# Dendrobium Areas 2, 3A and 3B: Terrestrial Ecology Monitoring Program Annual Report 2019

FINAL REPORT

Prepared for Illawarra Metallurgical Coal

28 May 2020

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# Summary

During the 2019 monitoring period, Longwall 14 extraction within Dendrobium Area 3B was completed, followed by extraction of Longwall 15 which was completed in January 2020. Longwall 16 extraction is currently underway, having commenced in February 2020. This sequence followed Longwall 14 in 2018, Longwall 13 in 2017, Longwall 12 in 2016, Longwall 11 in 2015, Longwall 10 in 2014 and Longwall 9 in 2013. Dendrobium Area 2 and Area 3A were previously mined beneath by Longwalls 3, 4, 5, 6, 7 and 8. Subsidence related physical impacts following mining can include lowering of shallow groundwater in upland swamps, increase in the rate of recession of shallow groundwater within upland swamps following rainfall, and loss or alteration in the quality of pool water for first and second order streams within these areas.

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

- Vegetation within upland swamps in Dendrobium Area 2, 3A and Area 3B.
- Littlejohn's Tree Frog *Litoria littlejohni* (Listed as Vulnerable under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and NSW *Biodiversity Conservation Act 2016* (BC Act)) along selected streams providing suitable habitat in Dendrobium Area 3A and Area 3B.

The program includes monitoring and analysis of seven upland swamp sites as post-mining sites, Swamp 15B, Swamp 15A(2), Swamp 1A, Swamp 1B, Swamp 5, Swamp 11 and Swamp 13. The remaining swamps were monitored and analysed as controls or pre-mining sites. Parameters analysed were Total Species Richness (TSR) and species composition as well as swamp size and the extent of groundwater dependent swamp sub-communities.

The results of the TSR analysis demonstrate the response to mining at individual swamps is complex with the monitoring data likely confounded by non-mining related changes within swamps. The monitoring data indicated a decline and subsequent increase in TSR following mining and changes in shallow groundwater. Meanwhile Swamp 1A, Swamp 1B and Swamp 5 displayed no significant decline in TSR, despite observed changes in shallow groundwater availability.

A statistically significant change in TSR and species composition post-mining was found at Swamp 15B. These changes were observed immediately following the swamp being mined beneath and have continued at Swamp 15B for at least four years post-mining.

The detection of Littlejohn's Tree Frog was low in 2019 in comparison to the high reproduction rate in the breeding year of 2016 and was comparable to that recorded in 2018, also part of the extended drought experienced in 2019. Variation between the years 2018 and 2019 was observed in terms of the relative abundance of different life stages. Variation was observed among sites generally, including paired control sites, during 2019. A combination of environment driven factors, such as survey timing coinciding or not coinciding with rainfall and habitat differentiation of sites based on landscape position in response to such stimuli, are likely contributors to the variation observed.

The results are consistent with those recorded in 2018, with the key difference being the triggering of a Level 2 Trigger Action Response Plan (TARP) from a Level 1 TARP at site DC(1). This is in line with the number of years since the reduction in habitat, impacts resulting in a loss of flow and a reduction in pool level observed has continued.

The monitoring program will continue to achieve the following four key objectives:

- Ongoing monitoring of biophysical characteristics within Dendrobium Area 3A and 3B.

- Determine if mining results in changes to the biological integrity of the Dendrobium mining area through comparison of baseline and control data with that collected through ongoing monitoring.
- Provide input to the design of any rehabilitation programs that may be necessary.
- Monitor the success of any remedial works.

# 1 Introduction

## 1.1 Project background

Biosis Pty Ltd was commissioned by Illawarra Metallurgical Coal to undertake terrestrial ecology monitoring for the Dendrobium Coal Mine in accordance with the Flora and Fauna Environmental Management Program (Subsidence) (Biosis 2003) and as required by the Dendrobium Development Consent, originally granted in 2001, and as modified, including in 2008 and 2010.

The Dendrobium Coal Mine includes longwall mining of Areas 1, 2 and 3. Extraction of coal from Area 1 began in April 2005 and concluded in January 2007. Extraction of coal from Area 2 commenced in March 2007 and concluded in December 2009. A Section 75W modification, approved in December 2008, split Area 3 into Areas 3A, 3B and 3C. Extraction of coal in Area 3A commenced in February 2010 and concluded in December 2012. Extraction of coal from Area 3B commenced in February 2013 and has continued through to the current monitoring year.

The Dendrobium Terrestrial Ecology Monitoring Program (the 'program') commenced in 2003 and is expected to continue throughout the duration of mining activities and after the completion of mining within each area. Ecological monitoring in Area 1 was completed in the 2008/09 financial year, and the final report for Area 1 was completed in early 2010 (Biosis 2010). Monitoring in Area 2 occurs once every two years and was monitored in the current monitoring period. Monitoring within 3A and 3B is ongoing (refer to Section 1.3.1).

The aim of the program is to monitor and determine whether subsidence effects associated with longwall mining results in impacts to terrestrial ecological values located above the longwalls. In order to achieve this aim, a Before-After Control-Impact (BACI) experimental design has been established and implemented. The BACI design investigates how sites that have been mined beneath change over time (Before-After) compared with change at control sites that have not been mined beneath (Control-Impact).

As many of the terrestrial ecology values present within the study area (Section 1.3) are unlikely to be impacted as a result of mining, the program focuses on those values considered the most likely to be impacted from subsidence effects, namely those values reliant on shallow groundwater or surface water. Ecological values which are currently being monitored include vegetation communities (species and diversity) of upland swamps, and threatened frog species Littlejohn's Tree Frog (Vulnerable EPBC Act and BC Act), within suitable habitats (second and third order streams) throughout the three domains.

The current report includes new monitoring data collected during 2019 and provides an analysis of data collected to date for the program.

## 1.2 Aims of this report

The aims of this monitoring report are to:

- Describe surveys undertaken in Area 3A and Area 3B during the 2019 monitoring program.
- Discuss results of statistical analysis undertaken for 2019 survey data in the context of the results of the program since its inception.
- Report on the potential impacts of subsidence on vegetation in creek and upland swamp environments.

- Report on the potential impacts of subsidence on Littlejohn's Tree Frog populations along creek environments.
- Provide an assessment of the results against key performance measures described in relevant management plans.
- Summarise key issues identified during the 2018 monitoring year and how they were addressed in 2019.
- Describe future ecological monitoring to be undertaken and propose improvements to environmental management or performance.

## 1.3 Location of the study area

Ecological monitoring is undertaken across three broad study areas, all of which are located within the Metropolitan Special Area and Southern Coalfield of New South Wales (Figure 1). The areas monitored include three mining domains (Dendrobium 2, Dendrobium Area 3A and Dendrobium Area 3B) as well as control sites.

A range of natural features located within each of the mining domains are monitored for a minimum of two years prior to impacts. Sites are referred to as pre-impact, until the closest point of secondary extraction is located within the 400 metre (m) risk management zone (RMZ) of the natural feature. From that point, they are then referred to as post-mining impact sites. Monitoring focusses on terrestrial ecological values within the RMZ which are sensitive to valley closure, uplifts, strains, and fracturing. This is in accordance with recommendations made by the Department of Planning (2008). Given that impacts to natural features become most evident after the natural feature is mined beneath, the date the site has been mined beneath has also been considered in the assessment of trends over time.

All terrestrial ecological monitoring sites located within Dendrobium Area 2 and Dendrobium Area 3A have experienced mining within the RMZ and are therefore now considered to be post-mining impact sites. Several monitoring sites within Dendrobium Area 3B were surveyed up until spring 2012 as pre-impact sites. Mining commenced within this area prior to the autumn 2013 season and a total of three upland swamps were classified as post-mining impact sites (or at least one monitoring point within the swamp) by the end of the 2013 monitoring period (30 November 2013) resulting in one year of baseline.

A summary of each of the areas monitored is provided below.

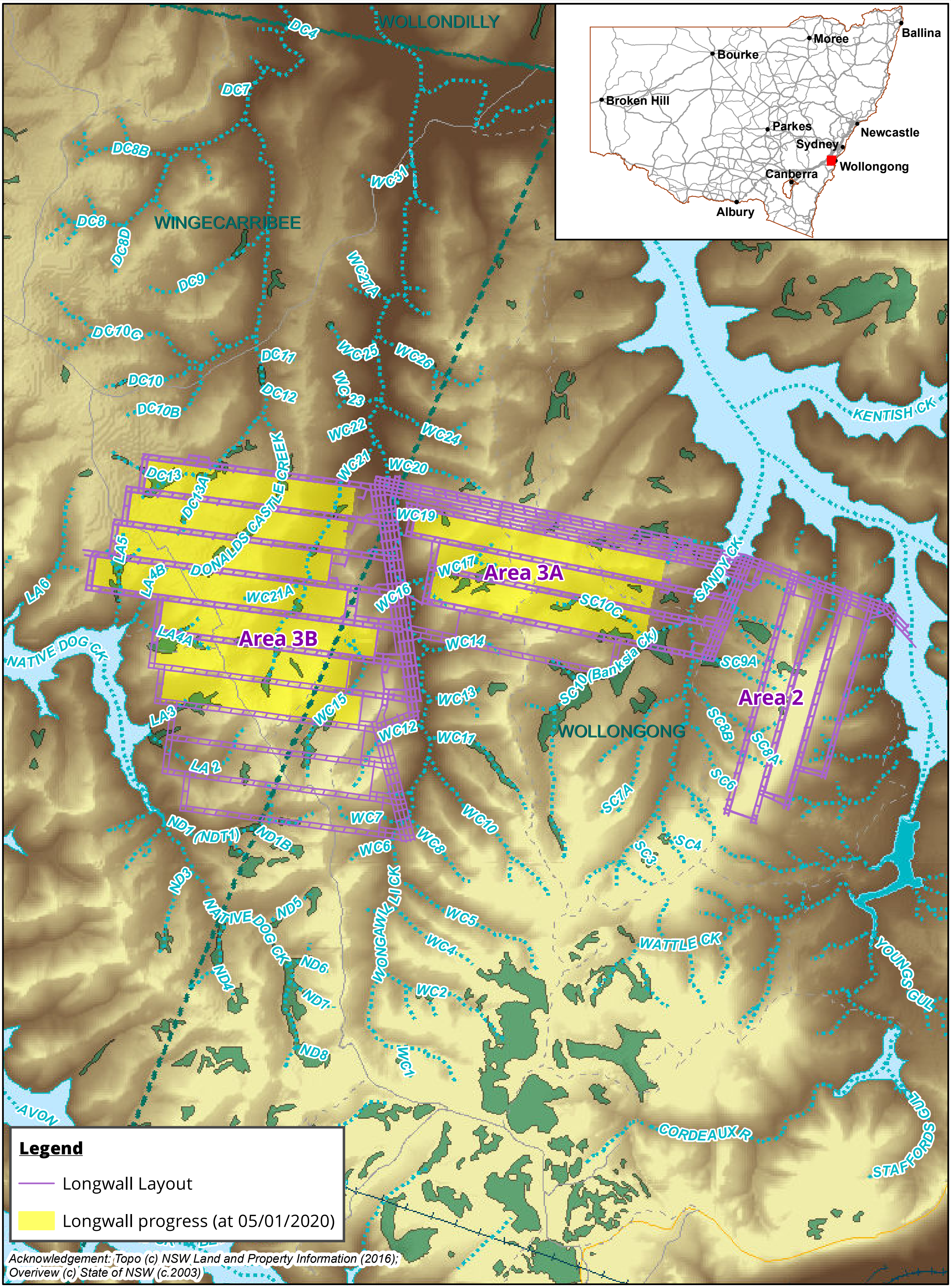


Figure 1 Location of the study area

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Biosis Pty Ltd
Albury, Ballarat, Melbourne,
Newcastle, Sydney, Wangaratta & Wollongong

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Date: 21 May 2020,
Checked by: LS, Drawn by: AEDM, Last edited by: amurray
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### 1.3.1 Dendrobium Area 2

Dendrobium Area 2 originally included a sample of natural features located above Longwalls 3, 4 and 5. Mining of Area 2 commenced in March 2007 and concluded in December 2009.

Given that no impacts to SC6 were observed following three years of post-mining impact monitoring, it was removed from the spring/autumn monitoring program following autumn 2012. This site has been retained in the program as a control site specifically to check activity levels of Littlejohn's Tree Frog during breeding season due to the presence of a significant population of the species. Although not directly mined beneath, this site is located within the RMZ of Longwall 5 in Dendrobium Area 2.

One site that has been directly mined beneath (S1) continues to be monitored biennial (every two years) as a part of this program (Figure 1).

### 1.3.2 Dendrobium Area 3A

Dendrobium Area 3A includes Longwalls 6, 7, 8 and 19. Mining of Area 3A commenced in 2010 and concluded with Longwall 8 in December 2012. Mining is proposed to commence at Longwall 19 following the completion of Dendrobium Area 3B.

Natural features monitored as a part of this program include two upland swamps, Swamp 15A(2) and Swamp 15B, and five threatened frog monitoring transects across four creeks (Figure 2). Swamp 15A(2) is located at the eastern end of the proposed Longwall 19 of Dendrobium Area 3A. The downstream end of Swamp 15A(2) has had mining occur within the RMZ, and as such the whole of swamp 15A(2) is considered to be potentially subject to the associated impacts.

Monitoring of Littlejohn's Tree Frog transects is undertaken at five locations in four creeks located within Dendrobium Area 3A during winter; 6CDL, SC10 (two sections), SC10C and WC17 (Figure 2). As a result of impacts to SC10C and WC17 observed for consecutive years in 2015 and 2016, monitoring of streams within Dendrobium Area 3A continued in 2017 through 2019.

### 1.3.3 Dendrobium Area 3B

Dendrobium Area 3B includes Longwalls 9 through to 18. Mining of Area 3B commenced with Longwall 9 in February 2013 and has continued through to Longwall 15. Monitoring in Dendrobium Area 3B is conducted using a staged approach whereby monitoring sites are added to the program at least two years prior to longwall mining within the RMZ of a site to enable collection of adequate baseline data.

Natural features currently monitored as a part of this program in 2019 include seven upland swamps (Swamp 1A, Swamp 1B, Swamp 5, Swamp 11, Swamp 13, Swamp 14 and Swamp 23). Two sites, Swamp 14 and Swamp 23 were added to the program in 2017 to commence pre-mine baseline monitoring. The RMZ of Swamp 14 was mined beneath by Longwall 15 in December 2018, therefore is considered to be an impact site for monitoring in 2019. In June 2018, the RMZ of Swamp 23 was mined beneath by Longwall 15, and is also treated as an impact site for monitoring in 2019 (Figure 3).

During 2019 a total of six creeks and tributaries were monitored for Littlejohn's Tree Frog as part of the Dendrobium Area 3B program; continued monitoring at DC(1), DC13, LA4A, WC15, WC21 and LA2 (Figure 3).

### 1.3.4 Control sites

A number of control sites have been established for comparison with sites that have been or will be mined beneath. Control sites for vegetation monitoring include three upland swamps, Swamp 15A(1), Swamp 22 and Swamp 33 (Figure 4).

There are three additional control swamps monitored specifically for the Dendrobium Area 3B program; Swamp 88 (previously named Gallahers Creek Swamp), Swamp 87 (previously named FT15E Swamp) and

Swamp 86 (previously named FT6X Swamp). These sites were established to ensure an even mix of impact and control sites in the BACI experimental design.

Ten control sites are surveyed as part of the Littlejohn's Tree Frog monitoring program including SC7 (two transects), SC7A, SC8, WC10, WC11, SC6, DC8, NDC, ND1 and ND2 (Figure 5).

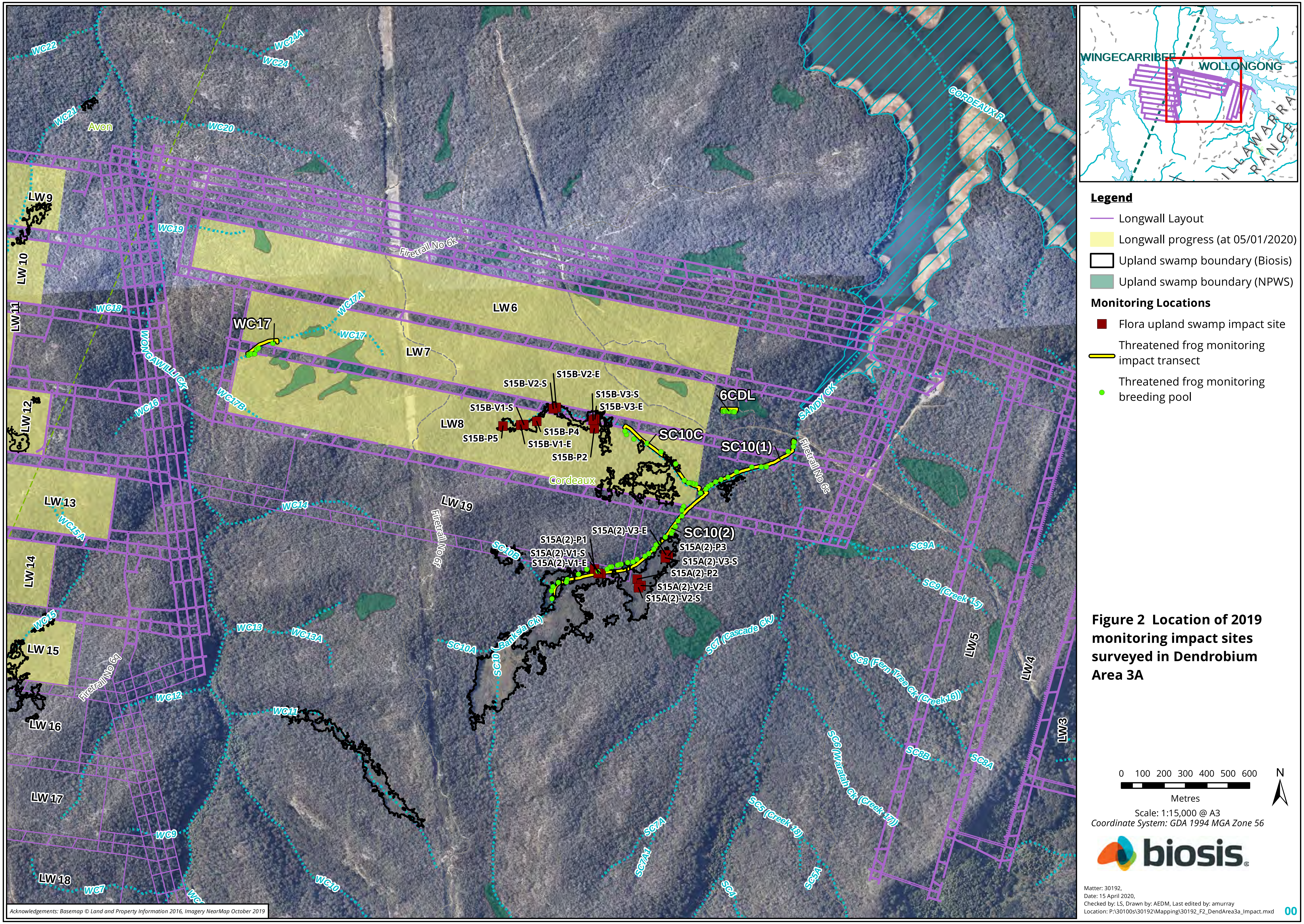
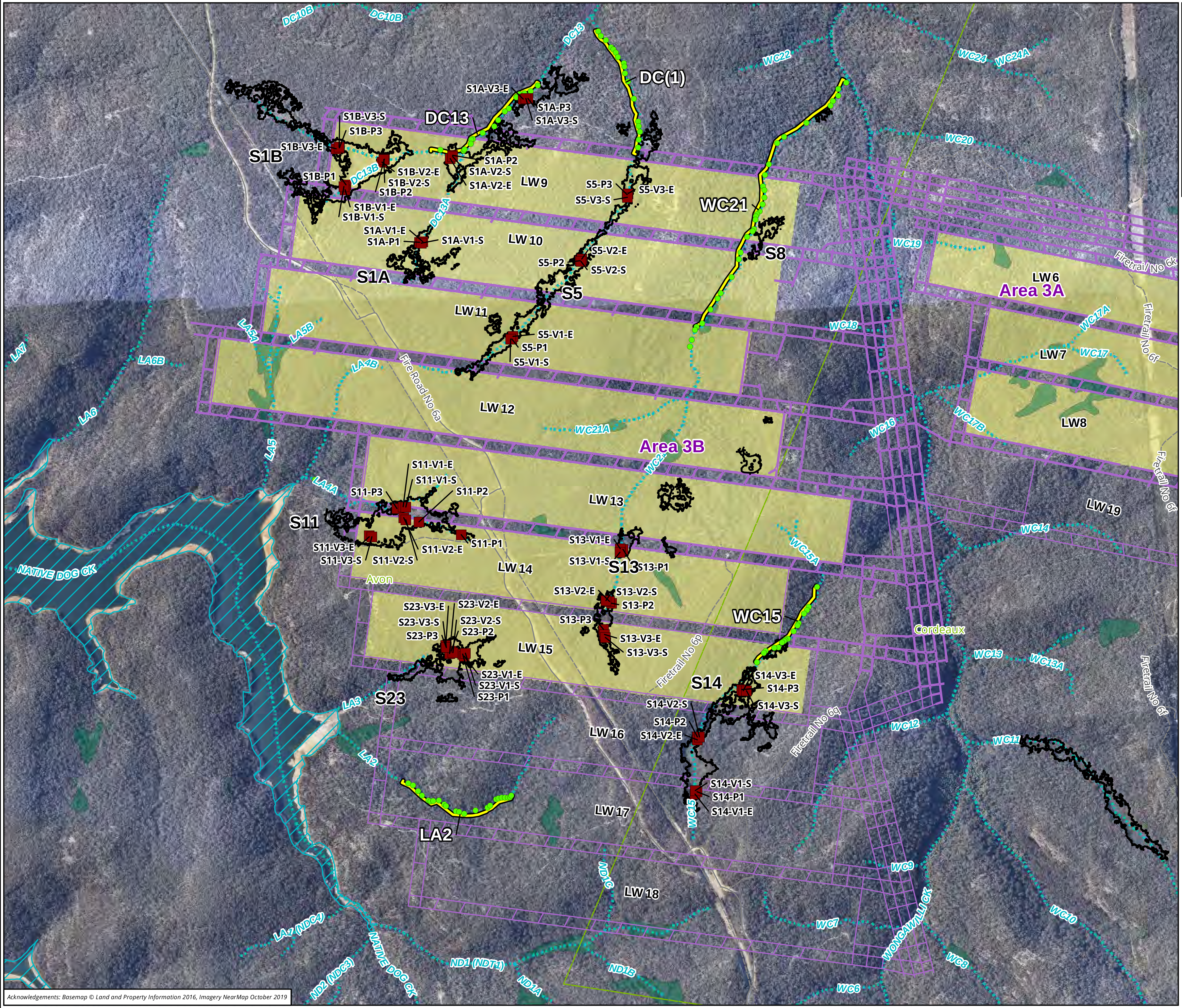
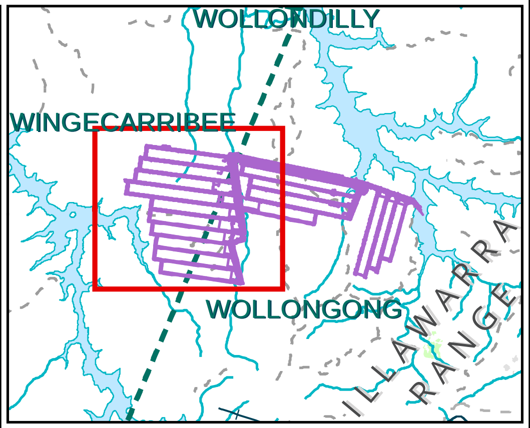



**Figure 2 Location of 2019 monitoring impact sites surveyed in Dendrobium Area 3A**




**Legend**

- Longwall Layout
- Longwall progress (at 05/01/2020)
- Upland swamp boundary (Biosis)
- Upland swamp boundary (NPWS)

**Monitoring Locations**

- Flora upland swamp impact site
- Threatened frog monitoring breeding pool
- Threatened frog monitoring impact transect

**Figure 3 Location of 2019 monitoring impact sites surveyed in Dendrobium Area 3B**

0 200 400 600
Metres

Scale: 1:16,000 @ A3
*Coordinate System: GDA 1994 MGA Zone 56*

biosis

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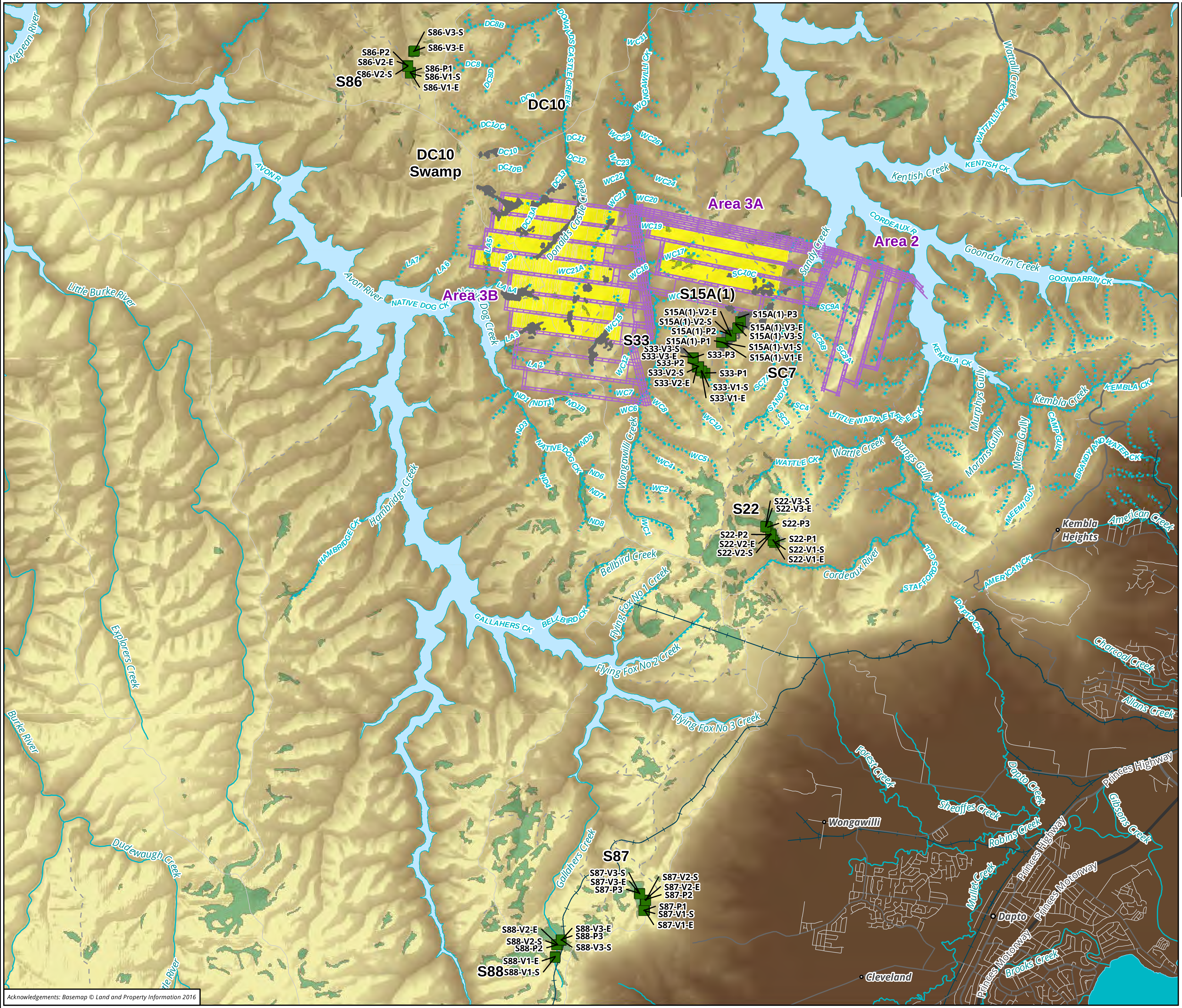


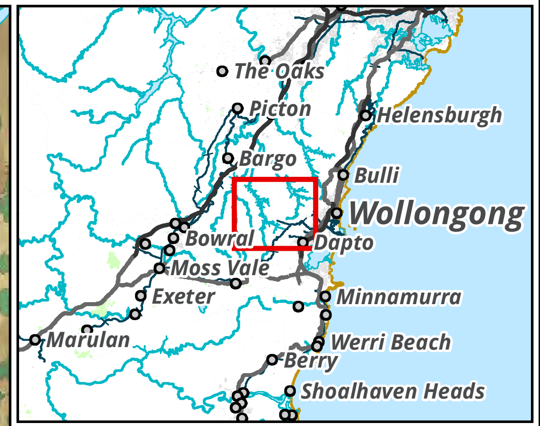


**Legend**

- Longwall Layout
- Longwall progress (at 05/01/2020)
- Upland swamp boundary (Biosis)
- Upland swamp boundary (NPWS)

**Monitoring Locations**

- Flora upland swamp control site

**Figure 4 Location of flora monitoring control sites used in the 2019 program**

0 0.5 1 1.5 2 2.5 Kilometres

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Scale: 1:65,000 @ A3

*Coordinate System: GDA 1994 MGA Zone 56*

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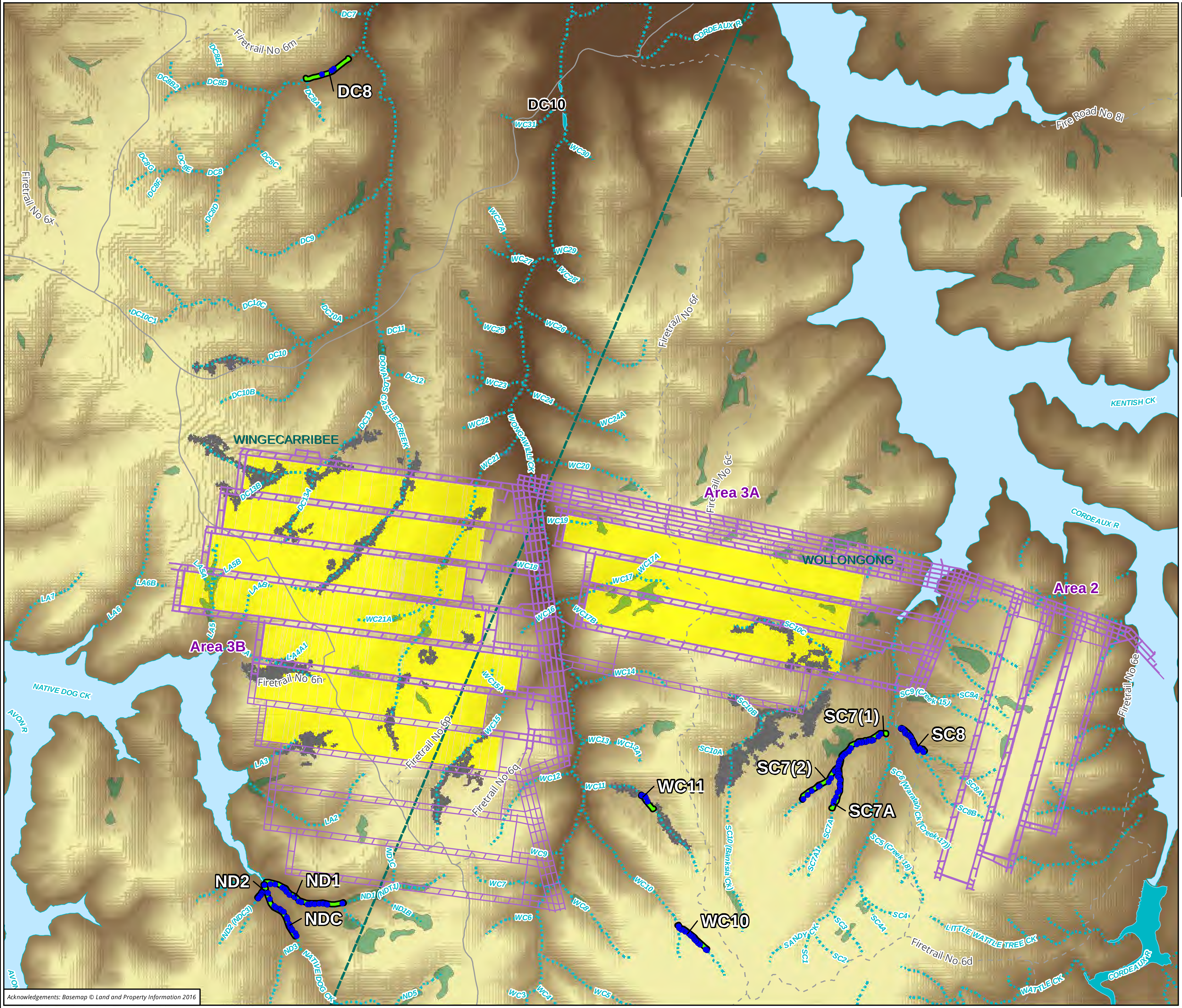


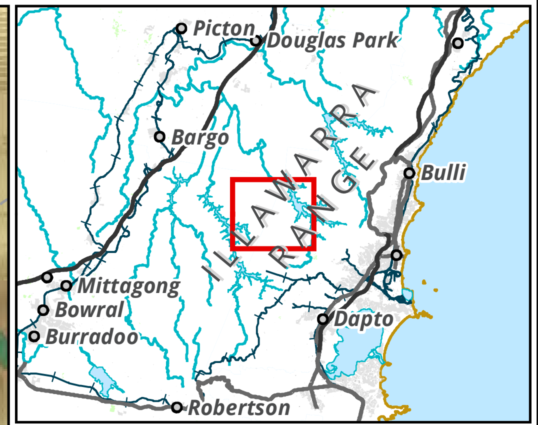


**Legend**

- Longwall Layout
- Longwall progress (at 05/01/2020)
- Upland swamp boundary (Biosis)
- Upland swamp boundary (NPWS)

**Monitoring Locations**

- Threatened frog monitoring control transect
- Threatened frog monitoring breeding pool

**Figure 5 Location of threatened frog monitoring control transects used in the 2019 program**

0 200 400 600 800 1,000

Metres

Scale: 1:30,000 @ A3

*Coordinate System: GDA 1994 MGA Zone 56*

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## 1.4 Survey sites and monitoring periods

A summary of all impact sites and corresponding control sites has been provided below in Table 1 and Table 2.

**Table 1 Summary of vegetation monitoring sites**

| Area | Impact site | Monitoring commenced | Mining progress | | Control sites |
|---|---|---|---|---|---|
| **Dendrobium Area 2** | S1 (Swamp 1) | 2005 – spring 2014, then 2015 (spring only) | Within mining RMZ:<br>• V1 15/05/2008<br>• V2 Aug 2007<br>V3 Jul 2007 | Mined beneath:<br>• V1 03/09/2009<br>• V2 29/08/2009<br>V3 Jun 2008 | S15A(1) (Swamp 15A(1))<br>S11 (Swamp 11) |
| **Dendrobium Area 3A** | S15B (Swamp 15B) | 2003 | Within mining RMZ:<br>• 18/09/2010 | Mined beneath:<br>• 25/08/2012 | S15A(1) (Swamp 15A(1))<br>S11 (Swamp 11) |
| | S15A (2) (Swamp 15A(2)) | 2009 | Within mining RMZ:<br>• 20/10/2012 | Mined beneath:<br>• All points beyond goaf | S15A(1) (Swamp 15A(1))<br>S33 (Swamp 33)<br>S22 (Swamp 22) |
| **Dendrobium Area 3B** | S1A (Swamp 1A) | 2012 | Within mining RMZ:<br>• 23/02/2013 | Mined beneath:<br>• 11/04/2013 | S86 (Swamp 86)<br>S87 (Swamp 87)<br>S88 (Swamp 88)<br>S15A(1) (Swamp 15A(1)) |
| | S1B (Swamp 1B) | 2005-2009, then 2012-present | Within mining RMZ:<br>• 08/02/2013 | Mined beneath:<br>• 13/02/2013 | S86 (Swamp 86)<br>S87 (Swamp 87)<br>S15A(1) (Swamp 15A(1))<br>S22 (Swamp 22)<br>S33 (Swamp 33) |
| | S5 (Swamp 5) | 2012 | Within mining RMZ:<br>• 18/05/2013 | Mined beneath:<br>• 25/07/2013 | S86 (Swamp 86)<br>S87 (Swamp 87)<br>S88 (Swamp 88)<br>S15A(1) (Swamp 15A(1)) |
| | S11 | 2003 | Within mining RMZ:<br>• 21/05/2016 | Mined beneath:<br>• 15/04/2017<br>• | S15A(1) (Swamp 15A(1))<br>S22 (Swamp 22)<br>S33 (Swamp 33) |
| | S13 (Swamp 13) | 2013 (spring only) | Within mining RMZ:<br>• 10/07/2017 | Mined beneath:<br>• 01/11/2018 | S86 (Swamp 86)<br>S87 (Swamp 87)<br>S88 (Swamp 88)<br>S15A(1) (Swamp 15A(1)) |
| | S14 | 2017 | Within mining RMZ:<br>• 01/12/2018 | Mined beneath:<br>• 13/11/2019 | S86 (Swamp 86)<br>S87 (Swamp 87)<br>S88 (Swamp 88)<br>S15A(1) (Swamp 15A(1)) |

| Area | Impact site | Monitoring commenced | Mining progress | | Control sites |
|---|---|---|---|---|---|
| | S23 | 2017 | Within mining RMZ:<br>• June 2018 | Mined beneath:<br>• 01/06/2019 | S86 (Swamp 86)<br>S87 (Swamp 87)<br>S88 (Swamp 88)<br>S15A(1) (Swamp 15A(1)) |

**Table 2 Littlejohn's Tree Frog monitoring sites**

| Area | Impact site | Monitoring commenced | Mining progress | | Control sites |
|---|---|---|---|---|---|
| **Dendrobium Area 3A** | SC10(1) | 2006 | Within mining RMZ:<br>• End November 2011 | Mined beneath:<br>• All pools beyond goaf | SC6 (Waratah Creek)<br>SC7(1)<br>SC7A |
| | SC10(2) | 2006 | Within mining RMZ:<br>• End November 2011 | Mined beneath:<br>• Predicted Longwall 19 | NDC (Native Dog Creek)<br>SC6 (Waratah Creek)<br>SC7(1)<br>SC7A |
| | SC10C | 2006 | Within mining RMZ:<br>• End October 2010 | Mined beneath:<br>• End October 2012 | SC6 (Waratah Creek)<br>SC7(1) (Cascade Creek)<br>SC7A |
| | 6CDL | 2009 | Within mining RMZ:<br>• 5 Dec 2010 | Mined beneath:<br>• All pools beyond goaf | ND2<br>SC6 (Waratah Creek)<br>SC7(2) (Cascade Creek)<br>SC8 (Fern Tree Creek) |
| | WC17 | 2011 | Within mining RMZ:<br>• March 2010 | Mined beneath:<br>• 26 Apr 2011 | NDC (Native Dog Creek)<br>ND1 (also referred to as NDT1)<br>SC6 (Waratah Creek)<br>SC8 (Fern Tree Creek)<br>WC10 (Easement Creek)<br>WC11 |
| **Dendrobium Area 3B** | DC (1) (Donald's Castle Creek) | 2013 | Within mining RMZ:<br>• End June 2013 | Mined beneath:<br>• All pools beyond goaf | DC8<br>SC6 (Waratah Creek)<br>SC7(1) (Cascade Creek)<br>SC7(2) (Cascade Creek)<br>SC7A<br>SC8 (Fern Tree Creek)<br>WC11 |
| | DC13 | 2010 | Within mining RMZ:<br>• 21 February 2013 | Mined beneath:<br>• End March 2013 | SC6 (Waratah Creek)<br>SC7(1) (Cascade Creek)<br>SC7(2) (Cascade Creek)<br>SC7A<br>SC8 (Fern Tree Creek) |

| Area | Impact site | Monitoring commenced | Mining progress | | Control sites |
|---|---|---|---|---|---|
| | LA4A (Downstream of DA3B) | 2007 | Within mining RMZ:<br>• 31 March 2016 | Mined beneath:<br>• All pools beyond goaf | ND1<br>SC6 (Waratah Creek)<br>SC7(2) (Cascade Creek)<br>SC8 (Fern Tree Creek) |
| | WC15 | 2011 | Within mining RMZ:<br>• January 2019 | Mined beneath:<br>• December 2019<br>• Predicted Longwall 14 | DC8<br>NDC (Native Dog Creek)<br>SC6 (Waratah Creek)<br>SC7(1) (Cascade Creek)<br>SC7A<br>SC8 (Fern Tree Creek) |
| | WC21 | 2013 | Within mining RMZ:<br>• 27 October 2013 | Mined beneath:<br>• 21 December 2013 | DC8<br>SC6 (Waratah Creek)<br>SC7(1) (Cascade Creek)<br>SC7(2) (Cascade Creek)<br>SC7A<br>SC8 (Fern Tree Creek)<br>WC10 (Easement Creek)<br>WC11 |
| | LA2 | 2017 | Within mining RMZ:<br>• Predicted Longwall 16, 17, 18 | Mined beneath:<br>Predicted Longwall 17 | SC7(1) (Cascade Creek)<br>SC7(2) (Cascade Creek)<br>SC7A<br>SC8 (Fern Tree Creek)<br>WC10 (Easement Creek)<br>WC11 |

# 2 Methods

The baseline survey methodology, results of the statistical analysis and revised survey methodologies are detailed in previous Biosis annual monitoring reports (Biosis 2005, 2007a, 2007b, 2010, 2013a, 2013b, 2014, 2015a, 2016, 2017, 2018 and 2019). The following is a brief description of the survey methodology.

## 2.1 Survey techniques

Table 3 provides a summary of the survey method used in each of the Dendrobium monitoring programs.

**Table 3 Summary of survey methodology**

| Survey type | Area | Timing |
|---|---|---|
| **Upland Swamp Vegetation Monitoring** | Dendrobium Area 3A<br>Dendrobium Area 3B | Vegetation survey once in autumn and once in spring each year. |
| **Littlejohn's Tree Frog Breeding Habitat Monitoring** | Dendrobium Area 3A<br>Dendrobium Area 3B | Once in winter each year. |
| **Photo-point Monitoring** | Dendrobium Area 3A<br>Dendrobium Area 3B | Once in autumn and once in spring at all flora monitoring locations. |

### 2.1.1 Upland swamp vegetation monitoring

The following sections describe the field and data collection methodology completed to assess the following components of the Dendrobium Area 3B Swamp Monitoring TARP:

- Terrestrial flora – ecosystem functionality; and
- Terrestrial flora – composition and distribution of species.

#### Transect monitoring program

Vegetation monitoring in upland swamps is undertaken along three 15 m transects within each swamp. The presence of all species within thirty 0.5 x 0.5 metre quadrats located along the 15 m transect is recorded. A maximum score of 30 per transect for a species indicates it is present in all quadrats.

Where there is potential for misidentification, or where species cannot be reliably identified to species level in the field, species have been grouped into identification units for analysis, with each member of a grouping sharing the same functional attributes. Each of these units is referred to as a species complex.

Surveys are undertaken once in spring and once in autumn each year.

### 2.1.2 Littlejohn's Tree Frog monitoring

Littlejohn's Tree Frog is listed as Vulnerable under the BC Act and EPBC Act, and is known to breed within first and second (and occasionally third) order waterways within Dendrobium Area 3A and Dendrobium Area 3B.

Targeted surveys for Littlejohn's Tree Frog are undertaken annually from mid-winter to early spring, when the species is known to be breeding in the area (and thus calling), and is therefore most detectable. Timing of surveys has been developed with consideration of state and federal survey guidelines (DECC 2009 and CoA 2010), particularly as they apply to Littlejohns Tree Frog. The aims of the surveys are to monitor known locations of this threatened frog species within Dendrobium impact areas, in order to detect any changes in abundance and breeding of individuals, or condition of habitat following mining, and to monitor associated non-impacted (control) sites within the Dendrobium area in order to compare impact site data against natural fluctuations in local Littlejohn's Tree Frog populations.

Transects have been established in breeding habitat (along a waterway) within each site to create repeatable survey effort, and enable direct comparison of the numbers of individuals detected at each site from one year to the next. Baseline surveys prior to longwall mining within the RMZ of a stream allow comparison of frog abundance pre- and post-mining. Transects are surveyed at night to determine the presence of adult frogs, tadpoles and eggmasses (DECC 2009 and CoA 2010). Transects are surveyed by walking slowly down the stream line, and counting all target amphibians seen or heard on either side of the line. Any tadpoles or eggmasses located during the survey are also recorded. The location of any individuals detected during the targeted nocturnal surveys or any other significant incidental sightings are recorded using a GPS. Sites are surveyed once each year, or are repeated if climatic conditions result in a lack of detection of the target species. Opportunistic sightings, including threatened species such as the Giant Burrowing Frog *Heleioporus australiacus* are also documented when surveying for Littlejohn's Tree Frog.

### 2.1.3 Photo-point monitoring

Photo-point monitoring is conducted at or in proximity to all vegetation monitoring sites (impact and control). Photographs are taken at each site, at a fixed location and view angle. With the majority of flora sites having six or more years of photo point monitoring.

All photos from all seasons and years are reviewed as part of our analysis to directly compare habitat condition. An interpretation of the photo-point monitoring is provided in Section 3.2.

### 2.1.4 LiDAR and UAV imagery analysis

In response to the *Dendrobium Area 3B Swamp Impact, Monitoring, Management and Contingency Plan*, annual monitoring for upland swamps includes the use of Light Detection and Ranging (LiDAR) data to detect changes in the total swamp size of upland swamps and extent of groundwater dependent upland swamp sub-communities within each swamp.

To determine whether subsidence associated within longwall mining has resulted in changes to the extent of upland swamps, the total swamp size mapped using most recent (2018) LiDAR data will be compared with the total swamp size of each swamp during the baseline year mapped using LiDAR data from 2012.

In addition to using a comparison in LiDAR data between current and baseline years, high resolution aerial imagery captured by Illawarra Metallurgical Coal's Environment Field Team using an unmanned aerial vehicle (UAV) (specifically a DJI Phantom 4 Pro) will be analysed to identify reasons for changes in swamp extents detected in the LiDAR data.

### 2.1.5 On ground dieback mapping with hand held tablet devices

Following a review of data recording practices in 2018, Biosis developed a spatial data recording map to be used in conjunction with the existing data recording methods on hand held tablet devices. This additional data recording process has enabled the mapping of areas of dieback on the ground and the geolocation of ecological or impact observations. Specific observations relating to identified frog breeding pools will also be made to improve the understanding of how identified frog breeding habitat changes over time and how this may relate to climatic conditions or mining impacts. After one season, these additional data have improved the tracking and interpretation of observational changes in swamp condition over time, as well as the changes in the extent or location of dieback directly mapped on the ground.

Ongoing use of this additional monitoring measure, supplemented by high resolution UAV imagery will improve the capacity of the observational data to support the interpretation of the statistical analysis and further aid the ecological understanding of these systems and changes that occur within them.

Monitoring for visual changes between impact sites and control sites provides a gross, qualitative comparison of vegetation structure and colouration on a year to year basis. Changes in vegetation coloration may be indicative of vegetation stress (e.g. change in vigour of a species or suite of species due to change in soil moisture or nutrient content) or of change in the composition or relative abundance of species within strata (e.g. an increase in vigorous, green groundwater dependent groundcover species). Fluctuations in both vegetation colour and vegetative structure are expected in response to natural climatic variability, stochastic events (e.g. fire) and potential mining-induced changes.

## 2.2 Statistical analysis

### 2.2.1 Background to analysis

Following collection in the field, vegetation and Littlejohn's Tree Frog monitoring data was entered into a dedicated database and validated prior to analysis. Control sites selected for analysis are paired to impact sites based on similarity, as assessed in the field on the basis of presence of similar upland swamp vegetation sub-communities and other relevant variables. Sites are then compared using exploratory data analysis to confirm that the data were statistically suitable and available for the same period of time as impact sites.

### 2.2.2 Measures of analysis

Mining-induced impacts to vegetation may be evidenced by a change to the number of species at different sites, or an overall change in the species composition, as some species may be less affected by impacts than others. In affected areas, these impacts may manifest as the following:

- Change in floristic Total Species Richness (TSR): the number of individual species, calculated by the total number of unique species detected at each monitoring transect during each season and year. This is a simple presence-absence measure and does not account for the relative abundance of each species.
- Changes in the floristic species composition: the assemblage of different individual plant species that make up a vegetation community.
- Changes in upland swamp extent: The contraction or expansion of the area of upland swamps and the communities the comprise them.

These indicators are described in further detail (Section 2.2.3).

Impacts to Littlejohn's Tree Frog may be evidenced by a decline in populations or disruption of the breeding cycle, following changes to key breeding habitat features. The impacts are measured quantitatively through Littlejohn's Tree Frog detection rates, measured as the number of adults, tadpoles and eggmasses detected along the monitoring reach. To standardise the varying lengths of survey reaches, the total number of each life stage is divided by the number of 100 metre sections within the survey reach. This equates to a Catch-per-unit-of-effort (CPUE) and is presented as *n*/100 m.

Changes in upland swamp TSR, floristic composition, and Littlejohn's Tree Frog detection rates may be due to mining impacts or unrelated landscape scale effects; for example local climatic variation, bushfire, etc. As such a Before-After-Control-Impact (BACI) experimental design has been employed to increase confidence in the interpretation of observed changes. However, the ability to model the (potentially competing) influences of any long term adult frog abundance trends and after mining effects using a traditional BACI design is limited, as two out of the three post-mining impact sites within Dendrobium Area 3B were not a requirement of the original monitoring program. Therefore, since these changes there is only one year of before mining data for two thirds of monitoring sites.

In BACI studies, the aim is to assess whether any trend in the response variable (e.g. total species richness, species composition or abundance) at sites that have been directly impacted (e.g. mining) differs after impact to that measured before and also differs to any global trend (i.e. trends observed at control sites that did not experience an impact).

### 2.2.3 Data analysis procedure

Biosis commissioned The Analytical Edge Statistical Consulting Pty Ltd (TAE) to undertake a review of the statistical analysis and data collection methodology following the completion of the 2019 program to assist in providing a robust, statistically valid and quantitative assessment against the relevant TARPs.

TAE was commissioned by Biosis to undertake statistical analyses of vegetation collected at upland swamps (TAE 2020a; TAE 2020b). The analysis provides a statistical comparison of impact and control sites with the aim to identify, understand and manage any mining impacts.

The following methodology was designed and applied to the Dendrobium dataset by TAE in consultation with Biosis ecologists.

#### Vegetation data analysis

TSR was calculated for swamp sites as the sum of individual taxa detected at each transect for each survey. Exploratory data analysis included plotting TSR for all sites grouped by mining status; 'control or pre-mining', 'post-mining (within RMZ)' or 'post-mining (mined beneath)' for each survey year. Such groupings may mask individual swamp-level effects of mining status (i.e. richness at some swamps might go up, others might go down, but on average total richness appears stable). Hence the TSR in each year for each swamp were also plotted individually.

Differences in TSR between sites and years was first explored using box plots, which allow visual comparison of the variation and distribution of TSR about the median, interquartile range and range values for TSR.

To test whether trends detected visually represent statistically relevant changes in TSR and species composition, *t*-tests were applied to Level 1, 2 and 3 triggers for all impact sites; whereby two-, three-, and four-consecutive year periods, respectively, after impact were compared to TSR at paired control swamps and to the TSR before impacts. *t*-tests analysed the influence of year and mining status (pre, post or mined beneath) on TSR. Incorporating the year factor allows for identification of long-term trends in time across all sites. Mining status is a key factor of the analysis and indicates whether observed trends differ at sites where mining does and does not occur.

Total swamp area was assessed based on a differential canopy height of 8 metres to determine swamp margins with the 2014 data set used as the baseline, in accordance with recommendations made in Biosis (2017). In this report the LiDAR data used was collected in April 2019. Therefore, the analysis presented herein for assessing the extent of upland swamp vegetation represents two years of change. The results are expected to graphically appear overstated, but analysis and interpretation of this data set considers the results over a longer (2 year) time period. This extended time period is considered advantageous to data analysis and does not represent a limitation, and will further characterise the influence of confounding factors that are not mining related.

All modelling and the creation of graphs, for TSR and species composition, was completed in the statistical software program R by The Analytical Edge Statistical Consulting (2020a; 2020b).

A species list of all unique species detected at each transect in each survey has been recorded. This data has been used to describe the species composition of each swamp and identify changes in species composition over time.

The 'manyglm' function in the 'mvabund' package (in the program R), were used to fit presence-absence models to each detected species. These models correct the correlation between species (which otherwise violates an assumption of standard generalised linear models) by using generalized estimating equations. Analysis of variance (ANOVA) was used to formally test the significance of explanatory variables (i.e., 'year', 'season' and mining status). If the mining status explanatory variable were found to be significant, univariate tests were completed to determine which individual species were driving the change in flora community composition. Level 1, 2 and 3 triggers were investigated by fitting the multivariate model and sub-setting data accordingly, whereby 2-, 3-, and 4- consecutive year periods were analysed post-impact, for the Level 1, 2 and 3 TARPs, respectively.

In a standard BACI study, where monitoring is conducted across many years prior to, and after the impact event, at both the impact and paired control sites, the aim would be to determine if there is any significant interaction between site (control:impact) and time (before:after) which would suggest the trend before the impact event (i.e. mining) at the impact site is different to after the impact event.

To address the specific requirements of the Dendrobium TARPs, Biosis completed multiple testing at the 2-year, 3-year and 4-year means to test the Level 1, Level 2, and Level 3 triggers, respectively. It should be noted however, that conducting multiple testing such as this can lead to erroneous interpretation of results. For example at the 95% confidence interval (or p-value=0.05), through statistical chance alone, 5% of tests may be erroneously concluded as statistically significant, and this chance is elevated when multiple tests are conducted. This is known as a Type I error. Methods exist for correcting multiple testing (e.g., Holm–Bonferroni, Holm 1979) but this will decrease statistical power to detect a difference, if one exists. To minimise potential for Type 1 error, the outputs of the statistical analysis have been interpreted in conjunction with results of the Illawarra Metallurgical Coal Environmental Field Team's landscape and piezometer monitoring, as well as qualitative observations of upland swamp vegetation made during surveys conducted in 2019.

### Littlejohn's Tree Frog data analysis

All Littlejohn's Tree Frog adult, tadpole and egg mass numbers were standardised to represent abundance per 100 metre length of stream. This data was then used to create line-plots of the abundance of each life stage at each impact site, alongside associated control sites. Visual analysis of graphed data was undertaken to identify trends in adult, tadpole and egg mass abundance within streams, over time and between treatment groups.

## 2.3 Limitations

Common to ecological monitoring programs, is the availability of suitable and logistically practical impact and control sites that makes it difficult to achieve a balanced BACI design. Suitable monitoring locations immediately above longwalls or with potential to be impacted by mining are by definition limited in their geographic extent. Nearby, ecologically similar sites free from historic and or future mining influences which can be used as control sites are also limited. Therefore, this monitoring program employs the use of multiple control sites for each impact monitoring site to establish multiple lines of evidence to differentiate between catchment wide influences, such as low rainfall, and potential mining impacts. The program also has the advantage of drawing long term monitoring data for many of these sites, and on additional data sets such as groundwater monitoring conducted by Illawarra Metallurgical Coal.

Despite efforts to identify all individuals during a survey, Littlejohn's Tree Frog data is biased to presence-only given the inherent limitations regarding the ability to distinguish between a true absence record (i.e. no Littlejohn's Tree Frog present), and a false absence record (i.e. Littlejohn's Tree Frog present but not detected). Additionally, like many fauna surveys, the dataset is not normally distributed and is skewed by a high number of zero counts at the pool level. Due to these limitations, the scope to conduct statistical analysis on this data is limited. The data is graphically displayed and trends are instead analysed visually. While this limitation means that subtle patterns in the ecological life stages of this species may not be as apparent, it is anticipated that potential impacts associated with mining will be visually observable in the field (e.g. bedrock cracking, flocculation) and in this data, given the scale of these impacts on this species. As with the flora data, multiple control sites for each impact monitoring site have been established to differentiate between catchment wide influences, such as low rainfall, and potential mining impacts.

In response to the complexity that arises with cryptic flora species, such as those that are inconspicuous unless flowering or in fruit, plant species complexes have been developed that link plant species that are known to be easily confused in the field. These linked species have been treated as one in the data analysis to streamline the data. Species complexes have been developed based on site specific experience and ecological understanding of these species developed over many years and have only been employed where all individual species within a complex are considered likely to respond to mining and non-mining induced change in similar ways. The species complexes utilised in the data analysis were reviewed and modified in 2018 and further refined in 2019 (see Appendix 1). Species complexes are now applied consistently across the entire flora monitoring dataset, rather than on a site by site basis as was the case prior to 2018. As a result, the output values of the statistical analysis comparing change over time provided in this report differ from those provided in previous reports for the same periods. The trends, statistical significance and ecological interpretation that are based on these statistical outputs; however, remain consistent with those previously described, despite the change in individual values. The outcome of applying this more consistent approach to species complexes is a more scientifically robust approach, which improves confidence in the ecological interpretation and meaningfulness of any statistically significant trends.

The BACI experimental design, on which the program is based, is limited by the spatial availability of appropriate monitoring sites. Any long-term monitoring program must strike a balance between what is optimal to allow powerful statistical analyses and meaningful data interpretation and what is practical to implement on the ground given the resources available and ecosystems and species involved. Biosis is committed to an adaptive monitoring approach whereby sites included in the program, data collection methods and statistical analysis techniques are regularly reviewed and the efficacy of the program continuously improved.

Where possible within the monitoring framework, actions have been taken to overcome the above limitations and increase the confidence in the monitoring outputs. The current monitoring data collection and methods of analysis are considered suitable to address the relevant monitoring TARPs.

# 3 Results

The 2019 monitoring results are described in the following sections in the context of data recorded in previous years of the monitoring program.

## 3.1 Rainfall

Rainfall is considered to be a key factor influencing year on year change in upland swamps and stream habitat conditions, including through fluctuations in stream flow, soil water infiltration and groundwater recharge. Surface runoff also contributes to longitudinal and latitudinal connectivity in aquatic ecosystems with implications for nutrient cycling, aquatic habitat maintenance and rejuvenation. As rainfall contributes to plant growth and habitat maintenance in upland swamps through surface infiltration and groundwater recharge, it may be expected that rainfall will influence changes in swamp extent.

Available rainfall data recorded from Cordeaux Dam No.1 (station no. 68018) across the years of available data (2010 to 2019) is summarised in Table 4 and is displayed below (Figure 6). As only 10 years of data are available, these data have been checked for consistency with data from the Buxton Amaroo station (station no. 68166) which provides a longer dataset covering the 1967-2019 period.

**Table 4 Total annual rainfall recorded between 2010 and 2019 (station no. 68018)**

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total annual rainfall (mm)** | 1381.4 | 1323.2 | 1188.6 | 1406.1 | 1096.6 | 1243.9 | 1197.0 | 891.7 | 648.0 | 583.0 |
| **Percentage of median total annual rainfall from 2010-2019 (979.1 mm)** | 116% | 111% | 100% | 118% | 92% | 104% | 100% | 75% | 54% | 49% |

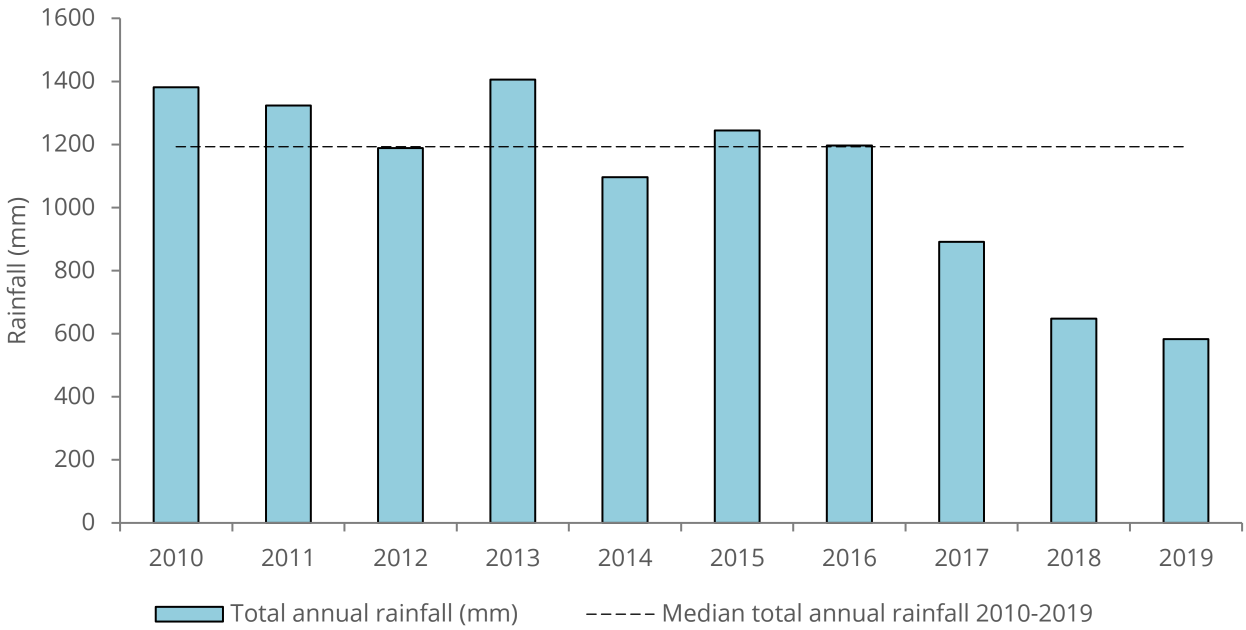



**Figure 6 Total annual rainfall recorded between 2010 and 2019 (station no. 68018)**

Rainfall was relatively stable between 2010 and 2016. Then dropping substatntially below the average in 2017, with rainfall continuing to fall in 2018 and fall again in 2019. The total annual rainfall recorded in 2019 was 583 millimetres (mm), which is less than half the average annual rainfall of 1192.8 mm recorded between the years 2010 and 2019 and is the lowest level of annual rainfall recorded in this period.

The values for total monthly rainfall were consistently below the average (Figure 7) during 2019. Rainfall was below the average in nine of the twelve months. With the most significant rainfall recorded in March of 2019, only otherwise exceeding the average of each month in Janurary and September of 2019. Rainfall was particularly low in February, November and December when compared to the average rainfall recorded in those months. Notably, rainfall was below average in each of the winter months and also in October, the known Littlejohn's Tree Frog key breeding period within the study area, with only September recording above average rainfall in this period.

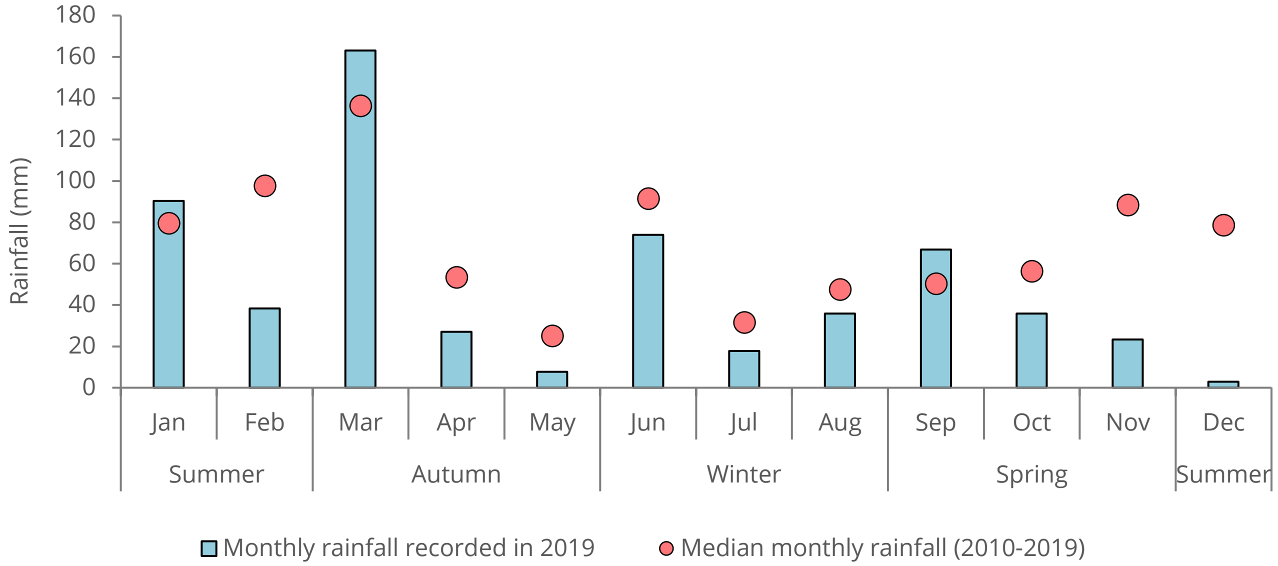



**Figure 7 Total monthly rainfall recorded in 2019 (station no. 68018)**

The extended reduction in rainfall through 2017 to 2019 led to a substantial reduction in water level of Cordeaux Dam in 2019, displayed in Figure 8. In summer 2018 the water level of Cordeaux Dam was 69% (WaterNSW 2018a) of the total storage capacity, falling to 48% in winter of 2018 (WaterNSW 2018b). In summer and winter of 2019 dam levels remained reduced at 37% (WaterNSW 2019a), rising only to 41% (WaterNSW 2019b) in winter of the same year, before falling to 38% in summer of 2020 (WaterNSW 2020). The low water levels also resulted in the level of dam influence moving a substantial distance downstream with drying of large pools and drying of aquatic habitats previously inundated in 2019. These levels are indicative of drying across the study area and broader landscape during 2019.

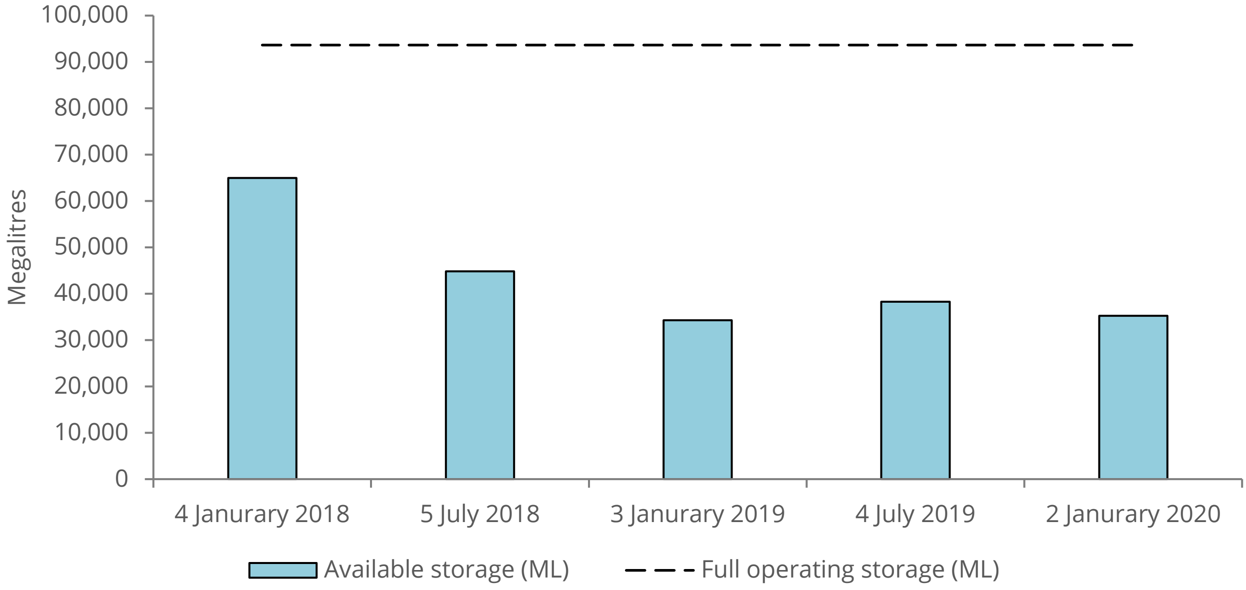



**Figure 8 Cordeaux Dam level change between Janurary 2018 and 2020**

## 3.2 Site observations - photo point monitoring and UAV imagery analysis

An examination of available rainfall data (Table 4) shows a correlation with the years of lower rainfall and recorded reduced swamp extents. Following a period of relative stability in 2014 to 2016, rainfall for the region was below the average of 844.6 mm in both 2017 and 2018, with a continued trend of below average rainfall in 2019 (Table 4). The percentage change in rainfall compared to the 2014 baseline year identifies a decrease in 2017 and then a further marked decrease in 2018 and 2019. This decrease is proportionally similar to the percentage change in swamp extent observed across the upland swamps during these periods. This indicates that reduced rainfall during 2017 and 2019, when compared to the 2014 baseline has likely played a key role in the reduction of upland swamp extents at both impact and control sites.

Periods of extended drying, as has been experienced in 2017, 2018 and 2019, can be reasonably expected to result in changes to habitat or landscape features that are unfavourable to species that require a relatively high degree of soil moisture or water availability, such as upland swamp vegetation. Periods of extended drying can be expected to reduce water availability through decreased surface infiltration and groundwater recharge via rainfall. Periods of extended drying will also favour terrestrial species, through providing more suitable conditions for growth and establishment in areas of upland swamp that would have been previously too wet to occupy or occupied by upland swamp species, better adapted to wetter environments. Facilitating in turn, an expansion of terrestrial species or communities in place of upland swamp vegetation.

However, in consideration of this, it is unlikely that during the observed drier than average conditions that terrestrial vegetation has expanded into upland swamps and attained a height of 8 metres. This further supports the requirement to reassess the use of the 8 metre height differential from the first and last returns, particularly for sub-communities MU42 and MU43 where the change recorded is more apparent. As these have a typically higher canopy than the MU44 (a,b,c) sub-communities.

The site observations for 2019 in relation to structural changes in vegetation, or indicators of impacts relating to mining, were relatively consistent with those described in 2018. This section describes the observational data in light of this consistency, with a focus on sites where the most substantial changes have occurred. The photographs that best illustrate the observational data have been selected for presentation, rather than displaying all photos recorded at each monitoring point, in order to best describe the changes observed.

Photo-point monitoring has been conducted at Dendrobium Area 3A and associated control sites since spring 2009; and, at Dendrobium Area 3B and associated control sites since spring 2012 (and spring 2009 at Swamp 11).

A number of photo-point monitoring sites within upland swamps display minimal visual changes within photo-records from the start of monitoring to current photos. Three pre-mining sites (S13, S14 and S23) and four control sites (S15A(1), S86, S87 and S88) displayed minimal change.

Photo-point monitoring indicates structural changes in vegetation were typically those within the, sub-community, Upland Swamps: Banksia Thicket. The most common structural changes were increased height and density of shrub species within the vegetation community, considered likely due to the natural growth of vegetation over time. This type of successional species progression occurs naturally within upland swamp vegetation communities and has been attributed to environmental factors, such as long inter-fire intervals and periods of drought which favour establishment and growth of Heath Banksia *Banksia ericifolia* subsp. *ericifolia* and Needlebush *Hakea teretifolia* (Keith 2006). Evidence of natural progressive vegetation structural change was observed at both impact and control sites, including S15A(2) and S33. Yellowing of foliage in the shrub layer at Swamp S22 was observed, particularly at points S22-F2 and S22-F3. This is consistent with the ongoing unseasonably dry conditions since 2017.

Photo monitoring at impact sites S1B, S11, S15B, S1A and S5 also contained visual evidence of structural change of upland swamp vegetation. Yellowing of Needlebush observed at S11-F3 and a reduction in cover of Pouched Coral Fern *Gleichenia dicarpa* at S11-F5 were observed. Drying of Restioid heath species at all three monitoring sites within S1B was observed. Ongoing field observation and photo monitoring will be undertaken in 2020, with continuing focus on mapping the extent of dieback in these areas.

Changes in vegetation identified at photo points were reinforced by additional observations made by Biosis field staff during surveys. Visible changes observed at S15B, S1A and S5 are detailed below.

### 3.2.1 Swamp 15B

Vegetation dieback areas within Swamp 15B were observed to have increased in extent, with patches of dieback or dying vegetation evident throughout the swamp during 2019 monitoring events. The increased occurrence of dieback recorded in 2018, stretching from the east of S15B – P2 (292905 E; 6192692 N) and west to the eastern patch south of S15B - V3, including the patch that extends from east of S15B – V2 (292 760.62 E; 6192 762.34 N), has continued to expand. This patch now also extends to S15B – V1 (292 546 E; 6192 715 N).  The majority of dieback continues to occur within Tea-tree Thicket resulting in the loss of cyperoid sedges such as, *Chorizandra* sp. and *Baumea* sp., with substantial decreases in Razor Sedge *Lepidosperma limicola,* Wire Rush *Empodisma minus, Lepidosperma neesii* and Pouched Coral Fern (Plate 1)*.* Species such as Red-fruited Saw-sedge *Gahnia sieberi*, *Leptospermum* sp. and Heath Banksia have not been similarly affected.

This dieback patch includes two sub-communties; Cyperoid heath (MU44c) and Tea-tree Thicket (MU43). Species affected by dieback within cyperoid heath vegetation include Buttongrass *Gymnoschoenus sphaerocephalus*, which was recorded as browning and having a very reduced crown size, in addition to the observed reductions in the cover of sedge and fern species detailed above (Plate 2).

The loss of *Chorizandra* sp. and *Baumea* sp. indicates a loss of seasonally pooled water, with other sedges most likely to be affected by the loss of vadose zone water close to the ground surface following being mined beneath in 2012. These areas were marked using flagging tape by Biosis to show the change in extent since spring 2016.

A separate section of Swamp 15B, west of S15B-V2 (located at 292642 E; 6192775 N) recorded a reduction of approximately 30% vegetated cover in autumn 2014, in areas transitioning between Tea-tree Thicket and Banksia Thicket. This section has again recorded dieback greater than 50% of total vegetated cover for

*Chorizandra* sp. and *Baumea* sp., Razor Sedge, Wire Rush, *Lepidosperma neesii* and Pouched Coral Fern, covering an area of approximately 0.5 hectares (Plate 3).

The western extent of S15B continues to have seedling recruitment and growth of *Eucalyptus* spp. in areas mapped in spring 2016, and was noted between transects S15B –V1 and S15B – P5. The established trees observed within the southern edges of the swamp continue to show vigorous growth through an increase in height and development of a low canopy. This growth was also evident in the LiDAR and UAV imagery data analysis; with a reduction in swamp extent in the western portion of the swamp. This was predominantly attributed to growth of Banksia Thicket and Tea-tree Thicket above 8 metres and eucalyptus canopy encroachment around the edge of the swamp. Overall trends identified during UAV imagery analysis are discussed further in Section 3.3.

Plate 1. Dieback of restioid heath within an area of Swamp 15B at photopoint P2 (15/08/2019).

Plate 2. Vegetation dieback (approximately 100 m²) within Swamp 15B recorded between Swamp 15B – V3 and Swamp 15B – V2 (25/06/2018).

Plate 3. Dieback of ground layer vegetation at Swamp 15B – V3 (15/08/2019).

### 3.2.2 Swamp 1A

Since the initial observation in spring 2015, Needlebush within Swamp 1A has continued to show yellowed foliage and stunted new growth. The yellowing is concentrated between 288904.17 E; 6193991.89 N and 288849.33 E; 6193909.71 N (Plate 4) with yellowed plants recorded more often from this area to the south-west towards monitoring point S1A – V1. The dieback surrounding S1A – V1 has increased in area, apparent as yellowed Needlebush. No signs of yellowing of Needlebush was observed at the drainage line along the north-west edge of the swamp.

Dieback of cyperoid heath was also observed within the areas surrounding S1A - V1 and S1A - V3. Extensive areas of dead ground cover vegetation were recorded, including death of Buttongrass, *Leptocarpus tenax* and *Schoenus brevifolius*. Razor Sedge was showing visible signs of stress, with remaining living vegetative material yellowing (Plate 5). The complete dieback shown in Plate 5 has occurred since Autumn 2017. The photo-points for S1A-P3 are also showing reductions in vegetation cover for Buttongrass, Wire Sedge, Pouched Coral Fern and *Sprengelia incarnata* (Plate 6 and Plate 7).

**Plate 4. Area of Needlebush within Swamp 1A showing signs of vegetation stress by yellowing (09/07/2018).**

**Plate 5.Dieback of cyperoid heath at the boundary of Banksia Thicket vegetation at S1A – V3 (08/08/2019).**

**Plate 6. Reduction in vegetation cover at S1A-P3 (08/11/2019).**

**Plate 7. Reduction in vegetation cover to the north of S1A-P3 (08/08/2019).**

### 3.2.3 Swamp 5

Monitoring of Swamp 5 began in 2012, with mining within the RMZ and mining beneath the swamp beginning in 2013. Observations at S5-P3 indicate that swamp groundcover has greatly reduced when comparing control to post impact photo point images shown in Plate 8 to Plate 9. The images show clear reductions in Pouched Coral Fern and Wire Rush have occurred.

Results of piezometric monitoring, directed at shallow groundwater levels and monitoring of soil moisture profiles undertaken by the Illawarra Metallurgical Coal Field Team, at this swamp indicate a decreasing trend in groundwater availability since the swamp was mined beneath in 2013 (Biosis 2016). However, annual rainfall for 2013 was 970.8 mm, which is above the average of 844.6 mm (station number 68166). Annual rainfall in the following years was below the total recorded in 2013, and also below average in 2014, 2017, 2018 and 2019 (Table 4). Reduced rainfall is, therefore, likely to have also contributed to the reduction of cover of swamp vegetation.

A trending decline in total swamp extent and the extent of previously mapped upland swamp vegetation communities were identified in 2019 LiDAR data (Section 3.3). Ongoing field validations of this decline has identified a trending decline in the extent of Banksia Thicket and Tea-tree Thicket communities for three consecutive monitoring periods. The limited amount of pre-mining data for Swamp 5 needs to be taken into account when drawing conclusions from the monitoring data. However, pairing the site observations with the reduced swamp vegetation community extents may indicate a reduced degree of resilience at Swamp 5 to drying conditions following mining.

**Plate 8. Swamp 5 – P3 (East - Spring 2013) the year of mining within the RMZ and mining beneath (26/11/2013).**

**Plate 9. Swamp 5 – P3 (East - Autumn 2019) showing reduction of Pouched Coral Fern and Wire Rush (07/08/2019).**

Plate 10. Swamp 5 – P3 (North - Spring 2013) prior to mining (26/11/2013).


Plate 11. Swamp 5 – P3 (North- Spring 2017) showing reduction of Pouched Coral Fern and Wire Rush (07/11/2019).

Plate 12. Swamp 5 – P3 (South - Spring 2013) prior to mining (26/11/2013).

Plate 13. Swamp 5 – P3 (South- Autumn 2017) showing reduction of Pouched Coral Fern and Wire Rush (02/05/2017).

Plate 14. Swamp 5 – P3 (West - Spring 2013) prior to mining (26/11/2013).

Plate 15. Swamp 5 – P3 (West - Spring 2019) showing reduction of Pouched Coral Fern and Wire Rush (07/11/2019).

## 3.3 LiDAR mapping of upland swamp extents

### 3.3.1 Total swamp area

Total swamp area was assessed based on a differential canopy height of 8 metres to determine swamp margins with the 2014 data set used as the baseline, in accordance with recommendations made in Biosis (2017).

The total area of all upland swamps decreased in 2019, relative to the 2014 baseline (Figure 9). This trend was observed across all impact and control swamps assessed. This is a continuation of the same trend identified in 2017 (Biosis 2018). The total area of all upland swamps was also found to decrease between 2017 and 2019. The overall extent of the smaller control swamps (S89, S91, S92 and S93) remained relatively stable during the 2014 to 2017 period, but show small but more marked decreases in the 2019 data relative to the other years. The changes observed in impact swamp total areas appear to be comparable to those observed at the control swamps, indicating that catchment scale conditions, rather than mining impacts are driving the reduction in total swamp area.

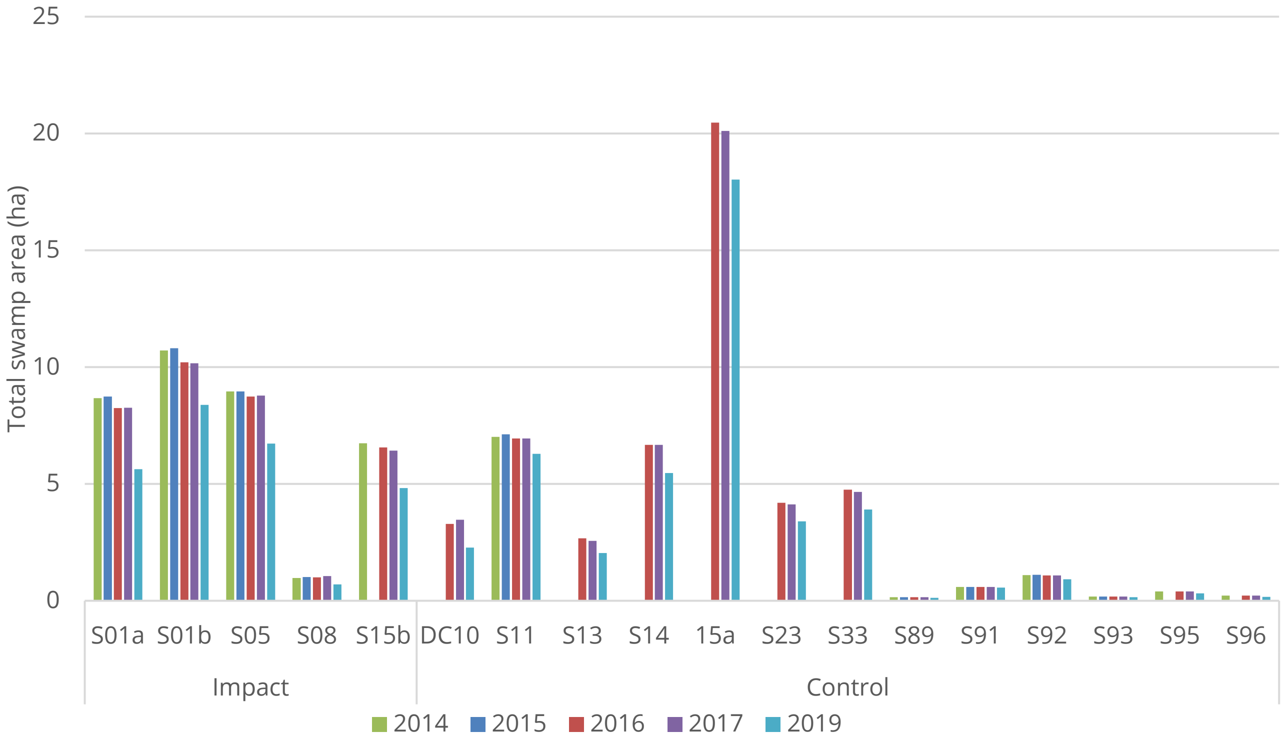



**Figure 9 Total upland swamp area from 2014 to 2019**

### 3.3.2 Percentage change in swamp extents

The percentage change in swamp extent for each year when compared to the baseline data of 2014 is shown in Figure 10. These percentage changes are large, and must be considered in the context of actual swamp area (Figure 9), which are substantial but do not appear as dramatic as presented in Figure 10. The swamp extent change from the baseline for 2019 is expressed by a decline in percentage change across all swamps (both control and impact). This trend was reflected in the majority of swamps in 2017 and 2016, however the 2017 data shows a marked difference in the extent of the relative percentage change across all swamps. The average reduction in swamp extent observed across impact sites in 2019 compared to baseline was 25.04%, and 13.53% across control sites. The greatest reduction in swamp extent at impacted swamps in 2019 was observed at S1A, where swamp extent has declined by 32.22% relative to baseline. With the greatest reduction of the control swamps being 22.69%, observed at S96.


**Figure 10 Percentage change in upland swamp extent from baseline (2014)**

Figure 10 shows that the relative percentage change experienced at impact sites is greater than that recorded at the control sites, when they are considered as groups. Considering this trend is observed in all monitoring periods, the changes observed in impact upland swamp extents between all years, when compared to the baseline, appear to be comparable to those observed at the control swamps. This supports the interpretation that the overall changes in total swamp area described in section 3.3.1 are consistent between impact and control sites. Given the trend in decreasing swamp extent can be observed across both impact and control swamps, the contributing forces behind these overall decreases can be attributed to changing catchment wide conditions.

### 3.3.3 Change in upland swamp vegetation communities

Changes in the extent of upland swamps is considered to be primarily driven by the proportion of more sensitive or robust vegetation communities, therefore analysis of the changes in extent of vegetation communities has been undertaken. Upland swamps within the study area are primarily comprised of five vegetation communities:

- Upland Swamp: Banksia Thicket (MU42).
- Upland Swamp: Tea-tree Thicket (MU43).
- Upland Swamp: Sedgeland-Heath Complex (Cyperoid heath) (MU44a).
- Upland Swamp: Sedgeland-Heath Complex (Restioid heath) (MU44b).
- Upland Swamp: Sedgeland-Heath Complex (Sedgeland) (MU44c).

The percentage change in mapped upland swamp vegetation communities averaged across the impact and control swamps from the 2014 baseline is shown in Figure 11 below. The percentage change is based upon mapping of communities conducted in 2012 and as such does not provide a fully reliable indication of communities on site at each swamp. Ground-truthing of vegetation communities would increase the reliability of these vegetation community extents.


**Figure 11 Percentage change in the average extent of mapped vegetation communities compared to the 2014 baseline**

The change in extent of vegetation communities within upland swamps from the baseline is most notable at impact sites, with declines from the 2014 baseline identified for all vegetation communities in 2019 (**Error! Reference source not found.**). This is a continuation of the trend across the impact sites, first recorded in 2014. Although the degree of change is increased in 2019.. A similar pattern has been observed across the control swamps, although the degree of change is not as great as that recorded at the impact swamps. This is also consistent with the trend observed of the change in total swamp extents. Variability, indicated by the standard error bars (**Error! Reference source not found.**), also tends to be greater at the impact sites and suggests that there may be a range of responses or resilience within the vegetation communities. For example, Sedgeland-Heath Complex (MU44c). It should be noted that Sedgeland-Heath Complex (Cyperoid heath) (MU44a) does not occur in the control swamps and is therefore only assessable via inferences of change over time.

**Error! Reference source not found.** compares the percentage change in upland swamp vegetation communities to the 2014 baseline for each impact swamp compared to the control sites as a group. Swamp S1A and swamp S5 recorded a reduction in Banksia Thicket (MU42), Tea-tree Thicket (MU43) and Sedgeland-Heath Complex (Restioid heath) (MU44b) that exceeded the degree of change observed within the control group. Swamp 1B recorded a reduction in Tea-tree Thicket (MU43) and Sedgeland-Heath Complex (Restioid heath) (MU44b) that exceeded the degree of change observed within the control group. Swamp S8 recorded a reduction in Banksia Thicket (MU42) that exceeded the degree of change observed within the control group. Swamp 15B recorded a reduction in Banksia Thicket (MU42), Tea-tree Thicket (MU43) and Swamp: Sedgeland-Heath Complex (Cyperoid heath) (MU44a) that exceeded the degree of change observed within the control group.

### 3.3.4 UAV imagery analysis

As swamp vegetation extent has until now primarily been monitored via LiDAR and compared to the initial pre-mining extents of swamp vegetation, ground-truthing the composition of vegetation under 8 metres, on the periphery of swamps, and areas of "non-swamp" vegetation greater than 8 metres was recommended for monitoring in 2019 (Biosis 2019). Ground-truthing was not undertaken as per this recommendation, however analysis of changes in swamp extent between 2014 baseline LiDAR data and 2019 LiDAR data was instead undertaken via interpretation of UAV imagery. UAV data was provided by Illawarra Metallurgical Coal for six impact swamps; S1B, S5, S11, S14, S15B and S23. Note- limited quality aerial imagery was available for control swamps. Following analysis of high resolution imagery, reasons attributed to reductions in swamp extent between these years were:

- encroachment by eucalypts, predominantly at the boundary of swamp vegetation and adjacent woodland;
- dieback of swamp species vegetative cover; and
- growth of swamp vegetation (particularly Banksia Thicket and Tea-tree Thicket) exceeding 8 metres in height.

Areas of swamp extent loss between 2014 and 2019 LiDAR data were assigned 'polygons' in ArcGIS, each of which were attributed a likely cause of swamp reduction and the resultant data calculated as a percentage, across all six swamps (Table 5) and across swamp vegetation communities (Table 6).

**Table 5 Interpretation of reduction in swamp extent based on UAV imagery**

| Reasons for observed loss in swamp extent between baseline and 2019 LiDAR data (%)% of reason attributed to loss in swamp extent between baseline and 2019 LiDAR data | | | | | | | |
|---|---|---|---|---|---|---|---|
| | S1B | S5 | S11 | S14 | S15B | S23 | Overall |
| **Eucalyptus encroachment** | 98.9 | 87 | 67 | 62 | 57 | 77 | 78 |
| **Dieback of swamp vegetation** | 0.4 | 12 | 12 | 32 | 5 | 9 | 8 |
| **Growth of swamp vegetation (Banksia Thicket and Tea-tree Thicket)** | 0.74 | 2 | 22 | 6 | 38 | 14 | 14 |

It is apparent that the majority of loss in swamp extent detected via LiDAR analysis is from encroachment of eucalyptus trees from adjacent woodland vegetation. The prolonged period of below average rainfall supports this shift in vegetation composition, with available groundwater reduced at the edges of swamps facilitating the encroachment of woodland species including eucalypts into areas previously occupied by species with a greater moisture tolerance, typical of a swamp community. In swamps S11 and S15B, for example, the growth of Banksia and Tea-tree Thicket has pushed the height of a proportion of swamp vegetation above 8 metres, therefore categorised as 'non-swamp vegetation' in LiDAR data (Figure 12). Dense Banksia Thicket is commonly observed in upland swamps following prolonged periods without fire (Keith 2007).


**Figure 12 Tea-Tree Thicket growth at the edge of S15B evident in the UAV imagery. Red polygons indicate a reduction in swamp extent between 2014 and 2019 LiDAR datasets.**

As seen within each swamp, eucalyptus encroachment was also the most common reason for swamp extent reduction when compared within vegetation communities; particularly apparent in restioid heath (Table 6Table 20). This aligns with infield observations where areas of eucalyptus encroachment have been observed; most often at the edge of swamps where restiod heath transitions to woodland vegetation along a decreasing soil moisture gradient (Figure 13**Error! Reference source not found.**). Reduction in swamp extent attributed to dieback was most frequently observed within cyperoid heath. Dieback was typically observed within the middle of swamps and along watercourses, rather than along the edges of swamps, and was evident as either bare areas devoid of vegetation or drying vegetation (Figure 14**Error! Reference source not found.**). This pattern of cyperoid heath dieback is consistent with infield observations of swamp dieback.

**Table 6 Interpretation of reduction in extent of swamp vegetation communities based on UAV imagery**

| Reason | Reasons for observed loss in swamp extent between baseline and 2019 LiDAR data (%) | | | |
|---|---|---|---|---|
| | Banksia Thicket | Tea-tree Thicket | Sedgeland-Heath Complex (Restioid heath) | Sedgeland-Heath Complex (Cyperoid heath) |
| **Eucalyptus encroachment** | 74 | 73 | 92 | 58 |
| **Dieback of swamp vegetation** | 4 | 22 | 8 | 31 |
| **Growth of swamp vegetation (Banksia Thicket and Tea-tree Thicket)** | 22 | 5 | 0 | 11 |

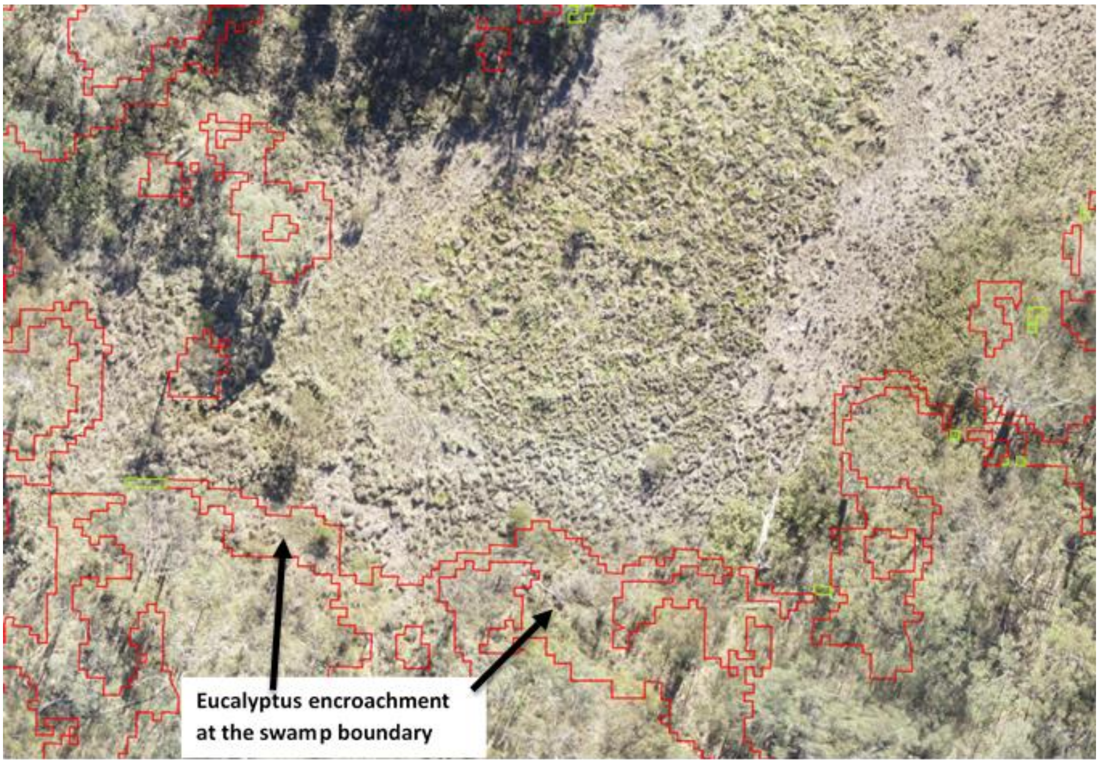



**Figure 13 Eucalyptus encroachment at S1B evident in the UAV imagery. Red polygons indicate a reduction in swamp extent between 2014 and 2019 LiDAR datasets.**

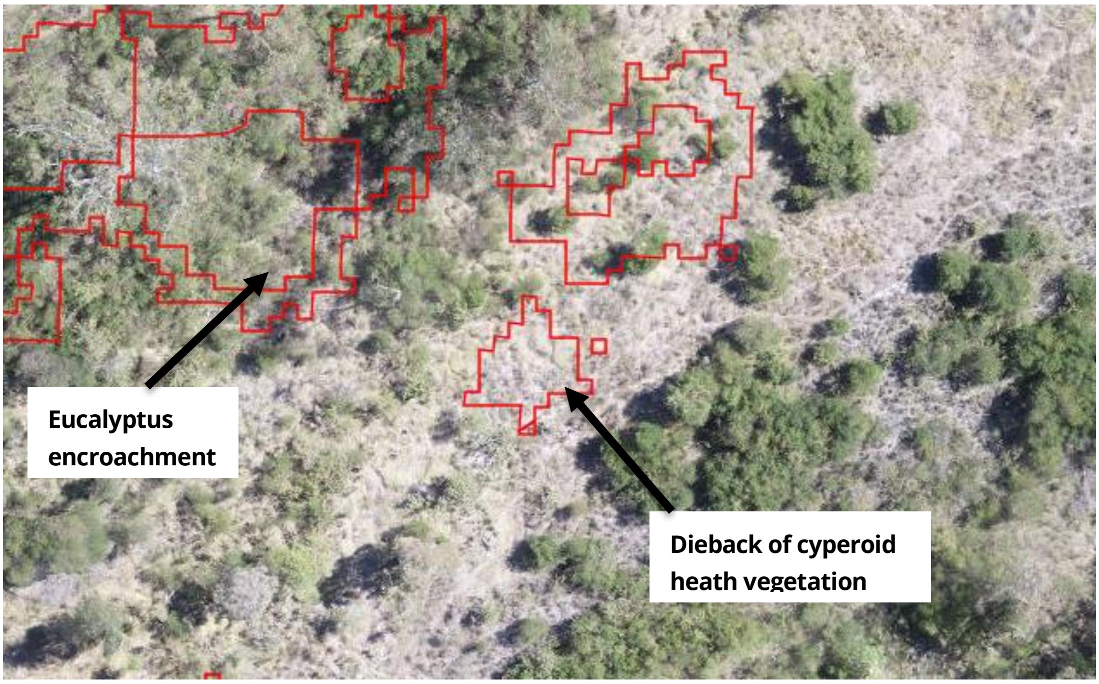



**Figure 14 Eucalyptus encroachment and dieback of restioid heath at S5 evident in the UAV imagery. Red polygons indicate a reduction in swamp extent between 2014 and 2019 LiDAR datasets.**

### 3.3.5 Potential catchment scale impacts

The trend of decreasing total swamp area in 2017, followed by a strengthening of that trend in 2019 can be observed across both impact and control swamps (Figure 9). This is supported by Figure 10, which shows the percentage decrease in swamp extent increasing markedly across all swamps in 2019. Therefore the contributing factors behind the decreasing swamp area are not associated with mining, given such impacts would be expressed and observed only at impact swamps. The LiDAR data suggests that catchment wide factors are considered to be a key driver of decreasing swamp extent in 2019.

Rainfall is a key factor likely to be influencing the change in extent of upland swamps each year, contributing to plant growth and habitat maintenance through surface infiltration and groundwater recharge. An examination of available rainfall data (Table 7) shows similarities in the years that recorded reduced swamp extents and reduced rainfall. Following a period of relative stability in 2014 to 2016, rainfall for the region was below the average of 844.6 mm in 2017, 2018 and 2019, with a continued trend of below average rainfall (Table 7). The percentage change in rainfall compared to the 2014 baseline year shows a decrease in 2017 and then a further marked decrease in 2019, which is proportionally similar to the percentage change experienced across the upland swamps during these periods. Reduced rainfall from 2017 to 2019, when compared to the 2014 baseline has likely played a key role in the reduction of upland swamp extents at both impact and control sites.

Periods of extended drying such as has been observed from 2017 to 2019 can be reasonably expected to result in changes to habitat or landscape features that are unfavourable to species that require a relatively high degree of soil moisture or water availability, such as upland swamp vegetation. Periods of extended drying can be expected to reduce water availability through decreased surface infiltration and groundwater recharge via rainfall. Periods of extended drying will also favour terrestrial species, through providing more suitable conditions for growth and establishment in areas of upland swamp that would have been previously too wet to occupy or be occupied by upland swamp species better adapted to wetter environments. Facilitating in turn an expansion of terrestrial species or communities in place of upland swamp vegetation.

**Table 7 Rainfall data between 2012 and 2019**

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019** |
|---|---|---|---|---|---|---|---|---|
| **Total annual rainfall (mm)** | 915.6 | 970.8 | 841.6 | 912.6 | 901.0 | 626.6 | 469.6 | 663.8 |
| **Percentage change in total rainfall per year compared to baseline (2014)** | - | - | - | 8.44% | 7.06% | -25.55% | -44.20% | -21.1% |

**Rainfall data has been derived from station number 68166 at Buxton (Amaroo) as a proxy for rainfall experienced at the monitoring swamps. **2019 Rainfall data is 12 months from April 2018 to April 2019 to facilitate analysis of the expanded "2018" dataset.*

However, in consideration of this, it is unlikely that during the observed drier than average conditions that terrestrial vegetation has expanded into upland swamps and attained a height of 8 metres. This further supports the requirement to reassess the use of the 8 metre height differential from the first and last returns, particularly for sub-communities MU42 and MU43 where the change recorded is more apparent. As these have a typically higher canopy than the MU44 (a,b,c) sub-communities.

## 3.4 Vegetation

### 3.4.1 Total species richness (TSR)

Exploratory analysis of the TSR data collected at each swamp suggests that richness is highly variable between years and in response to mining status (control or pre-mining, post-mining or mined beneath) (Figure 15). When averaged for all swamps, it appears that there is high variability in TSR, regardless of year or mining status. TSR may have less variability in post-mining areas compared to pre-mined areas, but areas that are mined beneath appear to be more variable. This is consistent with observations made in previous monitoring reports. Whether this is an artefact of the sampling (i.e. some swamps have only been sampled a few times), or real (e.g. the invasion of non-swamp species) cannot be determined from this analysis alone and as such analysis of species composition (Section 3.3.3) is undertaken to compliment TSR analysis.

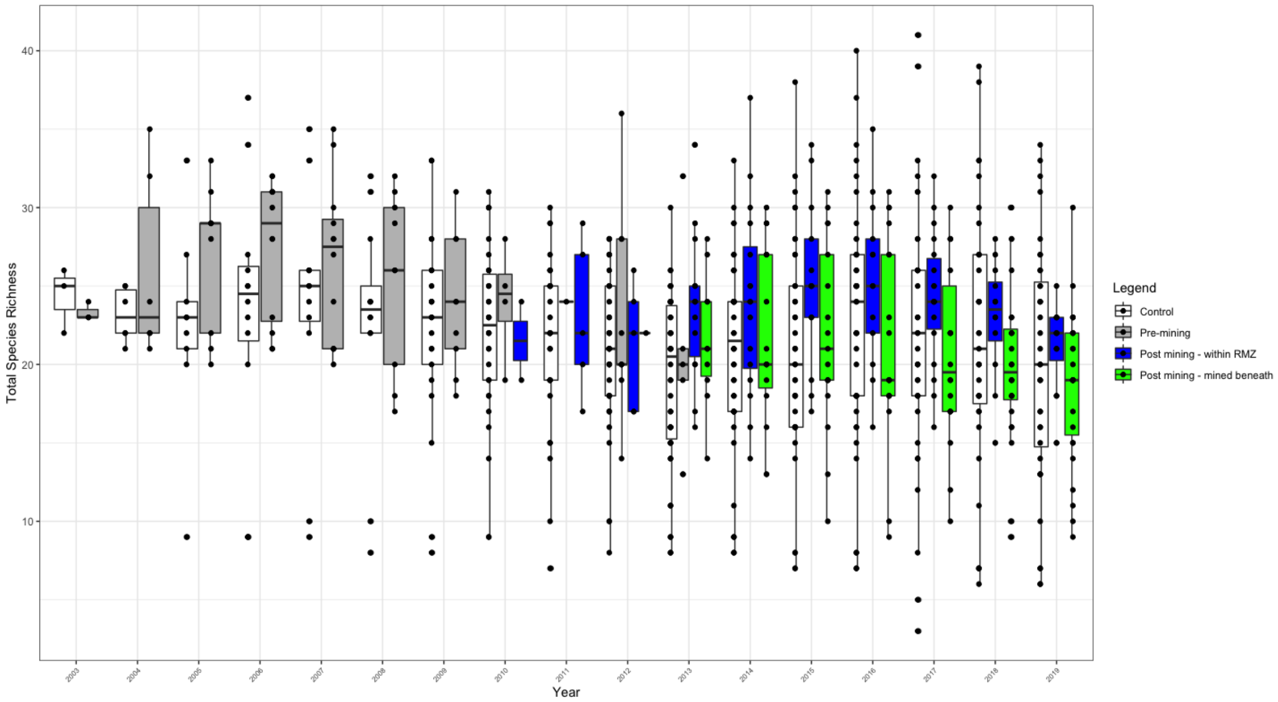



**Figure 15 Boxplot of total TSR each year at all surveyed swamps located in Dendrobium Area 3A and Dendrobium Area 3B and associated control sites.**

To further investigate trends in TSR, analyses were completed on a site-by-site basis in comparison to paired control sites.

#### Analysis of Swamp 15B (Dendrobium Area 3A)

Monitoring of Swamp 15B commenced in 2003 and was mined beneath in August 2012. The boxplot of TSR data for Swamp 15B contrasted against its paired control swamps indicates that prior to impact, TSR was more variable at control sites and typically yielded a lower TSR. This variability makes the detection of any small changes in TSR difficult.

Post-impact, TSR variability at the control sites appears to remain similar to that measured prior to impact (i.e. TSR variability remained large) while at impact sites, TSR is slightly lower than it was prior to impact (Figure 16).

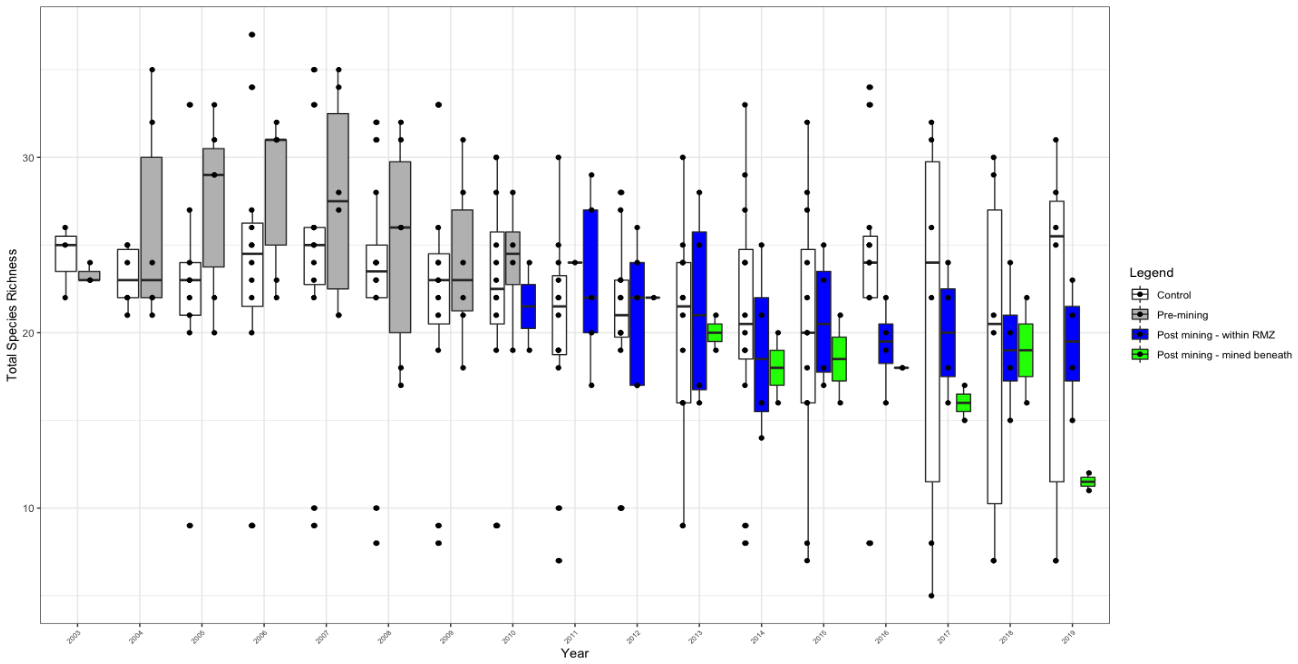



**Figure 16 Boxplot of TSR for each transect, at impact site S15B, contrasted against two paired control swamps (S15A(1) and S11).**

Figure 16**Error! Reference source not found.** outlines the change in TSR for Swamp 15B since mining within the RMZ in 2010. The median Post mining – mined beneath TSR has been below that of the Post mining – within RMZ, Control and Pre-mining groups since data collection began in 2013. The median TSR at S15B continues to be lower than the median TSR observed at control sites.

The decline in TSR in the first two four year periods examined immediately following mining within RMZ in 2010 was not significant at the α=0.05 level. However, a continued decline in TSR at impact Swamp 15B in the period 2012 through to 2019 resulted in a statistically significant reduction in TSR at the α=0.05 level, during a period of stability at control swamps. It is important to note that p values below the α =0.1 level are used to indicate that the level of change is approaching a higher degree of confidence regarding the statistical significance of the results.

The steadily decreasing p-value since commencement of monitoring at S15B indicates a reduction in TSR becoming increasingly significant following being mined beneath (Table 8). The results indicate a statistically significant reduction in TSR since Swamp 15B was mined beneath in 2012, remaining at a consistent difference in TSR and significance level since becoming mined beneath.

**Table 8 Results for t-tests of four-consecutive yearly difference in TSR between Swamp 15B and paired control swamps (S15A(1) and S11).**

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| **Four consecutive years of impact** | 2010, 2011, 2012, 2013 | -3.81 | 0.06 |
| | 2011, 2012, 2013, 2014 | -4.52 | 0.05 |
| | 2012, 2013, 2014, 2015 | -5.27 | 0.04 |
| | 2013, 2014, 2015, 2016 | -5.89 | 0.03 |
| | 2014, 2015, 2016, 2017 | -6.48 | 0.03 |
| | 2015, 2016, 2017, 2018 | -5.58 | 0.04 |

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| | 2016, 2017, 2018, 2019 | -7.19 | 0.02 |

**Table notes:** Those values identified in red indicate a statistically significant change detected at the α=0.05 level. Those in blue indicate statistically significant changed detected at α=0.1 level which provides for a conservative approach to detecting potential impacts. In consultation with Illawarra Metallurgical Coal, Biosis have identified changes significant at the α=0.1 level as an indicator of a pre-cursor to a potential future significant impact detected at the α=0.05 level. This will guide the early implementation of management actions to mitigate impacts. *As no Dendrobium Area 3A TARP for swamps are applicable, the assessment has applied the Dendrobium Area 3B TARP levels for assessment purposes.

### Analysis of Swamp 15A(2) (Dendrobium Area 3A)

Monitoring at S15A(2) commenced in 2009 and mining within the RMZ commenced in 2013; however no monitoring sites were mined beneath. Post-impact, variability at the control sites appears to remain similar to that measured prior to impact (i.e. was still large); and at impact sites variability in TSR (range) appears to be lower following impacts, particularly in 2018 and 2019 (Figure 17).

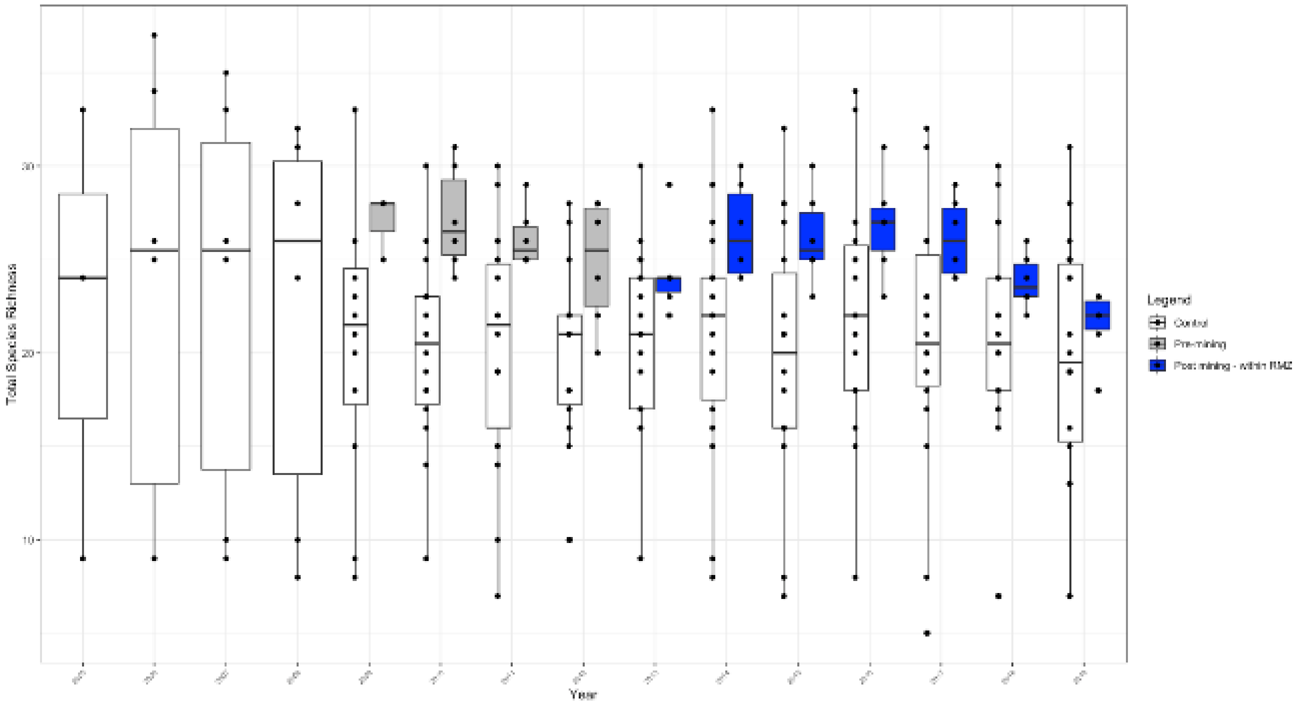



**Figure 17 Boxplot of the TSR for each transect at impact Swamp S15A(2), contrasted against two paired control swamps (S15A(1), S22 and S33).**

No statistically significant difference was detected in TSR at Swamp 15A(2) between the control and impact sites, regardless of time period. This is indicated by all p-values being greater than 0.05 (Table 9**Error! Reference source not found.**).

**Table 9 Results for t-tests to test any four-consecutive yearly difference in TSR at Swamp 15A(2) when compared to paired control swamps (S15A(1), S22 and S33).**

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| **Four consecutive years of impact** | 2012, 2013, 2014, 2015 | -0.62 | 0.76 |
| | 2013, 2014, 2015, 2016 | -0.33 | 0.95 |

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| | 2014, 2015, 2016, 2017 | 0.12 | 0.75 |
| | 2015, 2016, 2017, 2018 | -0.54 | 0.81 |
| | 2016, 2017, 2018, 2019 | -1.71 | 0.30 |

### Analysis of Swamp 1A (Dendrobium Area 3B)

Monitoring of S1A commenced in 2012, with mining within the RMZ for all three sites having commenced in 2013 and were mined beneath in 2013 and 2014. The boxplot of TSR data for S1A (Figure 18) contrasted against its paired control swamps suggest that TSR at control sites is similar to the TSR at post mining (mined beneath). Post-impact, there is only very minor overlap between swamps that have been mined beneath and transects that have experienced mining within the RMZ. In all years except 2018, swamps that have been mined beneath record a lower median TSR than that of the control swamps.

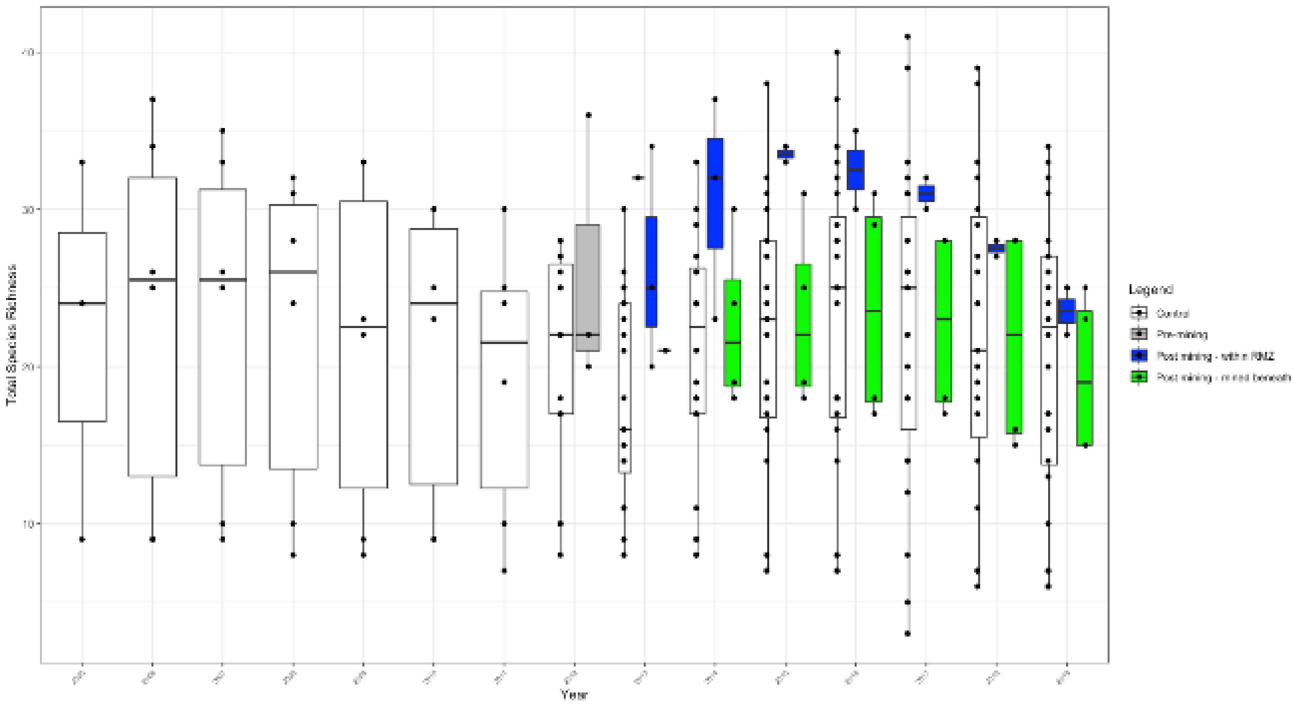



**Figure 18 Boxplot of the TSR for each transect at impact Swamp 1A, contrasted against three paired control swamps (S15A(1), S86, S87, and S88).**

None of the changes in TSR across monitoring years were found to be significantly different to TSR at paired control sites (p-values > 0.05, **Error! Reference source not found.**).

**Table 10 Results for t-tests to test for four-consecutive yearly difference in TSR at Swamp 1A when compared to paired control swamps (S15A(1), S86, S87, and S88).**

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| **Four consecutive years of impact** | 2013, 2014, 2015, 2016 | -2.88 | 0.31 |
| | 2014, 2015, 2016, 2017 | -2.76 | 0.33 |
| | 2015, 2016, 2017, 2018 | -3.38 | 0.27 |

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| | 2016, 2017, 2018, 2019 | -4.83 | 0.2 |

### Analysis of Swamp 1B (Dendrobium Area 3B)

Monitoring at S1B commenced in 2005, mining within the RMZ and beneath all three S1B sites occurred in 2013. The boxplot of TSR data for S1B compared with its paired control swamps, indicate that the pattern of change over time in median TSR are largely mirrored at control and impact sites, however a greater variability in TSR is observed at control sites. Post-mining, the changes in TSR at sites that were mined beneath appear to be comparable to the range of change in TSR recorded in the pre-mining data (Figure 19).

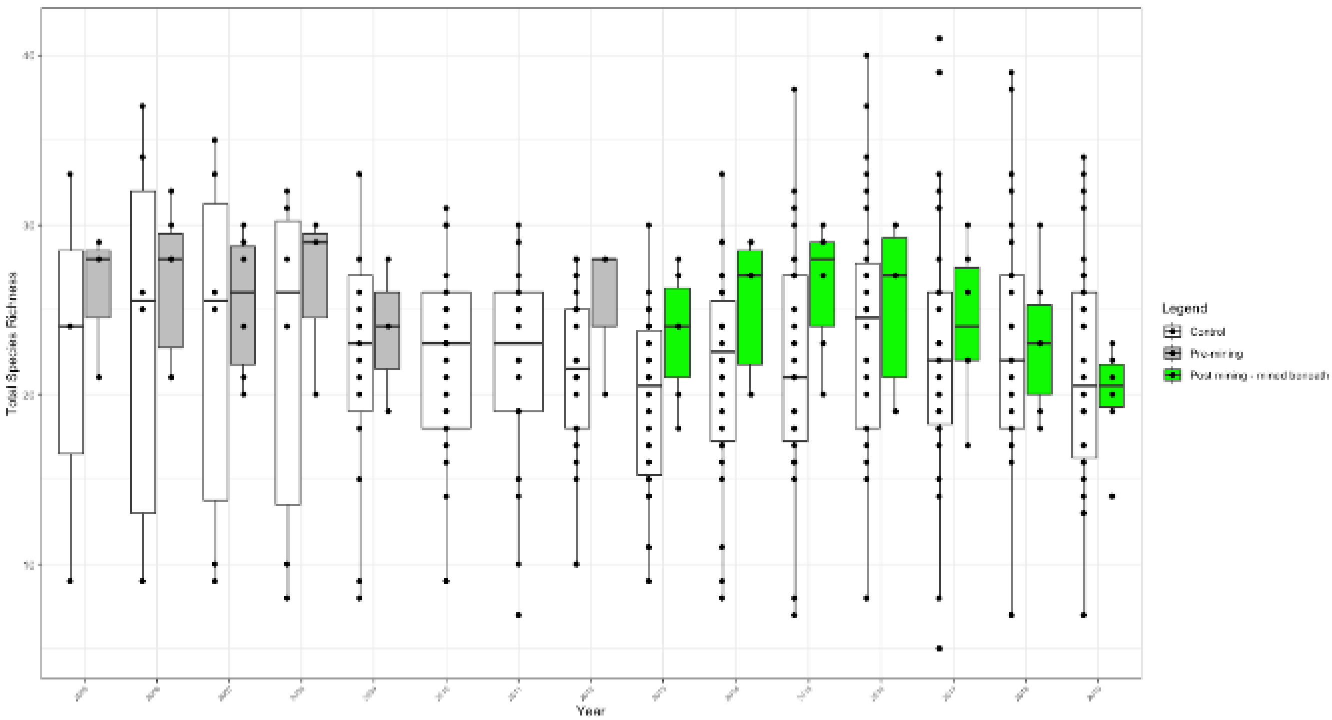



**Figure 19 Boxplot of the TSR for each transect, at impact Swamp 1B, contrasted against five paired control swamps (S15A (1), S86, S87, S22 and S33).**

No statistically significant difference was detected in TSR between the control and impact sites, regardless of time (p-values > 0.05) (Table 11).

**Table 11 Results for t-tests to test four-consecutive yearly difference in TSR at Swamp 1B when compared to paired control swamps (S15A(1), S86, S87, S22 and S33).**

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| **Four consecutive years of impact** | 2013, 2014, 2015, 2016 | -0.43 | 0.57 |
| | 2014, 2015, 2016, 2017 | -0.26 | 0.6 |
| | 2015, 2016, 2017, 2018 | -0.81 | 0.5 |
| | 2016, 2017, 2018, 2019 | -2.43 | 0.3 |

### Analysis of Swamp 5 (Dendrobium Area 3B)

Monitoring at S5 commenced in 2012 and mining within the RMZ commenced in 2013. Mining beneath S5 commenced in 2013 and continued through to 2015. The boxplot of TSR data for S5 (Figure 20) demonstrates that while the median TSR post mining is typically lower than that of the control swamps, it is within the range observed at control sites. Variability at control sites is greater than that observed at impact sites; however, minimal change in TSR has been observed post-mining.

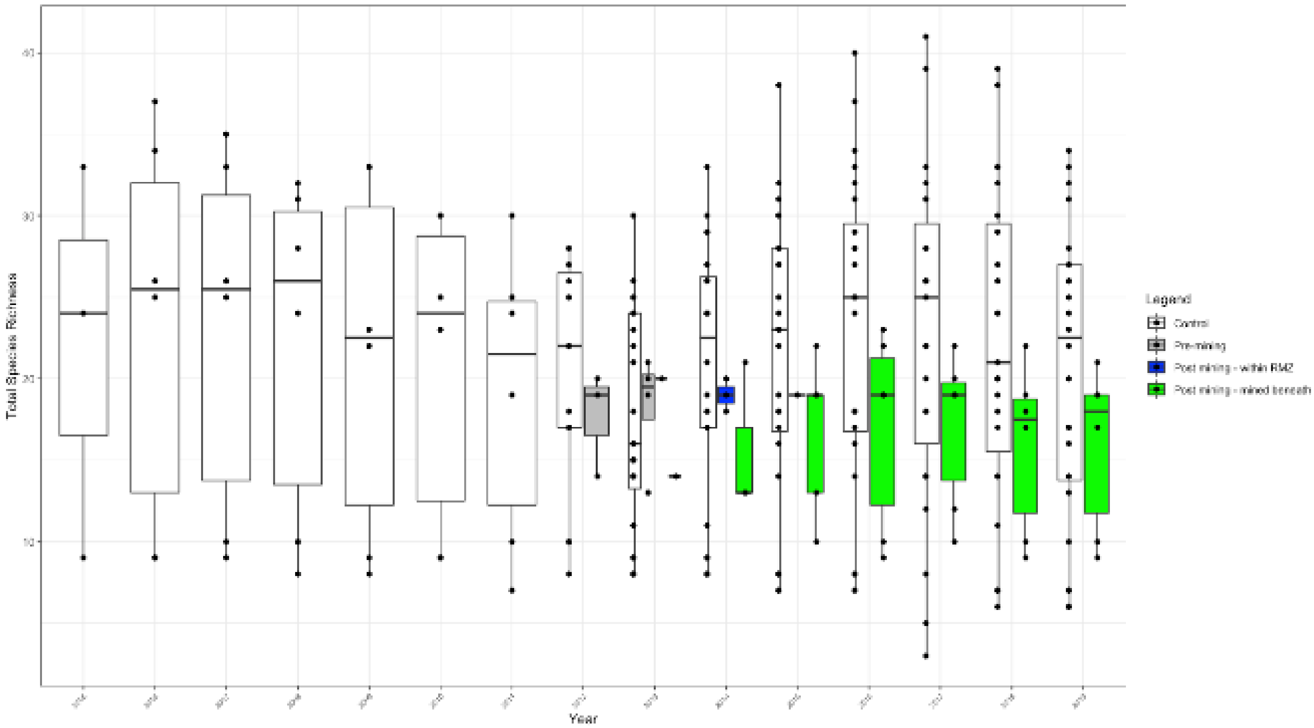



**Figure 20 Boxplot of the TSR for each transect, at impact Swamp 5, contrasted against two paired control swamps (S15A(1), S86, S87 and S88).**

No statistically significant difference was detected in TSR between the control and impact sites, regardless of time (p-values > 0.05) (Table 12).

**Table 12 Results for t-tests to test any four-consecutive yearly difference in TSR at Swamp 5 when compared to paired control swamps (S15A(1), S86, S87 and S88).**

| Change in TSR tested | Years tested | Difference in TSR | p-value |
|---|---|---|---|
| **Four consecutive years of impact** | 2013, 2014, 2015, 2016 | -0.88 | 0.59 |
| | 2014, 2015, 2016, 2017 | -0.88 | 0.59 |
| | 2015, 2016, 2017, 2018 | -1.25 | 0.53 |
| | 2016, 2017, 2018, 2019 | -1.54 | 0.49 |

### 3.4.2 Species composition

All data for each monitoring site was combined to analyse changes in flora species composition over time using a multivariate presence-absence model. Statistically significant yearly, and occasionally seasonal, trends in species composition were detected at most sites, regardless of mining area (Dendrobium Area 3A or 3B) or treatment (control or impact sites) when applying a conservative 0.1 alpha significance threshold.

In addition to the yearly and seasonal trends across all sites, a statistically significant change in species composition, comparing pre-mining to post-mining, was found at two of the six sites; Swamp 15B and Swamp 1B. At the remaining sites there is no statistical significance in floristic composition when compared to before and after mining and between control and impact sites.

### Analysis of Swamp 15B (Dendrobium Area 3A)

A total of 63 unique species have been detected at Swamp 15B, of which 11% have only been detected on one occasion. A background yearly-trend in species composition was found to be statistically significant at the α=0.05 level across all years. This is not surprising, as it is reasonable to expect natural species turnover to occur at the swamp. However, a statistically significant change in species composition at the α=0.05 level was detected two, three and four consecutive years following mining, commencing in 2013 (Table 13). This indicates a long term shift in the flora species comprising the Swamp 15B community.

**Table 13 Results of four consecutive yearly comparisons of species composition at Swamp 15B assessing TARP Level 3**

| Change in species composition tested | Years tested | Statistically significant change in species composition before and after mining (p-value) |
|---|---|---|
| **Four consecutive years of impact** | 2010-2013 | 0.053 |
| | 2011-2014 | 0.064 |
| | 2012-2015 | 0.15 |
| | 2013-2016 | 0.042 |
| | 2014-2017 | 0.052 |
| | 2015-2018 | 0.037 |
| | 2016-2019 | 0.032 |

**Table notes:** Those values identified in red indicate a significant change detected at the α=0.05 level. Those in blue indicate a statistically significant change detected at α=0.10 level which provides for a conservative approach to detecting potential impacts and has been treated with caution and further ecological interpretation for the purposes of this assessment. *As no Dendrobium Area 3A TARP for swamps are applicable, the assessment has applied the Dendrobium Area 3B TARP trigger levels.

Some species were consistently found to be less common following impact (e.g. *Goodenia dimorpha, G. stelligera, G. bellidifolia* species complex), whereas other species were consistently found to be more common after impact (e.g. *Tetraria capillaris*).

When considering the most recent four year period, 2016 to 2019, the following five species were found to be the key indicators of change:

- *Tetraria capillaris* (increasing in abundance, since 2012).
- *Goodenia dimorpha, G. stelligera, G. bellidifolia* species complex (decreasing since 2010).
- *Xanthosia dissecta. pilosa. tridentata* species complex (decreasing since 2015).
- *Platysace linearifolia* (decreasing since 2010).
- *Monotaxis linifolia* (decreasing since 2016).

Although not ranked within the top five most influential species within the most recent four year period (2016-2019), *Lepidosperma neesii/Ptilothrix deusta* sp. complex has also been consistently increasing in abundance at this swamp. Of the taxa indicating change, *Lepidosperma neesii/Ptilothrix deusta* sp. complex, along with *Tetraria capillaris*, typically prefer moist, free-draining sandy soils. Whereas, *Goodenia dimorpha stelligera bellidifolia* complex is characteristic of shallow, free draining heath and mallee-heath within the Woronora plateau (NPWS 2003) and swamps (Harden 1992). This species complex has a low tolerance to dry soils. This indicates that species composition is becoming dominated by species that prefer drier soils (while still common upland swamp species), most frequently observed in Restioid Heath (MU44b) communities, as opposed to species preferring water-logged substrate.

### Analysis of Swamp 15A(2) (Dendrobium Area 3A)

A total of 63 unique species have been detected at Swamp 15A(2), of which 5% have only been detected on one occasion. A background yearly-trend in species composition was not found to be statistically significant at the α=0.05 level across all years. A statistically significant change in species composition at the α=0.05 level was not detected for any period following mining (Table 14).

**Table 14 Results of four consecutive yearly comparisons of species composition at Swamp 15A(2) assessing TARP Level 3**

| Change in species composition tested | Years tested | Statistically significant change in species composition before and after mining (p-value) |
|---|---|---|
| **Four consecutive years of impact** | 2013-2016 | 0.966 |
| | 2014-2017 | 0.807 |
| | 2015-2018 | 0.533 |
| | 2016-2019 | 0.525 |

**Table notes:** *As no Dendrobium Area 3A TARP for swamps are applicable, the assessment has applied the Dendrobium Area 3B TARP trigger levels.

Some species were consistently found to be more common prior to impact (e.g. *Banksia spinulosa* and *Gonocarpus* sp. complex), whereas other species were consistently found to be more common after impact (e.g. *Bauera microphylla–B rubioides* sp. *complex* and *Lepidosperma neesii/Ptilothrix deusta* sp. complex).

Previous results at this swamp indicated a trend in increasing density of Banksia Thicket associated with prolonged fire absence (Biosis 2019). Infield observations detected drying and dieback of Heath Banksia at this swamp in 2019. The above statistical results support the field observations at this swamp; indicating dieback of Banksia Thicket, likely associated with prolonged drought. Coupled with a decrease in shallow groundwater retention as indicated by the piezometer data, drying of swamp vegetation is evident, facilitating the increased density of species tolerant of dry soils including *Lepidosperma neesii/Ptilothrix deusta* sp. complex.

### Analysis of Swamp 1A (Dendrobium Area 3B)

A total of 61 unique species have been detected at Swamp 1A, 2% of which have been detected only once during the monitoring program. No statistically significant change in species composition was identified in any of the monitoring periods examined (Table 15).

**Table 15 Results of four consecutive yearly comparisons of species composition at Swamp 1A assessing TARP Level 3**

| Change in species composition tested | Years tested | Statistically significant change in species composition before and after mining (p-value) |
|---|---|---|
| **Four consecutive years of impact** | 2013-2016 | 0.829 |
| | 2014-2017 | 0.976 |
| | 2015-2018 | 0.892 |
| | 2016-2019 | 0.634 |

Some species were consistently found to be more common prior to impact (e.g. *Tetrarrhena turfosa–Hemarthria uncinata* sp. complex and *Drosera binata*), whereas other species were consistently found to be more common after impact (e.g. *Lepidosperma filiforme–L. urophorum* sp. complex). This indicates a trend favouring species preferring dry soils. *Drosera binata* particularly thrives in well sheltered, damp microhabitats.

### Analysis of Swamp 1B (Dendrobium Area 3B)

A total of 62 unique species have been detected at Swamp 1B, of which 8% have only been detected on one occasion. A background yearly-trend in species composition was found to be statistically significant at α=0.05 level across all years. Such trends are indicative of natural turnover of species within upland swamps in response to seasonal and annual variability in climate, as well as stochastic factors including nutrient availability.

No significant interaction has been detected between monitoring periods at this swamp to date. However, comparison between 2018 and 2019 results indicate a significant change in species composition at α=0.05 for this period (p = 0.008). Analysis of the compositional data for this period indicated that *Grevillea patulifolia–G. sericea–G.* speciosa sp. complex and *Tetrarrhena turfosa–Hemarthria uncinata* sp. complex are indicators of change in species composition. These species were more common at this swamp prior to being mined beneath. These species groups have a preference for moister areas of heath (Harden 1992), indicating a progressive drying of soil is occurring at this swamp.

The monitoring results suggest that species composition at this swamp has not changed to a significant degree post impact. However, in the two most recent periods of analysis, the statistical change is approaching, the α=0.05 level (Table 16**Error! Reference source not found.**). It appears that following being mined beneath in 2013, Swamp 1B has reduced resilience to environmental stressors such as the recent prolonged periods of below average rainfall.

**Table 16 Results of two, three and four consecutive yearly comparisons of species composition at Swamp 1B assessing TARP Level 3**

| Change in species composition tested | Years tested | Statistically significant change in species composition before and after mining (p-value) |
|---|---|---|
| **Four consecutive years of impact** | 2013-2016 | 0.666 |
| | 2014-2017 | 0.489 |
| | 2015-2018 | 0.074 |

| Change in species composition tested | Years tested | Statistically significant change in species composition before and after mining (p-value) |
|---|---|---|
| | 2016-2019 | 0.062 |

Analysis of the compositional data from 2016-2019 indicated that some species were consistently found to be more common at Swamp 1B prior to impact (e.g. *Amperea xiphoclada* and *Sprengelia incarnata*), whereas other species were consistently found to be more common after impact (e.g. *Hypericum japonicum–H. gramineum* sp. complex *and Caesia parviflora* var. *parviflora*). These species are not considered to be indicator species indicative of changing swamp vegetation composition, thus the change in occurrence of the above species since the commencement of monitoring do not indicate a definitive trend in vegetation composition change that can be attributable to impacts from mining and/or drying conditions. Given a statistically significant result has been detected for 2018-2019, continued analysis of species compositional change will be imperative to determining the most likely reason for a shift in species at this swamp.

### Analysis of Swamp 5 (Dendrobium Area 3B)

A total of 44 unique species have been detected at Swamp 5, of which 7% have only been detected on one occasion. No yearly trends in species composition were found to be statistically significant. No significant change in species composition was identified when comparing the pre and post mining impact data (Table 17).

**Table 17 Results of four consecutive yearly comparisons of species composition at Swamp 5 assessing TARP Level 3**

| Change in species composition tested | Years tested | Statistically significant change in species composition before and after mining (p-value) |
|---|---|---|
| **Four consecutive years of impact** | 2013-2016 | 0.439 |
| | 2014-2017 | 0.800 |
| | 2015-2018 | 0.794 |
| | 2016-2019 | 0.493 |

Some species were consistently found to be more common prior to impact (e.g. *Sprengelia incarnata* and *Grevillea patulifolia–G. sericea–G. speciosa* sp. complex), whereas other species were consistently found to be more common after impact (e.g. *Grevillea oleoides*). All of these species are recorded from heath environments. Interestingly, *G. oleoides* and *G. patulifolia*, for example, both have a preference for moister areas of heath, indicating that there may be localised patches of drying surrounded by areas that are retaining moisture within this swamp. Continued monitoring of the changes in species composition within Swamp 5 will be important in determining the drivers for change observed in the field (Section 3.2.3).

## 3.5 Littlejohn's Tree Frog transect monitoring

A summary of the Littlejohn's Tree Frog data for all lifecycle stages (i.e. adult, tadpole or egg mass) that were recorded in winter 2019 is provided in Table 19. Littlejohn's Tree Frogs were detected in at least one lifecycle stage at seven of the nine post-mining (mined beneath and within RMZ) impact sites monitored. The species was detected at both of the two pre-impact sites. The species was also recorded at nine of the ten control sites.

When considering the 2019 overall detection results in the broader context of previous years of monitoring the 2019 results are relatively low, especially in comparison to 2016 which was a successful year for breeding due to high levels of rainfall (with results much higher in 2016 than previous years). This is in line with expected trends in the data given the extended drought through 2019, with field observations noting widespread pool drying and associated reductions in habitat as well as the reduced rainfall resulting in fewer triggers for breeding behaviour. When considering the 2019 data across all sites against those recorded in 2018, the 2019 results recorded marked increase in detection of adult and tadpole life stages of Littlejohn's Tree Frog, but a decrease in the detection of egg mass (Table 18). A number of factors, and combinations of these factors, may be at play here given the relatively similar environmental conditions between the 2018 and 2019 years of survey. Reduced eggmass detection and increased tadpole detection may indicate that survey timing has coincided more frequently with transition from eggmass to tadpoles. The very low rainfall conditions through the 2018 and 2019 periods may have also encouraged a greater proportion of tadpoles to overwinter from 2018, increasing the 2019 numbers detected. The reduction in eggmass may also be indicative of more limited triggers or opportunities for breeding due to the limited rainfall in 2019.

**Table 18 Total Littlejohn's Tree Frog detection by life stage for years 2018 and 2019**

| Total abundance per year | Adult | Eggmass | Tadpoles |
|---|---|---|---|
| **2019** | 237 | 310 | 4129 |
| **2018** | 122 | 673 | 764 |

Over the long-term, the abundance of all life stages detected has varied substantially year to year, at both impact and control sites. This can be seen at the individual site level in 2019 results and likely indicates a differing response to any sporadic rainfall recorded throughout the breeding (and monitoring) season and is likely to be exacerbated in 2019 following the extended drought and limited opportunities or triggers for breeding. The reduced detection of the species during 2019 was apparent at both control and impact sites, and is therefore considered to be a reflection of lower regional rainfall during and preceding the survey period. This reduction in detection is explored in detail for each impact monitoring site in sections 3.3.1 and 3.3.2.

**Table 19 Summary of the results from the winter 2019 threatened frog monitoring**

| Site | Total number recorded | | |
|---|---|---|---|
| | Adult | Eggmass | Tadpoles |
| **Control** | | | |
| **DC8** | 8 | 24 | 100 |
| **ND1** | 9 | 70 | 380 |
| **ND2** | 0 | 0 | 0 |
| **NDC** | 13 | 0 | 9 |
| **SC7(1)** | 17 | 23 | 125 |
| **SC7(2)** | 2 | 8 | 60 |
| **SC7A** | 7 | 23 | 519 |

| Site | Total number recorded | | |
|---|---|---|---|
| | Adult | Eggmass | Tadpoles |
| **SC8** | 4 | 9 | 2 |
| **WC10** | 110 | 38 | 684 |
| **WC11** | 2 | 5 | 841 |
| **Pre-mining** | | | |
| **LA2** | 19 | 16 | 353 |
| **Post-mining sites (within RMZ)** | | | |
| **6CDL** | 0 | 0 | 50 |
| **DC(1)** | 2 | 1 | 4 |
| **SC10(1)** | 15 | 23 | 27 |
| **SC10(2)** | 9 | 66 | 862 |
| **LA4A** | 0 | 0 | 0 |
| **Post-mining sites (mined beneath)** | | | |
| **DC13** | 0 | 0 | 9 |
| **SC10C** | 0 | 0 | 0 |
| **WC15** | 7 | 0 | 2 |
| **WC17** | 4 | 0 | 2 |
| **WC21** | 9 | 4 | 100 |

Subsidence related impacts including cracking of bedrock, lowering of water levels and build-up of iron flocculent have been recorded at sites SC10C, SC10(1), WC17, WC21, DC1 and DC13, with each of these sites triggering either Level 1 (SC10(1), DC1) or Level 3 (SC10C, WC17, WC21 and DC13) of the *Dendrobium Area 3 Watercourse TARP* (Illawarra Coal 2015a). This is discussed further in Sections 4.1.3 and 4.2.2.

### 3.5.1 Dendrobium Area 3A

#### Sandy Creek and tributaries

Sandy Creek and its tributaries form part of a large and significant sub-population of Littlejohn's Tree Frog. This sub-population includes the creek as well as a number of tributaries including SC10C, SC10(1), SC10(2), 6CDL, SC7(1), SC7(2), SC7A and SC8. A number of the transects are on waterways that are interconnected (e.g. SC10C with SC10(1) and SC10(2), SC7(1) with SC7(2) and SC7A. It is considered likely that the species moves throughout this area in response to a number of environmental variables and seasonal cues.

#### SC10C

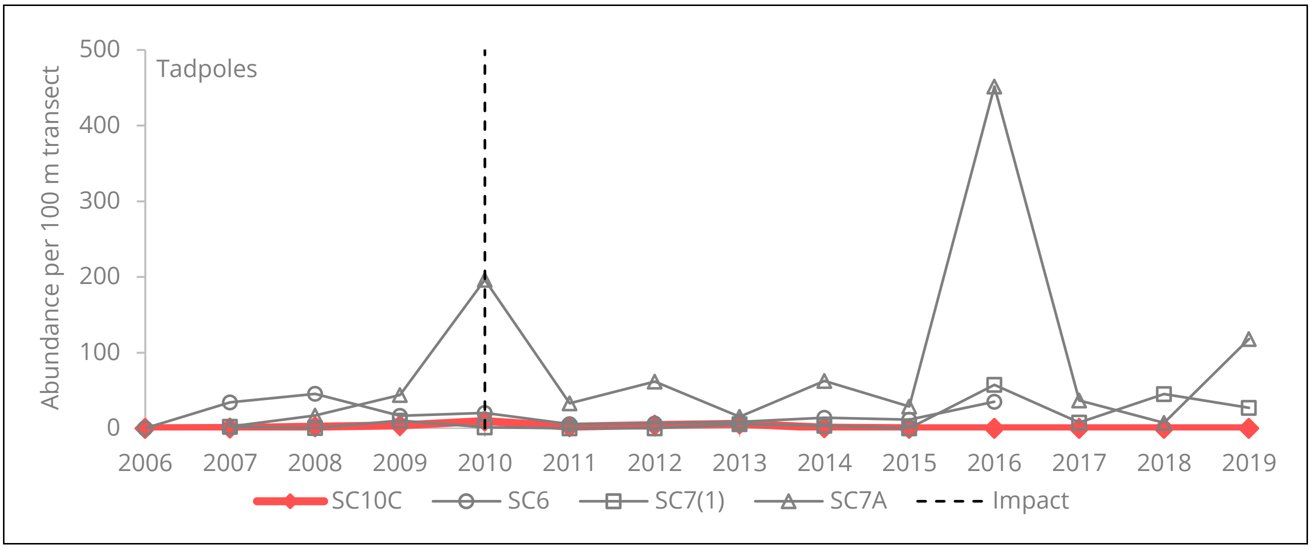
Mining within the RMZ of transect SC10C occurred in October 2010, with mining beneath the transect in October 2012. Transect SC10C is approximately 460 metres in length with 11 potential breeding pools identified, however water was restricted to the most downstream three pools along the transect in 2019. The substrate of each was covered with flocculent, consistent with previous observations at this site. All other pools along the transect were dry. No Littlejohn's Tree Frogs of any life stages were detected in 2019, Figure 21. The numbers of Littlejohn's Tree Frog detected at this transect are typically low, with tadpoles not being observed since 2015.

Littlejohn's Tree Frog tadpoles and eggmasses have been detected at SC10C in consistently low numbers over the past 13 years of monitoring, and small fluctuations do not appear to be associated with timing of mining. However a decline in the abundance of adult frogs was observed following subsidence impacts detected at

SC10C resulting from the extraction of Longwall 7 and Longwall 8 during 2011 and 2012 (two years after the initial mining within the RMZ), and numbers have not recovered (Figure 21).

In 2019, as in 2018, the low number of adults was also consistent with patterns seen at control sites, and so it is difficult to separate seasonal patterns and those associated with mining impacts given the low levels of rainfall. Due to the continuation of this pattern and given the limitation of applying frog species in the relevant TARPs, it is determined that SC10C continues to trigger Level 1 of the revised *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012)* (Illawarra Coal 2012c), i.e. no significant statistical difference between Before After Control Impact sites. This assessment is consistent with that made in the annual monitoring report for 2017 (Biosis 2018) and 2018 (Biosis 2019) and is discussed further in Section 4.2.2. Further monitoring at this transect in seasons with greater rainfall will assist in evaluating these trends further.

The decline in abundance of adult frogs at SC10C appears to be correlated with reductions in the pool water levels along the transect following the extraction of Longwall 7 and Longwall 8, as observed since 2012 (Biosis 2013a). In 2018, very high levels of iron flocculent were observed throughout the site, consistent with previous years, and most pools remained dry. Follow up monitoring of identified breeding habitat pools at the site conducted in summer 2016/2017 concluded that most pools were unable to retain water for a sufficient period after the winter breeding season for tadpoles to complete metamorphosis. Thus, there has been a significant reduction in the breeding habitat at this pool for Littlejohn's Tree Frogs for more than 3 years, triggering Level 3 of the *Dendrobium Area 3A Watercourse TARP* (Illawarra Metallurgical Coal 2012).



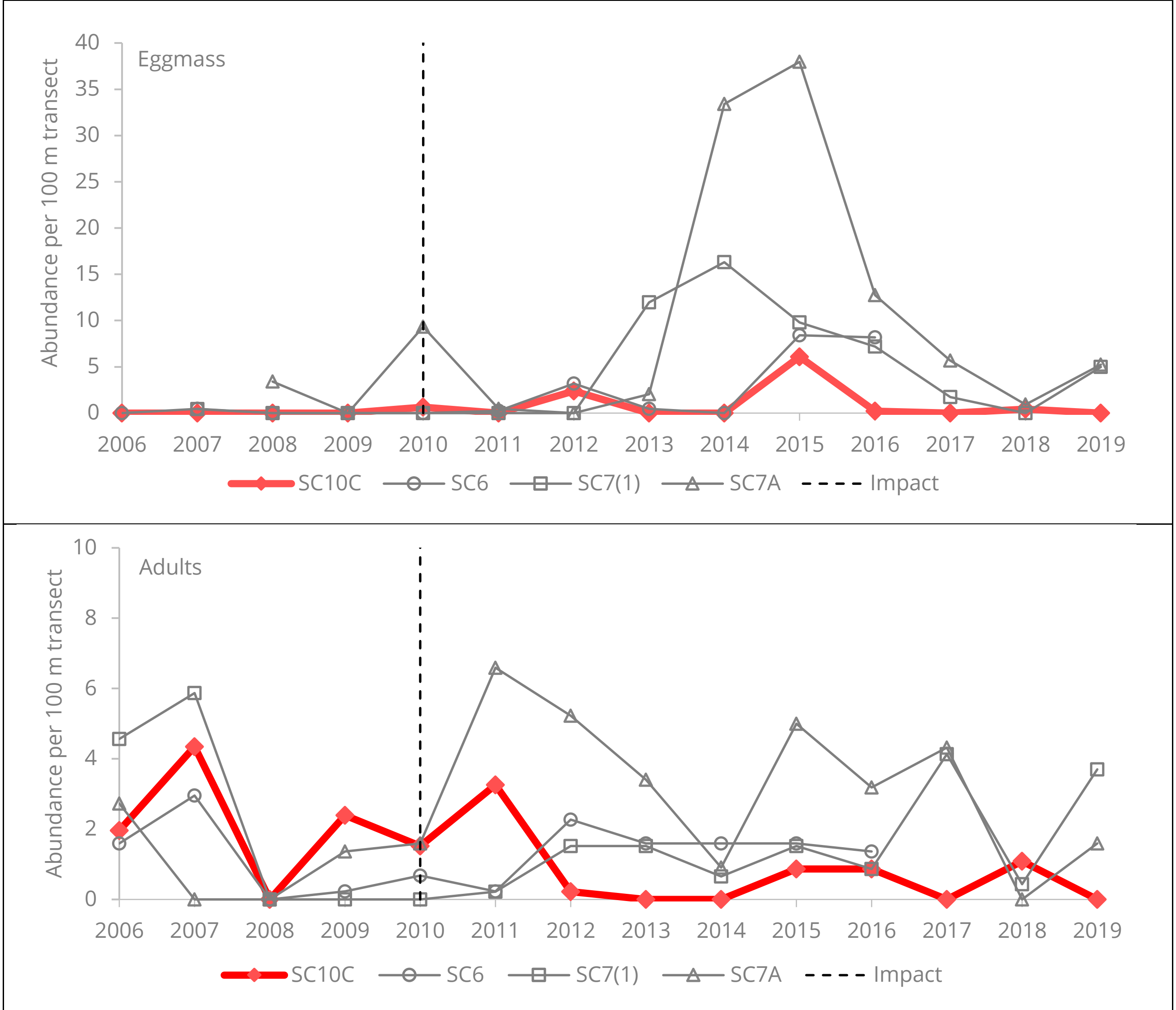



**Figure 21 Littlejohn's Tree Frog abundance at impact site SC10C and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

**SC10(1)**

Mining within the RMZ of transect SC10(1) occurred in November 2011. Transect SC10(1) is approximately 530 metres in length with 13 breeding pools identified, all of which held some water during the 2019 survey. Relatively good water availability was observed, with many long pools and the combined presence of water, snags and overhanging vegetation providing suitable habitat for laying eggs. Multiple frogs and eggmasses were recorded, with some flocculent coating observed throughout the transect in line with previous observations.

There was an increase in detection of all life stages compared to previous years in 2018, however 2019 saw a minor reduction in relative abundance across all life stages. The detection of all lifestages are within the ranges previously recorded at this site, including the abundances recorded prior to any mining commencing at this transect. As such, the *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012) has not been triggered.

In general there has been a small relative increase in the detection of adult Littlejohn's Tree Frogs at SC10(1) since mining began in 2011 (Figure 22), although this trend has not always been linear. In 2019, the detection of adults was lower than in 2018. The increase in abundance of adult Littlejohn's Tree Frog may be associated with displacement of breeding adults from impacted areas such as SC10C into nearby streams. Water security is higher at SC10(1) when compared to the other waterways assessed, thereby providing refuge habitat during dry periods. While water levels were somewhat reduced in 2019, the relatively high availability of water suggests that this difference is not a result of habitat suitability. A similar trend was seen in 2015 and 2017 which recorded fewer adults than the previous year but are part of an overall trend of increasing detection of adult frogs.

During the 2019 winter survey, iron flocculent was again observed covering stream surfaces within the SC10(1) transect. This was first observed in the 2017 survey. This represents a reduction in breeding habitat for Littlejohn's Tree Frogs, and Level 1 of the *Dendrobium Area 3A Watercourse TARP* (Illawarra Coal 2012) remains triggered.

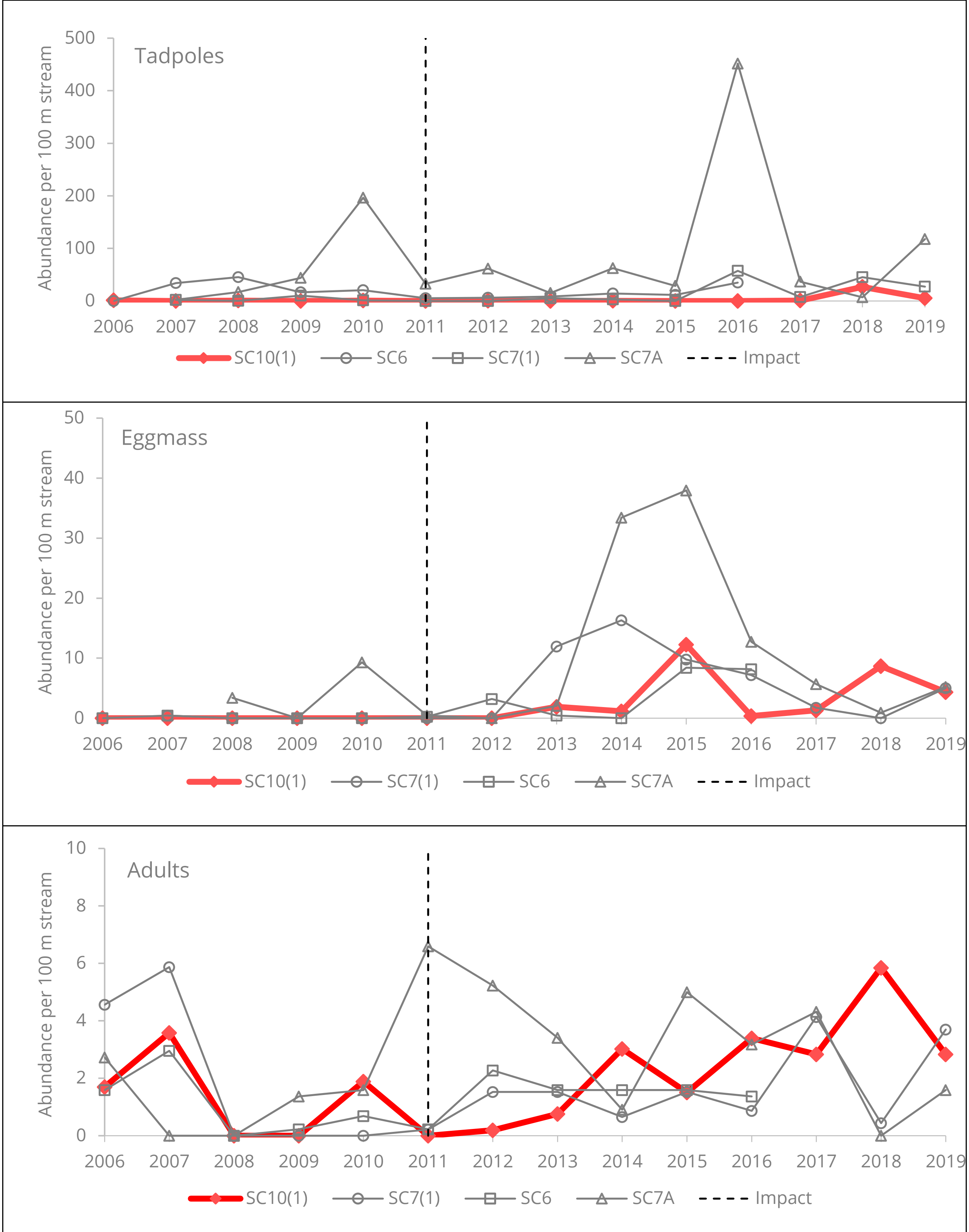



**Figure 22 Littlejohn's Tree Frog abundance at impact site SC10(1) and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

**SC10(2)**

While numbers have fluctuated, there has been no overall continuous pattern of decline in Littlejohn's Tree Frog abundance at SC10(2) since mining began in 2011 (Figure 23**Error! Reference source not found.**). The numbers of tadpoles, eggs and adults observed have consistently been within the range of values of previous results and those recorded at control sites within the area. As such the *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012) has not been triggered. The pattern described above has continued in 2019, albeit with a reduction in detection of adult frogs and egg mass when compared to the 2018 results, which is contrary to the pattern of increasing detection of these life stages at the paired control sites. In 2018 an opposite trend was seen in the data for these life stages, with detection at SC10(2) increasing where detection at the paired control sites decreased.

It is interesting to note that adult abundance and tadpole abundance spiked in 2018 at SC10(2), with tadpole abundance then spiking in 2019 with adult and eggmass life stages declining at this time. It may be that dry conditions throughout 2018-2019 resulted in the over-wintering of a larger number of tadpoles at this site, which may explain the increased number of tadpoles observed in 2019 and in turn explain the reduction in detection of other life stages. It is considered likely that the variation in trends described above reflect differences in site based conditions, although further analysis is difficult, due to the variation in abundance per 100 metres of transect being relatively low. Such differences may include variations in survey timing and populations responses to breeding triggers, such as rainfall. In addition to other site based factors such as inter and intra-specific competition. For example, predation of adult Littlejohn's by Spiny Crayfish *Euastacus* sp. has been observed in heathland pools at the upstream extent of transect SC10(2). The trends described above should be revisited in future iterations of the monitoring program to determine whether the decline is part of an ongoing trend that extends beyond previously recorded values or outside the range of values detected at the control sites.

In the 2015 to 2018 period, a consistent increase in egg mass numbers was observed when compared to the previous records, including pre-mining records. This trend may have been associated with displacement of breeding adults from impacted areas such as SC10C, and into nearby streams. While this increase did not continue in 2019, the number of egg mass detected in 2019 remained markedly above the pre-impact values and may be a reflection of the extended reduced rainfall and lower water levels at this site resulting in less frequent breeding triggers or suitable conditions for the species.

In 2017, minor flocking was observed in pools within the SC10(2) transect, however it was unclear whether this was associated with current or past mining activities or part of the natural expression of groundwater influence. No flocking was observed within the SC10(2) transect in 2018 or 2019. Although the *Dendrobium Area 3 Watercourse TARP* has not been triggered, it is recommended that the site is continued to be monitored to determine any further change in pool conditions.

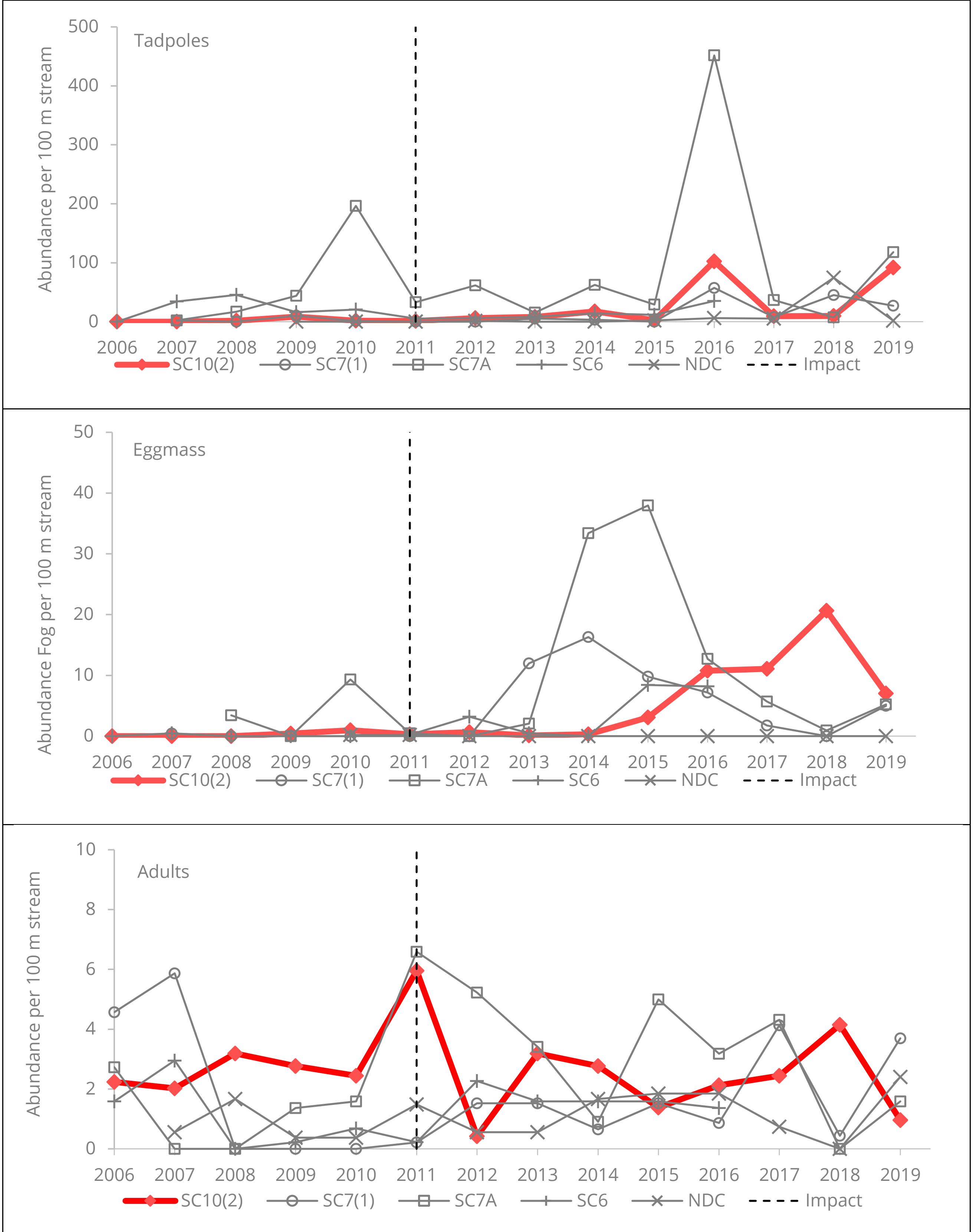
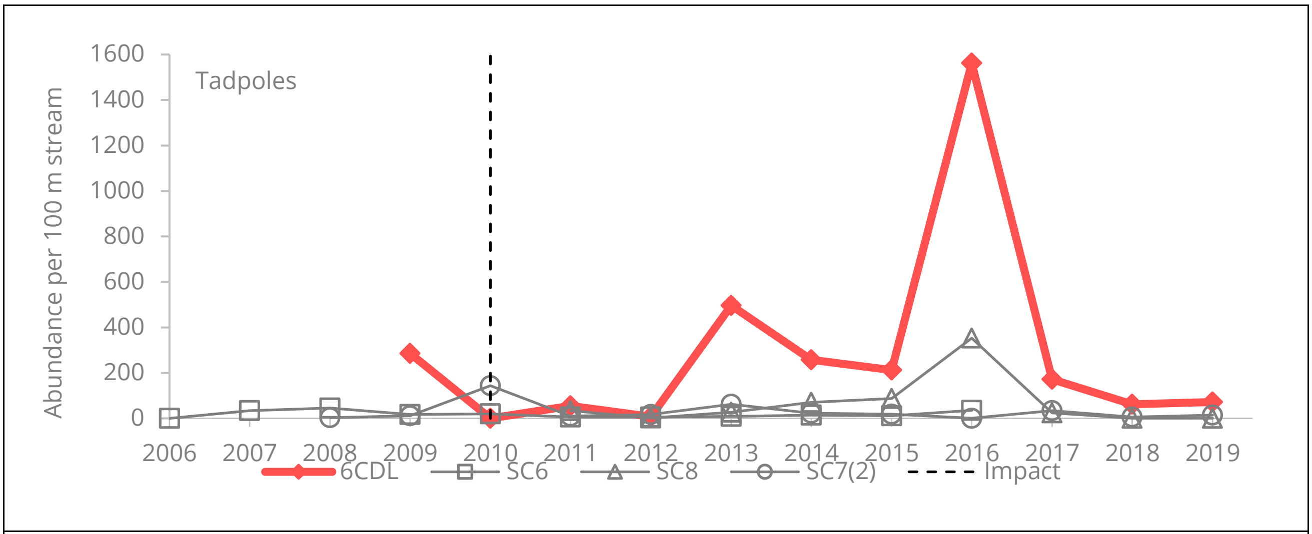
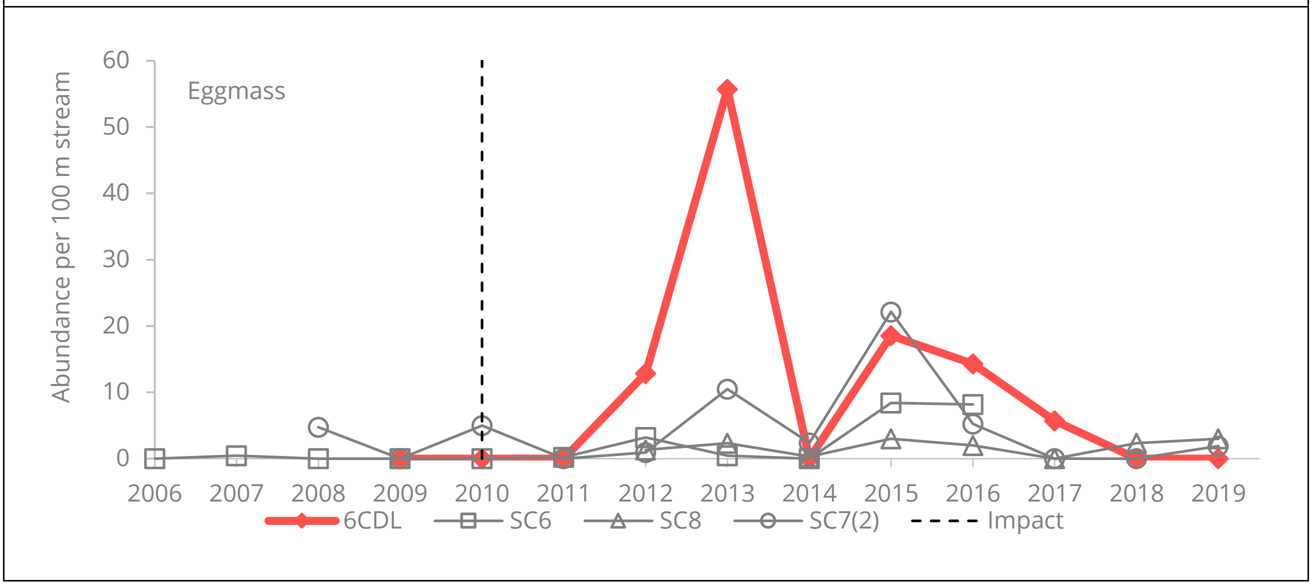



**Figure 23 Littlejohn's Tree Frog abundance at impact site SC10(2) and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

**6CDL**

There were no adults observed at 6CDL during the 2019 survey, consistent with results since 2016 and pre-mining data collected in 2009. Fluctuations in numbers of tadpoles and eggmasses are consistent with fluctuations observed at the control sites (Figure 21). This indicates that the species is responding and being detected annually, without any obvious response to mining activity. In light of these results, the number of adults being detected during surveys appears inconsistent with the other life history stages recorded at 6CDL, and is likely a factor of survey timing or detectability. Tadpole and eggmass records have remained consistently within or above the abundance range recorded at control sites within the area. The *Dendrobium Area 3A Landscape TARP - Terrestrial Flora and Fauna* has not been triggered. No subsidence impacts were observed at 6CDL during the 2019 winter survey, and the *Dendrobium Area 3 Watercourse TARP* has not been triggered.



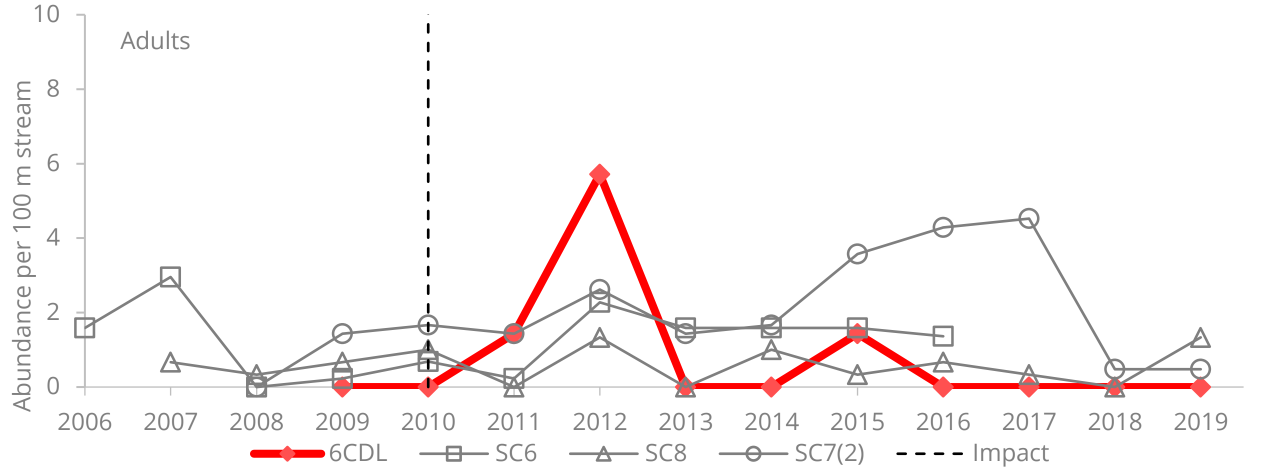



**Figure 24 Littlejohn's Tree Frog abundance at impact site 6CDL and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

## Wongawilli Creek tributaries

As with the Sandy Creek catchment, Wongawilli Creek and its tributaries form a second, large and significant sub-population of the Littlejohn's Tree Frog in the study area. The species is known to occur along a number of first and second order streams associated with Wongawilli Creek (WC2, WC4, WC7, WC10, WC11, WC15, WC17 and WC21), as well as the upper reaches of Wongawilli Creek itself. These waterways are interconnected and it is likely that the species moves throughout this area in response to a number of environmental and seasonal variables.

### WC17

Pre-mining data does not exist for WC17. In 2017, it was determined that WC17 no longer triggered the revised *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012c), as frog numbers had returned to 2011 levels when monitoring commenced.

Four adults were recorded in 2019, with no egg mass recorded and only two tadpoles recorded. These low abundances reflect the almost completely dry condition of the transect at the time of survey, with water only present within sandstone potholes in bedrock dominated stream sections. Similar conditions were observed at a number of sites across the study area and as such it is unclear whether the reduction in water availability is entirely due to the drought, or whether observed impacts (nearby bedrock cracking) have significantly lowered the resilience of the waterway to such periods of drought. Additionally a degree of site-by-site variation across all life stages was recorded in 2019 at the paired control sites which likely reflects the natural variation in habitat resilience to drought as a function of landscape setting, water supply, stream geology and geomorphology as well as survey timing in relation to rainfall as a trigger for breeding. These factors combine to make detailed interpretation of the processes contributing to Littlejohn's Tree Frog abundance difficult at this site and among the control sites.

On the basis that comparable abundances of tadpoles (SC8, NDC), egg mass (NDC) and adults (SC8, ND1, NDC, WC11) were recorded for at least one of the paired control sites in 2019, it is determined that WC17 does not trigger the revised *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Metallurgical Coal 2012c). However monitoring should continue to determine any ongoing impacts from mining. Although the *Dendrobium Area 3 Watercourse TARP* has not been triggered, it is recommended that the site is monitored to determine any further change in pool conditions.

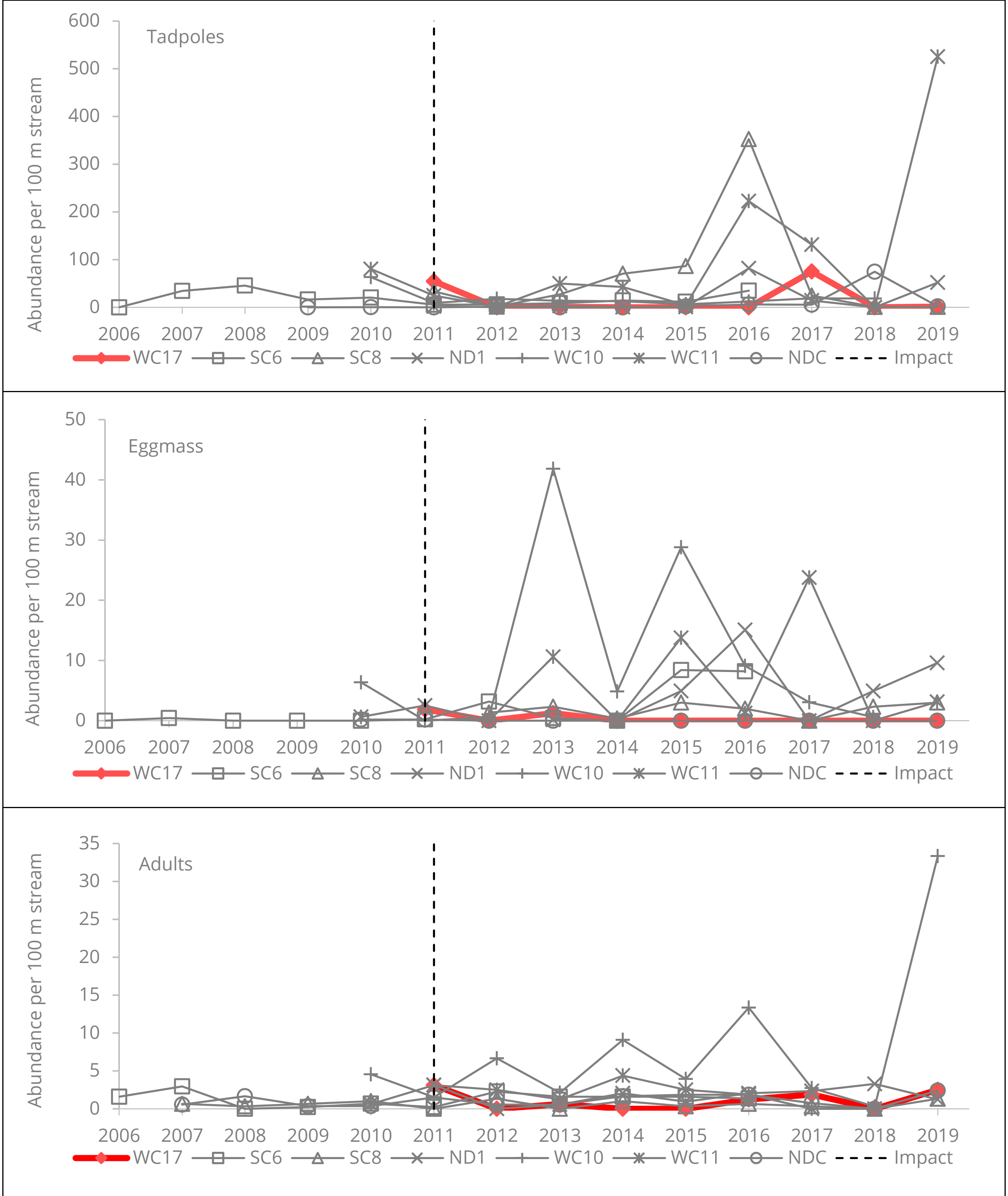



**Figure 25 Littlejohn's Tree Frog abundance at impact site WC17 and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

### 3.5.2 Dendrobium Area 3B

#### Wongawilli Creek tributaries

The remaining Wongawilli Creek tributaries monitored for Littlejohn's Tree Frog (WC21 and WC15) occur within Dendrobium Area 3B.

**WC21**

Pre-mining Littlejohn's Tree Frog data for WC21 does not exist. Impacts to WC21 were previously recorded by the Illawarra Metallurgical Coal Environmental Field Team between Pool 10 and the end of the transect to Pool 31, following the extraction of Longwall 9, Longwall 10, Longwall 11 and Longwall 12, and these included fracturing of bedrock, cracking, uplift and flow diversion. This triggered Level 2 of the *Dendrobium Area 3B Watercourse TARP* in 2016 (Biosis 2017). These impacts continued to be observed again during the 2017, 2018 and 2019 surveys. Disruption to water flow along the monitoring transect has been detected, and thus, available habitat for the species along this transect has been substantially reduced. Follow up surveys undertaken by Biosis in summer 2016/2017 confirmed that many of the identified breeding pools had dried up before any tadpoles or eggs would have metamorphosed following breeding in winter 2016. Downstream of the areas of cracking, high levels of flocculent have also been observed in the lower extent of the transect where water availability is relatively higher, and in particular downstream of the significant waterfall that occurs in the lower portion of the transect.

The detection of Littlejohn's Tree Frog at WC21 has been consistently low since surveys began in 2013 (Figure 26. Adult, egg mass and tadpole abundance at WC21 in 2019 were generally consistent with the results of previous years at this site. The majority of Littlejohn's Tree Frog adult detection occurred at the lower section of the transect where water availability was greater, coincident with the detection of other adult frogs of other species including *Litoria citropa* and *Litoria nudidigita*/*Litoria phyllocroa* complex at this section of the transect. With *Crinia signifera* the only other amphibian species detected throughout the upstream sections of the transect, aside from isolated occurrences of various life stages of Littlejohn's Tree Frog. Detection of adult Littlejohn's Tree Frog decreased in the upstream extents of the transect and was generally incidental rather than relating to an identified breeding pool, which were generally dry. Only four eggmasses were observed at two locations across the 1.38 kilometre transect, with three of these located downstream Pool 6 within an area with higher pool water persistence. It is noted that despite the relative persistence of water in the lower section of the transect and presence of adult Littlejohn's Tree Frogs and egg mass, no tadpoles were observed here. With tadpoles limited to two small isolated refuge pools upstream.

The paired control sites show varying trends in 2019, with some maintaining relatively low scores and some showing spikes in detection of certain life stages. As discussed above, this likely reflects the natural variation in habitat resilience to drought as a function of landscape setting, water supply, stream geology and geomorphology as well as survey timing in relation to rainfall as a trigger for breeding. While also reflecting the impacts of dry conditions, the very low abundances detected in 2019 are consistent with the 2017 and 2018 findings. The Level 3 *Dendrobium Area 3B Watercourse TARP* (dated 12 October 2015) is considered to remain triggered in 2019. This is determined on the basis of continued very low abundances of all life stages as well as obvious physical impacts resulting in habitat reduction across considerable sections of the transect.

The aforementioned reduction in habitat at WC21 has now been recorded for five monitoring periods (four years), thus triggering Level 3 of the *Dendrobium Area 3B Watercourse TARP.* This is discussed further in Section 4.2.2.

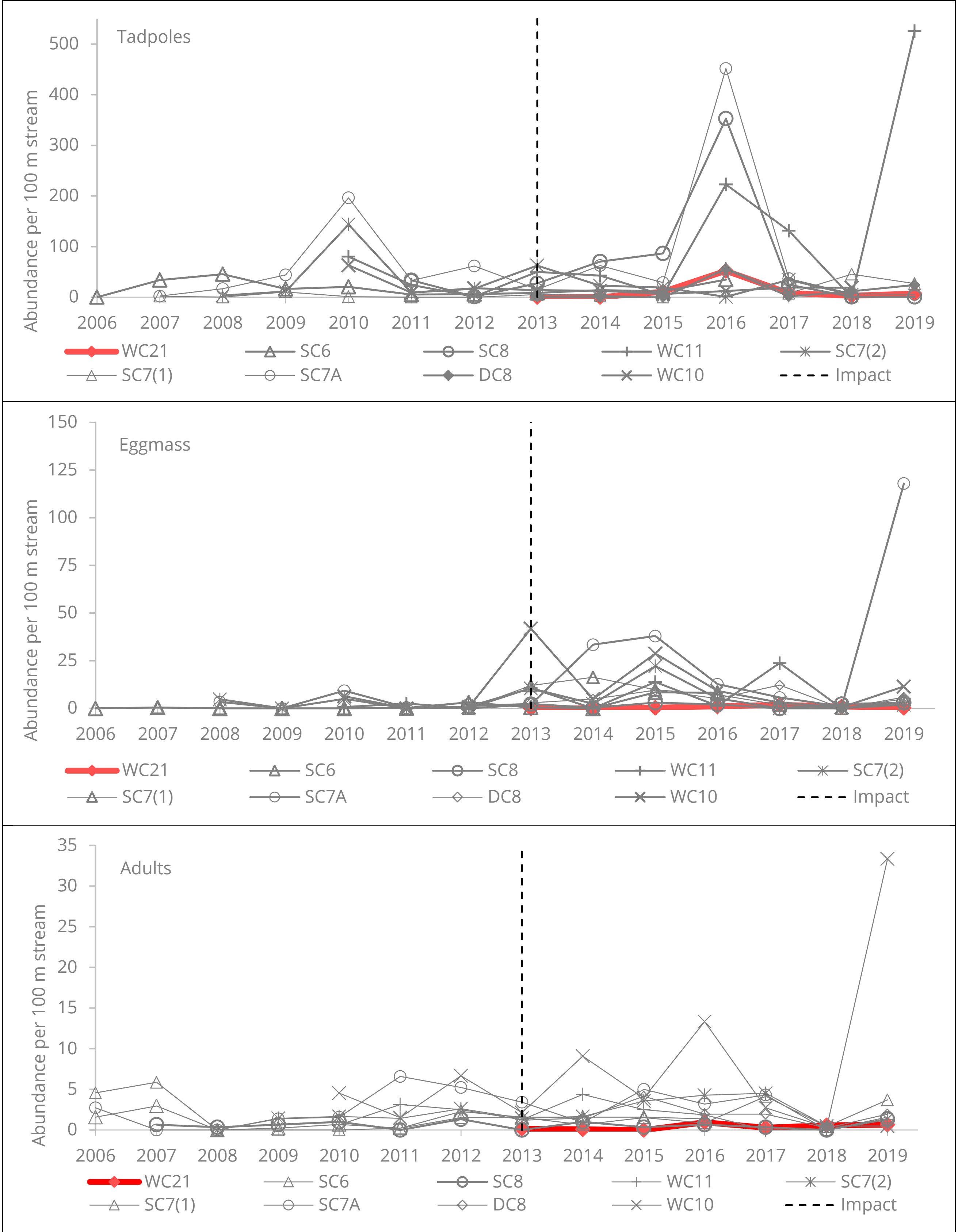


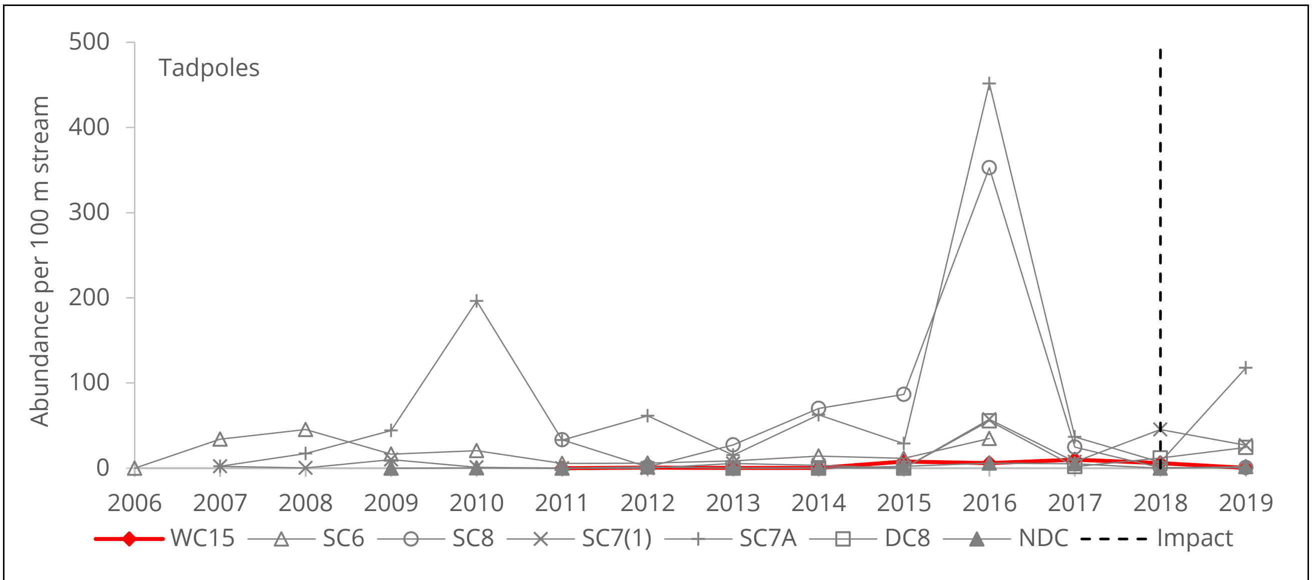

**Figure 26** Littlejohn's Tree Frog abundance at impact site WC21 and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.

**WC15**

Monitoring began at WC15 in 2011, and the site was a pre-impact site up until the 2018 epoch (Figure 27). In 2019 all identified breeding pools along the transect were dry, with fracturing also identified along the transect. The relative contribution of drought and any impact associated with fracturing is unknown and is difficult to gauge given the extent of the drought during this period.

Detection of tadpoles at WC15 has remained consistently low since 2011. Detection of tadpoles has declined at WC15 since 2017, however the values recorded during these years are comparable to values recorded pre-mining in 2011, 2013 and 2014 and at control site SC8 in 2019. Egg mass observations were broadly increasing from 2014 to 2017, before declining in 2018 which was consistent with the control sites and drying conditions. Egg mass abundance declined again in 2019, which is unsurprising given the dry conditions at this transect. In 2019 most of the paired control sites showed somewhat increased egg mass abundance, except NDC which did not record any egg mass consistent with WC15. No eggmasses have previously been recorded at this site prior to mining in 2012, 2013 and 2014. Observations of adults within WC15 have remained consistent, and have generally been within the range of observations at the comparable control sites, which continued in 2019.

On the basis of consistent adult abundances detected in 2019, and comparable numbers of tadpoles and egg mass being recorded in at least one paired control transect in 2019 and in the pre-mining data, it is determined that WC15 does not trigger the *Dendrobium Area 3B Watercourse TARP*. However monitoring should continue to determine any ongoing impacts from mining.



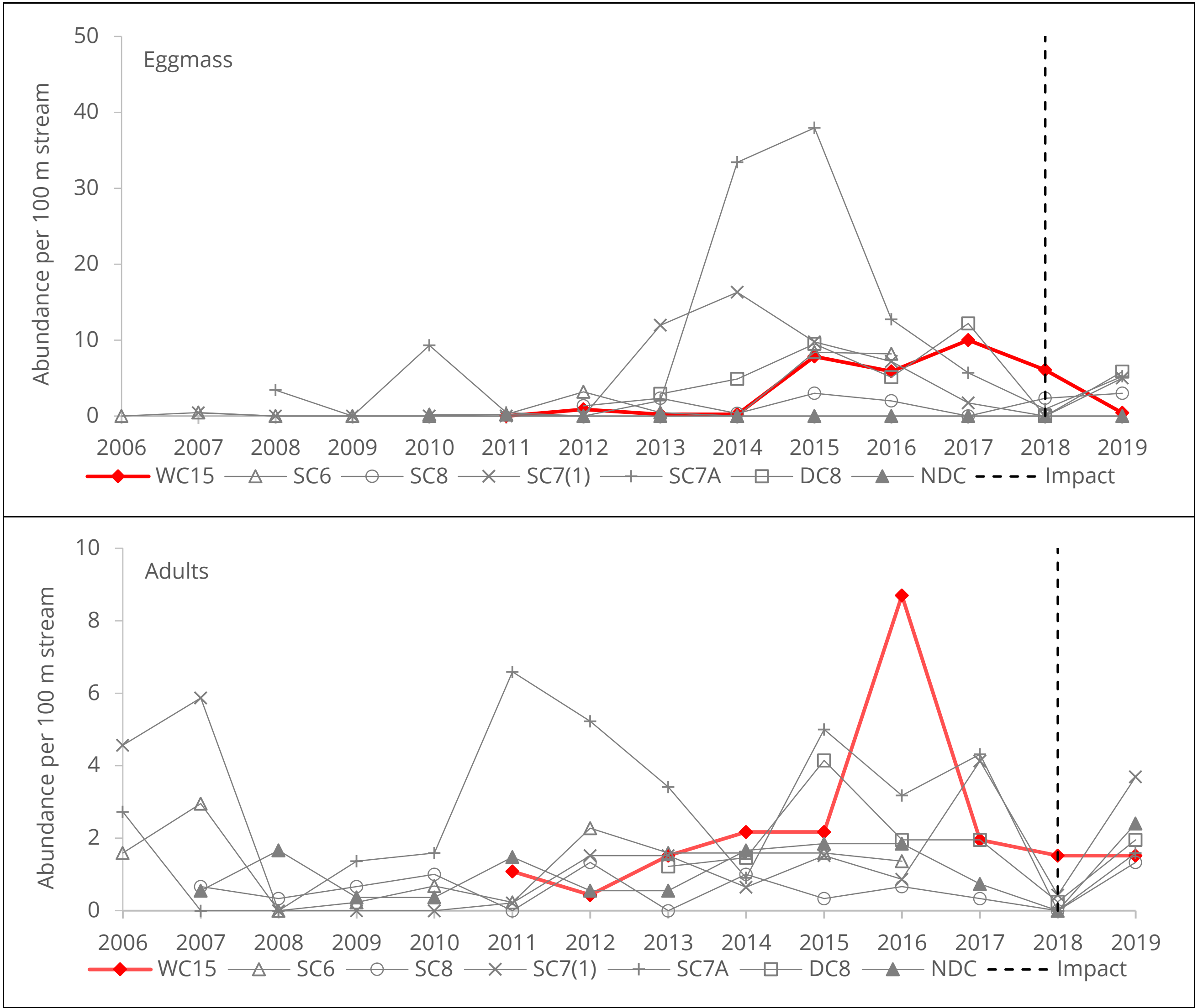



**Figure 27 Littlejohn's Tree Frog abundance at impact site WC15 and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

## Donald's Castle Creek

The Littlejohn's Tree Frog also occurs along Donald's Castle Creek (DC1) and its tributaries (DC13). Although the species has been known to occur in DC13 since 2010, new locations of Littlejohn's Tree Frog were recorded in the upper reaches of Donald's Castle Creek (DC1) and at DC8 (used as a control site) in winter 2013.

### DC1

No pre-mining Littlejohn's Tree Frog data exists for DC1. This transect has been monitored for Littlejohn's Tree Frogs since 2013, the year of Longwall 9 extraction. Detection of the species at DC1 has been consistently low, with relative abundance falling either within or below the range observed at nearby control sites (Figure 28). In 2019, pools within the upstream section of the transect, including Pool 30, were dry. Pools that held water were generally disconnected from each other, with previously recorded impacts evident in 2019, described below.

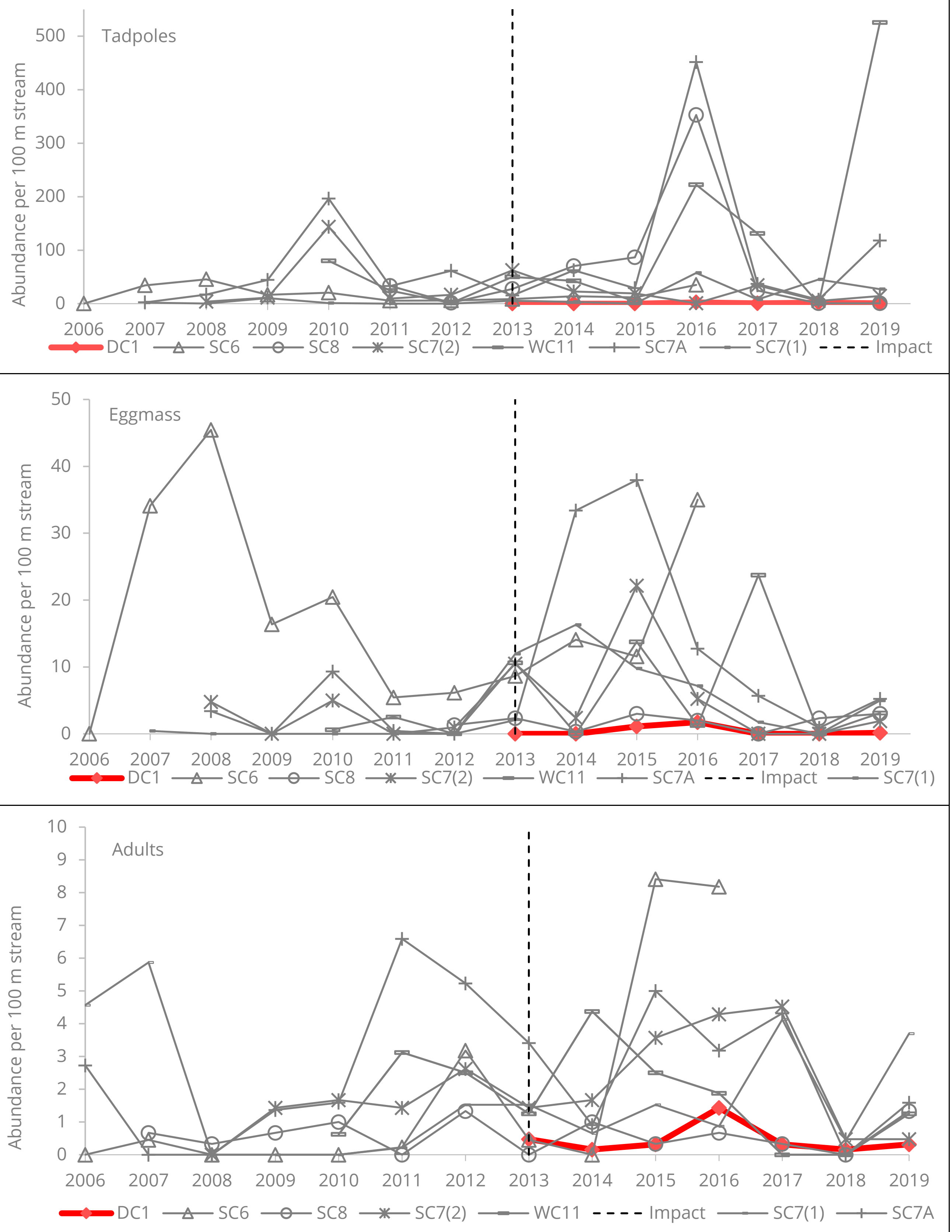



**Figure 28 Littlejohn's Tree Frog abundance at impact site DC1 and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

Following the extraction of Longwall 9, changes in pool water levels at DC1 were recorded by the Illawarra Metallurgical Coal Environmental Field Team, and has continued to be observed (Biosis 2017). Longwall 9 is located within the RMZ of the upper section of DC1 and changes to the hydrology of pools along this transect is a result of impacts that occurred upstream and within Swamp 5. A loss of flow and a reduction in pool water from the DC1 Littlejohn's Tree Frog transect was observed between Pool 31 and Pool 35 during the 2016 winter surveys. In order to confirm whether water remained present in pools for a period sufficient for Littlejohn's Tree Frog tadpoles and eggs to develop and metamorphose, follow up surveys were undertaken in summer 2016/2017 by Biosis. These surveys confirmed that pool water had dried before recorded tadpoles and eggs had a chance to metamorphose, resulting in zero survival, and indicating a loss of Littlejohn's Tree Frog breeding habitat within those pools in DC1 (Biosis 2018).

Level 1 of the *Dendrobium Area 3B Watercourse TARP (Illawarra Coal 2015a)* was first triggered in 2017 and remained triggered in 2018. As a result of the impacts described above and continued low detection rate of all life stages in comparison to previous data and control sites when considered as a group, Level 2 of the *Dendrobium Area 3B Watercourse TARP* has now been triggered. This is discussed further in Section 4.2.2.

**DC13**

In line with previous results, detection of Littlejohn's Tree Frog at DC13 in 2019 was very low (Figure 29). The upper reaches of DC13 were mined within the RMZ and mined beneath by Longwall 9 in 2013. Subsidence impacts following mining have since resulted in the loss of water in pools located above this longwall. In 2016, subsidence impacts extended along approximately 30% of the monitoring transect. Pools located within this reach (Pools 18A through to the transect end) provided known habitat for Littlejohn's Tree Frog during the baseline monitoring period. Pools along approximately 40% of the total length of the transects had experienced a reduction in water in 2016. The remaining pools, located in the lower reaches, contained water in 2016 and provided habitat for the majority of Littlejohn's Tree Frog adults, tadpoles and egg mass detected. At the time of the 2016 survey, tadpoles and egg mass were detected in Pool 9 through to 17, again, downstream of Longwall 9.

In 2019 DC13 was almost entirely dry, with areas of heath dieback immediately adjacent to the transect observed. Only one pool held a small amount water providing refuge for a very small number of Littlejohn's Tree Frog tadpoles, no other individuals or other life stages were recorded. No Littlejohn's Tree Frog were recorded within the DC13 transect during 2018, with comparable results also seen at a number of the shared control sites. The presence of tadpoles in 2019 indicates marginal episodic habitat remains at DC13. Only 2016 (post impact) saw substantial numbers recorded following rainfall within the LittleJohn's breeding period. Follow up monitoring in summer 2016/2017 however, confirmed that many of the identified breeding pools had experienced a significant reduction in water, and were no longer appropriate habitat for Littlejohn's Tree Frogs to survive to metamorphosis. The detection of Littlejohn's Tree Frog has otherwise remained consistently low since monitoring began (Figure 29).

The post impact data indicates more occurrences of no individuals from a life stage being recorded, although it is important to note that there are more post impact monitoring years of data and the extended drought conditions through 2018 and 2019 which may influence this interpretation. In the same regard, there were generally more adults recorded in the pre-impact monitoring data than post-impact monitoring data, which may provide an indication of a decline in habitat suitability given the consistently low numbers of individuals from other life stages recorded and larger numbers of adults relative to this. In 2019 DC13 recorded lower numbers of LittleJohn's Tree Frog than the paired controls, aside from the low number of tadpoles, but it should be noted that the low number of individuals recorded at DC13 and some controls confound interpretation. On the basis of the continued low numbers of individuals recorded at this site and comparisons to the pre-mining and control site data, along with the impacts outlined above it is determined that Level 3 of the *Dendrobium Area 3B Watercourse TARP* (dated 12 October 2015) remains triggered at DC13.

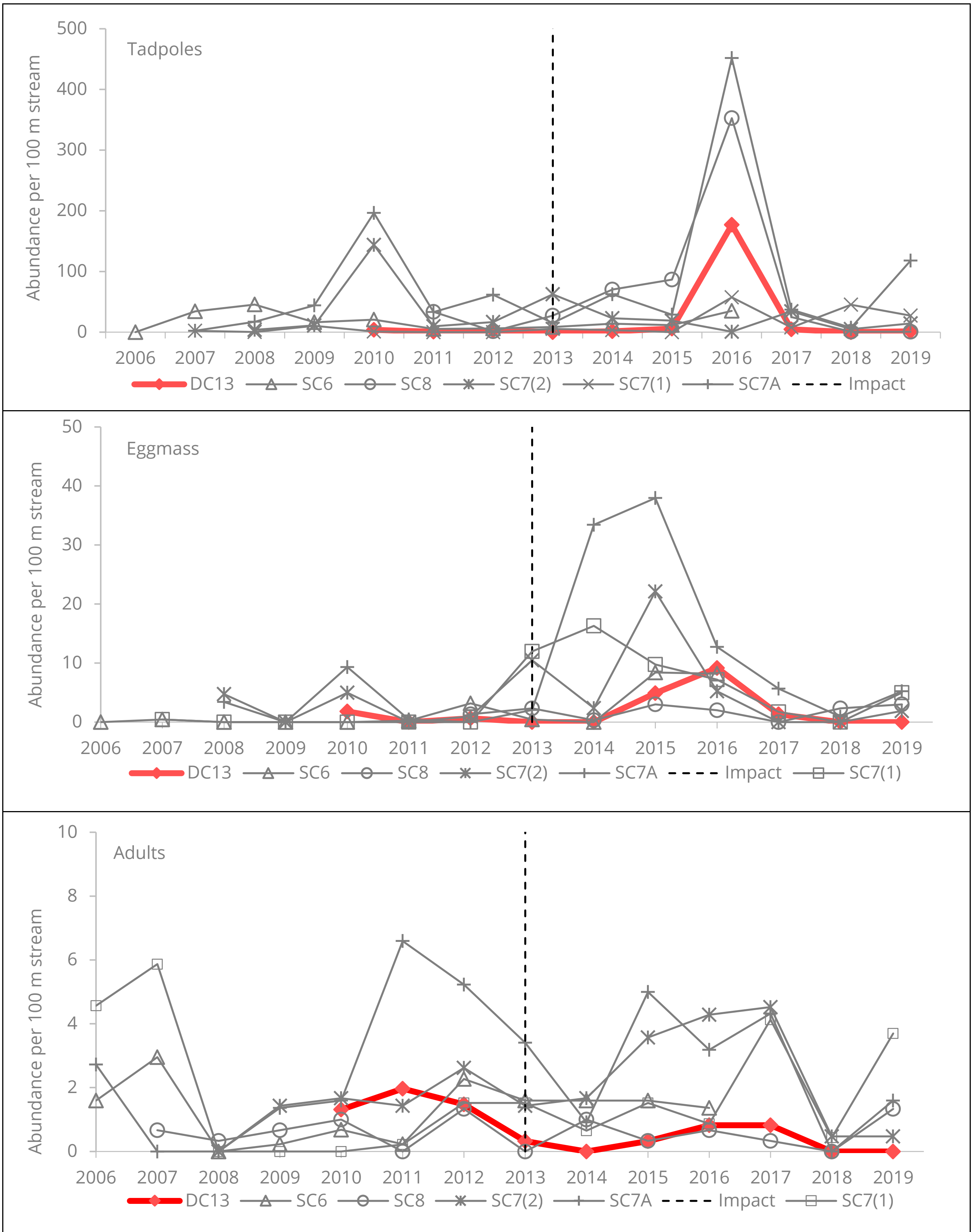



**Figure 29 Littlejohn's Tree Frog abundance at impact site DC13 and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

**LA4A**

Throughout the monitoring program, adult, tadpole and egg mass abundance at LA4A has been extremely low, with values below the majority of control sites, including during the pre-mining period. It should be noted that only adult Littlejohn's Tree Frogs have been detected at this transect, and only in 2007, 2008 and 2010. In 2018 and 2019, no Littlejohn's Tree Frogs were detected at LA4A, nor any other species of frog. This does not appear to be related to mining impacts, rather a reflection of the dry conditions during the time of survey. This may be a factor of the landscape position of LA4A which lies at the base of the usual level of dam influence of Lake Avon and hence, under drought conditions receives much lower water input from landscape runoff and stream flow. This is evidenced by the significant dam level reduction and associated retreat of the dam influence extent.

The conditions within transect LA4A in 2019 were consistent with those observed in 2018. No observed impacts have been detected at the one breeding pool, LA4A-P1 along this stream. Some fracturing and flow diversion has been detected at the lower end of the transect where it becomes LA4, however this does not appear to have resulted in a reduction of breeding habitat for the species. The *Dendrobium Area 3B Watercourse TARP* has not been triggered.

**LA2**

Site LA2 was monitored for the third time during the 2019 winter survey and is currently a pre-mining site. In 2017, 73 tadpoles, 70 eggmasses and 3 adults were recorded at the site. In 2018 the transect was extremely dry, with the majority of pools dry and only one adult and one tadpole recorded at the site. At this time of survey in 2019, water availability was increased and while pools were generally shallow and disconnected many held water. In 2019 an increase in detection occurred with 353 tadpoles, 16 eggmass and 19 adults, recorded. The site will continue to be monitored as part of this program.

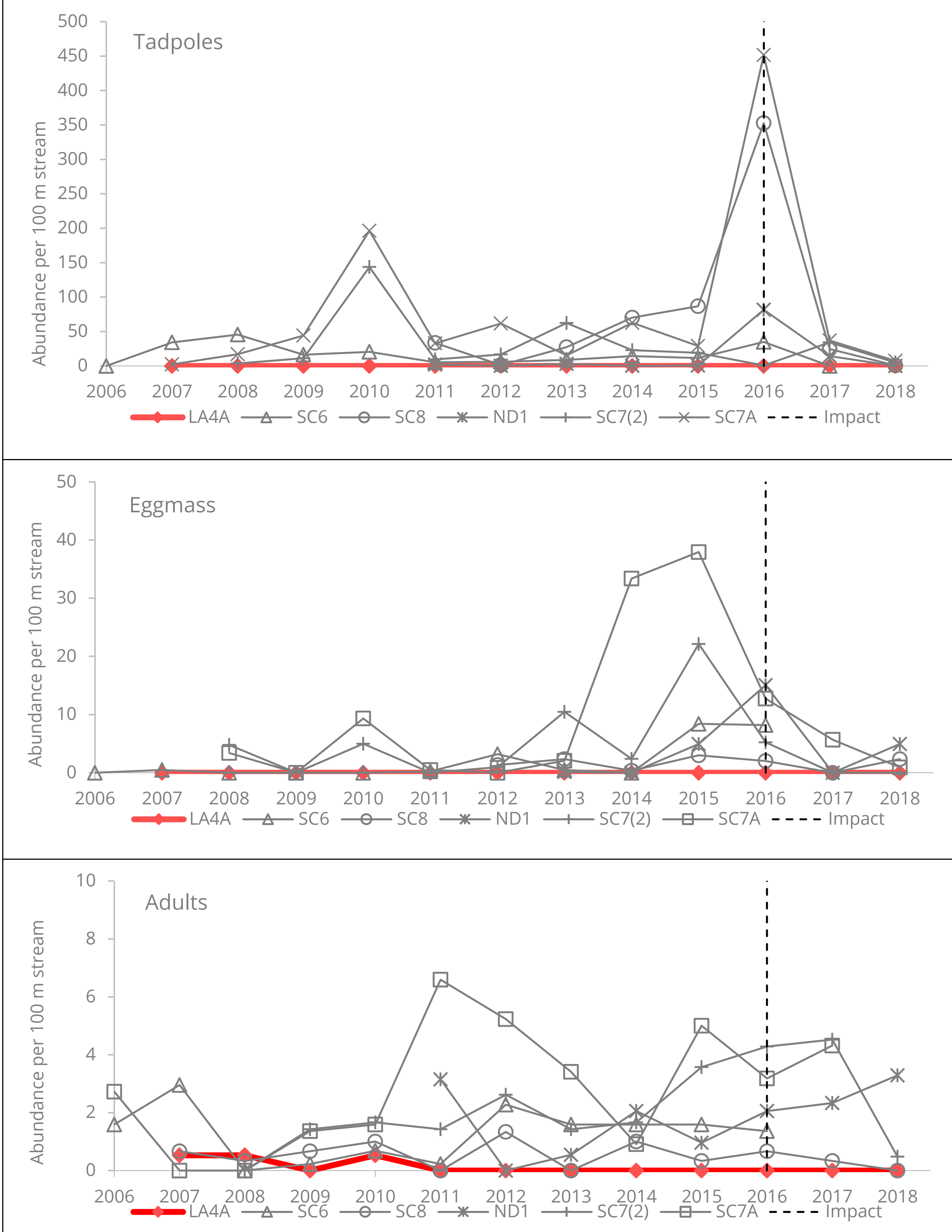



**Figure 30 Littlejohn's Tree Frog abundance at impact site LA4a and associated control sites in 2019. Dashed line represents the first year mining commenced within the RMZ.**

# 4 Conclusions and recommendations

At the completion of the 2019 ecological monitoring program, 13 years of data has been collected for Dendrobium Area 2; 9 to 15 years of data has been collected for Dendrobium Area 3A; and 6 years of data collected for the majority of Dendrobium Area 3B (aside from Swamp 11 where monitoring has been undertaken for 14 years).

To align with the requirements of the NSW Government *Annual Review Guideline* (NSW Government 2015) the following sections provides a summary analysis of the terrestrial ecology monitoring program for the 2019 period, including:

- Section 4.1 - A summary and conclusion of the results presented in Section 3.
- Section 4.2 - A comparison of the data to predictions made in the Environmental Impact Statement and Subsidence Management Plans.
- Section 4.3 - Identification of any management implications and proposed improvements to environmental management or performance.

Area 3B TARP trigger levels and the relevant corrective actions are discussed herein for Area 3B monitoring sites. For monitoring sites in Area 3A, where the TARP trigger levels are not applicable and do not relate to corrective actions, TARPs have been used to frame the discussion of trends.

## 4.1 Discussion of ecological trends

### 4.1.1 Upland swamp total species richness

Piezometric data indicates changes in shallow groundwater levels following extraction of longwalls in Dendrobium Areas 3A and 3B. Therefore, it is possible that the observed statistically significant decline in TSR at Swamp 15B is attributed to alterations in retention of shallow groundwater. At Swamp 15B, the decline in TSR post-mining was not statistically different to TSR pre-mining and at control swamps immediately after mining but by 2013 became statistically significant, with the level of significance continuing to increase. This trend towards an increasingly significant difference between TSR compared with TSR before mining and at control swamps is suggestive of a lag-effect, whereby the impacts of mining have been gradual, and accumulating over time.

The results of the TSR analysis demonstrate the response to mining at individual swamps is complex, with Swamp 15B generally showing a decline in TSR following mining and changes in shallow groundwater, and Swamp 15A(2), Swamp 1A, Swamp 1B and Swamp 5 showing no statistically significant decline in TSR despite observed changes in shallow groundwater availability.

### 4.1.2 Upland swamp species composition

Statistically significant yearly background trends in species composition were detected at most sites, regardless of mining area or treatment. Such trends are indicative of natural turnover of species within upland swamps in response to seasonal and annual variability in climate, competition, disturbance and edaphic factors.

When accounting for yearly effects, a statistically significant change in species composition post-mining was found at Swamp 15B, triggering a Level 2 TARP. These changes were observed immediately following undermining and have continued at Swamp 15B for at least four years post-mining. A statistically significant change in species composition post-mining, once yearly effects were accounted for, was detected at Swamp

1B for the period 2018-2019, therefore a Level 1 TARP has been triggered. A clear trend in vegetation composition change that can be attributable to impacts from mining and/or drying conditions has not been observed at Swamp 1B to date. Biosis recommends that S1B is continued to be monitored in the future.

Observed reduction in woodland species recorded at Swamp 15B is likely linked to vegetation changes following a significant period since fire and subsequent increased shading by shrub species such as Heath Banksia and Needlebush. As such, the observed decrease in the *Goodenia dimorpha, G. stelligera, G. bellidifolia* complex at Swamp 15B is likely indicative of changes in structure (increased shading) and likely a cumulative change in shallow groundwater (drying trend) based on its preference for shallow, free draining moist soils. While a statistically significant change of 21.1% has been observed in the data analysis, it is likely that less than average rainfall, following a prolonged period of dryer than average conditions (Table 7) is a primary driver of this change.

A statistically significant change in species composition has previously been recorded at S15A(2), however this is no longer the case. An internal review and consolidation of species complexes described in Section 2.3 has likely led to a substantial change in the data analyses compared with previous years. Future analyses based on an improved data collection process are likely to more closely reflect this year's results than previous years.

### 4.1.3 Littlejohn's Tree Frog

When considering all sites together, there was a low level of detection of Littlejohn's Tree Frogs across all sites when compared to the excellent breeding year in 2016. The 2019 results were more consistent with those of 2018, which also recorded low abundances as part of the continued dry conditions through the extended drought. The continued reduction in the detection of Littlejohn's Tree Frog across all sites is attributed to the extremely dry conditions preceding and during the survey. These dry conditions were driven by sustained periods of below average rainfall operating at the catchment scale, reducing the condition and availability of suitable habitat. This includes the reduction in pool water levels or the complete drying of pools, which reduced the availability of suitable egg laying sites (e.g. submerged woody debris), conditions suitable for maintaining tadpole survival (water) and is also likely to increase the effects of intra-specific and inter-specific competitive interactions.

Since commencement of threatened frog monitoring in Areas 3A and 3B, the abundance of all life stages detected has varied substantially year to year, at both impact and control sites. This is most likely due to movement of individuals amongst sites, as well as differences in environmental conditions (e.g. time since rain, volume of rain, temperature) at the time of survey. Environmental conditions such as rainfall can influence both detectability of individuals (adults may not be active if conditions are not suitable), as well as the timing of breeding events relative to survey. Conducting amphibian surveys at one time-point during the breeding season only provides a snapshot of frog abundance at that particular time, contributing to variation seen across years.

The ongoing lack of, or low detection at a number of monitoring sites since the commencement of monitoring indicates that these sites, while supporting the species on occasion, does not represent habitat permanently utilised by the species. Comparing these sites to control sites that frequently record the species in multiple life stages may result in false negatives. It is recommended that while these sites continue to be surveyed annually, the pairing of sites should be reviewed on an annual basis and any analysis of data remains qualitative at this stage.

Subsidence related impacts, including cracking of bedrock, lowering of water levels and build-up of iron flocculent have been recorded at sites SC10C, SC10(1), WC17, WC21, DC1 and DC13, with each of these sites triggering either Level 1 (SC10(1)), Level 2 (DC1) or Level 3 (WC21 and DC13) of the relevant TARP (section 4.2). Further monitoring of breeding pools conducted in summer 2016/2017 confirmed that at several of these sites, identified breeding pools contained sufficient water to support the laying of egg clutches in winter. However, these pools did not retain water for a sufficient period into summer for individuals to successfully reach metamorphosis. This represents a reduction in the available Littlejohn's Tree Frog breeding habitat within these pools at both Dendrobium Area 3A and Area 3B.

Site SC10(1) triggered the *Dendrobium Area 3 Watercourse TARP* (Illawarra Coal 2015a) in 2017 due to build-up of iron flocculent covering all stream surfaces during the 2017 winter survey, and is considered likely to reduce productivity, and therefore suitability, of the pools for tadpoles. While the majority of this transect was dry during 2018 and 2019, iron staining on bedrock steps was observed. It is anticipated that when water returns to this site, iron flocculent will remain an issue, however this should be reviewed in 2020.

SC10C showed a declining trend in detection of all Littlejohn's Tree Frog life stages. In 2017 it was determined that recruitment at this site before mining occurred was also extremely low, and numbers have remained low throughout the course of monitoring. Hence, the absence of Littlejohn's Tree Frogs at SC10C during 2017 was deemed not to be of immediate concern. Due to the dry conditions, the continued low numbers detected cannot be solely attributable to impacts associated with mining. It is anticipated that the continued low numbers detected have been exacerbated by the dry conditions and are not necessarily the direct result of mining impacts. Level 1 of the *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (12 November 2012) (Illawarra Coal 2012c) remains triggered. The monitoring results at SC10C should be reviewed in 2020.

In 2016 a declining trend in Littlejohn's Tree Frogs was recorded at post-mining site WC17, with no tadpoles or eggmasses recorded from 2014 – 2016. However, in 2017 120 tadpoles were recorded at the site. This indicated a return to pre-mining recruitment conditions, and removes the Level 1 – *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* trigger reported in 2016. In 2019, low numbers of individuals across life stages were recorded within the breeding pools. This is consistent with the trends observed in at least one of the control sites for at least one life stage, and is most likely due to the dry conditions experienced within the catchment at the time of survey. It is therefore concluded that WC17 does not trigger the revised Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (Illawarra Coal 2012c).

Consistent with previous years, Level 3 of the *Dendrobium Area 3B Watercourse TARP* (dated 12 October 2015) remains triggered at sites DC13 and WC21. This is on the basis of continued low detection numbers in comparison to the pre-mining data and shared controls, as well as the observations of considerable physical impacts leading to a reduction in habitat.

Following the 2016 survey at DC(1), breeding pools (Pools 32 and 33) had a reduced water level below the pool monitoring benchmark. In order to confirm whether water remained present in pools long enough for Littlejohn's Tree Frog tadpoles and eggs to develop and metamorphose, follow up surveys were undertaken in summer 2016/2017 by Biosis. These surveys confirmed that pool water had dried up before recorded tadpoles and eggs had sufficient time to metamorphose, resulting in zero survival, and indicating a loss of Littlejohn's Tree Frog breeding habitat within DC1 (Biosis 2017). The level 1 TARP was triggered in 2017 and low detection numbers have continued since that year. As such a reduction in habitat for 2 years following the active subsidence period has now occurred and Level 2 TARP has been triggered. Recommendations are made by Biosis in relation to the TARPS triggered in Section 4.2.2.

## 4.2 Assessment against performance measures

### 4.2.1 Upland swamp vegetation monitoring

Area 3B TARP trigger levels and the relevant recommended corrective actions are discussed herein for Area 3B monitoring sites. These TARPs apply to Area 3B swamps only and were established under the current approvals. Area 3A TARP trigger levels and relevant corrective actions are also discussed in the context of results observed at Area 3A swamps; Swamp 15A(2) and Swamp 15B.

### Total species richness and species composition

Impacts on the distribution of vegetation within a swamp, as well as changes in water levels, were predicted as a result of mining beneath swamps in the Subsidence Management Plans for each area (Illawarra Coal 2012a; 2012b). Specifically, localised water diversion and lowering of shallow groundwater levels within Swamp 1A, Swamp 1B and Swamp 5 was predicted (Illawarra Coal 2012a; 2012b).

The following *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012)* (Illawarra Coal 2012c) sets out the trigger levels for terrestrial flora:

- Level 1 - Vegetation impacted by mining (by rockfalls, soil slippage, gas emissions) that is likely to naturally regenerate within the monitoring period; or no significant statistical difference between Before After Control Impact sites.
- Level 2 - Vegetation impacted by mining (by rockfalls, soil slippage, gas emissions) that is unlikely to naturally regenerate within the monitoring period; or statistically significant difference of species richness and species diversity between Before After Control Impact sites as a result of mining.
- Level 3 - Vegetation impacted by mining that is not responding to Corrective Management Actions (CMAs).

Data analysis continues to show that TSR across all sites, irrespective of mining status, is generally variable. However, a period of stability in TSR between 2010 and 2016 is discernible when considering pooled TSR data from control swamps. While this variation occurs, trends of stability are evident at all control sites paired with impact swamps located within Dendrobium Area 3A and 3B (as demonstrated in Section 3.3.1).

Yearly changes in species composition were detected in most sites, regardless of area or treatment. This variation is considered a function of natural turnover of species in response to climatic variability, stochastic events and successional changes (particularly the time period post-fire). When accounting for yearly effects, a statistically significant change in species composition in post-mining data to pre-mining data was found at Swamp 15B (Dendrobium 3A), consistent with the findings at this site from 2018. However, a statistically significant change in species composition in post-mining data to pre-mining data was recorded at Swamp 15A(2) in 2018 (Biosis 2019). This is no longer the case for Swamp 15A(2); no statistically significant changes have been detected.

As with TSR, changes in species composition were observed immediately following being mined beneath and have continued at Swamp 15B for at least four years post-mining. No statistically significant declines in species composition were detected for Dendrobium Area 3B swamps.

No statistically significant declines in TSR were detected for Dendrobium Area 3B swamps (S1A, S1B, S5). A statistically significant decline was detected at impact Swamp 15B, but not at impact Swamp 15A(2) (Dendrobium 3A). Declines in TSR were observed immediately following Swamp 15B being mined beneath.

Additionally, the following trigger levels have been set for terrestrial flora within upland swamps within the *Dendrobium Area 3B Swamp Monitoring – Terrestrial Flora: Composition and Distribution of Species* (Illawarra Coal 2015b):

- Level 1 - A 2% or otherwise statistically significant decline in species richness or diversity during a period of species richness/diversity stability or increase in a reference swamp for two consecutive years.

- Level 2 - A 5% or otherwise statistically significant decline in species richness or diversity during a period of species richness/diversity stability or increase in a reference swamp for three consecutive years.
- Level 3 – An 8% or otherwise statistically significant decline in species richness or diversity during a period of species richness/diversity stability or increase in a reference swamp for four consecutive years.
- Exceeding prediction - Mining results in a >10% or otherwise statistically significant decline in species richness or diversity during a period of species richness/diversity stability or increase in a reference swamp for five consecutive years.

A summary of the assessment of the results of the 2019 analysis against the Dendrobium 3A and 3B TARPs is presented below in Table 20.

**Table 20 Summary of the assessment of impact swamps in Dendrobium Area 2, 3A and 3B against the TARPs.**

| Swamp | Predicted impact | Results and TARP justification | TARP (2018) | TARP (2019) | Recommendations |
|---|---|---|---|---|---|
| **Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012)** | | | | | |
| **S15B** | Level 1, 2 or 3 TARP. | A statistically significant difference in TSR at Swamp 15B was detected (following being mined beneath) from 2013 through to 2019 at the α=0.1 level. This difference was detected during a period of stability at control swamps over three consecutive years (2013 to 2015), which was followed by an increase in TSR between 2015 and 2016 at these control swamps.<br><br>A statistically significant (p-values < = 0.05) change in species composition was detected at S15B during four of the most recent monitoring periods.<br><br>Biosis understands that no CMAs have been initiated, therefore a Level 3 trigger cannot be assessed. | **Level 2 triggered** | **Level 3 triggered.** | Continue monitoring S15B in spring and autumn each year.<br><br>Consult with technical specialists to identify need and type of CMA required and implement any agreed CMA.<br><br>Swamp offsetting has been provided as per Schedule 2 Condition 15 of the Consent. |
| **S15A(2)** | Level 1, 2 or 3 TARP. | No statistically significant decline in TSR was detected at S15A(2) at the p=0.05 level.<br><br>Additionally, no statistically significant decline in species composition was found post-mining at S15A(2). | **Level 2 triggered** | **No TARP levels triggered.** | Due to the detection of decreased groundwater and soil moisture, continued monitoring S15A(2) in spring and autumn each year is recommended. |

| Dendrobium Area 3B Swamp Monitoring – Terrestrial Flora: Composition and Distribution of Species (dated 12 October 2015) | | | | | |
|---|---|---|---|---|---|
| **S1A** | Level 1, 2 or 3 TARP. | TSR within S1A showed no statistically significant decline when compared to control sites.<br><br>Additionally, no statistically significant decline in species composition was found post-mining at S1A. | **No TARP levels triggered.** | **No TARP levels triggered.** | Due to the detection of decreased groundwater and incidental observations of Needlebush yellowing, continued monitoring of S1A is recommended. |
| **S1B** | Level 1, 2 or 3 TARP. | TSR within S1B showed no statistically significant decline when compared to control sites.<br><br>However, a statistically significant change in species composition was found post-mining at S1B. | **No TARP levels triggered.** | **Level 1 triggered.** | Due to the Level 1 trigger and detection of decreased groundwater, continued monitoring of S1B is recommended. |
| **S5** | Level 1, 2 or 3 TARP. | TSR within S5 showed no statistically significant decline when compared to control sites.<br><br>Additionally, no statistically significant decline in species composition was found post-mining at S5. | **No TARP levels triggered.** | **No TARP levels triggered.** | Due to the detection of decreased groundwater and soil moisture along with the yellowing of Needlebush, continued monitoring of S5 is recommended. |

### Upland swamp extent

The analysis of the most recent LiDAR data used to assess the extent of upland swamps and their composite vegetation communities has identified that the extent of all upland swamps (impact and control swamps) within the study area have decreased substantially from the 2014 baseline.

The results of the 2019 LiDAR data analysis has identified continued declines in the extent of vegetation communities that comprise upland swamps, recorded in 2017. These are MU43 (Tee-tree Thicket) and MU44c (Sedgeland). Declines in the extent of MU44c, while triggering a Level 1 TARP, require further investigation to determine why this community is increasing in extent at some swamps and decreasing at others. MU44b (Sedgeland-Heath Complex) was also identified as being reduced in extent at a number of impact sites in 2019.

The *Dendrobium Area 3B Swamp Monitoring – Terrestrial Flora: Composition and Distribution of Species* (Illawarra Coal 2015c) sets out the following trigger levels for 'ecosystem functionality' (taken to be represented by the maintenance of groundwater dependent vegetation sub-communities that comprise upland swamps):

- **Level 1:** A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.

- **Level 2:** A trending decline in the extent of any individual groundwater dependent community within a swamp for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.
- **Level 3:** A trending decline in the extent of any individual groundwater dependent community within a swamp for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.
- **Exceeding Prediction:** Mining results in a trending decline in the extent of any individual groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.

The results of the 2019 LiDAR data analysis is assessed against swamp size and ecosystem functionality TARPS in Table 21 below.

**Table 21 Summary of the assessment of impact swamps in Dendrobium Areas 2, 3A and 3B against the TARPs**

| Swamp | Predicted impact | Results and TARP justification | TARP | Recommendations |
|---|---|---|---|---|
| **S15B** | No prediction made at EIS | TARPS relating to swamp size and extent of groundwater dependent sub-communities do not currently apply to swamps within Dendrobium Area 3A. | **None** | Continue on-ground and UAV imagery monitoring in 2020. |
| **S1A** | Level 1, 2 or 3 TARP. | Two years of decline in total swamp extent greater than the mean (±SE) decline of the control group.<br><br>Trending decline in the extent of sub-community MU43 for three consecutive monitoring periods greater than the mean (±SE) decline of MU43 in the control group. Trending decline in the extent of sub-community MU42 and MU44b for three consecutive monitoring periods greater than the mean (±SE) decline of MU42 and MU44b in the control group. | **Swamp Size: Level 1 TARP triggered.**<br><br>**Ecosystem Function: Level 2 TARP triggered.** | Continue on-ground and UAV imagery monitoring in 2020.<br><br>Ground truth swamp extent and swamp vegetation community extent in 2020.<br><br>Investigate practical remediation measures.<br><br>Swamp offsetting has been provided for as per Schedule 2 Condition 15 of the Consent. |
| **S1B** | Level 1, 2 or 3 TARP. | Two years of decline in total swamp extent greater than the mean (±SE) decline of the control group.<br><br>Trending decline in the extent of sub-community MU43 and MU44b for two consecutive monitoring periods greater than the mean (±SE) decline in the MU42 and MU43 control group. | **Swamp Size: Level 1 TARP triggered.**<br><br>**Ecosystem Function: Level 1 TARP triggered** | Continue on-ground and UAV imagery monitoring in 2020.<br><br>Ground truth swamp extent and swamp vegetation community extent in 2020.<br><br>Investigate practical remediation measures.<br><br>Swamp offsetting has been provided for as per Schedule 2 Condition 15 of the Consent. |

| Swamp | Predicted impact | Results and TARP justification | TARP | Recommendations |
|---|---|---|---|---|
| **S05** | Level 1, 2 or 3 TARP. | One year of decline in total swamp greater than the mean (±SE) decline of the control group.<br><br>Trending decline in the extent of sub-community MU42, MU43 for three consecutive monitoring periods greater than the mean (±SE) decline in the control group. | **Swamp Size: No TARP triggered.**<br><br>**Ecosystem Function: Level 2 TARP triggered.** | Continue monitoring in 2020.<br><br>Capture UAV imagery for this swamp in 2020.<br><br>Ground truth swamp extent and swamp vegetation community extent in 2020.<br><br>Investigate practical remediation measures.<br><br>Swamp offsetting has been provided for as per Schedule 2 Condition 15 of the Consent. |
| **S08** | Level 1, 2 or 3 TARP. | One year of decline in total swamp extent greater than the mean (±SE) decline of the control group.<br><br>One year of trending decline in the extent of MU42 over the monitoring period. | **Swamp Size: No TARP triggered.**<br><br>**Ecosystem Function: No TARP triggered.** | Continue monitoring in 2020.<br><br>Capture UAV imagery for this swamp in 2020.<br><br>Ground truth swamp extent and swamp vegetation community extent in 2020. |

### 4.2.2 Littlejohn's Tree Frog monitoring

It was predicted that mining within Dendrobium Area 3A and 3B would have a significant impact to one or more local populations of Littlejohn's Tree Frog (Biosis 2007b; Niche 2012). Analysis of adult Littlejohn's Tree Frog standardised abundance for the combined Dendrobium Area 3A and Area 3B programs over all monitoring periods indicates that broadly the abundance of adult frogs is lower at impact sites than control sites. Due to the catchment wide dry conditions experienced in 2018 and 2019, the continuation of this trend is more difficult to determine for this year and the ability to confidently identify any new impacts may also be limited due to the decreased detection numbers across control sites.

Fracturing of the bedrock and resultant pool water level loss in SC10C has resulted in impacts to breeding habitat for Littlejohn's Tree Frog, seen in the decreasing number of individuals detected within the site over time. The revised *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (12 November 2012) (Illawarra Coal 2012c) sets out the trigger levels for terrestrial fauna:

- Level 1 - No significant statistical difference between Before After Control Impact sites.
- Level 2 - Statistically significant difference of species richness and species diversity between Before After Control Impact sites as a result of mining.
- Level 3 - Vegetation impacted by mining that is not responding to CMAs.

The above TARPS (dated 12 November 2012) relating to ecology are limited in the way they can be assessed due to the variability in the detection of Littlejohn's Tree Frog and limitations in analysis of the data due to lack of sufficient replication. As the focus of these TARPs is on vegetation, they also fail to stipulate specific actions to be undertaken following the detection of impacts to Littlejohn's Tree Frog habitat during monitoring.

It is understood however that Pool Water Level / Flow and Appearance triggers identified in the Dendrobium Area 3A Watercourse Impact Monitoring Management and Contingency Plan have been triggered at both SC10C (Level 3) and SC10(1) (Level 1), and CMAs are being considered by Illawarra Metallurgical Coal and the Department of Planning, Industry and Environment.

Table 22 assesses impact sites in Dendrobium Area 3A against the TARPs using the definitions outlined above.

**Table 22 Assessment of Littlejohn's Tree Frog monitoring results at impacted sites within the Dendrobium Area 3A against Dendrobium Area 3A TARPs**

| Stream | Predicted impact | Results and TARP justification | TARP | Recommendations |
|---|---|---|---|---|
| **Dendrobium Area 3A Landscape Monitoring TARP (dated 12 November 2012)** | | | | |
| **SC10C** | Significant impacts to the Littlejohn's Tree Frog. | A decline in the abundance of adult frogs was observed following subsidence impacts detected at SC10C following extraction of Longwall 7 and Longwall 8 during 2011 and 2012 (2 years after the initial mining within the RMZ), and numbers have not recovered.<br><br>The following Level 1 triggers relating to terrestrial fauna have been observed:<br>• No significant statistical difference between Before After Control Impact sites.<br><br>The following triggers relating to watercourse monitoring have been observed:<br>• Stream appearance at SC10C. | **Level 1 TARP triggered.** | Continue monitoring to investigate whether CMAs for related watercourse TARPs may address some impacts to threatened frog habitats. |
| **SC10(1)** | Significant impacts to the Littlejohn's Tree Frog. | There has been no significant decline in Littlejohn's Tree Frogs at SC10(1) since mining began in 2011. Although tadpole and egg mass numbers were low in 2017, this is consistent with pre-mining records, and does not appear associated with mining impacts. The 2019 results for Littlejohn's Tree Frogs at this site were considered nominal in comparison to the previous results and control sites during this year.<br><br>The following trigger relating to watercourse monitoring has been observed:<br>• Iron flocculent covering all stream surfaces<br>This represents a reduction in breeding habitat for Littlejohn's Tree Frogs. | **No TARP levels triggered.** | Continue approved monitoring program. |

| Stream | Predicted impact | Results and TARP justification | TARP | Recommendations |
|---|---|---|---|---|
| **SC10(2)** | Significant impacts to the Littlejohn's Tree Frog. | There has been no significant decline in Littlejohn's Tree Frogs at SC10(2) since mining began in 2011. | **No TARP levels triggered.** | Continue approved monitoring program. |
| **WC17** | Significant impacts to the Littlejohn's Tree Frog. | Due to the level of variation in the dataset and lack of replication of monitoring events each year, a statistical analysis of the data could not be completed. In 2017, detection of Littlejohn's Tree Frog continued to increase from previous years, with abundance records consistent with pre-mining numbers. Due to a lack of water at this site and associated control sites, and on the basis that comparable abundances of each life stage were recorded for at least one of the paired control sites in 2019, it is determined that the level 1 TARP continues not to be triggered. However, future monitoring results should be closely examined at this site. | **Level 1 TARP no longer triggered. No TARP levels triggered.** | Continue approved monitoring program. |

Littlejohn's Tree Frog transects within Dendrobium Area 3B have been assessed against the *Dendrobium Area 3B Watercourse TARP* (dated 12 October 2015) which include the following trigger levels for Threatened Frog Species:

- Level 1 - Reduction in habitat for 1 year.
- Level 2 - Reduction in habitat for 2 years following the active subsidence period.
- Level 3 - Reduction in habitat for >2 years or complete loss of habitat following the active subsidence period.

Biosis has defined a reduction or complete loss of habitat for the Littlejohn's Tree Frog as the following:

- A reduction in habitat is:
  - A reduction in potential breeding habitat, shown by dry pools along the transect during the breeding season. This prevents adults from laying egg mass in some portion of the habitat; or
  - A reduction in breeding habitat for egg mass and tadpole life stages, as shown by breeding pools recorded to be consistently dry during the breeding season or unable to hold water for a sufficient time to allow for full development to occur. This results in the unsuccessful hatching and completion of metamorphosis of egg mass and tadpoles; or
  - A significant reduction in the presence of Littlejohn's Tree Frog (all life stages) from a site where successful breeding occurred pre-mining.
- A complete loss of habitat is:
  - A reduction in potential breeding habitat, shown by dry pools along the transect during the breeding season. This prevents adults from laying egg mass in the entire section of habitat; and

- The absence of the species (all life stages) from a site where successful breeding occurred pre-mining.

Table 23 assesses impact sites in Dendrobium Area 3B against the TARPs using the definitions outlined above.

**Table 23 Assessment of Littlejohn's Tree Frog monitoring results at impact sites within the Dendrobium Area 3B against Dendrobium Area 3B TARPs**

| Stream | Predicted impact | Results and TARP justification | TARP | Recommendations |
|---|---|---|---|---|
| **Dendrobium Area 3B Watercourse Monitoring TARP (dated 12 October 2015)** | | | | |
| **DC(1)** | Significant impacts to the Littlejohn's Tree Frog. | Following the 2016 survey at DC(1), breeding pools (Pools 32 and 33) had a reduced water level below the pool monitoring benchmark. In order to confirm whether water remained present in pools long enough for Littlejohn's Tree Frog tadpoles and eggs to develop and metamorphose, follow up surveys were undertaken in summer 2016/2017 by Biosis. These surveys confirmed that pool water had dried up before recorded tadpoles and eggs had sufficient time to metamorphose, resulting in zero survival, and indicating a loss of Littlejohn's Tree Frog breeding habitat within DC1 (Biosis 2017).<br><br>The level 1 TARP was triggered in 2017. While also reflecting the impacts of dry conditions, the 2018 and 2019 data is consistent with that of the 2017 findings. As such a reduction in habitat for 2 years following the active subsidence period has occurred and Level 2 TARP has been triggered. | **Level 2 TARP triggered.** | Review monitoring frequency<br><br>Notify relevant technical specialists and seek advice on any CMA required<br><br>Implement agreed CMAs as approved (subject to stakeholder feedback)<br><br>Continue monitoring as a part of the approved terrestrial monitoring program. |
| **DC13** | Significant impacts to the Littlejohn's Tree Frog. | Subsidence impacts following mining has resulted in the loss of water in pools located above this longwall. In 2016, subsidence impacts extended along approximately 30% of the monitoring transect. Pools located within this stretch (Pools 18A through to the transect end) provided known habitat for Littlejohn's Tree Frog during the baseline monitoring period. Pools along approximately 40% of the total length of the transects had experienced a reduction in water in 2016.<br><br>Follow up monitoring in summer 2016/2017 confirmed that many of the identified breeding pools that had water in winter 2016 had experienced a significant reduction in water by | **Level 3 TARP triggered in 2017. Level 3 TARP is considered to remain triggered in 2019.** | Recommendations for reporting to the relevant authorities were made following the triggering of the Level 3 TARP in Biosis (2017).<br><br>Continue monitoring as a part of the terrestrial monitoring program. |

| Stream | Predicted impact | Results and TARP justification | TARP | Recommendations |
|---|---|---|---|---|
| | | summer, and were considered no longer appropriate habitat for Littlejohn's Tree Frogs to survive to metamorphosis. While also reflecting the impacts of dry conditions, the 2019 data is consistent with the 2017 and 2018 findings. The Level 3 TARP is considered to remain triggered and should be reviewed in 2020. | | |
| **WC21** | Significant impacts to the Littlejohn's Tree Frog. | A reduction in habitat for five monitoring periods (four years) has been recorded at WC21 following the extraction of Longwall 9, Longwall 10, Longwall 11 and Longwall 12. Approximately 57% of the potential breeding habitat along this stream is experiencing a reduction in water levels (between Pool 11 and Pool 30) including three confirmed breeding pools (observations by Biosis during monitoring in 2015).<br><br>While also reflecting the impacts of dry conditions, the 2019 data is consistent with the 2017 and 2018 findings. The Level 3 TARP is considered to remain triggered and should be reviewed in 2020. | **Level 3 TARP triggered. Level 3 TARP is considered to remain triggered in 2019.** | Recommendations for reporting to the relevant authorities were made following the triggering of the Level 3 TARP in Biosis (2017).<br><br>Continue monitoring as a part of the terrestrial monitoring program. |
| **LA4A** | Significant impacts to the Littlejohn's Tree Frog. | No observed impacts have been detected at the one breeding pool, LA4A-P1 along this stream. Some fracturing and flow diversion has been detected at the lower end of the transect where it becomes LA4, however this has not resulted in a reduction of breeding habitat for the species. | **No TARP Level triggered.** | Continue monitoring as a part of the approved terrestrial monitoring program. |

In response to the impacts to DC(1), DC13 and WC21, water level monitoring and tadpole surveys were undertaken during summer 2016/2017 to determine if metamorphosis was occurring along streams where reductions in habitat were detected (Biosis 2017b). Continuing tadpole development at DC13, WC21 and DC(1) varied based on the availability of sustained water levels within potholes and pools throughout the key development stages following the 2016 winter breeding season. Due to a limited number of breeding pools that contain water for sufficient time to allow for full development to metamorphosis and adults, the risk of losing a generation of a local population of Littlejohn's Tree Frogs at these sites has increased as a result of mining impacts. Continued monitoring and the consideration of CMAs are recommended in Biosis (2017b). The results of the 2019 monitoring period are consistent with those recorded in 2017, as such the recommended monitoring and CMAs in Biosis (2017b) remain relevant.

## 4.3 Site specific recommendations

### 4.3.1 Upland swamp terrestrial flora monitoring

Swamp 15B has been monitored over a considerable period of time. Statistically significant changes in TSR and species composition following mining have been recorded during this time. Further monitoring of these trends is recommended to collect additional long term data to continue to build scientific knowledge on the impacts of longwall mining on upland swamps.

Biosis recommends that the Illawarra Metallurgical Coal Environmental Field Team continue to observe the extent of the area of vegetation dieback within Swamp 15B at six monthly intervals using suitable methods; for example on-ground survey with a differential GPS (i.e. sub 1 meter accuracy) supplementary to high-resolution aerial imagery captured by a UAV, to track changes in the extent of affected vegetation over time. We recommend this mapping be completed at the time of seasonal swamp vegetation monitoring and with the assistance of a suitably experienced botanist.

The triggering of a Dendrobium Area 3A Swamp – Terrestrial Flora Level 2 TARP for S15B and Level 1 TARP for S1B (South32 2015) requires the following actions:

- Continue monitoring program.
  - Biosis proposes to continue monitoring all sites as part of the 2020 monitoring program.
- Review monitoring frequency and method.
- Report in the End of Panel Report.
- Summarise all actions and monitoring in Annual Environmental Monitoring Report (AEMR).
- Notify relevant technical specialists and seek advice on any CMA required.
- Implement agreed CMAs as approved.

#### 4.3.2 Dendrobium Area 3B upland swamps

While no TARP trigger levels were met at sites located within Dendrobium Area 3B, all three swamp sites currently monitored as impact sites (Swamp 1A, Swamp 5 and Swamp 1B) have experienced decreased groundwater levels and soil moisture at monitoring locations. Both Swamp 1A and Swamp 5 have also experienced yellowing of Needlebush vegetation and dieback of cyperoid heath vegetation. The continued monitoring of all three sites is therefore recommended in the event that there is a lag in the detection of change to TSR and species composition resulting from mining.

Biosis recommends that the Illawarra Metallurgical Coal Environmental Field Team monitor the areas of dieback observed at Swamp 1A, supplemented by high-resolution aerial imagery captured by a UAV. UAV imagery for this swamp was not captured in 2019. This data will further inform the ongoing changes in swamp vegetation extent observed at this swamp.

#### 4.3.3 SC10C and WC17 Littlejohn's Tree Frog monitoring

The triggering of a revised Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012) (Illawarra Coal 2012c) Level 1 TARP for SC10C requires the following actions:

- Continue monitoring program.
  - Biosis proposes to continue monitoring SC10C as part of the 2020 monitoring program.
- Report impacts to key stakeholders.
- Summarise impacts and Report in the End of Panel Report and AEMR.

#### 4.3.4 SC10(1) Littlejohn's Tree Frog monitoring

Pool Water Level / Flow and Appearance triggers (Level 1) in the Dendrobium Area 3 Watercourse TARP have been triggered at SC10(1) in 2017 due to the build-up of iron flocculent on stream surfaces. This requires the following actions:

- Continue monitoring program.
  - Biosis proposes to continue monitoring SC10(1) as part of the 2020 monitoring program.
- Report in the End of Panel Report.
  - Illawarra Metallurgical Coal to incorporate results in End of Panel report.
- Summarise actions and monitoring in AEMR.
  - Illawarra Metallurgical Coal to incorporate results in the AEMR.

#### 4.3.5 DC(1) Littlejohn's Tree Frog monitoring

The triggering of a Dendrobium Area 3B Watercourse – Terrestrial Fauna: Threatened Frog Species Level 2 TARP for DC(1) requires the following actions:

- Continue monitoring program.
  - Biosis proposes to continue monitoring DC(1) as part of the 2020 monitoring program.
- Submit an Impact Report to BCD, DPIE, WaterNSW and other relevant resource managers.
  - To be completed as part of the End of Panel report.
- Report in the End of Panel Report.
  - Illawarra Metallurgical Coal to incorporate results End of Panel report.
- Summarise actions and monitoring in AEMR.
  - Illawarra Metallurgical Coal to incorporate results in the AEMR.

#### 4.3.6 WC21 and DC13 Littlejohn's Tree Frog monitoring

The Dendrobium Area 3B Watercourse – Terrestrial Fauna: Threatened Frog Species Level 3 TARP for WC21 and DC13 was triggered in 2017, and remains so, and requires the following actions:

- Continue monitoring program.
  - Biosis proposes monitoring WC21 and DC13 as part of the 2019 monitoring program.
- Submit an Impact Report to BCD, DPIE, WaterNSW and other relevant resource managers.
  - To be completed as part of the End of Panel report.
- Report in the End of Panel Report.
  - Illawarra Metallurgical Coal to incorporate results in the End of Panel report.
- Summarise actions and monitoring in AEMR.
  - Illawarra Metallurgical Coal to incorporate results in the AEMR.
- Review monitoring frequency.
- Notify relevant technical specialists and seek advice on any CMA required.
  - Illawarra Metallurgical Coal to seek advice from relevant technical specialists as to the most appropriate CMAs.
- Implement agreed CMAs as approved (subject to stakeholder feedback).
- Attend a site visit with BCD, DPIE, WaterNSW and other resource manager/s (if requested).

- Review relevant TARP and Management Plan in consultation with key stakeholders.
- Develop site CMA (subject to stakeholder feedback). This may include:
  - Grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with BCD, DPIE, WaterNSW and other stakeholders.
  - Biosis should be consulted to provide advice regarding the most appropriate breeding pools to invest in CMAs.
- Completion of works following approvals and at a time agreed between Illawarra Metallurgical Coal, DPIE and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success.

## 4.4 Conclusion

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

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

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

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# Appendix 1

**Table 24 Swamp flora species and species complexes recorded during monitoring in Dendrobium Areas 2, 3A and 3B**

| Swamp flora species and species complexes |
|---|
| *Acacia linifolia* |
| *Acacia rubida* |
| *Acacia suaveolens* |
| *Acacia terminalis* |
| *Acianthus species complex* |
| *Acmena smithii* |
| *Actinotus minor* |
| *Adiantum aethiopicum* |
| *Allocasuarina littoralis* |
| *Allocasuarina paludosa* |
| *Almaleea paludosa* |
| *Amperea xiphoclada* |
| *Anisopogon avenaceus* |
| *Aotus ericoides* |
| *Austrostipa pubescens* |
| *Austrostipa rudis* |
| *Baeckea diosmifolia* |
| *Baeckea imbricata* |
| *Baeckea linifolia* |
| *Baloskion gracile* |
| *Banksia ericifolia* |
| *Banksia marginata* |
| *Banksia oblongifolia* |
| *Banksia paludosa* |
| *Banksia robur* |
| *Banksia spinulosa* var. *spinulosa* |
| *Bauera microphylla/ rubioides* sp *complex* |
| *Baumea acuta* |
| *Baumea articulata/ rubiginosa/ teretifolia sp. Chorizandra cymbaria/ sphaerocephalum species complex* |
| *Baumea juncea* |
| *Billardiera scandens* var. *scandens* |
| *Blandfordia Burchardia Caladenia Haemodorum Microtis Thelymitra species complex* |
| *Boronia parviflora* |
| *Bossiaea heterophylla* |
| *Bossiaea scolopendria* |
| *Brachyloma Monotoca Lissanthe Leucopogon complex* |
| *Brunoniella pumilio* |
| *Caesia parviflora* var. *parviflora* |
| *Callistemon citrinus* |

*Callistemon subulatus*
*Calochilus campestris*
*Calytrix tetragona*
*Cassytha glabella/ pubescens* sp *complex*
*Ceratopetalum apetalum*
*Chordifex fastigiatus*
*Cissus antarctica*
*Comesperma defoliatum*
*Comesperma ericinum f. A*
*Comesperma sphaerocarpum*
*Conospermum tenuifolium*
*Corybas sp_complex*
*Corymbia gummifera*
*Cryptandra ericoides*
*Cryptostylis sp_ complex*
*Cyathochaeta diandra*
*Cyclosorus interruptus*
*Cynodon dactylon*
*Dampiera purpurea*
*Dampiera stricta*
*Darwinia grandiflora*
*Dianella caerulea complex*
*Dianella longifolia* var. *longifolia*
*Dianella revoluta* var. *revoluta*
*Dillwynia floribunda retorta complex*
*Dodonaea camfieldii*
*Drosera binata*
*Drosera peltata*
*Drosera pygmaea*
*Drosera spatulata*
*Eleocharis pusilla*
*Empodisma minus*
*Entolasia species complex*
*Epacris microphylla*
*Epacris obtusifolia*
*Epacris paludosa*
*Epacris pulchella/ Woollsia pungens Sp_ complex*
*Eriochilus cucullatus*
*Eucalyptus species complex*
*Eurychorda complanata*
*Fleshy lily*
*Gahnia Sp_ complex*
*Genoplesium species complex*
*Gleichenia dicarpa/ microphylla sp complex*
*Gompholobium glabratum/ grandiflorum Sp_ complex*
*Gompholobium minus pinnatum complex*

| |
|---|
| *Gonocarpus sp_ complex* |
| *Goodenia dimorpha/ stelligera/ bellidifolia sp complex* |
| *Goodenia hedercacea/ heterophylla Sp_ complex* |
| *Grevillea oleoides* |
| *Grevillea patulifolia/sericea/speciosa complex* |
| *Grevillea sphacelata* |
| *Gymnoschoenus sphaerocephalus* |
| *Hairy couch* |
| *Hakea dactyloides/ salicifolia Sp_ complex* |
| *Hakea teretifolia/ sericea sp complex* |
| *Hibbertia aspera/ hermanniifolia/ obtusifolia Sp_ complex* |
| *Hibbertia bracteata* |
| *Hibbertia riparia species complex* |
| *Hybanthus monopetalus* |
| *Hypericum japonicum/ gramineum Sp_ complex* |
| *Kunzea ambigua* |
| *Lachnagrostis filiformis* |
| *Lagenifera stipitata* |
| *Lambertia formosa* |
| *Laxmannia gracilis* |
| *Leionema diosmeum* |
| *Lepidosperma filiforme/ urophorum complex* |
| *Lepidosperma forsythii* |
| *Lepidosperma limicola* |
| *Lepidosperma neesii/ Ptilothrix deusta complex* |
| *Leptocarpus tenax* |
| *Leptomeria acida* |
| *Leptospermum arachnoides* |
| *Leptospermum juniperinum* |
| *Leptospermum lanigerum* |
| *Leptospermum polygalifolium/ trinervium complex* |
| *Leptospermum rotundifolium* |
| *Leptospermum squarrosum* |
| *Lepyrodia anarthria* |
| *Lepyrodia cryptica* |
| *Lepyrodia muelleri/ scariosa complex* |
| *Lindsaea linearis* |
| *Lomandra confertifolia* |
| *Lomandra confertifolia subsp. rubiginosa* |
| *Lomandra cylindrica/ filiformis/ micrantha sp complex* |
| *Lomandra glauca* |
| *Lomandra longifolia* |
| *Lomandra multiflora subsp. multiflora* |
| *Lomandra obliqua* |
| *Lomatia silaifolia* |
| *Lycopodiella lateralis* |

 

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|---|
| *Lycopodium* sp. |
| *Melaleuca linariifolia* |
| *Melaleuca squarrosa* |
| *Melaleuca thymifolia* |
| *Micrantheum ericoides* |
| *Microlaena stipoides* |
| *Mirbelia rubiifolia/ speciosa Sp_ complex* |
| *Mitrasacme polymorpha/ pilosa species complex* |
| *Monotaxis linifolia* |
| *Morinda jasminoides* |
| *Olax stricta* |
| *Omphacomeria acerba* |
| *Opercularia diphylla/ aspera Sp_ complex* |
| *Orchidaceae indeterminate* |
| *Panicum simile* |
| *Parsonsia straminea* |
| *Patersonia species complex* |
| *Persoonia glaucescens* |
| *Persoonia lanceolata* |
| *Persoonia levis* |
| *Persoonia linearis* |
| *Persoonia mollis* subsp. *nectens* |
| *Persoonia nutans* |
| *Petrophile/ Isopogon complex* |
| *Pittosporum revolutum* |
| *Pittosporum undulatum* |
| *Platysace linearifolia* |
| *Plinthanthesis paradoxa* |
| *Poa Sp_ complex* |
| *Polyscias murrayi* |
| *Poranthera ericifolia* |
| *Pseuderantherum variable/ brunoniella sp complex* |
| *Pteridium esculentum* |
| *Pterostylis parviflora* |
| *Pultenaea aristata* |
| *Pultenaea divaricata* |
| *Pultenaea tuberculata* |
| *Rhytidosporum procumbens* |
| *Scaevola ramosissima* |
| *Schizaea bifida* |
| *Schizaea dichotoma* |
| *Schoenus apogon* |
| *Schoenus brevifolius/ lepidosperma sp complex* |
| *Schoenus melanostachys* |
| *Schoenus paludosus* |
| *Schoenus turbinatus* |

| |
|---|
| *Selaginella uliginosa* |
| *Sowerbaea juncea* |
| *Sphaerolobium/Stackhousia species complex* |
| *Sporadanthus gracilis* |
| *Sprengelia incarnata* |
| *Stylidium sp_ complex* |
| *Styphelia laeta subsp. laeta* |
| *Symphionema paludosum* |
| *Tetraria capillaris* |
| *Tetrarrhena juncea* |
| *Tetrarrhena turfosa/ Hemarthria uncinata complex* |
| *Thysanotus juncifolius* |
| *Trachymene incisa* |
| *Tricoryne Hypoxis species complex* |
| *Utricularia species complex* |
| *Villarsia exaltata* |
| *Viminaria juncea* |
| *Viola hederacea sieberiana complex* |
| *Xanthorrhoea resinosa/ media sp complex* |
| *Xanthosia dissecta/pilosa/ tridentata species complex* |
| *Xyris species complex* |