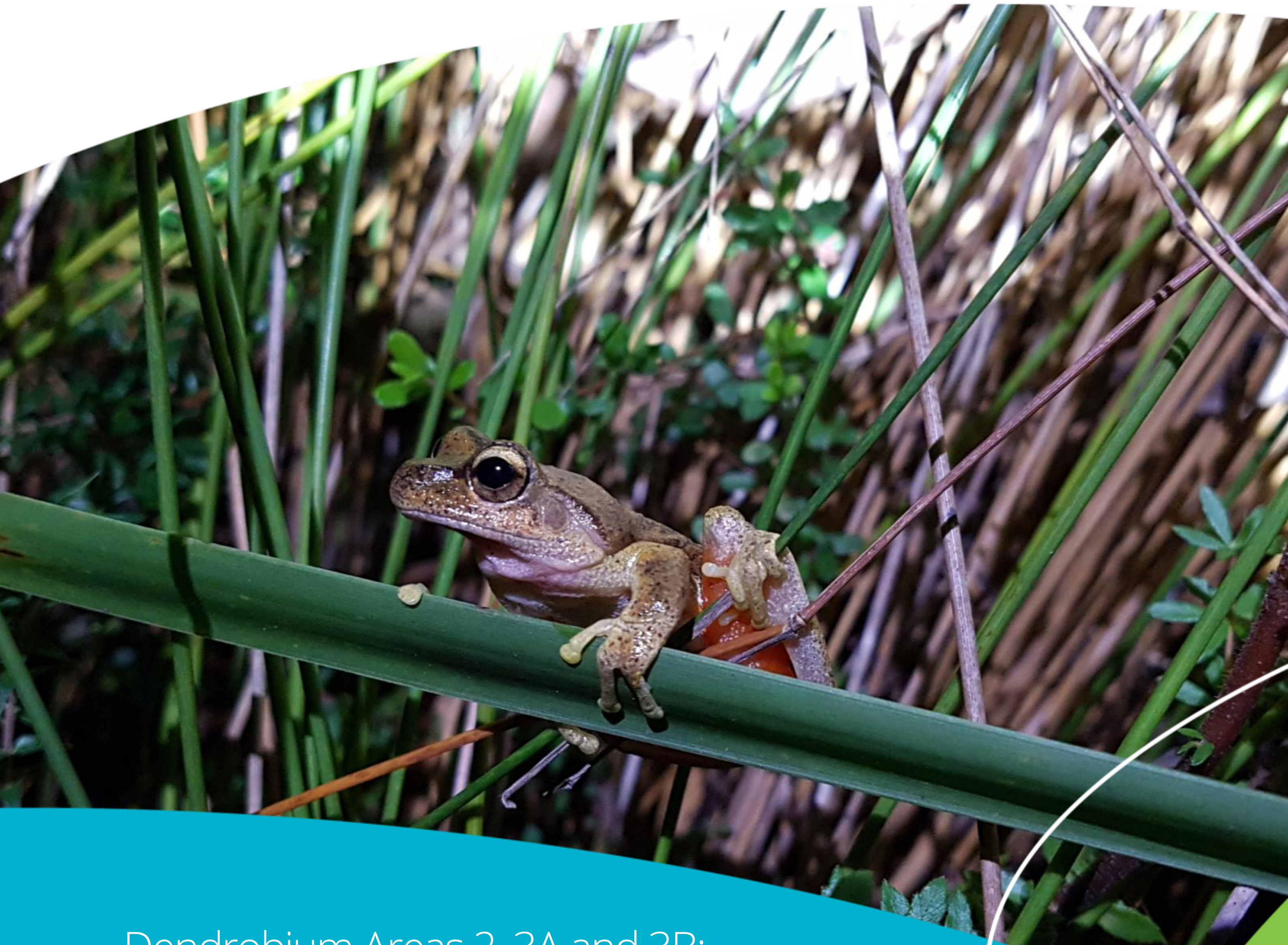

Dendrobium Areas 2, 3A and 3B: Terrestrial Ecology Monitoring Program Annual Report 2018

FINAL REPORT

Prepared for Illawarra Coal

21 June 2019

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Contents

Tables

Figures

Summary

During the 2018 monitoring period, Longwall 12 was extracted within Dendrobium Area 3B, followed by extraction of Longwall 13 and current extraction of Longwall 14. This followed 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 3A and Area 3B.
- Littlejohn's Tree Frog *Litoria littlejohni* (Vulnerable EPBC Act and 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 (S11) 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 species composition post-mining was found at Swamp 15B and Swamp 15A(2). As with TSR, these changes were observed immediately following undermining and have continued at Swamp 15B and Swamp 15A(2) for at least four years post-mining.

There was a decrease in detection of adult Littlejohn's Tree Frog in 2018 compared to 2016 by approximately 32%, and tadpoles by 84%. However, 2016 was an excellent year for breeding due to high levels of rainfall, and frog numbers recorded in 2016 were much higher than previous years. Detection of Littlejohn's Tree Frog in 2018 was comparable to detection in 2015.

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 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 Colliery Planning Approval, originally issued in 2001, and as modified 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 for a period 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 not monitored in the current monitoring period. Monitoring within 3A and 3B is ongoing (refer to Sections 1.3.1 and 1.3.2 respectively).

The aim of the program is to determine whether subsidence effects associated with longwall mining result 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 *Litoria littlejohni* (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 2018 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 2018 monitoring program.
- Discuss results of statistical analysis undertaken for 2018 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.
- 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 two mining domains (Dendrobium Area 3A and Dendrobium Area 3B) as well as control sites.

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 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.

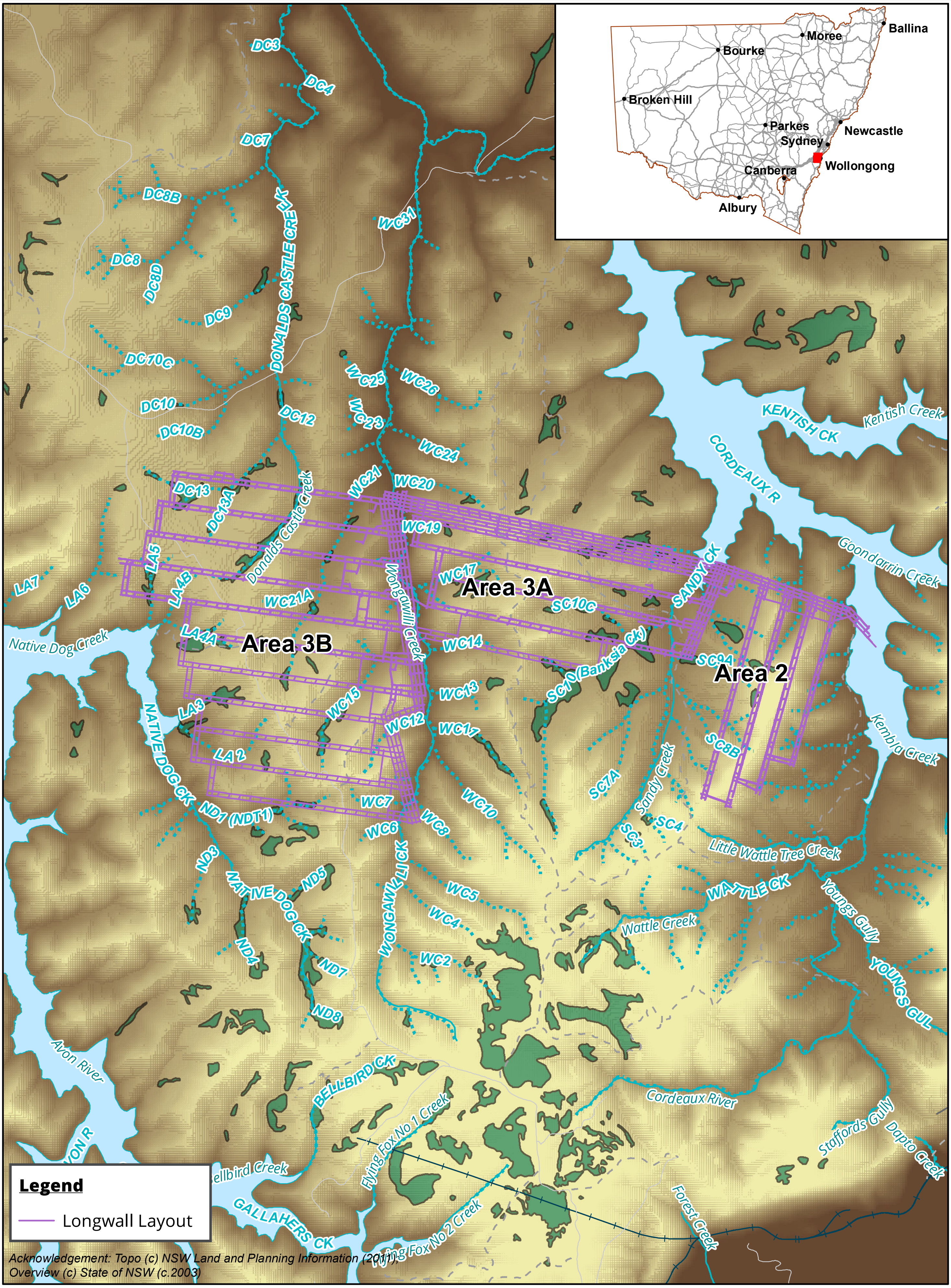

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Figure 1 Location of the study area in a regional context

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Kilometres
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1.3.1 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 2018.

1.3.2 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 14. 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 2018 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. In March 2017, the RMZ of Swamp 11 was mined beneath by Longwall 13. In 2017, the RMZ of Swamp 13 was mined beneath by Longwall 13 and is expected to be mined beneath by Longwall 14 during 2018 (Figure 3). Swamp 11 and Swamp 13 have therefore been included in the impact assessment of the 2018 program.

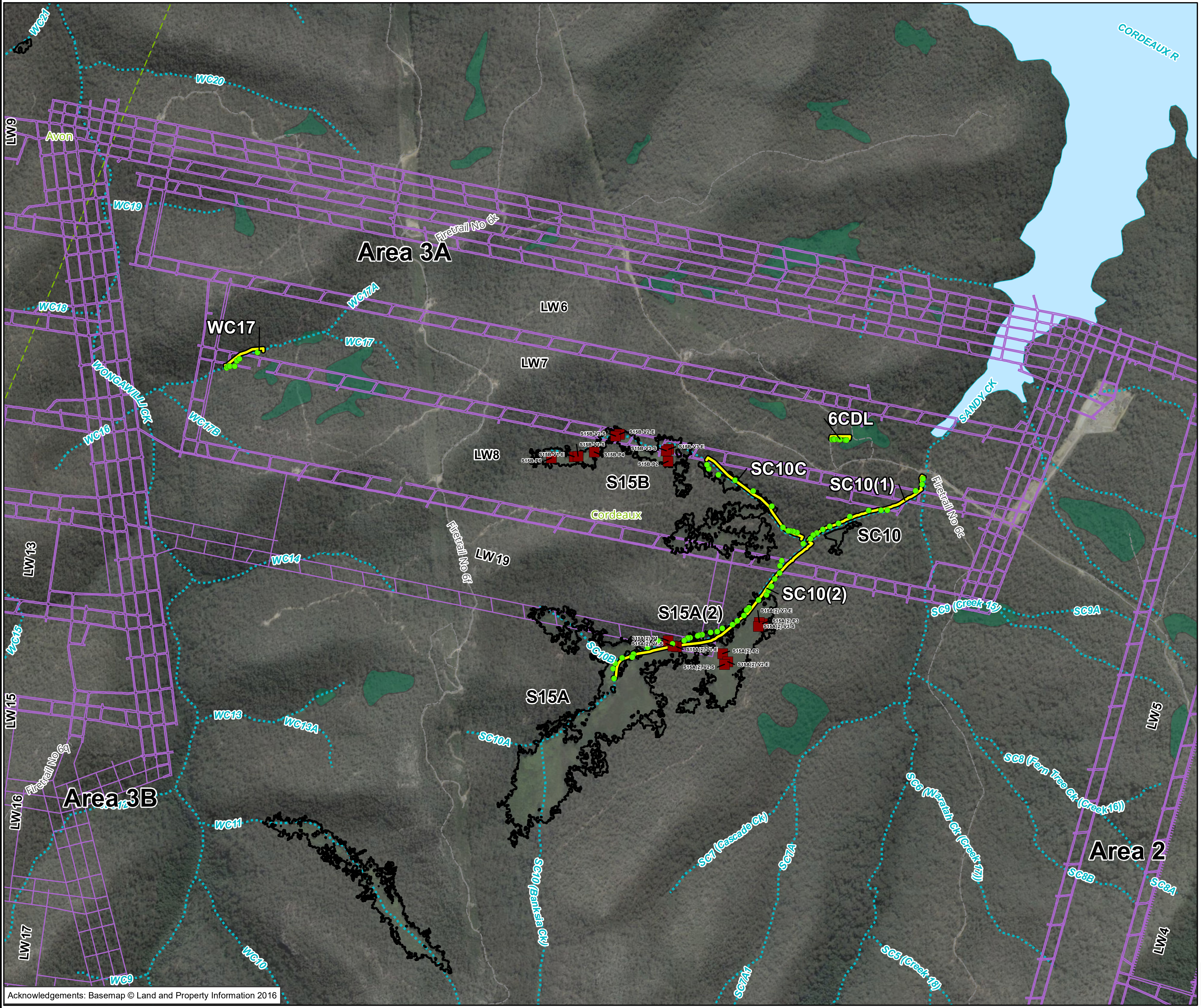
During 2018 a total of six creeks were monitored for Littlejohn's Tree Frog as part of the Dendrobium Area 3B program; continued monitoring at DC(1), DC13, LA4A, WC15, WC21 as well as the addition of LA2 to the program to commence two years of pre-mine baseline monitoring (Figure 3).

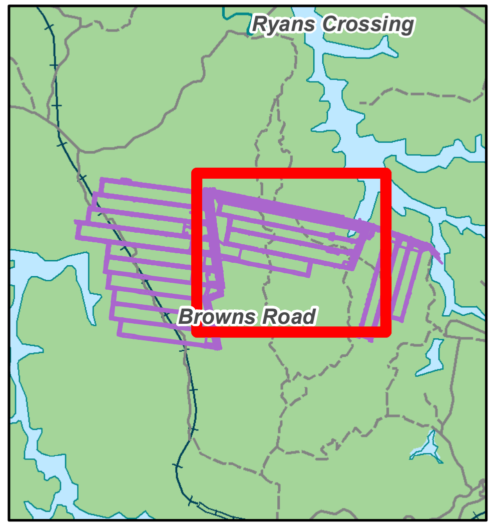
1.3.3 Control sites

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).





Legend

Monitoring Locations

- Flora upland swamp impact site
- Threatened frog monitoring impact transect
- Threatened frog monitoring breeding pool
- Upland swamp boundary (Biosis)

Survey Area

- Longwall Layout
- IC Creekline
- Upland swamp boundary (NPWS)

Figure 2 Location of 2018 monitoring impact sites surveyed in Dendrobium Area 3A

0 200 400 600
Metres
Scale: 1:13,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

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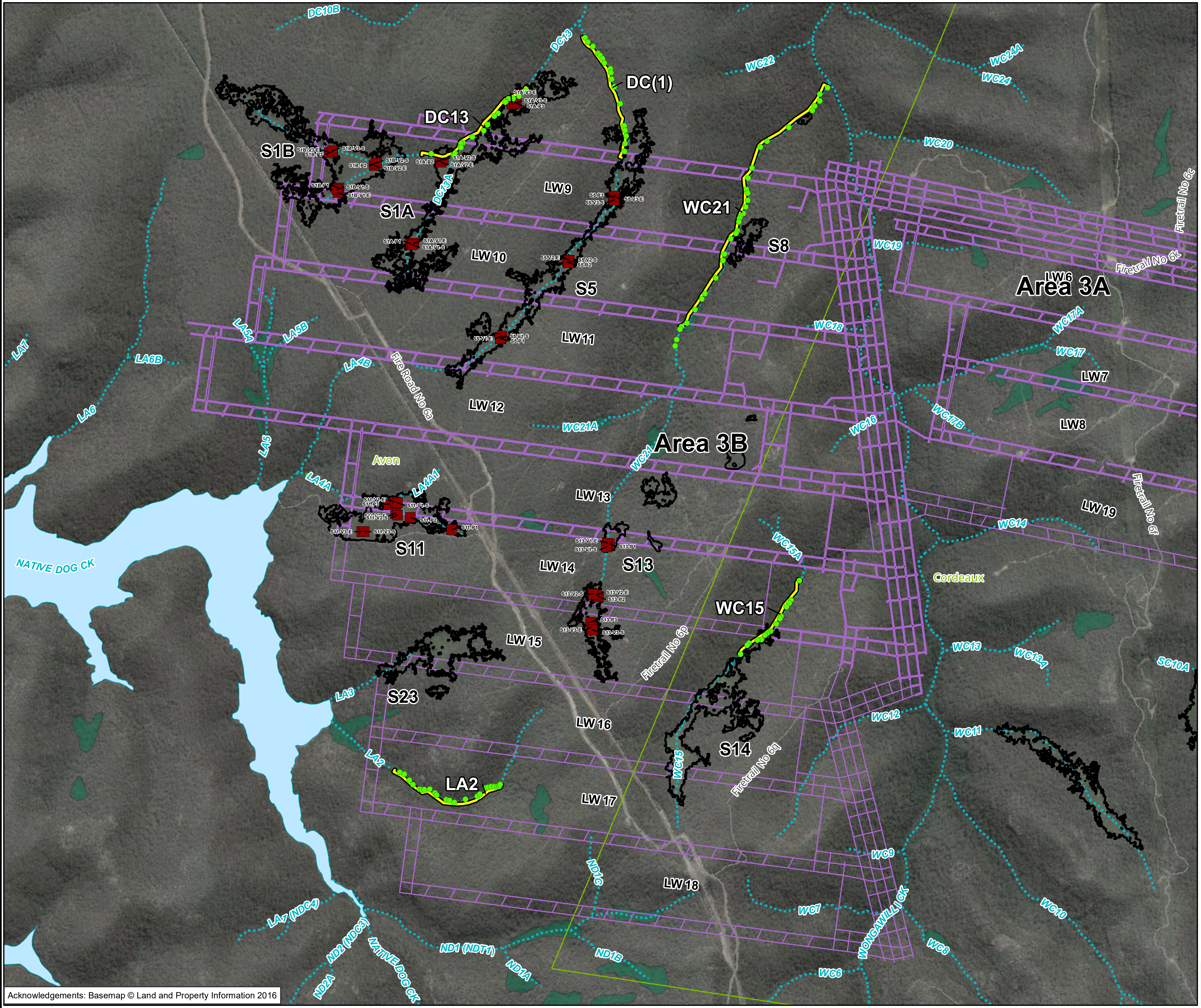

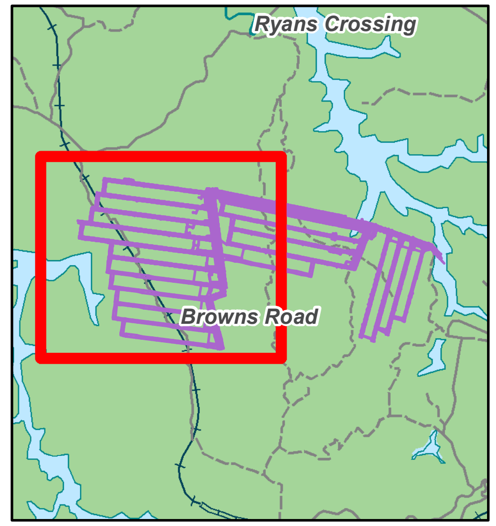

Legend

Monitoring Locations

- Flora upland swamp impact site
- Threatened frog monitoring impact transect
- Threatened frog monitoring breeding pool
- Upland swamp boundary (Biosis)

Survey Area

- Longwall Layout
- IC Creekline
- Upland swamp boundary (NPWS)

Figure 3 Location of 2018 monitoring impact sites surveyed in Dendrobium Area 3B

0 200 400 600 800

Metres

Scale: 1:16,500 @ A3

Coordinate System: GDA 1994 MGA Zone 56

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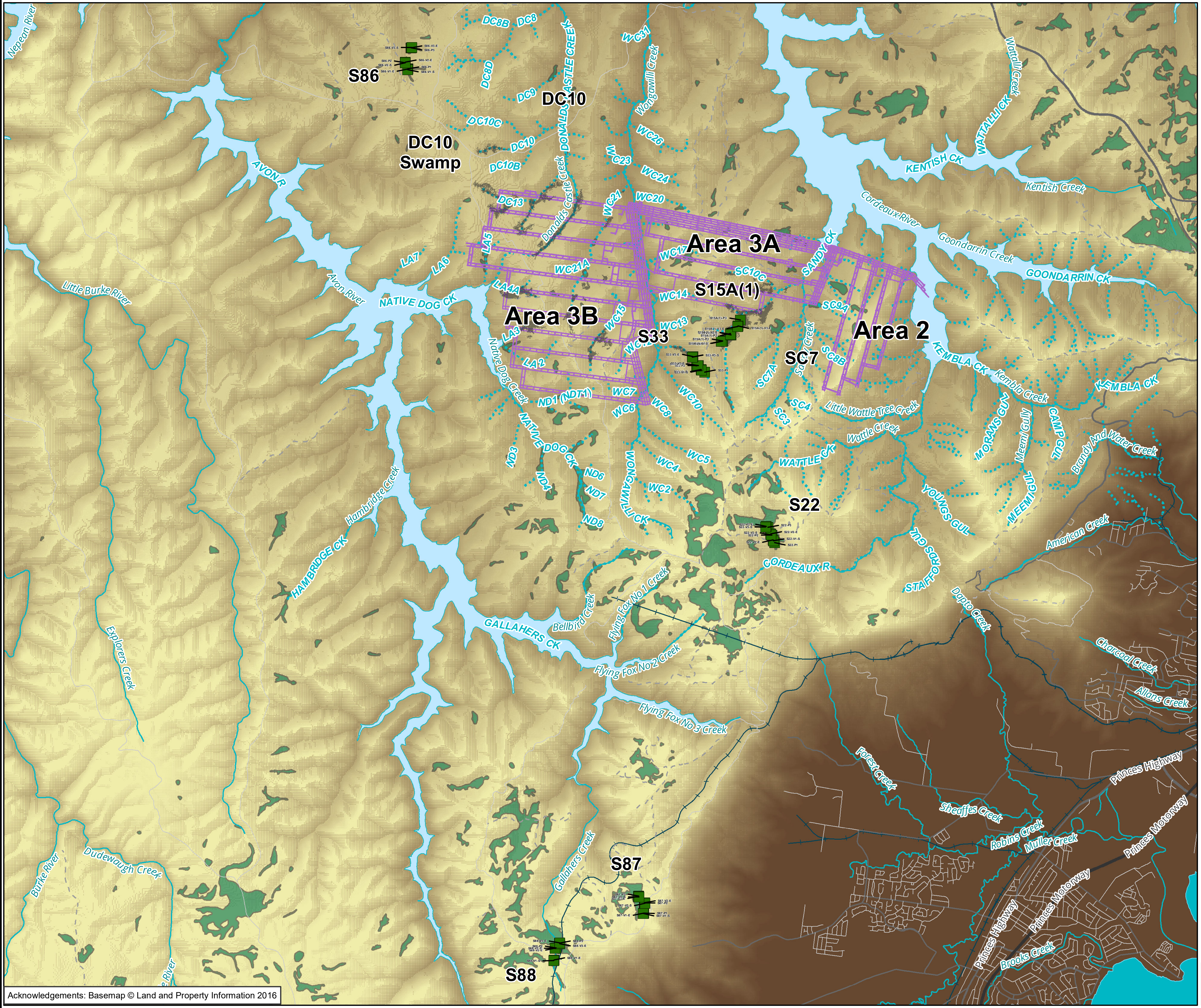

Legend

Monitoring Locations

- Flora upland swamp control site
- Upland swamp boundary (Biosis)

Survey Area

- Longwall Layout
- IC Creekline
- Upland swamp boundary (NPWS)

Figure 4 Location of flora monitoring control sites used in the 2018 program

0 1 2 3
Kilometeres
Scale: 1:65,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

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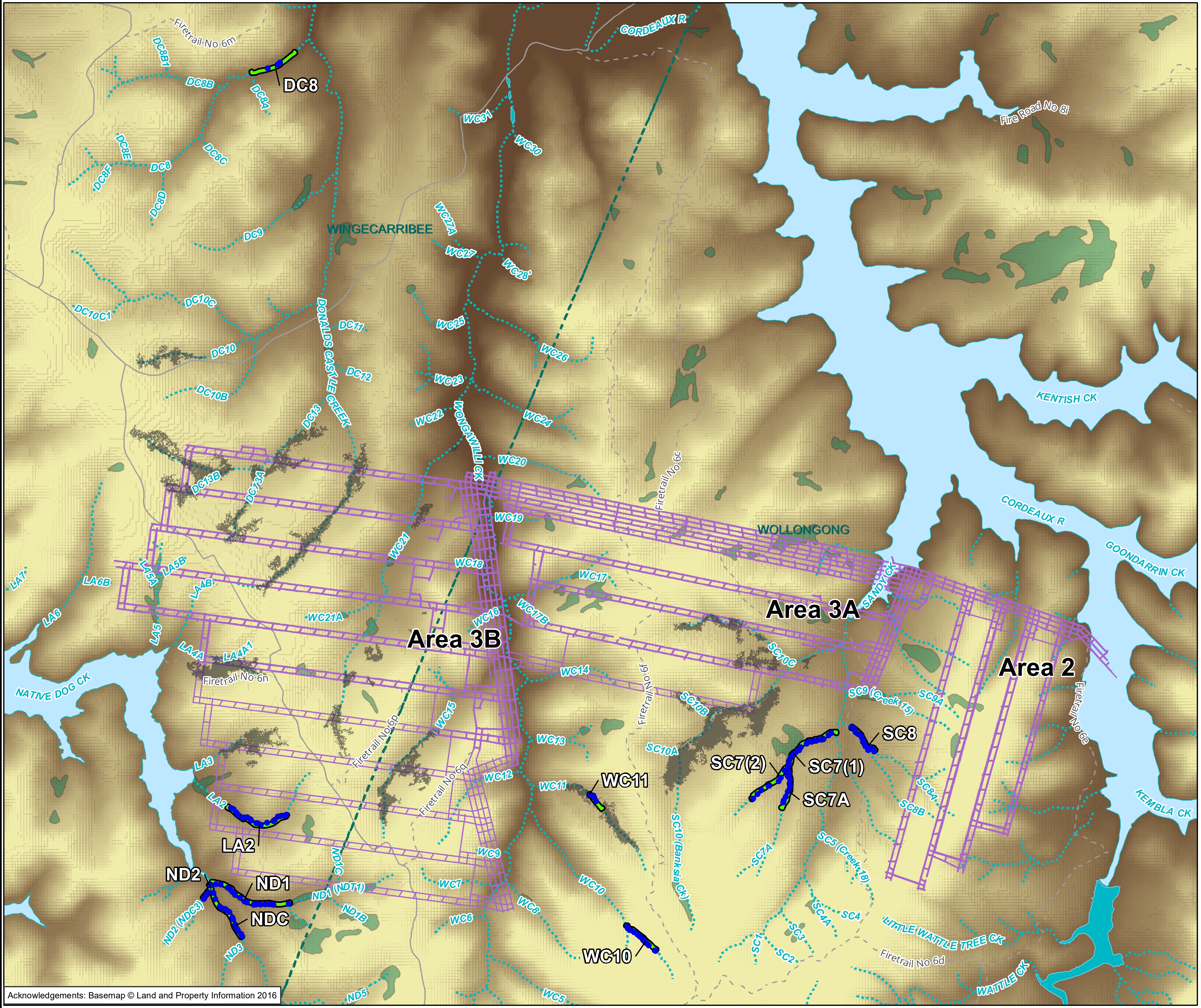

Legend

- Threatened frog monitoring control transect
- Threatened frog monitoring breeding pool
- Upland swamp boundary (Biosis)

Survey Area

- Longwall Layout
- IC Creekline
- Upland swamp boundary (NPWS)

Figure 5 Location of threatened frog monitoring control transects used in the 2018 program

0 0.5 1 1.5
Kilometres
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 3A	S15B (Swamp 15B)	2003	Within mining RMZ: • 18/09/2010	Mined beneath: • 25/08/2012	S15A(1) (Swamp 15A(1)) S11 (Swamp 11)
	S15A (2) (Swamp 15A(2))	2009	Within mining RMZ: • 20/10/2012	Mined beneath: • All points beyond goaf	S15A(1) (Swamp 15A(1)) S33 (Swamp 33) S22 (Swamp 22)
Dendrobium Area 3B	S1A (Swamp 1A)	2012	Within mining RMZ: • 23/02/2013	Mined beneath: • 11/04/2013	S86 (Swamp 86) S87 (Swamp 87) S88 (Swamp 88) S15A(1) (Swamp 15A(1))
	S1B (Swamp 1B)	2005-2009, then 2012-present	Within mining RMZ: • 08/02/2013	Mined beneath: • 13/02/2013	S86 (Swamp 86) S87 (Swamp 87) S15A(1) (Swamp 15A(1)) S22 (Swamp 22) S33 (Swamp 33)
	S5 (Swamp 5)	2012	Within mining RMZ: • 18/05/2013	Mined beneath: • 25/07/2013	S86 (Swamp 86) S87 (Swamp 87) S88 (Swamp 88) S15A(1) (Swamp 15A(1))
	S11	2003	Within mining RMZ: • 21/05/2016	Mined beneath: • beyond goaf • Predicted Longwall 14	S15A(1) (Swamp 15A(1)) S22 (Swamp 22) S33 (Swamp 33)
	S13 (Swamp 13)	2013 (spring only)	Within mining RMZ: • 10/07/2017	Mined beneath: • Predicted Longwall 14 • Predicted Longwall 15	S86 (Swamp 86) S87 (Swamp 87) S88 (Swamp 88) S15A(1) (Swamp 15A(1))

Area	Impact site	Monitoring commenced	Mining progress		Control sites
	S14	2017	Within mining RMZ: • Predicted Longwall 17 • Predicted Longwall 16 • Predicted Longwall 15	Mined beneath: • Predicted Longwall 17 • Predicted Longwall 16 • Predicted Longwall 15	S86 (Swamp 86) S87 (Swamp 87) S88 (Swamp 88) S15A(1) (Swamp 15A(1))
	S23	2017	Within mining RMZ: • Predicted Longwall 15	Mined beneath: • Predicted Longwall 15	S86 (Swamp 86) S87 (Swamp 87) S88 (Swamp 88) 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: • End November 2011	Mined beneath: • All pools beyond goaf	SC6 (Waratah Creek) SC7(1) SC7A
	SC10(2)	2006	Within mining RMZ: • End November 2011	Mined beneath: • Predicted Longwall 19	NDC (Native Dog Creek) SC6 (Waratah Creek) SC7(1) SC7A
	SC10C	2006	Within mining RMZ: • End October 2010	Mined beneath: • End October 2012	SC6 (Waratah Creek) SC7(1) (Cascade Creek) SC7A
	6CDL	2009	Within mining RMZ: • 5 Dec 2010	Mined beneath: • All pools beyond goaf	ND2 SC6 (Waratah Creek) SC7(2) (Cascade Creek) SC8 (Fern Tree Creek)
	WC17	2011	Within mining RMZ: • March 2010	Mined beneath: • 26 Apr 2011	NDC (Native Dog Creek) ND1 SC6 (Waratah Creek) SC8 (Fern Tree Creek) WC10 (Easement Creek) WC11

Area	Impact site	Monitoring commenced	Mining progress		Control sites
Dendrobium Area 3B	DC (1) (Donald's Castle Creek)	2013	Within mining RMZ: • End June 2013	Mined beneath: • All pools beyond goaf	DC8 SC6 (Waratah Creek) SC7(1) (Cascade Creek) SC7(2) (Cascade Creek) SC7A SC8 (Fern Tree Creek) WC11
	DC13	2010	Within mining RMZ: • 21 February 2013	Mined beneath: • End March 2013	SC6 (Waratah Creek) SC7(1) (Cascade Creek) SC7(2) (Cascade Creek) SC7A SC8 (Fern Tree Creek)
	LA4A (Downstream of DA3B)	2007	Within mining RMZ: • 31 March 2016	Mined beneath: • All pools beyond goaf	ND1 SC6 (Waratah Creek) SC7(2) (Cascade Creek) SC8 (Fern Tree Creek)
	WC15	2011	Within mining RMZ: • Longwall 14	Mined beneath: • Predicted Longwall 14 • Predicted Longwall 15	DC8 NDC (Native Dog Creek) SC6 (Waratah Creek) SC7(1) (Cascade Creek) SC7A SC8 (Fern Tree Creek)
	WC21	2013	Within mining RMZ: • 27 October 2013	Mined beneath: • 21 December 2013	DC8 SC6 (Waratah Creek) SC7(1) (Cascade Creek) SC7(2) (Cascade Creek) SC7A SC8 (Fern Tree Creek) WC10 (Easement Creek) WC11
	LA2	2017	Within mining RMZ:	Mined beneath:	SC7(1) (Cascade Creek) SC7(2) (Cascade Creek) SC7A SC8 (Fern Tree Creek) WC10 (Easement Creek) 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 and 2018). 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 Dendrobium Area 3B	Vegetation survey once in autumn and once in spring each year.
Littlejohn's Tree Frog Breeding Habitat Monitoring	Dendrobium Area 3A Dendrobium Area 3B	Once in winter each year.
Photo-point Monitoring	Dendrobium Area 3A 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
- Terrestrial flora – composition and distribution of species

Transect monitoring program

Vegetation monitoring in upland swamps is undertaken along three 15 metre transects within each swamp. The presence of all species within thirty 0.5 x 0.5 metre quadrats located along the 15 metre 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. 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 NSW *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (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 Littlejohn's 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 egg masses (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 egg masses 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 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 egg masses 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). Potential outcomes in this survey design are numerous with trends potentially occurring suddenly as a pulse event, or as is more likely, gradually over time.

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 2018 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 2019a; TAE 2019b). 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 were 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, as delays in reporting provided an opportunity to interrogate a more comprehensive data set for 2018 instead of using data capturing the height of upland swamp vegetation for only four months of 2018 (as undertaken in all previous analysis). Therefore, the analysis presented herein for assessing the extent of upland swamp vegetation represents two years of change. While the data represents two years of change, the period assessed is still referred to as 2018. 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 (2019a; 2019b).

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 Coal Environmental Field Team's landscape and piezometer monitoring as well as qualitative observations of upland swamp vegetation made during surveys conducted in 2018.

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

As is common to ecological monitoring programs, the availability of suitable and logistically practical impact and control sites 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 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 limitation, 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 have been reviewed and modified for the 2018 data analysis. Species complexes are now applied consistently across the entire flora monitoring dataset, rather than on a site by site basis. 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

Results, unless otherwise stated, are described in the following sections for the autumn, winter and spring 2018 sampling periods.

3.1 Site observations and photo point monitoring

The site observations for 2018 in relation to structural changes in vegetation or indicators of impacts relating to mining showed a large degree of consistency with those described in 2017. This finding is concurrent with the consistency seen in the statistical analysis between 2017 and 2018, which is described in sections 3.2.1 and 3.2.2. This consistency is likely to have been influenced by the unseasonably dry winters experienced in both 2017 and 2018, with the drying trends associated with low rainfall during these periods and groundwater recharge/flow continuing over time. 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 a particular 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).

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.

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. One impact site (S1B), three pre-mining sites (S13, S14 and S23) and four control sites (S15A(1), S86, S87 and S88) displayed minimal change.

Photo-point monitoring shows 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, 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 and Needlebush (Keith 2006). Both impact and control sites showed evidence of natural progressive vegetation structural change, including S15A(2) and S33. Swamp S22 showed evidence of yellowing of foliage in the shrub layer, particularly at points S22-F2 and S22-F3. This is considered to be a result of unseasonably dry winters in 2017 and 2018.

Photo monitoring at impact sites S11, S15B, S1A and S5 also showed visual evidence of vegetation structural change. Yellowing of Needlebush observed at S11-F3 and S11-F3, and a reduction in cover of Pouched Coral Fern at S11-F5 were observed. Ongoing field observation and photo monitoring will be undertaken in 2019, with attention focused on mapping the extent of dieback in this area.

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.

3.1.1 Swamp 15B

Vegetation dieback areas within Swamp 15B were observed to have increased in length and width. The die back has extended in 2018 to the east of S15B – P2 (292905 E; 6192692 N) and west to join the eastern patch south of S15B - V3, joining with the patch that extends from east of S15B – V2 (292 760.62 E; 6192 762.34 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 large decreases in Razor Sedge *Lepidosperma limicola,* Wire Rush *Empodisma minus, Lepidosperma neesii* and Pouched Coral Fern *Gleichenia dicarpa* (Plate 1). Species such as Red-fruited Saw-sedge *Gahnia sieberi, Leptospermum* sp. and Heath Banksia *Banksia ericifolia* have not been similarly affected.

This dieback patch now includes a lobe which extends north to 292835 E; 6192722 N. This area of impact is within Cyperoid Heath (MU44c) sub-community. Buttongrass *Gymnoschoenus sphaerocephalus* was recorded as browning and having very reduced crown size, in addition to 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 change in extent since spring 2016.

A separate area 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 area has again recorded dieback up to 50% of total vegetated cover for *Chorizandra* sp. and *Baumea* sp., Razor Sedge, Wire Rush, *Lepidosperma neesii* and Pouched Coral Fern (Plate 3).

The western extent of S15B continues to have seedling recruitment and growth of *Eucalyptus* sp. in areas mapped in spring 2016 from S15B –V1 to S15B – P5. The established trees observed within the southern edges of the swamp continue to show vigorous growth through height increase and development of a small tree canopy.

Biosis recommends that the Illawarra 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, 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.

Plate 1. Dieback of restioid heath within an area of Swamp 15B – V2 south from photopoint P2 (25/06/2018).

Plate 2. Dieback of cyperoid heath within the area of west of Swamp 15B – V3 (25/06/2018).

Plate 3. Vegetation dieback (approximately 100 m²) within Swamp 15B recorded between Swamp 15B – V3 and Swamp 15B – V2 (25/06/2018).

3.1.2 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 of yellowed Needlebush (Plate 5, Plate 6 and Plate 7) with unaffected plants being limited to the inferred drainage line along the north-west edge of the swamp. Biosis recommends that the Illawarra Coal Environmental Field Team monitor the area of yellowing at 6 monthly intervals to determine any trends in vegetation condition and extent.

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

Plate 5. Needlebush yellowing at monitoring point Swamp 1A – V1 showing vegetation stress by yellowing (looking north) (09/07/2018).

Plate 6. Needlebush yellowing at monitoring point Swamp 1A – V1 showing vegetation stress by yellowing (looking west) (09/07/2018).

Plate 7. Needlebush yellowing at monitoring point Swamp 1A – V1 showing vegetation stress by yellowing (looking south) (09/07/2018).

The area of Cyperoid Heath north of S1A-V3 has been gradually reducing in Buttongrass foliage cover (Plate 8 and Plate 9), with the complete dieback shown in Plate 9 having 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.*

Biosis recommends that the Illawarra Coal Environmental Field Team monitor this area at 6 monthly intervals to track trends in vegetation condition and extent.

Plate 8. Cyperoid heath diebackat S1A-V3 (09/07/2018).

Plate 9. Cyperoid heath dieback in the vicinity of S1A-V3 (09/07/2018).

3.1.3 Swamp 5

Observations at S5-P3 indicate that swamp groundcover has greatly reduced when comparing control to post impact photo point images shown in Plates 10 – 17. The images show obvious reductions in Pouched Coral Fern and Wire Rush have occurred since being mined beneath.

Monitoring of Swamp 5 began in 2012, with mining within the RMZ and mining beneath Swamp 5 beginning in 2013. Annual rainfall for 2013 was 970.8 millimetres, which is above average the average of 844.6 millimetres (station number 68166). Annual rainfall in the following years was below the total recorded in 2013, and also below average in 2014, 2017 and 2018. Drying conditions are therefore likely to have contributed to the reduction of swamp groundcover. Statistically significant changes in TSR or species composition over time have not been detected at Swamp 5 (Sections 3.2.1 and 3.2.2). However, total swamp extent and the extent of previously mapped upland swamp vegetation communities have been identified in 2018 (Section 3.3). A trending decline in the extent of Banksia Thicket and Tea-tree Thicket communities for three consecutive monitoring periods, greater than the mean and standard error decline in the control group has also been identified. The limited amount of pre-mining data for Swamp 5 must 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 10. Swamp 5 – P3 (East - Spring 2013) the year of mining within the RMZ and mining beneath (26/11/2013).

Plate 11. Swamp 5 – P3 (East - Spring 2017) showing reduction of Pouched Coral Fern and Wire Rush (02/11/2017).

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

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

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

Plate 15. Swamp 5 – P3 (South- Autumn 2017) showing reduction of Pouched Coral Fern and Wire Rush (02/05/2017).

Plate 16. Swamp 5 – P3 (West - Spring 2013) prior to mining (26/11/2013).

Plate 17. Swamp 5 – P3 (West - Spring 2017) showing reduction of Pouched Coral Fern and Wire Rush (02/11/2017).

Following a review of data recording practices in 2018, Biosis has 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 will enable the mapping of areas of dieback on the ground and the geolocation of ecological or impact observations as required. In future iterations of the monitoring program, observational records will be made for each transect based upon specific and relevant ecological criteria, improving the consistency of observation and comparison of observations between swamps and over time. 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. These additional data will improve the tracking and interpretation of observational changes in swamp condition over time, as well as the changes in the extent or location of die back that will be directly mapped on the ground. These additional measures will improve the capacity of the observational data to support the interpretation of the statistical analysis and further aid the ecological understand of these systems and changes that occur within them.

3.2 Vegetation

3.2.1 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 6). 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 the 2017 report. 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 3.2.2) is undertaken to compliment TSR analysis.

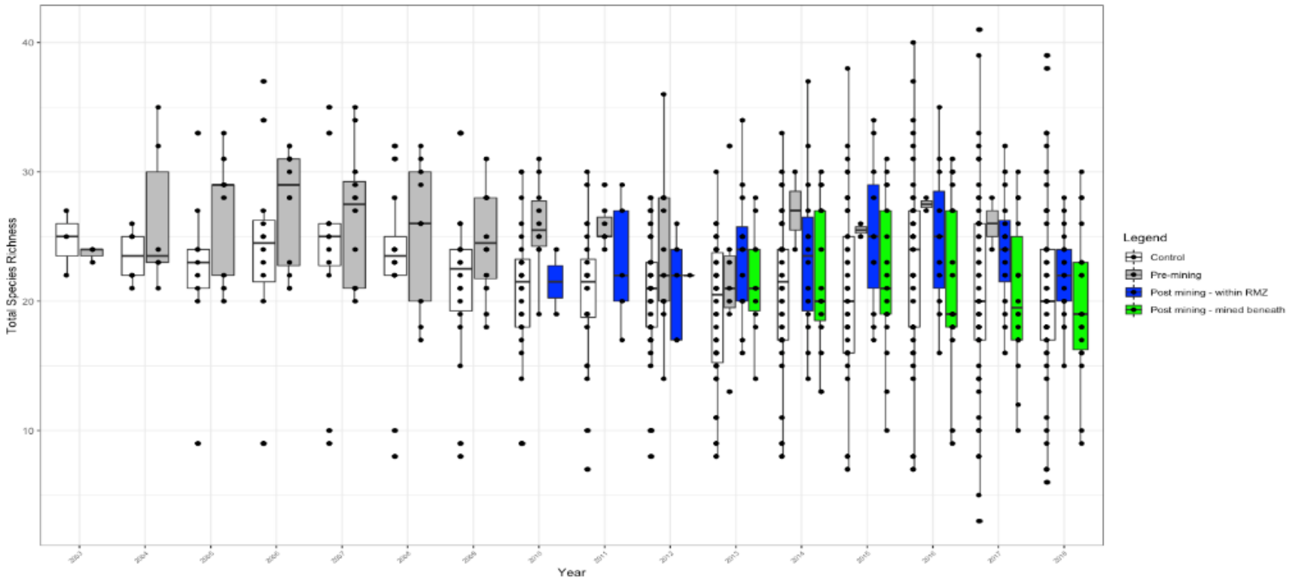


Figure 6 Boxplot of total TSR each year at all surveyed swamps located in Dendrobium Area 3A and Dendrobium Area 3B and associated control sites.

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 7).

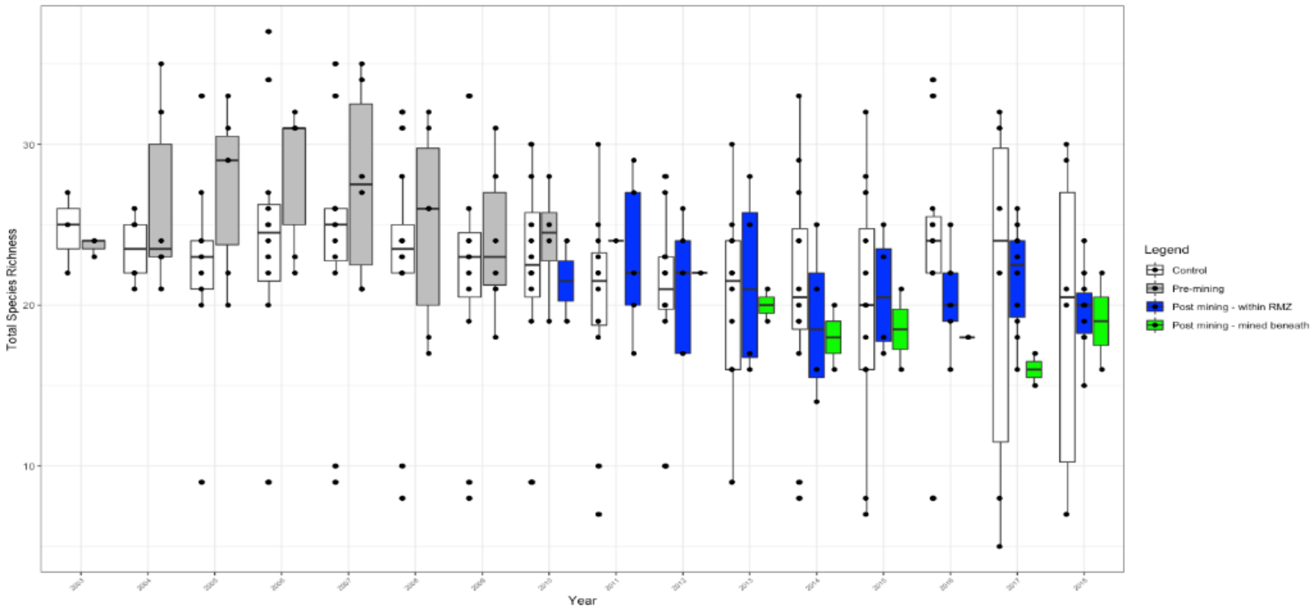


Figure 7 Boxplot of TSR for each transect, at impact site S15B, contrasted against two paired control swamps (S15A(1) and S11).

Figure 7 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 and range within the Post mining – mined beneath TSR shows a degree of variability over the monitoring, however a substantial increase in both the median TSR and range was recorded in 2018 when compared to the 2017 monitoring data.

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 2015 through to 2018 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 4). 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 4 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	-3.88	0.08
	2011, 2012, 2013, 2014	-4.59	0.06
	2012, 2013, 2014, 2015	-5.34	0.04
	2013, 2014, 2015, 2016	-5.75	0.04
	2014, 2015, 2016, 2017	-5.81	0.04
	2015, 2016, 2017, 2018	-5.58	0.04

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 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 2012; 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 slightly lower following impacts (Figure 8).

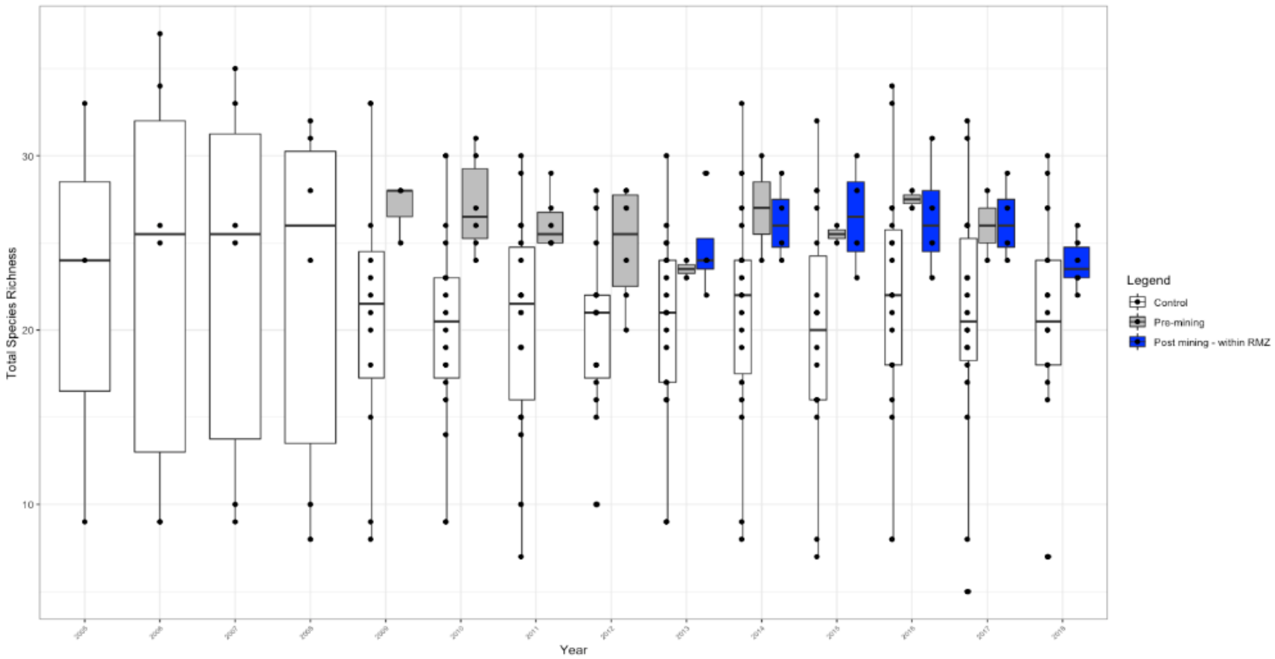


Figure 8 Boxplot of the TSR for each transect at impact Swamp S15A(2), contrasted against two paired control swamps (S15A(1), S22 and S33).

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 5).

Table 5 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	-0.24	0.95
	2013, 2014, 2015, 2016	-0.07	0.96
	2014, 2015, 2016, 2017	0.30	0.76
	2015, 2016, 2017, 2018	-0.30	0.91

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 9) 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.

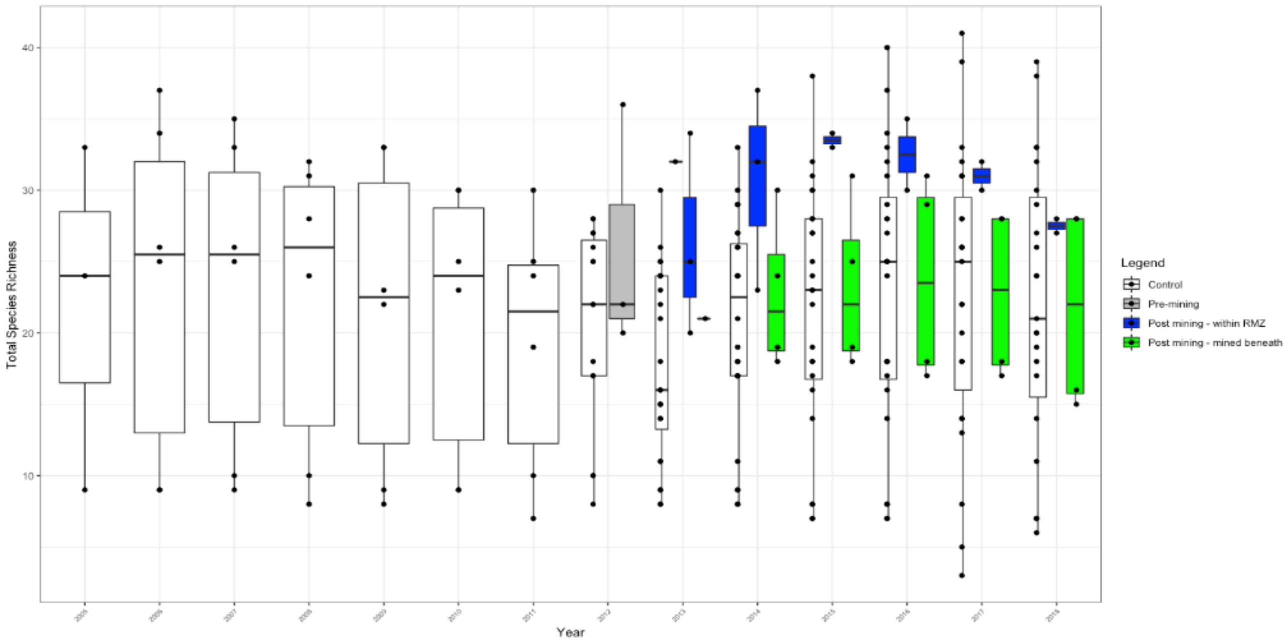


Figure 9 **Boxplot of the TSR for each transect at impact Swamp 1A, contrasted against three paired control swamps (S15A(1), S86, S87, and S88).**

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, Table 6).

Table 6 **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

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. 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 10).

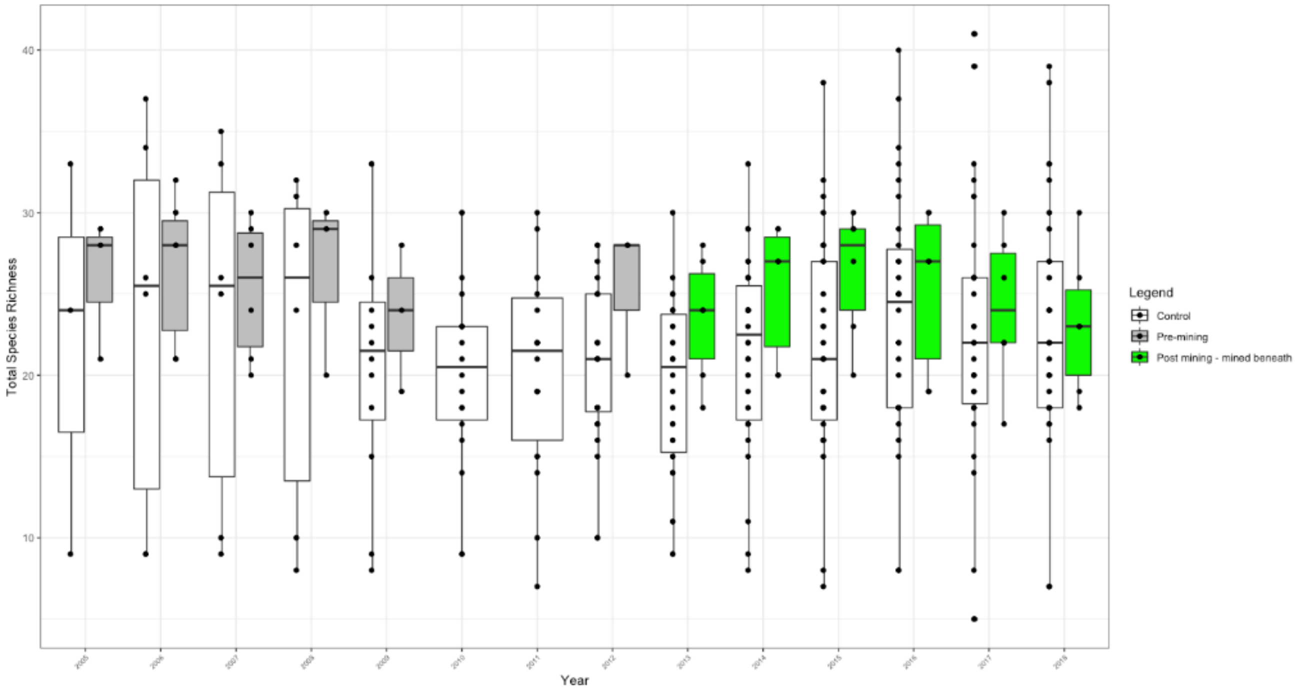


Figure 10 Boxplot of the TSR for each transect, at impact Swamp 1B, contrasted against five paired control swamps (S15A (1), S86, S87, S22 and S33).

No statistically significant difference was detected in TSR between the control and impact sites, regardless of time (p-values > 0.05 (Table 7).

Table 7 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

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 11) demonstrates that the Post mining TSR is typically lower than that of the control swamps. Since only two years of pre-mining data have been collected, visually interpreting whether this trend preceded mining impact is not possible.

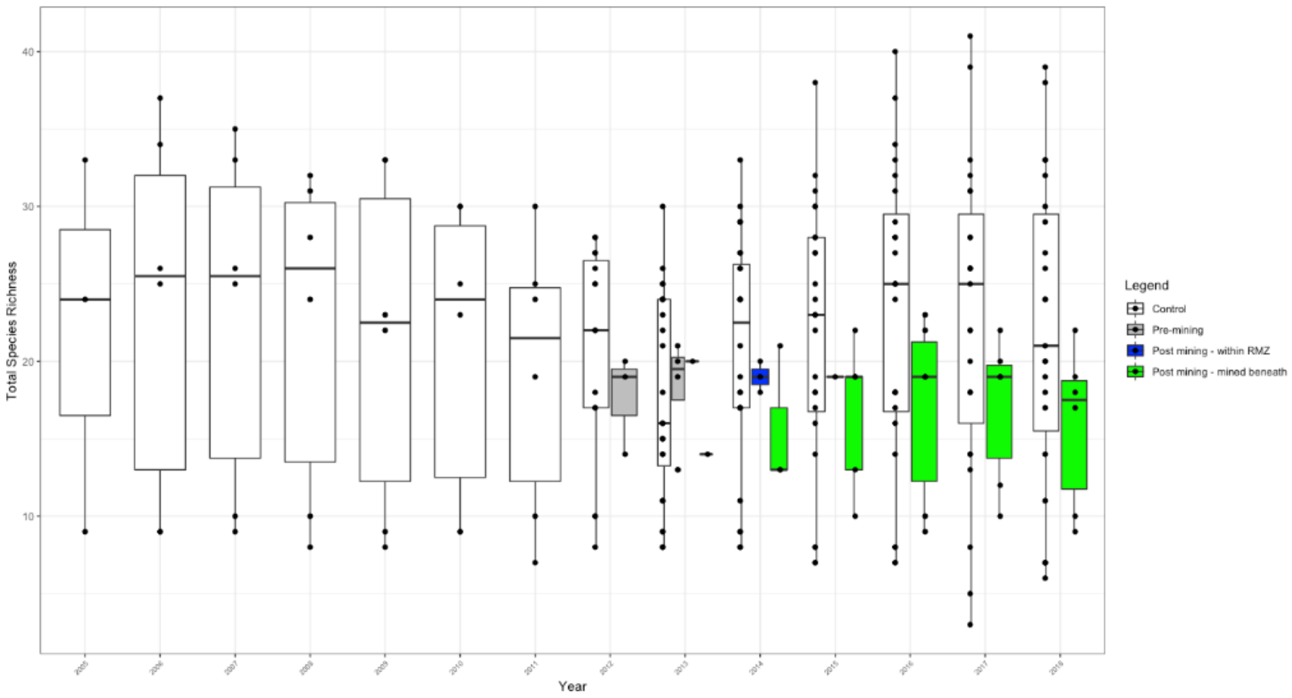


Figure 11 Boxplot of the TSR for each transect, at impact Swamp 5, contrasted against two paired control swamps (S15A(1), S86, S87 and S88).

No statistically significant difference was detected in TSR between the control and impact sites, regardless of time (p-values > 0.05 (Table 8).

Table 8 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	0.56
	2014, 2015, 2016, 2017	-0.88	0.56
	2015, 2016, 2017, 2018	-1.25	0.50

3.2.2 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 significant change in species composition, comparing pre-mining to post-mining, was found at two of the six sites; Swamp 15B and Swamp 15A(2). 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 62 unique species have been detected at Swamp 15B, of which 5% 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 2012 (Table 9). This indicates a long term shift in the flora species comprising the Swamp 15B community.

Table 9 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	0.044
	2011-2014	0.042
	2012-2015	0.101
	2013-2016	0.028
	2014-2017	0.018
	2015-2018	0.028

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. *Lepidosperma neesii/Ptilothrix deusta* species complex).

When considering the most recent four year period, 2015 to 2018, the following five species were found to be the key drivers of change:

- *Lepidosperma neesii/Ptilothrix deusta* species complex (increasing since 2010).
- *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 during the 2015 to 2018 period).
- *Gonocarpus teucrioides* (decreasing since 2013).
- *Sprengelia incarnata* (decreasing since 2015).

Of the taxa driving change, *Goodenia dimorpha stelligera bellidifolia* complex and *Sprengelia incarnata*, are characteristic of shallow, free draining heath and mallee-heath within the Woronora plateau (NPWS 2003) and swamps (Harden 1992). These species have a low tolerance to dry soils. Of the remaining species; *Tetraria capillaris* and *Lepidosperma neesii/Ptilothrix deusta*, typically prefer moist sandy soils. This indicates that species composition is becoming dominated by species that prefer drier soils (while still common upland swamp species) as opposed to species preferring water-logged substrate.

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

A total of 62 unique species have been detected at Swamp 15A(2), of which 2% 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. A statistically significant change in species composition at the α=0.05 level was detected in the three consecutive periods examined in the statistical analysis following mining commencing in 2013 (Table 10).

Table 10 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	0.002
	2014-2017	0.001
	2015-2018	0.001

Table notes: Those values identified in red indicate a significant change detected at the α=0.05 level. *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. *Selaginella uliginosa* and *Sprengelia incarnata*), whereas other species were consistently found to be more common after impact (e.g. *Banksia ericifolia* and *Cassytha glabella, C. pubescens* species complex).

When considering the most recent four year period, 2015 to 2018, the following five species were found to be the key indicators of change:

- *Selaginella uliginosa* (decrease since 2013).
- *Sprengelia incarnata* (decrease since 2013).
- *Xanthorrhoea resinosa media* sp. complex (decrease since 2013).
- *Banksia ericifolia* subsp. *ericifolia* (increase since 2013).
- *Almaleea paludosa* (increase since the 2015 to 2018 period).

The above results support the field observations at this swamp; indicating a natural transition into Banksia Thicket associated with prolonged fire absence. Coupled with a decrease in shallow groundwater retention as indicated by the piezometer data, Banksia Thicket is thriving. The increased density of vegetation, particularly heathy shrubs such as *Banksia* sp., within the swamp are likely shading out species in the lower strata. This indicates a notable shift in the floristic composition of Swamp 15A(2).

Analysis of Swamp 1A (Dendrobium Area 3B)

A total of 58 unique species have been detected at Swamp 1A, many 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 11).

Table 11 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	0.850
	2014-2017	0.938

Change in species composition tested	Years tested	Statistically significant change in species composition before and after mining (p-value)
	2015-2018	0.800

Some species were consistently found to be more common prior to impact (e.g. *Leptospermum polygalifolium. trinervium* complex, and *Drosera binata*), whereas other species were consistently found to be more common after impact (e.g. *Tetrarrhena juncea*).

Analysis of Swamp 1B (Dendrobium Area 3B)

A total of 65 unique species have been detected at Swamp 1B, of which 3.3% 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.

The monitoring results suggest that species composition at this swamp has not changed to a significant degree post impact. However, in the most recent period of analysis, 2015 to 2018, the statistical change is approaching, the α=0.05 level.

Table 12 Results of two, three and four consecutive yearly comparisons of species composition at Swamp 1B

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	0.712
	2014-2017	0.496
	2015-2018	0.089

Analysis of the compositional data 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 and Comesperma sphaerocarpum*). 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 definite trend in vegetation composition change that can be attributable to impacts from mining and/or drying conditions.

Analysis of Swamp 5 (Dendrobium Area 3B)

A total of 45 unique species have been detected at Swamp 5, of which 1.3% have only been detected on one occasion. No background 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 13).

Some species were consistently found to be more common prior to impact (e.g. *Grevillea oleoides* and *Grevillea patulifolia*), whereas other species were consistently found to be more common after impact (e.g. *Banksia robur* and *Grevillea sphacelata*). All four of these species are recorded from heath environments, however *G. oleoides* and *G. patulifolia* have a preference for moister areas of heath. Indicating that there may be a non-statistically significant trend towards dryer conditions with Swamp 5.

Table 13 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

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 2018, relative to the 2014 baseline (Figure 12). 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 2018. 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 2018 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.

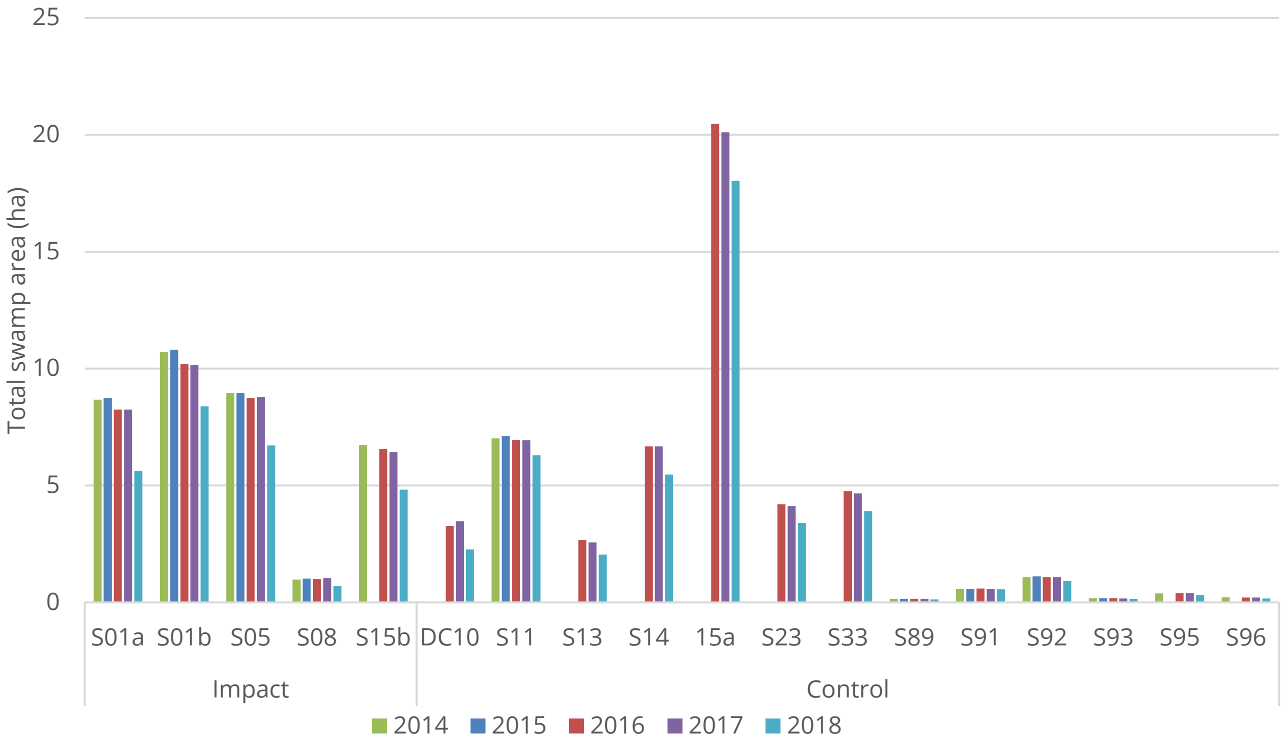


Figure 12 Total upland swamp area from 2014 to 2017

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 13. These percentage changes are large, and must be considered in the context of actual swamp area (Figure 12), which are substantial but do not appear as dramatic as presented in Figure 13. The swamp extent change from the baseline for 2018 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 2018 compared to baseline was 25.04%, and 13.53% across control sites. The greatest reduction in swamp extent at impacted swamps in 2018 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 13 Percentage change in upland swamp extent from baseline (2014)

Figure 13 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. However this is observable for all monitoring periods. 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 driving 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 Swamps: 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 14 below. The percentage change is based upon mapping of communities conducted in 2012 and as such does not provide a truly reliable indication of communities on site at each swamp. Ground-truthing of vegetation communities should be undertaken to increase the reliability of these vegetation community extents.

Figure 14 Percentage change in the average extent of mapped vegetation communities compared to the 2014 baseline

The change in extent of vegetation communities within upland swamp from the baseline is most notable at impact sites, with declines from the 2014 baseline identified for all vegetation communities in 2018 (Figure 14). This is a continuation of the trend across the impact sites, first recorded in 2014. Although the degree of change is increased in 2018, in line with that observed across the total swamp extent. 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 (Figure 14), 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.

Figure 15 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.

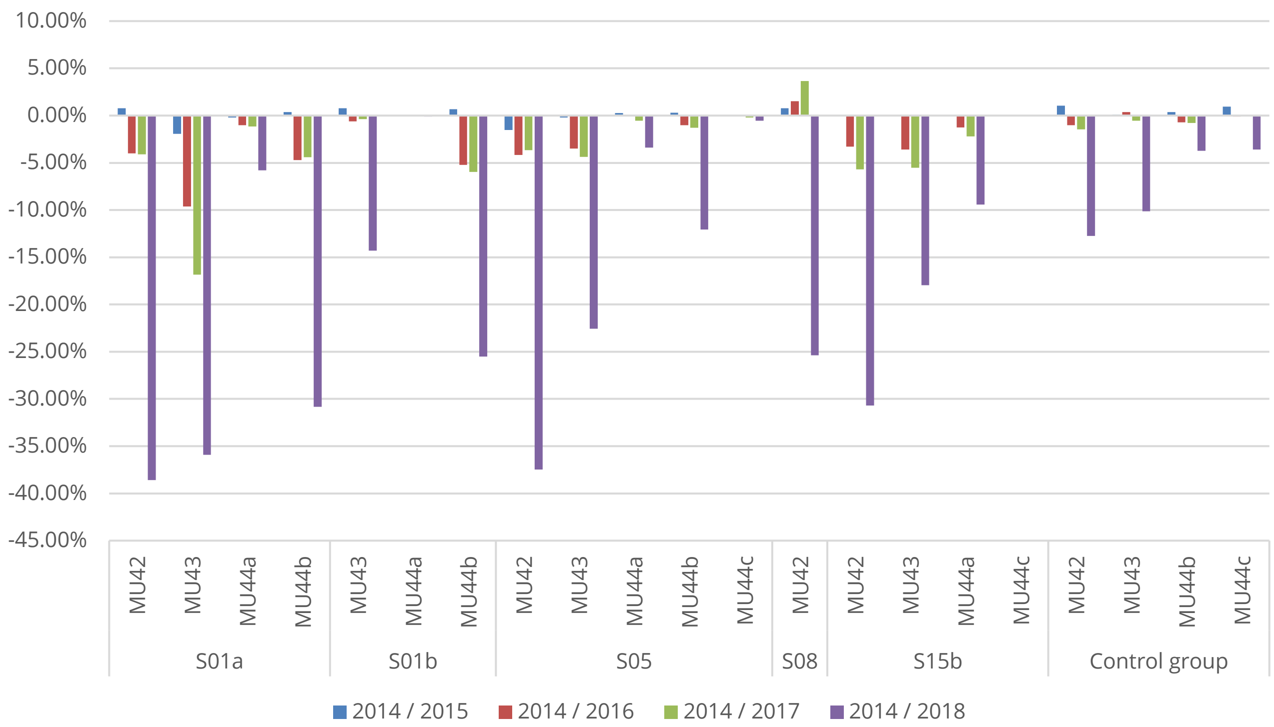


Figure 15 Percentage change in swamp vegetation communities compared to the 2014 baseline, comparning impact swamps to the control group

The degree of change in swamp extent and swamp vegetation community extent is beyond that previously recorded. While the pattern of declining swamp extent and swamp vegetation community extent is seen across impact and control sites, the degree of change in community extents is generally higher in 2018 than that observed at the control sites. The 2018 data indicates that the impact sites may display a reduced degree of resilience to environmental change, such as extended periods of drying. However it must be noted that the historical data suggests that variability is generally higher at the impact sites than the control sites and therefore applying the variability of control sites as a measure of whether impacts may be associated with mining or catchment scale factors, provides a conservative metric.

3.3.4 Potential catchment scale impacts

The trend of decreasing total swamp area in 2017, followed by a strengthening of that trend in 2018 can be observed across both impact and control swamps (Figure 12). This is supported by Figure 13, which shows the percentage decrease in swamp extent increasing markedly across all swamps in 2018. Therefore the driving forces 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 2018.

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 14) 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 millimetres in both 2017 and 2018, with a continued trend of below average rainfall (Table 14). The percentage change in rainfall compared to the 2014 baseline year shows a decrease in 2017 and then a further marked decrease in 2018, which is proportionally similar to the percentage change experienced across the upland swamps during these periods. Indicating that reduced rainfall during 2017 and 2018, 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. As swamp vegetation extent has been primarily 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 is recommended for 2019 monitoring.

Periods of extended drying such as has been experienced in 2017 and 2018 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 considered 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.

Table 14 Rainfall data between 2012 and 2018

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.*

3.4 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 2018 is provided in Table 15. Littlejohn's Tree Frogs were detected in at least one lifecycle stage at six 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 as seven of the ten control sites.

The 2017 Littlejohn's Tree Frog results saw a decrease in detection of adult Littlejohn's Tree Frog in 2017 by approximately 32%, and tadpoles by 84%, when compared to the 2016 results. However, 2016 was an excellent year for breeding due to high levels of rainfall, and frog numbers recorded in 2016 were much higher than previous years. The results of the 2018 surveys identified similar results to the 2017 surveys.

There was a decrease in detection of the adult and tadpole life stages of the Littlejohn's Tree Frog in 2017, when compared to data collected in 2016. With 2016 being an excellent year for breeding due to high levels of rainfall, frog numbers recorded in 2016 were much higher than previous years. In 2017, seven of the nine impact monitoring sites recorded reduced detection in one or more life stages. Broadly, this trend in reduction is mirrored in the control site detection data and therefore has been attributed to low rainfall during and preceding the survey period which operates across the catchment scale. This reduction in detection is explored in detail for each impact monitoring site in sections 3.3.1 and 3.3.2. Over the long-term, the abundance of all life stages detected has varied substantially year to year, at both impact and control sites. There is no broad scale visually discernible trend in detection across either year or mining status (Pre/Post mining) in both mining areas (Dendrobium Areas 3A and 3B), when considering the impact and control sites as groups.

Of the post-mining sites that have experienced subsidence related impacts, only SC10C shows a declining trend in detection – suggesting a decline in abundance - of all Littlejohn's Tree Frog life stages, triggering Level 1 of the *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012)* (Illawarra Coal 2012c). However, 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 in 2017 and 2018 is not considered indicative of a decline in the species population related to mining impacts.

In 2016 a declining trend in Littlejohn's Tree Frogs was recorded at post-mining site WC17, with no tadpoles or egg masses recorded from 2014 – 2016. However, in 2017 120 tadpoles were recorded at the site. Indicating a return to pre-mining recruitment conditions, and removing the Level 1 – *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* trigger reported in 2016. In 2018 Littlejohn's Tree Frog was not detected within the WC17 transect at any life stage. However, this is consistent with the trends observed at control sites, and is attributed to the dry conditions experienced within the catchment at the time of survey. Therefore it is determined that WC17 does not trigger the revised *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012c). Detection at site WC17 will again be reviewed in detail during the 2019 iteration of the monitoring program.

Subsidence related impacts including cracking of bedrock, lowering of water levels and build-up of iron flocculant 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.

Table 15 Summary of the results from the winter 2018 threatened frog monitoring

Mining status	Site	Survey date	Total number recorded			No. breeding pools
			Adult	Tadpoles	Egg mass	
Pre-mining sites	WC15	23/08/2018	7	28	2	14
	LA2	28/08/2018	1	1	0	23
					Total	**37**
Post-mining sites (Mined beneath)	DC13	25/06/2018	0	0	0	6
	SC10C	27/08/2018	5	0	2	3
	WC17	21/08/2018	0	0	0	2
	WC21	30/08/2018	8	38	13	3
					Total	**14**
Post-mining sites (Within RMZ)	6CDL	3/07/2018	0	43	0	5
	DC(1)	22/08/2018	1	12	0	3
	SC10(1)	27/08/2018	31	142	46	6
	SC10(2)	29/08/2018	39	91	194	26
	LA4A	25/07/2018	0	0	0	2
					Total	**42**
Control sites	DC8	23/08/2018	1	49	0	3
	ND1	29/08/2018	24	36	403	14
	ND2	29/08/2018	0	0	0	1
	NDC	29/08/2018	0	0	0	4
	SC7(1)	3/07/2018	2	208	0	4
	SC7(2)	3/07/2018	2	21	0	15
	SC7A	22/08/2018	0	32	4	11
	SC8	22/08/2018	0	2	7	3
	WC10	22/08/2018	1	61	2	12
	WC11	29/09/2018	0	0	0	4
					Total	**71**

Figure 6 Location of Threatened Frogs 2018 surveys

3.4.1 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. These waterways are interconnected and it is likely that the species moves throughout this area in response to a number of environmental variables and seasonal cues.

SC10C
Two egg masses and five adult frogs were found within the SC10C transect in 2018 (Figure 17). However, these were all found in Pool 1(the furthest pool downstream), and the majority of pools within the transect were dry. This included Pool 3 which was full during the 2017 survey. Littlejohn's Tree Frog tadpoles and egg masses 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 following 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 17). In 2018 the low number of adults was also consistent with patterns seen at control sites, and so it is difficult to disentangle seasonal patterns and those associated with mining impacts. 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), and is discussed further in Section 4.2.2. This assessment is consistent with that made in the annual monitoring report for 2017 (Biosis 2018).

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 flocculant 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 Coal 2012).

SC10(1)
There has been a small relative increase in Littlejohn's Tree Frogs at SC10(1) since mining began in 2011 (Figure 18). In 2018 there was also an increase in tadpole and egg mass numbers compared to previous years. The increase in abundance of Littlejohn's Tree Frog may be associated with displacement of breeding adults from impacted areas such as SC10C into nearby streams. SC10(1) is a relatively large stream and is likely to experience the impacts of dry conditions to a lesser extent than other streams, thereby providing refuge habitat during dry periods. The *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012) has not been triggered.

During the 2018 winter survey, iron flocculant 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.

SC10(2)
There has been no significant decline in Littlejohn's Tree Frogs at SC10(2) since mining began in 2011 (Figure 19). Numbers of tadpoles, eggs and adults observed per 100 metres of transect have consistently fallen within the abundance range recorded at control sites within the area. Over the past 4 years an increase in egg mass numbers has been observed at SC10(2) compared to pre-mining records, and this may also be associated with displacement of breeding adults from impacted areas such as SC10C, and into nearby streams, as

mentioned above. The *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012) has not been triggered.

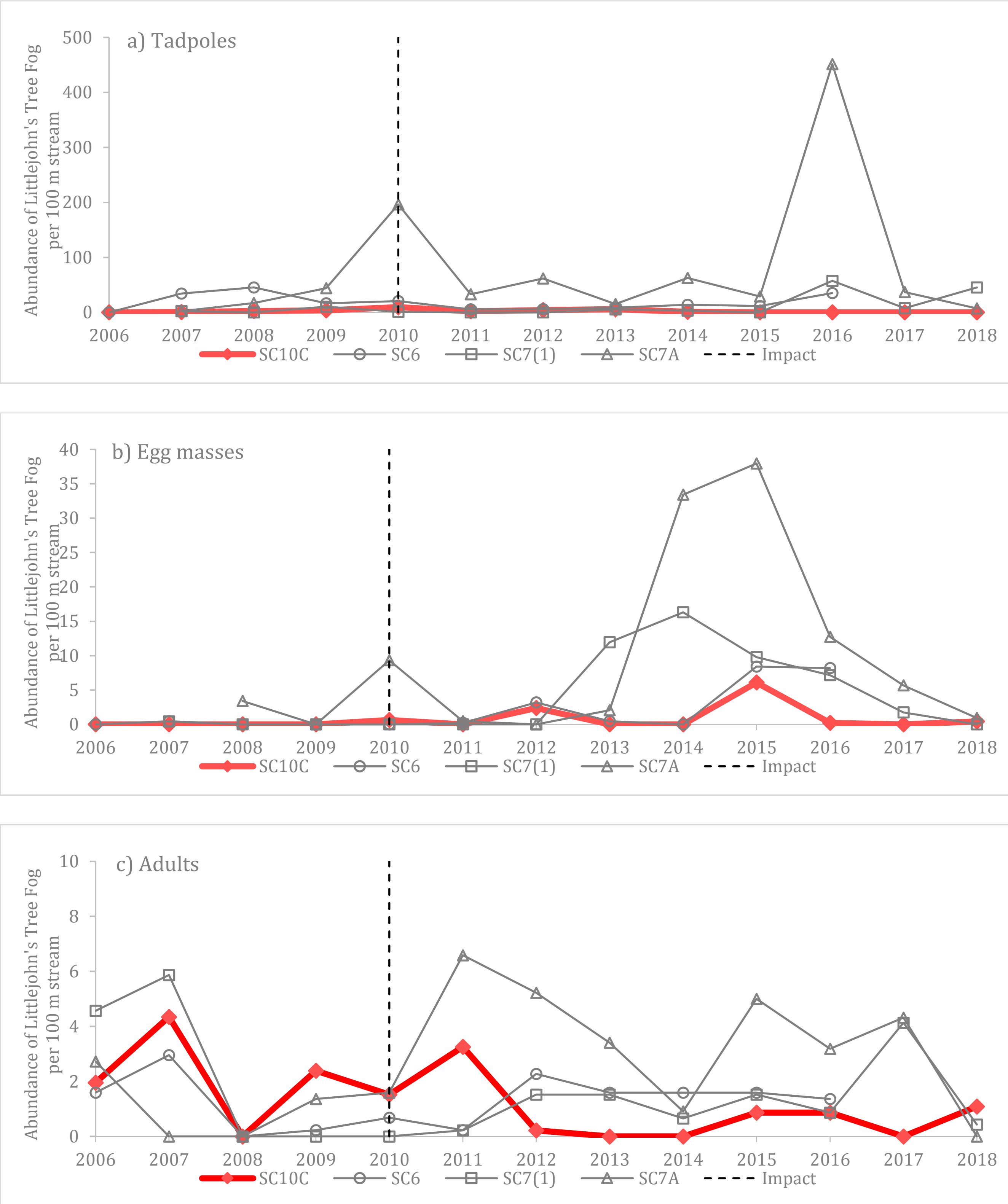


Figure 17 The number of Littlejohn's Tree Frog Litoria littlejohni a) tadpoles, b) egg masses and c) adults recorded at impact site SC10C (red line) and associated control sites SC6, SC7(1) and SC7A (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ.

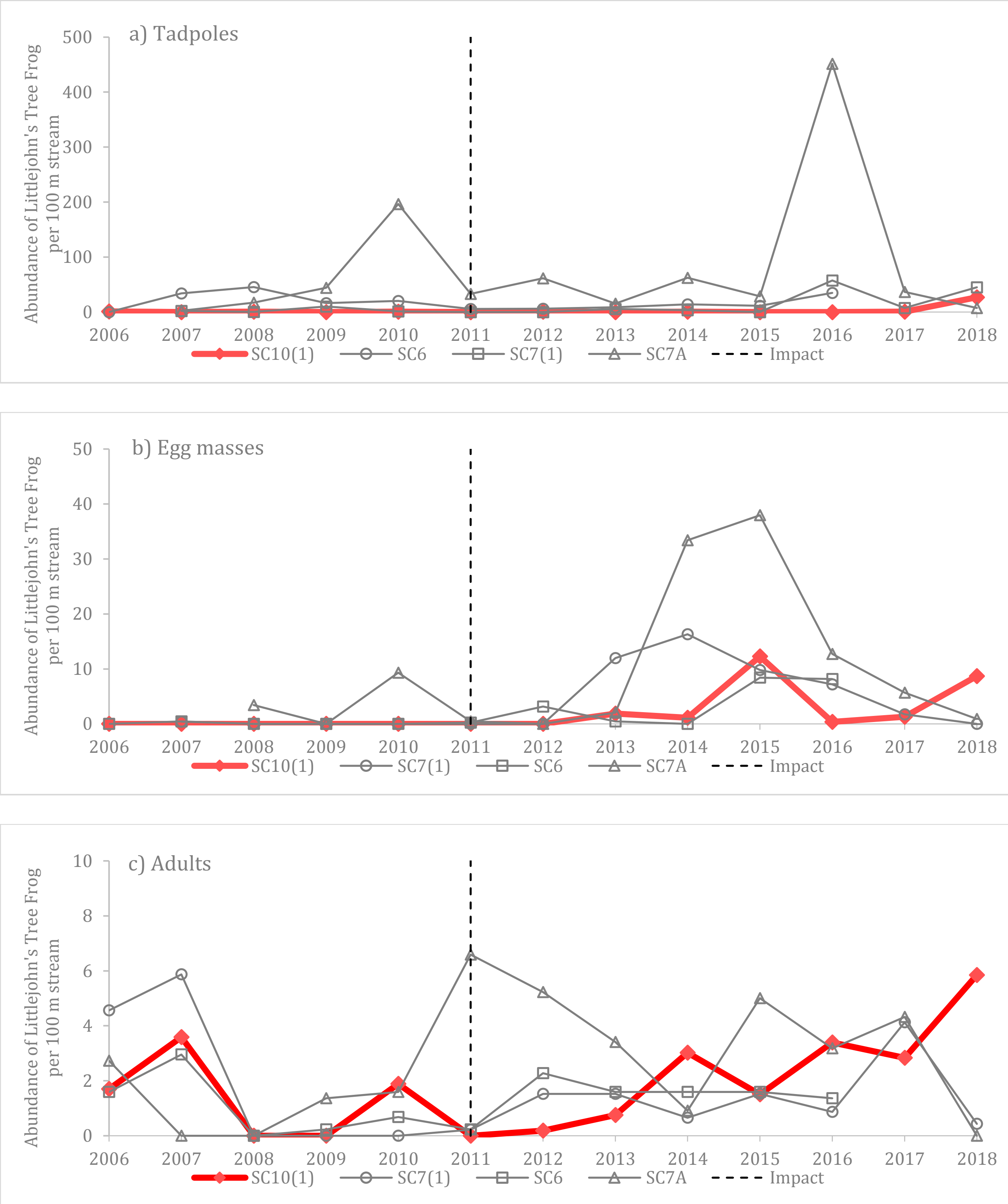


Figure 18 The number of Littlejohn's Tree Frog Litoria littlejohni a) tadpoles, b) egg masses and c) adults recorded at impact site SC10(1) (red line) and associated control sites SC7(1), SC6 and SC7A (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

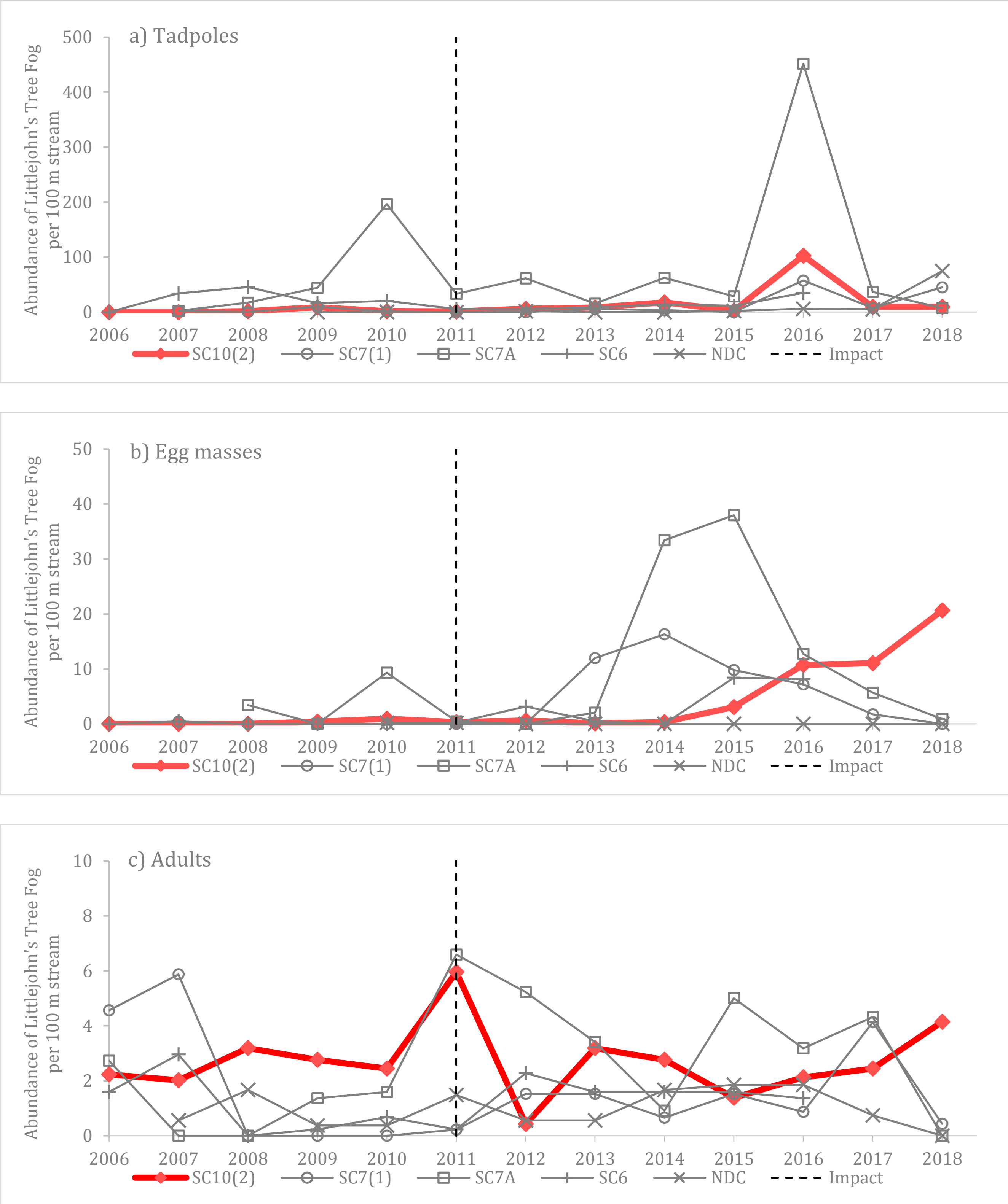


Figure 19 The number of Littlejohn's Tree Frog Litoria littlejohni a) tadpoles, b) egg masses and c) adults recorded at impact site SC10(2) (red line) and associated control sites SC7(1), SC7A, SC6 and NDC (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

In 2017, minor flocking was observed in pools within the SC10(2) transect, however it was unclear whether this was associated with mining activities. No flocking was observed within the SC10(2) transect in 2018. 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.

6CDL

Although highly variable over time, detection of Littlejohn's Tree Frogs at 6CDL has not shown a substantial increase or decrease since mining began in 2010 (Figure 20). There were no adults observed at 6CDL during the 2018 survey, however this is consistent with pre-mining records, and cannot be attributed to mining impacts. Tadpole and egg mass 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 2018 winter survey, and the *Dendrobium Area 3 Watercourse TARP* has not been triggered.

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

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 pre-mining levels. In 2018 Littlejohn's Tree Frog was not detected within the WC17 transect at any life stage. However, this is consistent with the trends observed at control sites, and is most likely due to the dry conditions experienced within the Catchment at the time of survey. It is determined that WC17 does not trigger the revised *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP* (Illawarra Coal 2012c), but monitoring should continue to determine any ongoing impacts from mining.

The transect was dry during the survey, with no pools containing water. It is unclear whether this was due to the dry conditions experienced around the time of survey, or due to the bedrock fracturing observed nearby the transect. 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.

3.4.2 Dendrobium Area 3B

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

WC21

Impacts to WC21 were previously recorded by the Illawarra 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 were observed again during the 2017 and 2018 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. The aforementioned reduction in habitat at WC21 has now been recorded for four monitoring periods (3 years), thus triggering Level 3 of the *Dendrobium Area 3B Watercourse TARP.* This is discussed further in Section 4.2.2.

The detection of Littlejohn's Tree Frog at WC21 has been consistently low since surveys began in 2013 (Figure 22). Adult, egg mass and tadpole abundance at WC21 in 2018 were generally consistent with previous years. The relevant control sites showed a decline in detection during 2018, attributed to the dry conditions at the time of survey. The pairing of this site with control sites will be reviewed in 2019, as the consistently low number of individuals detected at this site may indicate that it has always been less suitable as a monitoring site than other sites for the species.

WC15

Monitoring began at WC15 in 2011, and the site was a pre-impact site up until the 2018 epoch. Detection of tadpoles at WC15 has remained consistently low since 2011, however egg mass observations were increasing from 2013 to 2017 (Figure 23). Egg mass observations were lower than previous years in 2018, however this was consistent across most control sites, and was most likely a result of the dry conditions experienced across the Catchment during the survey period. Observations of adults within WC15 have remained consistent, and have generally fallen within the range of observations at the comparable control sites.

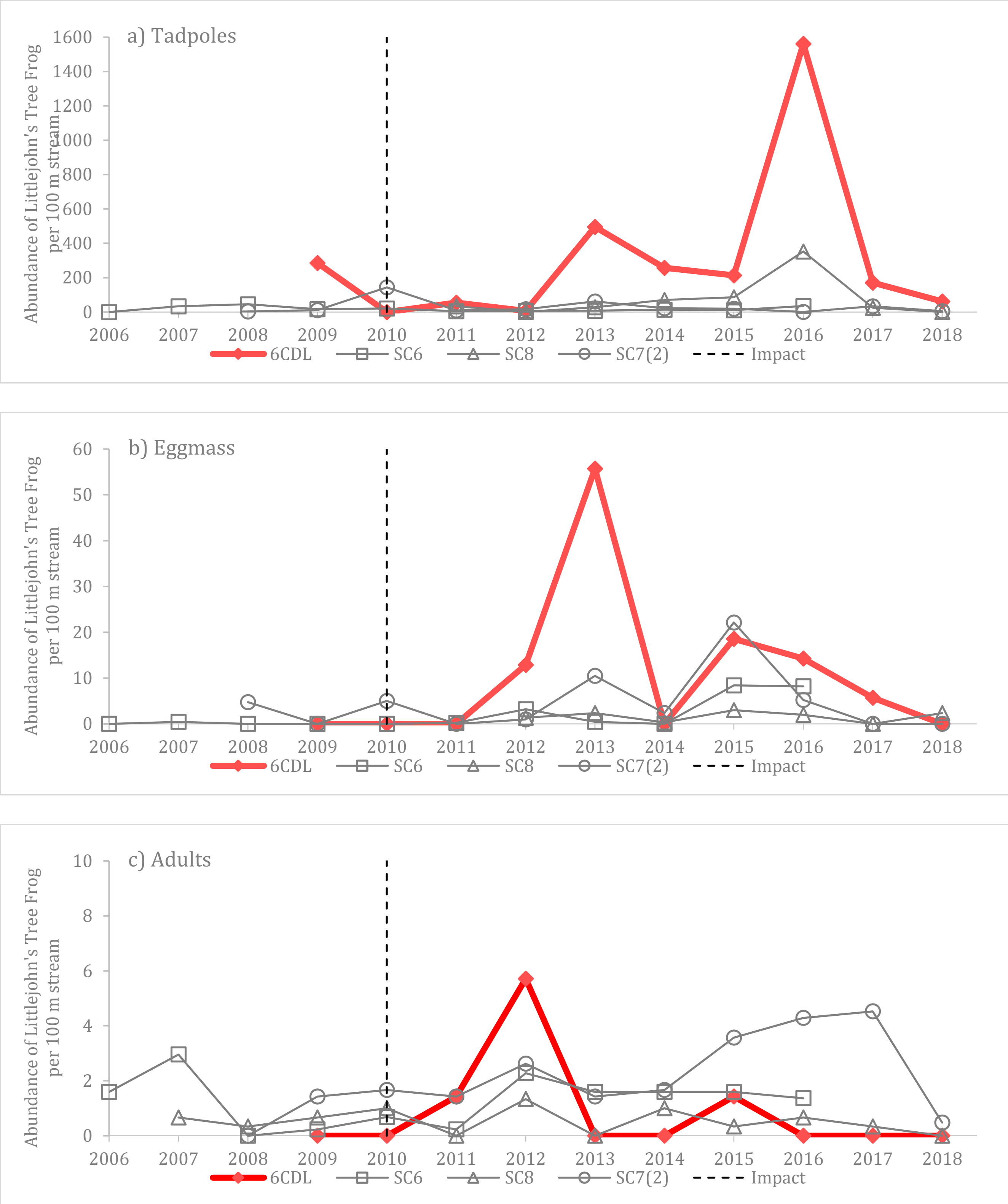


Figure 20 **The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site 6CDL (red line) and associated control sites SC6, SC8 and SC7(2) (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.**

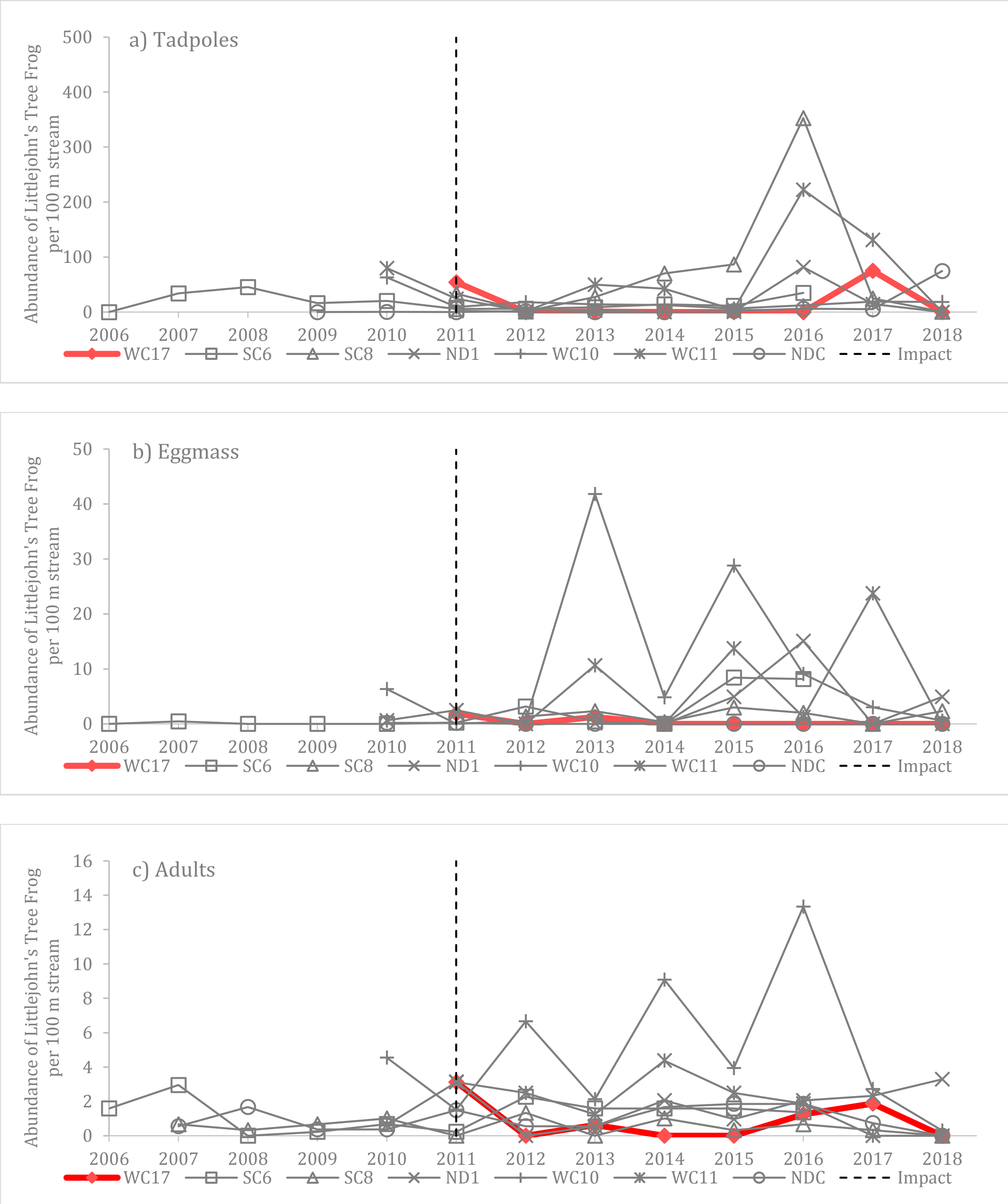
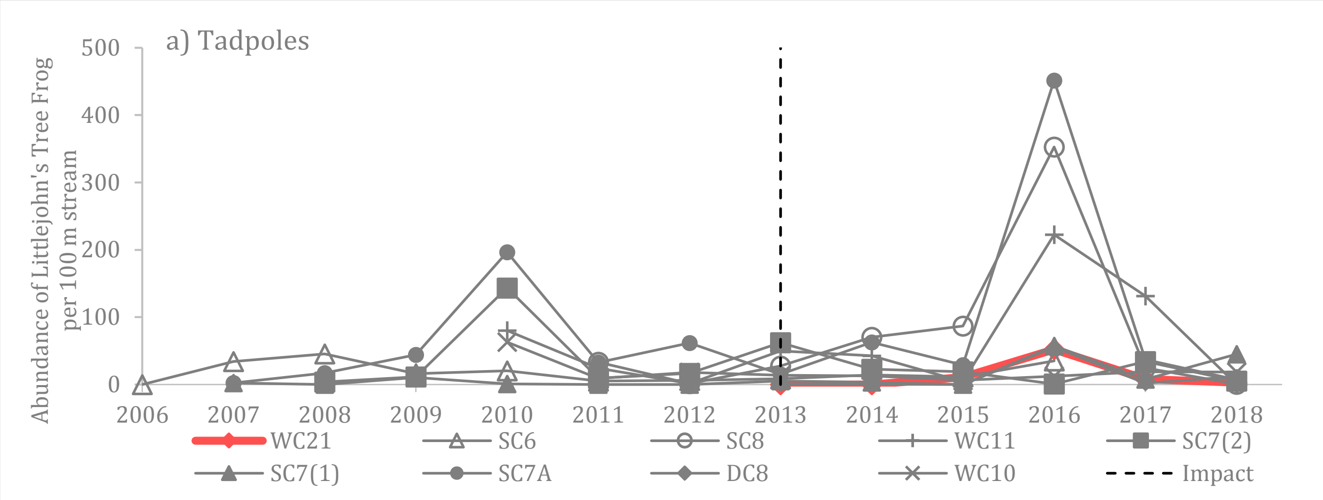
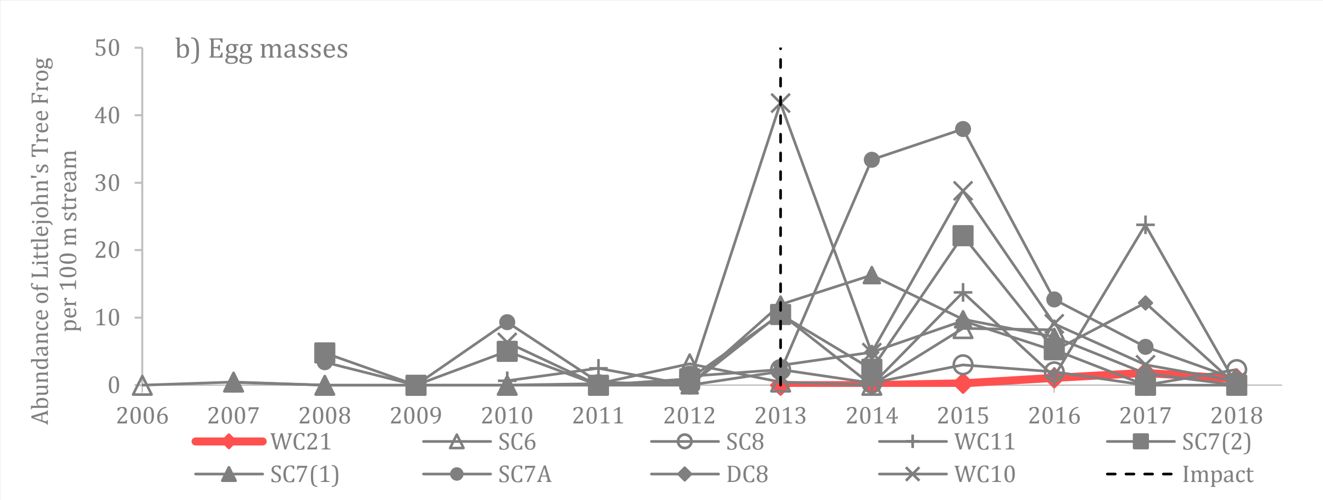


Figure 21 **The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site WC17 (red line) and associated control sites SC6, SC8, ND1, WC10, WC11 and NDC (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.**





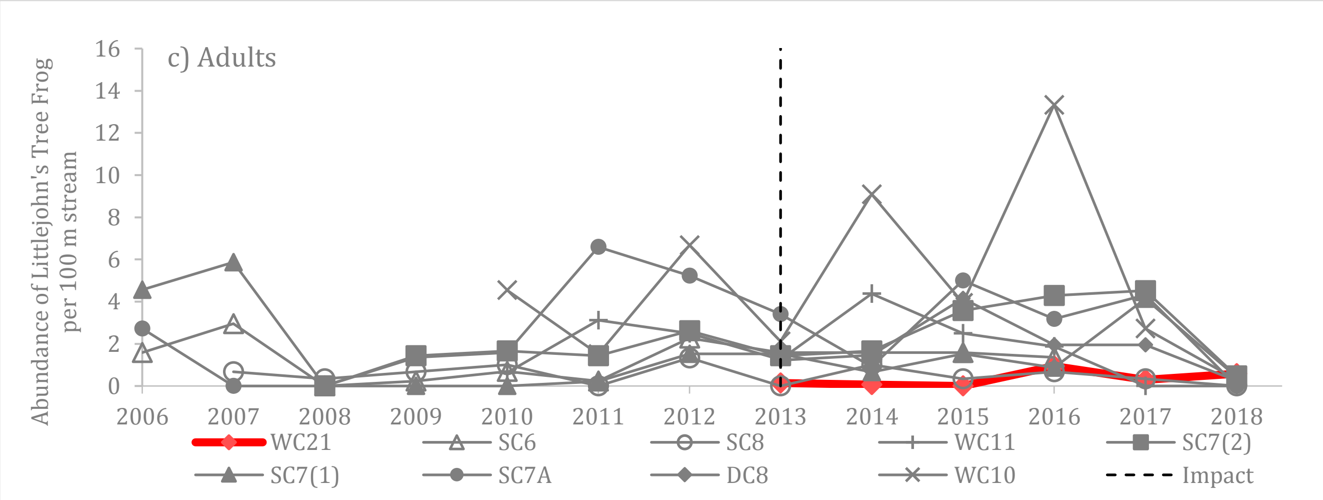


Figure 22 The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site WC21 (red line) and associated control sites SC6, SC8, WC11, SC7(2), SC7(1), SC7A, DC8 and WC10 (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

Donald's Castle Creek

A smaller, disjunct sub-population of Littlejohn's Tree Frog 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

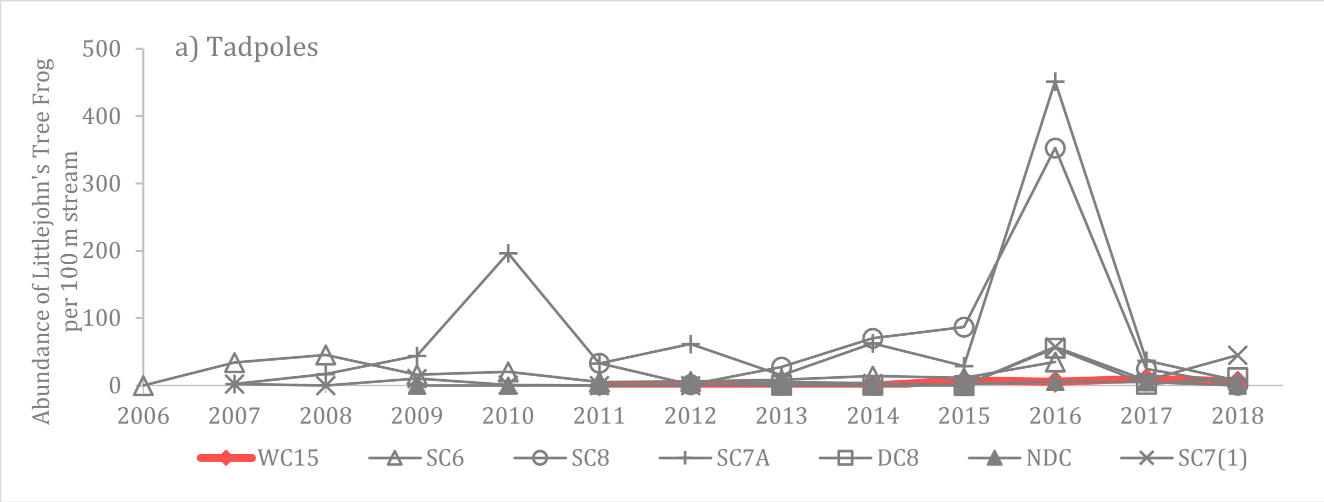
DC1 has been monitored for Littlejohn’s Tree Frogs since 2013, the year of Longwall 9 extraction. Since then, detection of the species has remained consistently low, with relative abundance falling either within or below the range observed at nearby control sites (Figure 24).

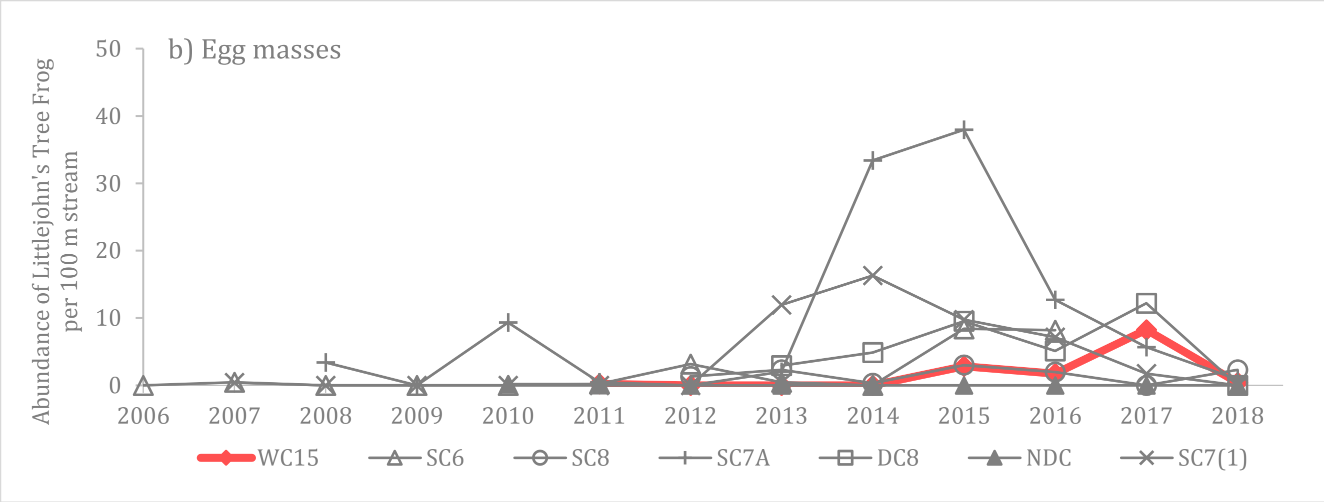
Following the extraction of Longwall 9, changes in pool water levels at DC1 were recorded by the Illawarra Coal Environmental Field Team, and has continued to date (Biosis 2017). Longwall 9 is located within the RMZ of the upper section of DC1 and changes to the hydrology of pools along this transect 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)* remains triggered as a result and this is discussed further in Section 4.2.2. The suitability of this site for the species is questionable, while recorded sporadically there does not appear to be any resident individuals or emigration by the species.

DC13

No Littlejohn’s Tree Frog were recorded within the DC13 transect during the 2018 survey. This is the same trend seen at comparable control sites, and is most likely due to the dry conditions experienced within the Catchment at the time of survey. Detection of Littlejohn’s Tree Frog at DC13 has remained consistently low since monitoring began, with relative abundance falling either within or below the range observed at nearby control sites (Figure 25). Adult, egg mass and tadpole abundance increased at DC13 in 2016, however this trend was consistent across most monitoring sites, and was most likely associated with particularly high rainfall prior to surveys.

The upper reaches of DC13 were 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 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. 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.





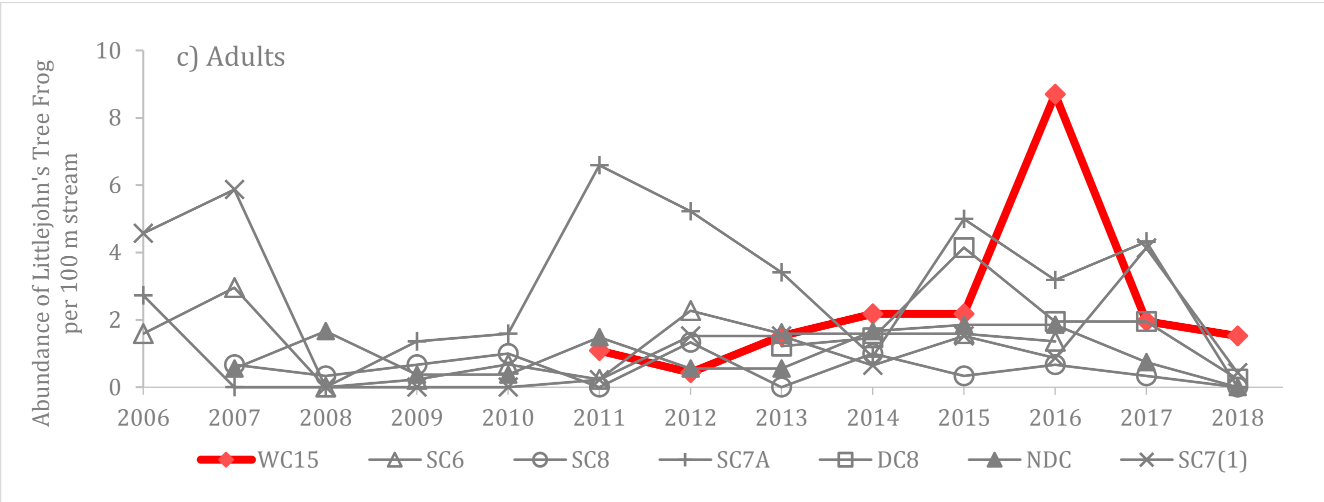


Figure 23 The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site WC15 (red line) and associated control sites SC6, SC8, SC7A, DC8 and NDC (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

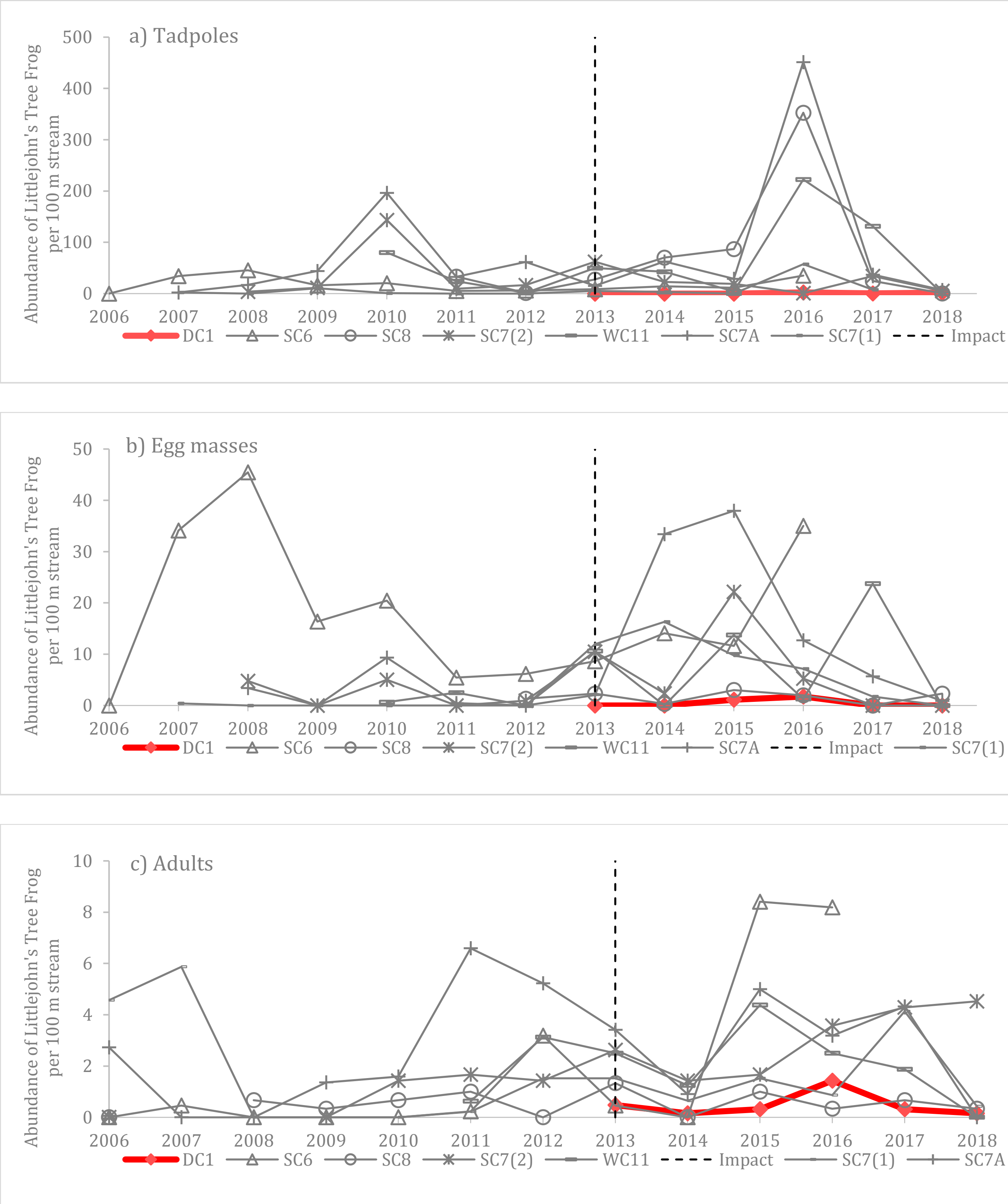


Figure 24 The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site DC1 (red line) and associated control sites SC6, SC8, SC7(2), WC11 and SC7A (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

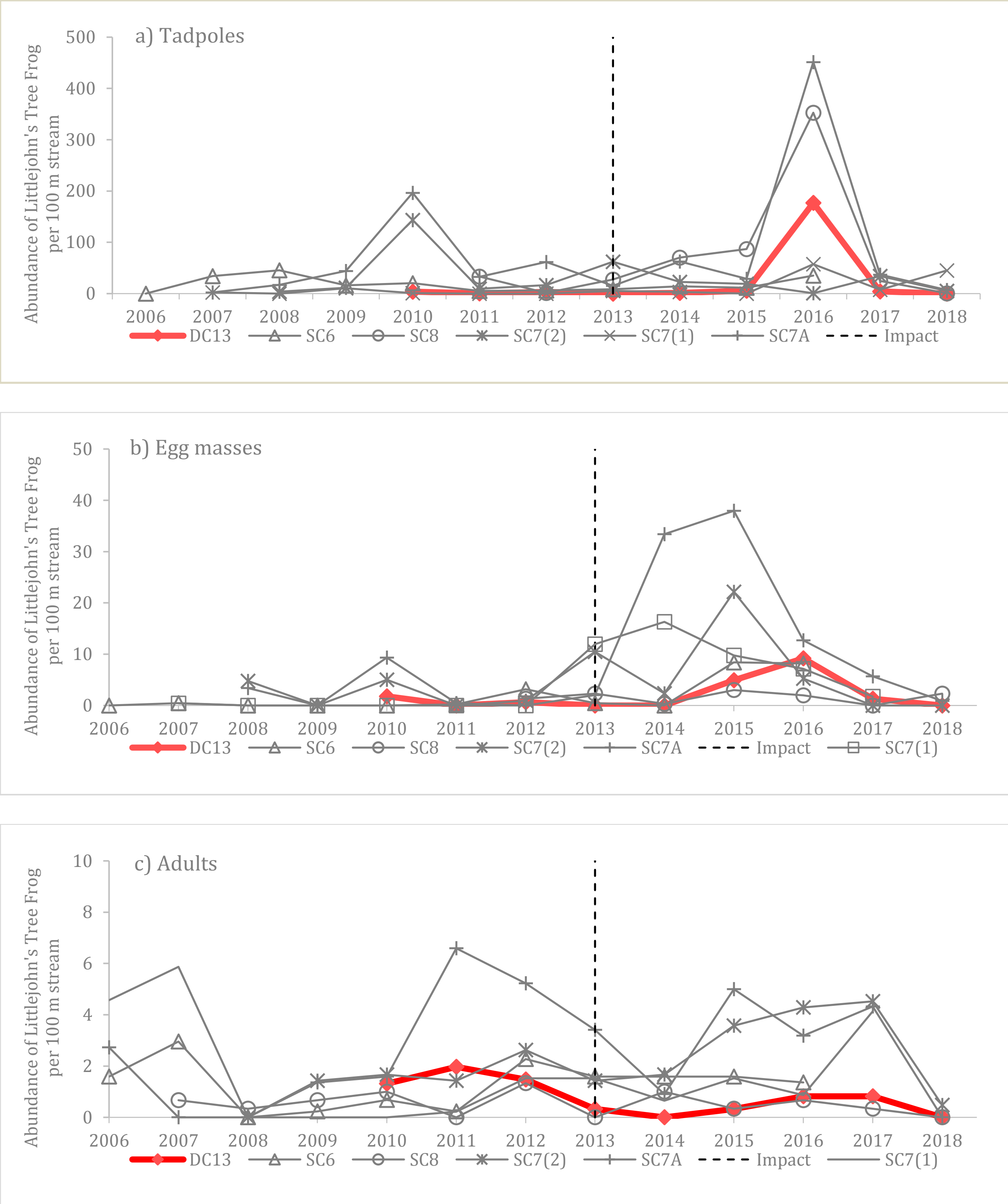


Figure 25 The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site DC13 (red line) and associated control sites SC6, SC8, SC7(2), and SC7A (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

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.

Due to the low numbers of individuals recorded at this site over the monitoring period and the dry conditions within the catchment, it was difficult to determine if the dry pools within the transect in 2018 were a result of environmental conditions, or mining impacts, or both. However, fracturing of bedrock was observed within the transect. It is determined that Level 3 of the *Dendrobium Area 3B Watercourse TARP* remains triggered and should be re-evaluated in 2019. This is discussed further in Section 4.2.2.

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. In 2018, no Littlejohn's Tree Frogs were detected at LA4A, in any lifecycle stage. This does not appear to be related to mining impacts, rather a reflection of the dry conditions during the time of survey.

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. The *Dendrobium Area 3B Watercourse TARP* has not been triggered.

LA2

Site LA2 was monitored for the second time during the 2018 winter survey. In 2017, 73 tadpoles, 70 egg masses and 3 adults were recorded at the site. In 2018 the transect was extremely dry, and only one adult and one tadpole were recorded at the site. The site will continue to be monitored as part of this program.

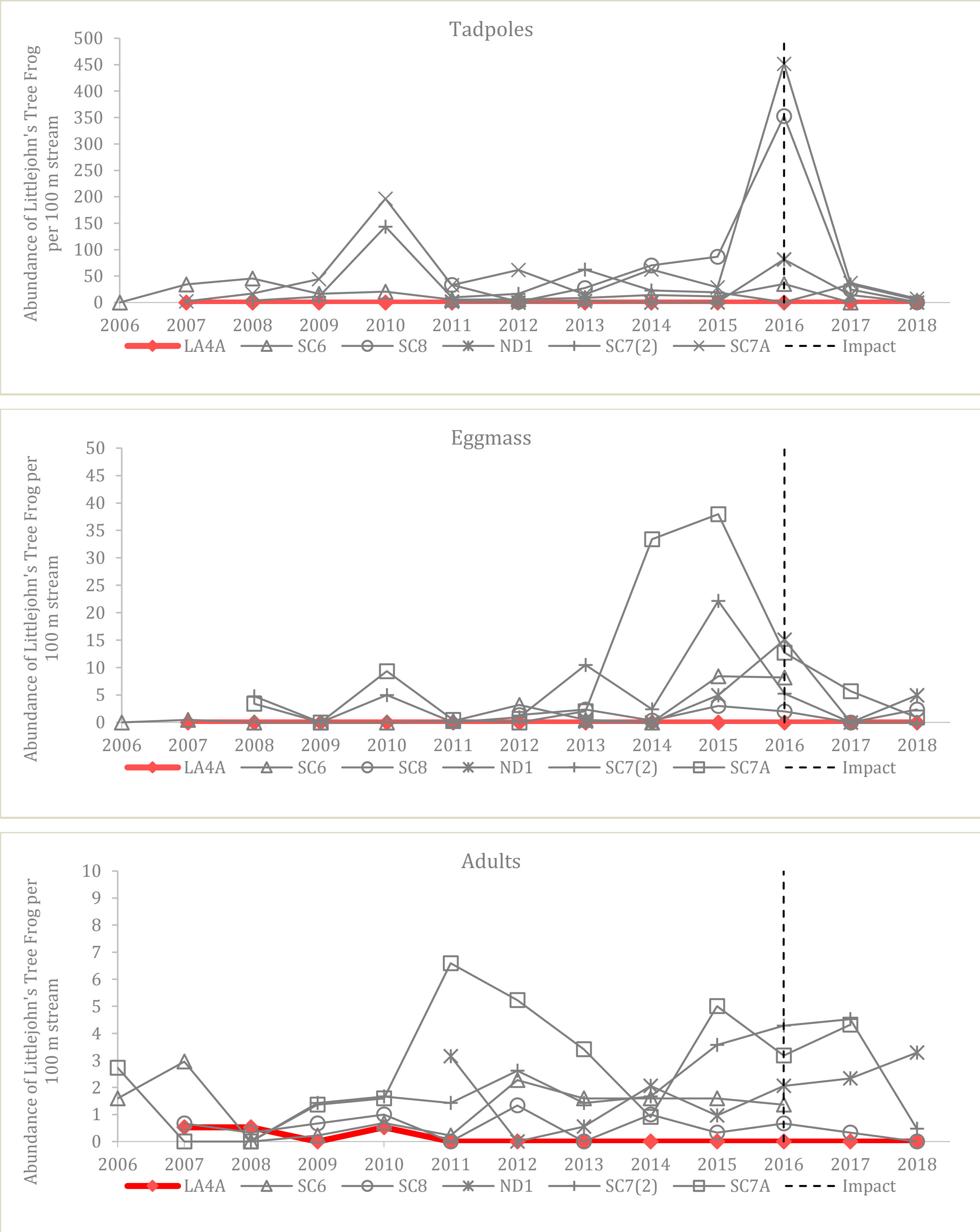


Figure 26 The number of Littlejohn's Tree Frog a) tadpoles, b) egg masses and c) adults recorded at impact site LA4A (red line) and associated control sites SC6, SC8, SC7(2), SC7A and ND1 (grey lines) per 100 metres of survey transect. The dashed line represents the first year mining commenced within the RMZ. The survey was undertaken in winter 2018.

4 Conclusions and recommendations

At the completion of the 2018 ecological monitoring program, 12 years of data has been collected for Dendrobium Area 2; 8 to 14 years of data has been collected for Dendrobium Area 3A; and 5 years of data collected for the majority of Dendrobium Area 3B (aside from Swamp 11 where monitoring has been undertaken for 13 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 2018 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 triggers 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 at Swamps 15A(2) and 15B following extraction of longwalls in Dendrobium Areas 3A and 3B. Therefore, it is possible that the observed statistically significant declines in TSR at these swamps is attributed to alterations in retention of shallow groundwater. At Swamp 15A(2), 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, accumulating over time. The analysis of data sets and observations of Swamp 15B present an identical change as observed at Swamp 15A(2), over the same time frame, in regards to TSR, floristic composition and reduction in shallow groundwater level.

The results of the TSR analysis demonstrate the response to mining at individual swamps is complex, with Swamp 15A(2) and Swamp 15B generally showing a decline in TSR following mining and changes in shallow groundwater, and 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 including nutrient availability.

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

At Swamp 15A(2), the increase in Heath Banksia over time described by statistical analysis corresponds to field observations of increased height and density of this species within S15A(2). The observed increased height and cover of Heath Banksia has increased shading in some parts of the swamp previously open. Decreases in water dependent groundcover and low shrub species, *Selaginella uliginosa, Xanthorrhea* species complex and *Sprengelia incarnata* is attributable to significant changes in the hydrological regime post-mining. The *Cassytha glabella / C. pubescens* species complex is widespread and proliferates by attaching to the canopy of the mid strata. An increase in this species within upland swamp vegetation is not likely to result in a structural change of the vegetation community, but represents a shift in the composition of the vegetation community.

Observed reduction in woodland species recorded at Swamp 15B is likely linked to vegetation changes following 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 and *Sprengelia incarnata*, 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 has been observed, it is likely to be overstated in the data analysis, as a 44% less rainfall than the average has been observed (Table 14) and is considered to be a primary driver of this change.

4.1.3 Littlejohn's Tree Frog

When considering all sites together, there was a decrease in detection of adult Littlejohn's Tree Frog across all sites in 2017 compared to 2016 by approximately 32%, and tadpoles by 84%. In 2018, there was a decrease in detection of adult Littlejohn's Tree Frog across all sites compared to 2017 by approximately 24%, tadpoles by 21% and egg mass also by 21%. It has been noted that 2016 was an excellent year for breeding due to high levels of rainfall, and frog numbers recorded in 2016 were much higher than previous years. Detection of Littlejohn's Tree Frog in 2017 and 2018 was comparable to detection in 2015. 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. However, there is no visually discernible trend in either year or mining status (Pre/Post mining) in either mining area (Dendrobium Areas 3A and 3B).

The ongoing lack of, or low detection at numerous monitoring sites since the commencement of monitoring indicates that the 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 results in false negatives. It is recommended that while these sites continue to be surveyed annually, 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 flocculant 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 (WC21 and DC13) of the *Dendrobium Area 3 Watercourse TARP* (Illawarra Coal 2015a). 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. 2017 is the first year that site SC10(1) has triggered the *Dendrobium Area 3 Watercourse TARP* (Illawarra Coal 2015a) due to build-up of iron flocculant 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, iron staining on bedrock steps was observed. It is anticipated that when water returns to this site, iron flocculant will remain an issue, however this should be reviewed in 2019.

SC10C was the only post-mining site that showed a declining trend in detection of all Littlejohn's Tree Frog life stages, triggering Level 1 of the *Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012)* (Illawarra Coal 2012c). However, 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. However 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. The monitoring results at SC10C should be reviewed in 2019.

In 2016 a declining trend in Littlejohn's Tree Frogs was recorded at post-mining site WC17, with no tadpoles or egg masses 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 2018, no individuals at any life stage were recorded within the breeding pools. This is consistent with the trends observed at the control sites, and is most likely due to the dry conditions experienced within the catchment at the time of survey. It is therefore determined that WC17 does not trigger the revised Dendrobium Area 3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (Illawarra Coal 2012c).

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 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 swamp located within Dendrobium Area 3A and 3B (as demonstrated in Section 3.2.1).

Yearly changes in species composition were detected in most sites, regardless of area or treatment. This variation is likely 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) and Swamp 15A(2) (Dendrobium 3A), consistent with the findings from 2017. As with TSR, these changes were observed immediately following undermining and have continued at Swamp 15B and Swamp 15A(2) 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 2018 analysis against the Dendrobium 3A and 3B TARPs is presented below in Table 16.

Table 16 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	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 2012 through to 2018 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. A statistically significant (p-values < = 0.05) change in species composition was detected at S15B during all but one of the six post-mining time periods examined, indicating a Level 2 TARP has been triggered. Biosis understands that no CMAs have been initiated, therefore a Level 3 trigger cannot be assessed.	Level 2 triggered.	Continue monitoring S15B in spring and autumn each year. Consult with technical specialists to identify need and type of CMA required and implement any agreed CMA.
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. A statistically significant (p-values < = 0.05) change in species composition was detected at S15A(2) during all of the post-mining time periods examined, indicating a Level 2 TARP has been triggered. Biosis understands that no CMAs have been initiated, therefore a Level 3 trigger cannot be assessed.	Level 2 triggered.	Continue monitoring S15A(2) in spring and autumn each year and investigate reasons for the TARP trigger. Consult with technical specialists to identify need and type of CMA required and implement any agreed CMA.
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. Additionally, no statistically significant decline in species composition was found post-mining at S1A.	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. Additionally, no statistically significant decline in species composition was found post-mining at S1B.	No TARP levels triggered.	Due to the 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. Additionally, no statistically significant decline in species composition was found post-mining at S5.	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 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 from the 2014 baseline substantially during 2018.

The results of the 2018 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 2018.

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.

Table 17 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 monitoring in 2019.
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. 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 two consecutive monitoring periods greater than the mean (±SE) decline of MU42 and MU44b in the control group.	Swamp Size: Level 1 TARP triggered. Ecosystem Function: Level 2 TARP triggered.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019. Investigate practical remediation measures, or offset if remediation deemed to be ineffective after 5 years.
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. 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. Ecosystem Function: Level 1 TARP triggered	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019. Investigate practical remediation measures, or offset if remediation deemed to be ineffective after 5 years.
S05	Level 1, 2 or 3 TARP.	One year of decline in total swamp greater than the mean (±SE) decline of the control group. 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. Ecosystem Function: Level 2 TARP triggered.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019. Investigate practical remediation measures, or offset if remediation deemed to be ineffective after 5 years.

Swamp	Predicted impact	Results and TARP justification	TARP	Recommendations
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. One year of trending decline in the extent of MU42 over the monitoring period.	Swamp Size: No TARP triggered. Ecosystem Function: No TARP triggered.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019.

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, 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 Corrective Management Actions (CMAs) are being considered by Illawarra Coal and the Department of Planning and Environment.

Table 18 assesses impact sites in Dendrobium Area 3A against the TARPs using the definitions outlined above.

Table 18 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.	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. However 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. The following Level 1 triggers relating to terrestrial fauna have been observed:	**Level 1 TARP triggered.**	Continue monitoring to investigate whether CMAs for related watercourse TARPs may address some impacts to threatened frog habitats.

Stream	Predicted impact	Results and TARP justification	TARP	Recommendations
		• No significant statistical difference between Before After Control Impact sites. The following triggers relating to watercourse monitoring have been observed: • Stream appearance at SC10C.		
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 2018 results show an increase in the detection of Littlejohn's Tree Frogs at this site, in contrast to declining numbers at the control sites during this year. The following trigger relating to watercourse monitoring has been observed: • Iron flocculant covering all stream surfaces This represents a reduction in breeding habitat for Littlejohn's Tree Frogs.	**No TARP levels triggered.**	Continue approved monitoring program.
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, 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.**	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 19 assesses impact sites in Dendrobium Area 3B against the TARPs using the definitions outlined above.

Table 19 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). The level 1 TARP was triggered in 2017. While also reflecting the impacts of dry conditions, the 2018 data is consistent with that of the 2017 findings.	**Level 1 TARP remains.**	Continue monitoring as a part of the approved terrestrial monitoring program.

Stream	Predicted impact	Results and TARP justification	TARP	Recommendations
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. 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 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 2018 data is consistent with the 2017 findings The Level 3 TARP is considered to remain triggered and should be reviewed in 2019.	**Level 3 TARP triggered in 2017. Level 3 TARP is considered to remain triggered in 2018.**	Recommendations for reporting to the relevant authorities were made following the triggering of the Level 3 TARP in Biosis (2017). Continue monitoring as a part of the terrestrial monitoring program.
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). While also reflecting the impacts of dry conditions, the 2018 data is consistent with the 2017 findings. The Level 3 TARP is considered to remain triggered and should be reviewed in 2019.	**Level 3 TARP triggered. Level 3 TARP is considered to remain triggered in 2018.**	Recommendations for reporting to the relevant authorities were made following the triggering of the Level 3 TARP in Biosis (2017). 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 corrective management actions are recommended in Biosis (2017b). The results of the 2018 monitoring period are consistent with those recorded in 2017, as such the recommended monitoring and corrective management actions in Biosis (2017b) remain relevant.

4.3 Site specific recommendations

4.3.1 S15A(2) and S15B upland swamp terrestrial flora monitoring

Swamp 15(A)2 and Swamp 15B have been monitored over a considerable period of time. Statistically significant changes in species composition following mining during this time, as well as statistically significant changes in TSR at site S15B. 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.

The triggering of a Dendrobium Area 3A Swamp – Terrestrial Flora Level 2 TARP for S15A(2) and S15B (South32 2015) requires the following actions:

- Continue monitoring program.
  - Biosis will continue to monitoring all of sites as part of the 2019 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 have experienced decreased groundwater levels and soil moisture at monitoring locations. Both Swamp 1A and Swamp 5 have also experienced yellowing of Needlebush 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.

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 will continue monitoring SC10C as part of the 2019 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 flocculant on stream surfaces. This requires the following actions:

- Continue monitoring program.
  - Biosis will continue monitoring SC10(1) as part of the 201 monitoring program.
- Report in the End of Panel Report.
  - Illawarra Coal to incorporate results in End of Panel report.
- Summarise actions and monitoring in AEMR.
  - Illawarra 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 will continue monitoring DC(1) as part of the 2019 monitoring program.
- Submit an Impact Report to OEH, DP&E, DPI, 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 Coal to incorporate results End of Panel report.
- Summarise actions and monitoring in AEMR.
  - Illawarra Coal to incorporate results in the AEMR.

4.3.6 LA4A Littlejohn's Tree Frog monitoring

No Dendrobium Area 3B Watercourse – Terrestrial Fauna: Threatened Frog Species TARPs were triggered for LA4A. It is recommended that the sites continue to be monitoring as part of the approved terrestrial monitoring program.

4.3.7 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 will continue monitoring WC21 and DC13 as part of the 2019 monitoring program.
- Submit an Impact Report to OEH, DP&E, DPI, 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 Coal to incorporate results in the End of Panel report.
- Summarise actions and monitoring in AEMR.
  - Illawarra Coal to incorporate results in the AEMR.
- Review monitoring frequency.
  - Additional tadpole monitoring should be completed during summer 2018/2019 to determine tadpole success and metamorphosis.
- Notify relevant technical specialists and seek advice on any CMA required.
  - Illawarra 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 OEH, DP&E, DPI, 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 OEH, DP&E, DPI, 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 Coal, DP&E, DPI and WaterNSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success.

4.4 Conclusion

Following the 2018 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 2018 terrestrial ecological monitoring should therefore be considered in this context. However, long term declines have been identified throughout this monitoring program and any further effects of low rainfall may be a result of a reduction in ecosystem resilience.

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