoria aurea	Green and Golden Bell Frog	E	V	Inhabits marshes, dams and stream-sides, particularly those containing bullrushes (Typha spp.) or spikerushes (Eleocharis spp.). Optimum habitat includes water-bodies that are un-shaded, free of predatory fish such as Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites available.	None	None
Litoria Littlejohni	Littlejohn's Tree Frog	V	V	Occurs in wet and dry sclerophyll forests associated with sandstone outcrops between 280 and 1000 m on the eastern slopes of the Great Dividing Range (Barker 1995). Prefers rock flowing streams, but individuals have also been collected from semi-permanent dams with some emergent vegetation (Barker 1995). Forages both in the tree canopy and on the ground, and has been observed sheltering under rocks on high exposed ridges during summer. It is not known from coastal habitats.	Known. Previously recorded in Swamps Den05, Den08, Den09 and Den10 in the study area.	High
Pseudophryne australis	Red-crowned Toadlet	V	-	Occurs on wetter ridge tops and upper slopes of sandstone formations on which the predominant vegetation is dry open forests and heaths. This species typically breeds within small ephemeral creeks that feed into larger semi-perennial streams. After rainfall these creeks are characterised by a series of shallow pools lined by dense grasses, ferns and low shrubs (Thumm 1997).	High	High

Mixophyes balbus	Stuttering Frog	E	V	This species is usually associated with mountain streams, wet mountain forests and rainforests (Barker 1995). It rarely wanders very far from the banks of permanent forest streams, although it will forage on nearby forest floors. Eggs are deposited in leaf litter on the banks of streams and are washed into the water during heavy rains (Barker 1995).	Low	Low
Birds						
Botaurus poiciloptilus	Australasian Bittern	E	E	The Australasian Bitterns is widespread but uncommon over south-eastern Australia. In NSW they may be found over most of the state except for the far north-west. Favours permanent freshwater wetlands with tall, dense vegetation, particularly bullrushes (Typha spp.) and spikerushes (Eleoacharis spp.).	Low	Low
Ninox connivens	Barking Owl	V	-	Generally found in open forests, woodlands, swamp woodlands and dense scrub. Can also be found in the foothills and timber along watercourses in otherwise open country (Pizzey 1997).	Moderate	Low
Ixobrychus flavicollis	Black Bittern	V	-	Usually found on coastal plains below 200 m. Often found along timbered watercourses, in wetlands with fringing trees and shrub vegetation. The sites where they occur are characterized by dense waterside vegetation.	Low	Low
Monarcha melanopsis	Black-faced Monarch	-	M	A migratory species found during the breeding season in damp gullies in temperate rainforests. Disperses after breeding into more open woodland (Pizzey 1997).	Moderate	Low
Artamus cyanopterus cyanopterus	Dusky Woodswallow	V	-	Often reported in woodlands and dry open sclerophyll forests, usually dominated by eucalypts, including mallee associations. It has also been recorded in shrublands and heathlands and various modified habitats, including regenerating forests; very occasionally in moist forests or rainforests.	Moderate	Low
Dasyornis brachypterus	Eastern Bristlebird	E	E	Found in coastal woodlands, dense scrub and heathlands, particularly where it borders taller woodlands (Pizzey and Knight 1997).	Low – not recorded on locality despite various targeted survey	Low

Petroica phoenicea	Flame Robin	V	-	Flame Robins are found in a broad coastal band from southern Queensland to just west of the South Australian border (Australian Museum 2009). The species is also found in Tasmania. The preferred habitat in summer includes eucalyptus forests and woodland, whilst in winter prefers open woodlands and farmlands. It is considered migratory. The Flame Robin breeds from about August to January (Morcombe 2003).	High	Low
Apus pacificus	Fork tailed Swift	-	M	The Fork-tailed Swift is almost exclusively aerial, flying from less than 1 m to at least 300 m above ground and probably much higher.	Low to moderate - overfly habitat only.	Low
Stictonetta naevosa	Freckled Duck	V	-	The freckled duck breeds in permanent fresh swamps that are heavily vegetated. Found in fresh or salty permanent open lakes, especially during drought. Often seen in groups on fallen trees and sand spits (Simpson, 1996).	Low	Low
Callocephalon fimbriatum	Gang-gang Cockatoo	V	-	In summer, occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests (Higgins 1999). Also occur in subalpine Snow Gum woodland and occasionally in temperate or regenerating forest (Forshaw 1981). In winter, occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas (Shields 1992). It requires tree hollows in which to breed (Gibbons 1997).	Known	Low
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	-	Inhabits forest with low nutrients, characteristically with key Allocasuarina spp. Tends to prefer drier forest types (NPWS 1999) with a middle stratum of Allocasuarina below Eucalyptus or Angophora. Often confined to remnant patches in hills and gullies (Higgins 1999). Breed in hollows stumps or limbs, either living or dead (Higgins and Davies 1996).	Known	Low
Tyto novaehollandiae	Masked Owl	V	-	Inhabits a diverse range of wooded habitat that provide tall or dense mature trees with hollows suitable for nesting and roosting (Higgins, 1999). Mostly recorded in open forest and woodlands adjacent to cleared lands. Nest in hollows, in trunks and in near vertical spouts or large trees, usually living but sometimes dead (Higgins 1999). Nest	High	Low

				hollows are usually located within dense forests or woodlands (Gibbons 1997). Masked owls prey upon hollow-dependent arboreal marsupials, but terrestrial mammals make up the largest proportion of the diet (Gibbons 1997, Higgins 1999).		
Cuculus optatus, Cuculus saturatus	Oriental Cuckoo	-	M, MA	Mainly inhabits coniferous, deciduous and mixed forests. Breeds in northern hemisphere. Brood parasite, laying eggs in nests of other birds.	Low	Low
Rostratula benghalensis	Painted Snipe (Australian subspecies)	E	-	In NSW, this species has been recorded at the Paroo wetlands, Lake Cowell, Macquarie Marshes and Hexham Swamp. Most common in the Murray-Darling Basin. Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds.	None	None
Ninox strenua	Powerful Owl	V	-	Occupies wet and dry eucalypt forests and rainforests. Can occupy both un-logged and lightly logged forests as well as undisturbed forests where it usually roosts on the limbs of dense trees in gully areas. It is most commonly recorded within Red Turpentine in tall open forests and Black She-oak within open forests (Debus 1994a;Debus 1994b). Large mature trees with hollows at least 0.5 m deep are required for nesting (Garnett, 1992). Tree hollows are particularly important for the Powerful Owl because a large proportion of the diet is made up of hollow-dependent arboreal marsupials (Gibbons, 1997). Nest trees for this species are usually emergent with a diameter at breast height of at least 100 cm (Gibbons 1997).	High	Low
Anthochaera phrygia	Regent Honeyeater	CE	CE	The Regent Honeyeater mainly inhabits temperate woodlands and open forests of the inland slopes of south-east Australia. Birds are also found in drier coastal woodlands and forests in some years. has contracted dramatically in the last 30 years to between north-eastern Victoria and south-eastern Queensland. There are only three known key breeding regions remaining: north-east Victoria (Chiltern-Albury), and in NSW at Capertee Valley and the Bundarra-Barraba region. In NSW the distribution is very patchy and mainly confined to the two	Moderate	Low

				main breeding areas and surrounding fragmented woodlands. In some years flocks converge on flowering coastal woodlands and forests.		
Rhipidura rufifrons	Rufous Fantail	-	M	Migratory species that prefers dense, moist undergrowth of tropical rainforests and scrubs. During migration it can stray into gardens and more open areas (Pizzey 1997).	Low	Low
Myiagra cyanoleuca	Satin Flycatcher	-	M	Migratory species that occurs in coastal forests, woodlands and scrubs during migration. Breeds in heavily vegetated gullies (Pizzey 1997).	High	Low
Petroica boodang	Scarlet Robin	V	-	In NSW Scarlet Robin occur from the coast to the inland slopes. After breeding, some Scarlet Robins disperse to the lower valleys and plains of the tablelands and slopes. Some birds may appear as far west as the eastern edges of the inland plains in autumn and winter.	Known	Low
Tyto tenebricosa	Sooty Owl	V	-	Often found in tall old-growth forests, including temperate and subtropical rainforests. In NSW mostly found on escarpments with a mean altitude <500 m. Nests and roosts in hollows of tall emergent trees, mainly eucalypts (Higgins 1999) often located in gullies (Gibbons and Lindenmayer 1997). Nests have been located in trees 125 to 161 centimetres in diameter (Gibbons and Lindenmayer 1997).	High	Low
Monarcha trivirgatus	Spectacled Monarch	-	M	Coastal north-eastern and eastern Australia, including coastal islands, from Cape York, Queensland to Port Stephens, New South Wales. Prefers thick understorey in rainforests, wet gullies and waterside vegetation, as well as mangroves.	Moderate	Low
Lophoictinia isura	Square-tailed Kite	V	-	Typically inhabits coastal forested and wooded lands of tropical and temperate Australia (Marchant and Higgins 1993). In NSW it is often associated with ridge and gully forests dominated by *Eucalyptus longifolia, Corymbia maculata, E. elata* or *E. smithii* (NPWS 1999f). Individuals appear to occupy large hunting ranges of more than 100 km2. They require large living trees for breeding, particularly near water with surrounding woodland /forest close by for foraging habitat. Nest sites are generally located along or near watercourses, in a tree fork or on large horizontal limbs (Marchant and Higgins 1993).	High	Low
Daphoenositta chrysoptera	Varied Sittella	V	-	Inhabits wide variety of dry eucalypt forests and woodlands, usually with either shrubby under storey or grassy ground cover or both, in all	High	Low

				climatic zones of Australia (Higgins and Peter 2002). Usually in areas with rough-barked trees, such as stringybarks or ironbarks, but also in paperbarks or mature Eucalypts with hollows.		
Haliaeetus leucogaster	White-bellied Sea-Eagle	V	MA	Inhabits coastal and near coastal areas, building large stick nests, and feeding mostly on marine and estuarine fish and aquatic fauna.	Low	Low
Epthianura albifrons	White-fronted Chat	V	-	Low vegetation in salty coastal and inland areas and crops. Runs along ground and is found in local flocks in Winter.	None	None
Motacilla flava	Yellow Wagtail	-	M	Breeds in temperate Europe and Asia. The Yellow Wagtail is a regular wet season visitor to northern Australia. Increasing records in NSW suggest this species is an occasional but regular summer visitor to the Hunter River region. The species is considered a vagrant to Victoria, South Australia and southern Western Australia. Habitat requirements for the Yellow Wagtail are highly variable, but typically include open grassy flats near water. Habitats include open areas with low vegetation such as grasslands, airstrips, pastures, sports fields; damp open areas such as muddy or grassy edges of wetlands, rivers, irrigated farmland, dams, waterholes; sewage farms, sometimes utilise tidal mudflats and edges of mangroves.	Low	Low
Invertebrates						
Petalura gigantea	Giant Dragonfly	E	-	The Giant Dragonfly is found along the east coast of NSW from the Victorian border to northern NSW. It is not found west of the Great Dividing Range. There are known occurrences in the Blue Mountains and Southern Highlands, in the Clarence River catchment, and on a few coastal swamps from north of Coffs Harbour to Nadgee in the south (DECCW undated b). Live in permanent swamps and bogs with some free water and open vegetation. Adults emerge from late October and are short-lived, surviving for one summer after emergence.	High	High – not recorded in the present study but numerous records within the locality and habitat present within most of the swamps of the study area
Mammals						
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	Found in rocky areas in a wide variety of habitats including rainforest gullies, wet and dry sclerophyll forest, open woodland and rocky	Low	Low

				outcrops in semi-arid country. Commonly sites have a northerly aspect with numerous ledges, caves and crevices (Eldridge 1995).		
Miniopterus schreibersii	Eastern Bentwing-bat	V	-	Eastern Bent-wing Bats occur along the east and north-west coasts of Australia. Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures.	Known	Moderate, however limited significance. Maternity caves would not occur within the study area. If roosting occurs it is unlikely to be widespread or significant and minimal impacts from subsidence of features such as cliffs are expected to occur given the limited propensity of roosting. No further assessment or offsetting is considered required.
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-	Inhabit sclerophyll forests, preferring wet habitats where trees are more than 20 m high (Churchill 1998). Two observations have been made of roosts in stem holes of living eucalypts (Phillips 1995). There is debate about whether or not this species moves to lower altitudes during winter, or whether they remain sedentary but enter torpor (Menkhorst 1995). This species also appears to be highly mobile and records showing movements of up to 12 km between roosting and foraging sites (Menkhorst 1995).	High	Low
Mormopterus norfolkensis	Eastern Freetail-bat	V	-	Most records are from dry eucalypt forests and woodlands to the east of the Great Dividing Range. Appears to roost in trees, but little is known of this species' habits (Allison 1995, Churchill 1998).	High	Low
Cercartetus nanus	Eastern Pygmy-possum	V	-	Inhabits rainforest through to sclerophyll forest and tree heath. Banksias and myrtaceous shrubs and trees are a favoured food source. Will often nest in tree hollows, but can also construct its own nest (Turner, 1995). Because of its small size it is able to utilise a range of hollow sizes including very small hollows (Gibbons 1997). Individuals will use a number of different hollows and an individual has been recorded using up to 9 nest sites within a 0.5 ha area over a 5 month period (Ward 1990).	High	Low

Kerivoula papuensis	Golden tipped bat	V	-	The Golden-tipped Bat is distributed along the east coast of Australia in scattered locations from Cape York Peninsula in Queensland to south of Eden in southern NSW. Also occurs in New Guinea. Found in rainforest and adjacent wet and dry sclerophyll forest up to 1000 m. Also recorded in tall open forest, Casuarina-dominated riparian forest and coastal Melaleuca forests.	Highstudy area	Low
Pseudomys novaehollandiae	New Holland Mouse	V		Known to inhabit open heathlands, woodlands and forests with a heathland understorey and vegetated sand dunes. It is a social animal, living predominantly in burrows shared with other individuals. Distribution is patchy in time and space, with peaks in abundance during early to mid stages of vegetation succession typically induced by fire.	Low	Low
Scoteanax rueppellii	Greater Broad-nosed Bat	V	-	Prefer moist gullies in mature coastal forests and rainforests, between the Great Dividing Range and the coast. They are only found at low altitudes below 500 m (Churchill, 1998). In dense environments they utilise natural and human-made opening in the forest for flight paths. Creeks and small rivers are favoured foraging habitat (Hoye 1995). This species roosts in hollow tree trunks and branches (Churchill, 1998).	High	Low
Petauroides volans	Greater Glider	-	V	The Greater Glider is restricted to eastern Australia, occurring from the Windsor Tableland in north Queensland through to central Victoria. It is typically found in highest abundance in taller, montane, moist eucalypt forests with relatively old trees and abundant hollows.	Moderate	Low
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and banksia woodlands. Bats commute daily to foraging areas, usually within 15 km of the day roost (Tidemann 1995) although some individuals may travel up to 70 km (Augee 1999).	High	Low
Phascolarctos cinereus	Koala	V	-	Inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall (Reed 1990).	Known	Low

Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Located in a variety of drier habitats, including the dry sclerophyll forests and woodlands to the east and west of the Great Dividing Range (Hoye 1995). Can also be found on the edges of rainforests and in wet sclerophyll forests (Churchill 1998). This species roosts in caves and mines in groups of between 3 and 37 individuals (Churchill 1998).	High	Low
Miniopterus australis	Little bent-wing bat	V	-	East coast and ranges of Australia from Cape York in Queensland to Wollongong in NSW. Moist eucalypt forest, rainforest, vine thicket, wet and dry sclerophyll forest, Melaleuca swamps, dense coastal forests and banksia scrub. Generally found in well-timbered areas.	High	Moderate, however limited significance. Maternity caves would not occur within the study area. If roosting occurs it is unlikely to be widespread or significant and minimal impacts from subsidence of features such as cliffs are expected to occur given the limited propensity of roosting. No further assessment or offsetting is considered required.
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	V	Inhabits coastal heath and wet and dry sclerophyll forests. Generally found in areas with rainfall greater than 760 mm. Requires relatively thick ground cover where the soil is light and sandy.	Moderate	Low
Isoodon obesulus	Southern Brown Bandicoot (eastern)	E	-	Prefers sandy soils with scrubby vegetation and/or areas with low ground cover that are burn from time to time (Braithwaite 1995). A mosaic of post fire vegetation is important for this species (Maxwell 1996).	High	Low
Myotis macropus	Southern Myotis	V	-	The Large-footed Myotis is found in the coastal band from the north-west of Australia, across the top-end and south to western Victoria. Generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage.	Moderate	Moderate
Dasyurus maculatus	Spotted-tailed Quoll	V	-	Spotted-tailed Quoll is found on the east coast of NSW, Tasmania, eastern Victoria and north-eastern Queensland.	Moderate	Low
Petaurus norfolcensis	Squirrel Glider	V	-	Generally occurs in dry sclerophyll forests and woodlands but is absent from dense coastal ranges in the southern part of its range	Low	Low

				(Suckling 1995). Requires abundant hollow bearing trees and a mix of eucalypts, banksias and acacias (Quin 1995). There is only limited information available on den tree use by Squirrel gliders, but it has been observed using both living and dead trees as well as hollow stumps (Gibbons 1997). Within a suitable vegetation community at least one species should flower heavily in winter and one species of eucalypt should be smooth barked (Menkhorst 1988). Endangered population in the Wagga Wagga LGA.		
Petaurus australis	Yellow-bellied Glider	V	-	Occur in tall mature eucalypt forest generally in areas with high rainfall and nutrient rich soils. Forest type preferences vary with latitude and elevation; mixed coastal forests to dry escarpment forests in the north; moist coastal gullies and creek flats to tall montane forests in the south. Found along the eastern coast to the western slopes of the Great Dividing Range, from southern Queensland to Victoria.	Low	Low
Saccolaimus flaviventris	Yellow-bellied sheathtail bat	V	-	The Yellow-bellied Sheathtail-bat is a wide-ranging species found across northern and eastern Australia. In the most southerly part of its range - most of Victoria, south-western NSW and adjacent South Australia - it is a rare visitor in late summer and autumn. There are scattered records of this species across the New England Tablelands and North West Slopes. Roosts singly or in groups of up to six, in tree hollows and buildings; in treeless areas they are known to utilise mammal burrows.	High	Low
Reptiles						
Hoplocephalus bungaroides	Broad-headed Snake	E	V	Mainly occurs in association with communities occurring on Triassic sandstone within the Sydney Basin. Typically found among exposed sandstone outcrops with vegetation types ranging from woodland to heath. Within these habitats they generally use rock crevices and exfoliating rock during the cooler months and tree hollows during summer (Webb 1996, Webb 1998).	Moderate	Moderate
Varanus rosenbergi	Rosenberg's Goanna	V	-	This species is a Hawkesbury/Narrabeen sandstone outcrop specialist (Wellington 1985). Occurs in coastal heaths, humid woodlands and both wet and dry sclerophyll forests (Cogger 1992).	High	Moderate

Key: CE = Critically Endangered; E, E1 = Endangered; EP = Endangered Population; V = Vulnerable; M = Migratory.

Fauna that are exclusively dependant on marine environments, including near shore environments, were not included in the assessment due to lack of suitable habitat. Migratory species were not considered as migratory species are not a 'controlling provision' for the project.

Habitat descriptions taken from the relevant profiles on the OEH Threatened Species website unless otherwise stated.

Appendix 2: Fauna Recorded from Targeted Survey (Niche 2017/2018)

Group	Scientific Name	Common Name	Status NSW	Status Common wealth	Quant ity	Latitude	Longitude
Amphibia	*Crinia signifera*	Common Eastern Froglet	P	-	10	-34.362350	150.725861
	Litoria citropa	Blue Mountains Tree Frog	P	-	4	-34.363518	150.703857
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	25	-34.376595	150.718262
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	4	-34.361507	150.709930
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	5	-34.361492	150.724121
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	4	-34.361149	150.723785
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	12	-34.362667	150.726746
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	150	-34.373226	150.727661
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	25	-34.373226	150.727737
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	30	-34.373352	150.728363
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	20	-34.373402	150.728836
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	25	-34.373550	150.729675
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	6	-34.373558	150.729843
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	20	-34.373966	150.731201
	Litoria littlejohni	Littlejohn's Tree Frog	V	V	200	-34.366688	150.742966
	Litoria nudidigitus	Southern Leaf Green Tree Frog	P	-	1	-34.362404	150.723175
	Litoria nudidigitus	Southern Leaf-green Tree Frog	P	-	2	-34.356884	150.710892
	Litoria nudidigitus	Southern Leaf-green Tree Frog	P	-	1	-34.363537	150.703766
	Litoria peronii	Emerald-spotted Tree Frog	P	-	1	-34.362400	150.723145
	Pseudophryne australis	Red-crowned Toadlet	V	-	2	-34.374104	150.731491
Aves	*Haliastur indus*	Brahminy Kite	P	-	1	-34.352901	150.711441
	Menura novaehollandiae	Superb Lyrebird	P	-	1	-34.360714	150.724670
	Myzomela sanguinolenta	Scarlet Honeyeater	P	-	1	-34.374641	150.712357
	Pachycephala pectoralis	Golden Whistler	P	-	1	-34.362778	150.721817
	Pycnoptilus floccosus	Pilotbird	P	-	1	-34.360714	150.724670
Mammalia	*Phascolarctos cinereus*	Koala	V	V	1	-34.360310	150.723389
Reptilia	*Cryptophis nigrescens*	Eastern Small-eyed Snake	P	-	1	-34.351475	150.712936
	Ctenotus taeniolatus	Copper-tailed Skink	P	-	1	-34.361416	150.729858
	Ctenotus taeniolatus	Copper-tailed Skink	P	-	6	-34.351467	150.712936
	Oedura lesueurii	Lesueur's Velvet Gecko	P	-	1	-34.362186	150.730804
	Oedura lesueurii	Lesueur's Velvet Gecko	P	-	1	-34.361210	150.729553

Appendix 3: Weather data from the survey period

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	0	0	20.6	0.2	0	0	0	10.0	0	0	0	0.2
2nd	1.4	3.6	5.2	0	0	0	0	0.2	0	0	0	0
3rd	0	0	19.6	3.0	0	0	0.2	0	0	0	0	10.6
4th	1.4	0	33.8	2.0	1.4	0	0.4	11.0	0	0	3.2	4.4
5th	0	0	0.8	4.8	0	0	0.2	0	0	0	1.0	3.4
6th	15.0	0	1.4	0.2	0	0	0	0	0	0	7.0	0
7th	15.4	0	0.2	0	0	22.4	0	0	0	0	6.8	2.2
8th	0	30.2	2.2	0	0	17.8	0	0	0	0	0	0
9th	0	5.2	1.0	0	0	0.4	0	0	0	0	0	0.6
10th	4.6	0	0	10.6	0	29.4	0.2	0	0	0	0	0
11th	1.6	0	0	0	0	4.0	0.2	0	0	0.2	0	0
12th	0	0	0	0	0	0.2	0	0	0	0.2	0	0
13th	0	0	0	0.2	0	0.4	0	0	0	0.2	0	0
14th	1.6	0	0.4	0	0	0	0	0	0	0	0	0
15th	0	0	17.6	0	0.2	0.2	0	0	0	0	0	0
16th	0	0	10.2	0	0	0	0	0.2	0	0	0	0.6
17th	0	0	16.2	0	0	0	0	0	0	0	0.4	2.4
18th	0	2.4	6.4	0	0	0	0	0	0	0	0.2	0.4
19th	0	0.6	11.0	0	0	0	0	0	0	0	3.4	0
20th	0.2	4.8	1.4	0.2	6.0	0	0	0	0	9.0	0	0
21st	4.0	0	0	0	0	0	0	0	0	7.8	0.4	2.6
22nd	0	0	16.0	0	0	0	0	0.2	0	0.2	0	0.2
23rd	0	0	24.8	0	0	0.2	0.2	0	0	2.6	0.2	3.0
24th	0.2	0	6.8	0	7.6	0	0	0	0	0	0	0
25th	2.2	0	0	0.2	0	0.2	0	0	0	0	0	0
26th	0	32.0	0	0	0	0	0	0	0	0.4	0	0
27th	0	3.6	0	0.6	0	0	0	0	0	25.6	0.2	0.2
28th	0	4.4	0	0	0.2	0	0	0.6	0	0.2	6.8	0
29th	0		0	0	0.2	0.6	0	0.2	0	0	0.2	0
30th	0		0.4	0	0	0	0	0	0	0.2	0.4	1.2
31st	0		29.6		0		0	0.2		0.2		0.2
Highest daily	15.4	32.0	33.8	10.6	7.6	29.4	0.4	11.0	0	25.6	7.0	10.6
Monthly Total	47.6	86.8	225.6	22.0	15.6	75.8	1.4	22.6	0	46.8	30.2	32.2

Annual total for 2017 = 606.6mm

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 43129026

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*145.8*	*55.2*	*83.4*	*46.0*	*146.6*	*28.0*	*50.2*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	5th 2008	8th 2012	21st 2015	24th 2013	6th 2016	22nd 2011	18th 2014	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	28.0	*25.1*	28.0	*25.7*	23.9	17.7	16.4	*18.0*	19.3	25.9	24.7	33.1
2nd	26.9	*27.8*	27.2	*22.6*	22.6	18.2	16.0	*18.2*	21.8	26.0	24.2	28.9
3rd	29.6	*26.8*	24.2	*20.4*	18.7	18.1	13.8	*17.6*	28.7	25.2	29.9	28.2
4th	27.1	*34.8*	24.6	*20.8*	18.9	19.8	21.4	*16.6*	21.1	26.3	16.9	20.5
5th	23.1	*39.7*	24.6	*22.5*	22.2	18.8	20.0	*19.2*	17.8	30.2	17.2	25.3
6th	26.0	*36.8*	26.6	*23.3*	24.3	17.2	17.6	*20.4*	17.7	24.1	24.2	26.0
7th	29.6	*26.0*	25.4	*24.2*	20.8	14.8	18.2	*17.2*	19.6	22.9	22.6	31.9
8th	34.3	*26.2*	22.9	*24.9*	19.0	19.0	17.1	*18.1*	19.2	20.7	21.2	30.3
9th	34.5	*35.0*	23.8	*27.2*	21.3	19.4	17.0	*19.9*	19.9	33.2	24.6	26.9
10th	35.5	*44.1*	26.6	*18.8*	21.2	16.0	17.0	*22.6*	20.2	23.5	25.4	29.2
11th	40.8	*45.6*	27.6	*23.9*	21.3	18.1	18.0	*23.1*	25.0	25.8	24.7	31.5
12th	30.8	*35.5*	31.1	*21.9*	20.0	21.3	17.0	*21.0*	28.4	28.2	24.3	30.9
13th	39.9	*29.5*	29.5	*23.5*	21.9	20.0	17.1	*21.1*	33.0	27.6	24.0	35.7
14th	38.3	*25.0*	24.4	*25.5*	20.1	20.3	18.6	*23.4*	16.8	19.7	25.4	41.5
15th	28.5	*28.8*	26.5	*24.8*	20.9	19.6	18.4	*22.5*	20.7	22.6	27.6	26.4
16th	33.0	*37.8*	24.1	*25.5*	21.2	16.2	16.6	*19.8*	22.5	26.0	26.8	37.6
17th	41.8	*37.5*	21.6	*24.3*	20.4	18.6	17.9	*21.6*	19.6	26.4	27.2	29.0
18th	42.7	*31.0*	24.8	*25.3*	22.3	18.1	22.3	*15.7*	26.6	26.6	24.0	34.6
19th	22.4	*28.4*	27.2	*24.0*	18.4	19.7	16.3	*16.6*	22.1	31.5	26.3	40.0
20th	30.6	*27.6*	29.5	*24.4*	22.9	20.2	15.3	*17.5*	21.1	19.5	23.7	39.8
21st	28.0	*28.6*	26.4	*23.9*	22.4	19.2	16.9	*15.0*	26.7	20.0	25.4	25.8
22nd	29.2	*31.3*	32.3	*24.4*	21.6	18.4	17.8	*20.3*	29.9	23.0	25.0	28.5
23rd	36.7	*35.5*	22.2	*26.4*	22.9	17.1	21.5	*21.9*	35.7	23.2	29.2	37.3
24th	37.1	*29.9*	24.8	*25.0*	21.4	18.6	19.6	*18.5*	28.9	29.5	33.6	39.3
25th	24.7	*22.0*	24.1	*23.5*	20.4	17.8	20.6	*18.7*	25.8	31.9	30.7	21.2
26th	25.2	*25.0*	29.3	*22.7*	20.5	18.0	20.0	*20.0*	23.6	24.8	30.8	22.5
27th	27.7	*26.9*	29.5	*19.2*	21.0	15.7	18.1	*18.8*	25.1	26.4	28.5	29.1
28th	38.2	*27.2*	23.7	*20.6*	22.0	14.4	18.3	*16.9*	25.6	28.7	28.0	34.0
29th	33.0		32.3	*22.7*	16.5	17.1	19.3	*17.9*	25.7	32.3	27.1	38.4
30th	43.3		22.1	*22.0*	17.8	15.5	27.1	*19.1*	23.6	35.0	29.4	36.6
31st	37.3		23.4		15.9		14.8	*18.1*		22.4		29.1
Highest daily	43.3	*45.6*	32.3	*27.2*	24.3	21.3	27.1	*23.4*	35.7	35.0	33.6	41.5
Lowest daily	22.4	*22.0*	21.6	*18.8*	15.9	14.4	13.8	*15.0*	16.8	19.5	16.9	20.5
Monthly mean	32.4	31.3	26.1	23.5	20.8	18.1	18.3	19.2	23.7	26.1	25.8	31.3

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, or precise date unknown

Product code: IDCJAC0010 reference: 43129035

Australian Government
Bureau of Meteorology

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.3	28.6	27.2	24.1	21.2	17.7	17.6	19.2	22.4	24.9	27.1	28.2
Highest monthly mean	32.7	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.1	45.6	39.7	36.1	28.8	22.6	27.1	28.9	35.7	36.7	42.1	42.1
Date of highest daily	7th 2018	11th 2017	18th 2018	9th 2018	1st 2016	9th 2016	30th 2017	23rd 2012	23rd 2017	5th 2015	20th 2009	17th 2009
Lowest daily	20.4	18.0	18.1	15.0	13.9	12.0	10.2	11.1	13.8	15.0	16.6	17.5
Date of lowest daily	5th 2016	2nd 2012	21st 2008	20th 2015	31st 2015	27th 2016	16th 2015	22nd 2008	9th 2011	3rd 2009	7th 2007	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*	*0*	*1.2*	*0*	*0*	*0*
2nd	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*
3rd	*2.2*	*0.2*	*0*	*0*	*0*	*0*	*1.2*	*0*	*0*	*0*	*3.8*	*0*
4th	*0.2*	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*	*6.0*	*5.6*	*0*	*0*
5th	*0*	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*	*1.4*	*25.4*	*0*	*1.0*
6th	*0*	*0*	*2.6*	*0*	*0*	*23.4*	*0*	*0*	*0.4*	*0.2*	*0*	*1.0*
7th	*0*	*0*	*2.6*	*0*	*0*	*10.2*	*0*	*1.0*	*3.0*	*0.6*	*0*	*0*
8th	*0*	*0*	*0.6*	*0*	*0*	*0.2*	*0*	*0*	*9.2*	*0.2*	*11.0*	*0*
9th	*24.4*	*0*	*0*	*0*	*0*	*8.2*	*0*	*0*	*0.4*	*0*	*0*	*0*
10th	*1.4*	*2.4*	*0*	*0*	*0*	*0.4*	*0*	*0*	*0.2*	*0*	*0*	*0*
11th	*0*	*2.4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3.0*	*0*	*0*
12th	*0.2*	*0.2*	*0*	*0*	*0*	*0.2*	*0*	*0*	*0*	*0.4*	*0*	*0*
13th	*0*	*0*	*0*	*0*	*0.6*	*0*	*0.2*	*0*	*0*	*0.6*	*0*	*1.0*
14th	*0*	*0*	*1.2*	*0*	*0*	*0*	*0*	*0*	*0*	*15.4*	*0*	*38.8*
15th	*0*	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*	*0*	*1.8*	*0.6*	*27.8*
16th	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.4*	*4.6*	*23.2*
17th	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*	*25.6*
18th	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*27.4*	*0*	*0*
19th	*0*	*0*	*0*	*0*	*0*	*2.4*	*0*	*0*	*0*	*3.2*	*0*	*0*
20th	*0*	*11.2*	*0*	*0*	*0*	*5.6*	*0*	*0*	*0.2*	*0.2*	*0*	
21st	*0*	*0.2*	*11.6*	*0*	*0*	*0*	*0*	*0*	*0*	*0.6*	*0.4*	
22nd	*0*	*0*	*5.4*	*0*	*0*	*0*	*0*	*0*	*0*	*0.2*	*3.2*	
23rd	*0*	*0*		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	
24th	*0.2*	*0*	*0*	*0*	*0*	*0.2*	*0*	*0.6*	*0*	*0*	*0*	
25th	*0*	*0.2*	*0.2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	
26th	*0*	*33.2*	*2.6*	*0*	*0*	*0*	*0*	*0.4*	*3.2*	*0*	*0*	
27th	*0*	*1.0*	*0*	*0*	*0*	*0.2*	*0*	*1.6*	*0.8*	*0*	*0*	
28th	*0*	*0.2*	*0*	*0*	*0*	*3.2*	*0*	*0.2*	*0*	*0*	*11.2*	
29th	*0*		*0*	*0*	*0.2*	*8.2*	*0.2*	*0.2*	*0*	*0*	*53.4*	
30th	*0*		*0*	*9.8*	*4.0*	*0.2*	*0*	*0*	*0*	*0*	*0.2*	
31st	*0*		*0*		*0*		*0*	*0*		*0*		
Highest daily	*24.4*	*33.2*	*11.6*	*9.8*	*4.0*	*23.4*	*1.2*	*1.6*	*9.2*	*27.4*	*53.4*	*38.8*
Monthly Total	*28.6*	*51.2*	*26.8*	*9.8*	*4.8*	*62.8*	*2.2*	*4.0*	*26.0*	*86.4*	*88.6*	

↓ This day is part of an accumulated total
Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Product code: IDCJAC0009 reference: 43129018

Daily Rainfall (millimetres)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest daily	*118.8*	*145.8*	*55.2*	*83.4*	*46.0*	*146.6*	*28.0*	*50.2*	*35.2*	*27.6*	*64.4*	*38.8*
Date of highest daily	29th 2013	5th 2008	8th 2012	21st 2015	24th 2013	6th 2016	22nd 2011	18th 2014	15th 2010	15th 2014	2nd 2010	14th 2018

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	32.4	*25.4*	*27.0*	34.3	*25.4*	*18.2*	18.2	*20.3*	*20.2*	*24.0*	*33.2*	*31.4*
2nd	31.9	*25.3*	*27.0*	34.7	*21.8*	*16.5*	17.5	*18.9*	*17.1*	*27.2*	*37.2*	*33.7*
3rd	26.5	*27.3*	*32.2*	23.2	*27.8*	*19.7*	18.4	*23.6*	*14.1*	*25.6*	*33.5*	*30.3*
4th	26.9	*28.4*	*28.2*	27.0	*27.2*	*19.1*	19.4	*18.7*	*18.1*	*16.2*	*28.8*	*25.5*
5th	33.2	*31.3*	*23.8*	30.7	*24.0*	*17.6*	23.9	*20.4*	*17.3*	*16.4*	*29.1*	*20.8*
6th	38.4	*30.6*	*25.4*	29.7	*23.8*	*19.1*	24.9	*18.3*	*20.9*	*19.5*	*32.9*	*26.9*
7th	45.1	*31.3*	*25.3*	30.8	*25.2*	*20.1*	17.3	*16.2*	*23.4*	*18.7*	*24.7*	*29.0*
8th	38.6	*36.0*	*26.1*	31.6	*26.1*	*14.0*	16.7	*19.4*	*16.8*	*22.9*	*20.2*	*32.0*
9th	30.7	*36.2*	*27.1*	36.1	*26.0*	*15.2*	17.2	*20.3*	*22.2*	*27.0*	*23.7*	*32.5*
10th	23.9	*34.7*	*27.2*	26.5	*24.8*	*18.3*	17.5	*23.0*	*23.2*	*16.4*	*24.7*	*27.9*
11th	26.8	*32.2*	*31.2*	31.8	*16.6*	*19.6*	17.2	*26.3*	*25.1*	*18.6*	*27.0*	*24.3*
12th	33.3	*33.3*	*29.2*	34.9	*16.5*	*16.6*	18.2	*15.9*	*30.1*	*18.8*	*27.1*	*23.9*
13th	33.5	*31.5*	*20.4*	35.2	*19.8*	*19.0*	17.0	*18.5*	*23.7*	*23.2*	*29.1*	*29.3*
14th	26.0	*38.6*	*28.8*	30.6	*20.9*	*18.3*	18.2	*23.7*	*27.9*	*20.9*	*23.6*	*24.0*
15th	28.8	*33.4*	*35.7*	24.0	*21.6*	*19.3*	17.2	*25.1*	*32.2*	*22.8*	*25.8*	*30.6*
16th	25.5	*31.9*	*27.0*	28.6	*20.0*	*17.6*	17.9	*20.1*	*19.3*	*25.0*	*20.7*	*33.3*
17th	27.9	*31.1*	*36.8*	24.9	*20.4*	*14.7*	22.1	*18.9*	*20.1*	*23.5*	*23.9*	*31.8*
18th	34.9	*34.0*	*39.7*	23.9	*22.3*	*17.6*	20.4	*21.8*	*26.8*	*26.7*	*23.5*	*27.8*
19th	38.7	*30.4*	*35.4*	28.2	*21.5*	*15.4*	18.9	*15.2*	*28.8*	*30.0*	*25.2*	
20th	38.3	*23.8*	*30.5*	28.1	*22.8*	*18.4*	17.6	*16.7*	*18.7*	*30.2*	*29.6*	
21st	37.2	*26.3*	*19.5*	24.1	*21.5*	*18.9*	17.7	*16.7*	*22.5*	*20.4*	*28.2*	
22nd	41.8	*28.2*	*21.9*	25.9	*23.5*	*18.5*	16.8	*18.3*	*25.1*	*25.7*	*24.2*	
23rd	32.5	*30.6*	*22.4*	26.7	*22.7*	*20.4*	18.2	*16.6*	*22.0*	*30.9*	*23.0*	
24th	38.2	*35.6*	*27.8*	27.4	*21.6*	*18.6*	23.4	*19.2*	*17.9*	*19.9*	*25.2*	
25th	31.0	*21.0*	*32.8*	26.8	*19.7*	*17.4*	22.1	*18.4*	*19.7*	*24.6*	*27.4*	
26th	33.1	*22.3*	*25.3*	27.1	*22.2*	*18.4*	20.4	*17.0*	*19.1*	*23.5*	*25.5*	
27th	34.0	*26.7*	*25.8*	22.6	*21.9*	*17.3*	20.8	*13.3*	*22.9*	*28.1*	*28.5*	
28th	32.9	*33.7*	*30.0*	22.1	*21.7*	*15.4*	21.1	*16.2*	*31.2*	*20.6*	*18.7*	
29th	32.4		*31.0*	22.8	*24.5*	*15.3*	24.1	*17.9*	*21.4*	*20.9*	*24.3*	
30th	36.2		*35.0*	22.7	*18.1*	*18.9*	18.7	*19.5*	*20.8*	*30.5*	*26.6*	
31st	23.6		*26.6*		*18.3*		21.0	*17.1*		*32.5*		
Highest daily	45.1	*38.6*	*39.7*	36.1	*27.8*	*20.4*	24.9	*26.3*	*32.2*	*32.5*	*37.2*	*33.7*
Lowest daily	23.6	*21.0*	*19.5*	22.1	*16.5*	*14.0*	16.7	*13.3*	*14.1*	*16.2*	*18.7*	*20.8*
Monthly mean	32.7	30.4	28.5	28.1	22.3	17.8	19.4	19.1	22.3	23.6	26.5	

Quality control: 12.3 Done & acceptable, *12.3* Not quality controlled or uncertain, or precise date unknown

Product code: IDCJAC0010 reference: 43129034

Daily Maximum Temperature (degrees Celsius)

CAMPBELLTOWN (MOUNT ANNAN)

Station Number: 068257 · State: NSW · Opened: 2006 · Status: Open · Latitude: 34.06°S · Longitude: 150.77°E · Elevation: 112 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	30.3	28.6	27.2	24.1	21.2	17.7	17.6	19.2	22.4	24.9	27.1	28.2
Highest monthly mean	32.7	31.3	29.2	28.1	23.0	18.6	19.4	20.9	25.0	27.1	30.1	31.3
Lowest monthly mean	27.6	25.4	24.8	22.1	19.7	16.3	16.4	17.4	21.2	22.6	25.2	23.9
Highest daily	45.1	45.6	39.7	36.1	28.8	22.6	27.1	28.9	35.7	36.7	42.1	42.1
Date of highest daily	7th 2018	11th 2017	18th 2018	9th 2018	1st 2016	9th 2016	30th 2017	23rd 2012	23rd 2017	5th 2015	20th 2009	17th 2009
Lowest daily	20.4	18.0	18.1	15.0	13.9	12.0	10.2	11.1	13.8	15.0	16.6	17.5
Date of lowest daily	5th 2016	2nd 2012	21st 2008	20th 2015	31st 2015	27th 2016	16th 2015	22nd 2008	9th 2011	3rd 2009	7th 2007	15th 2006

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 10 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-airtemp-data.shtml.

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Terrestrial
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Research and monitoring
Wildlife Schools and training

Heritage management
Aboriginal heritage
Historical heritage
Conservation management
Community consultation
Archaeological, built and landscape values

Environmental management and approvals
Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)