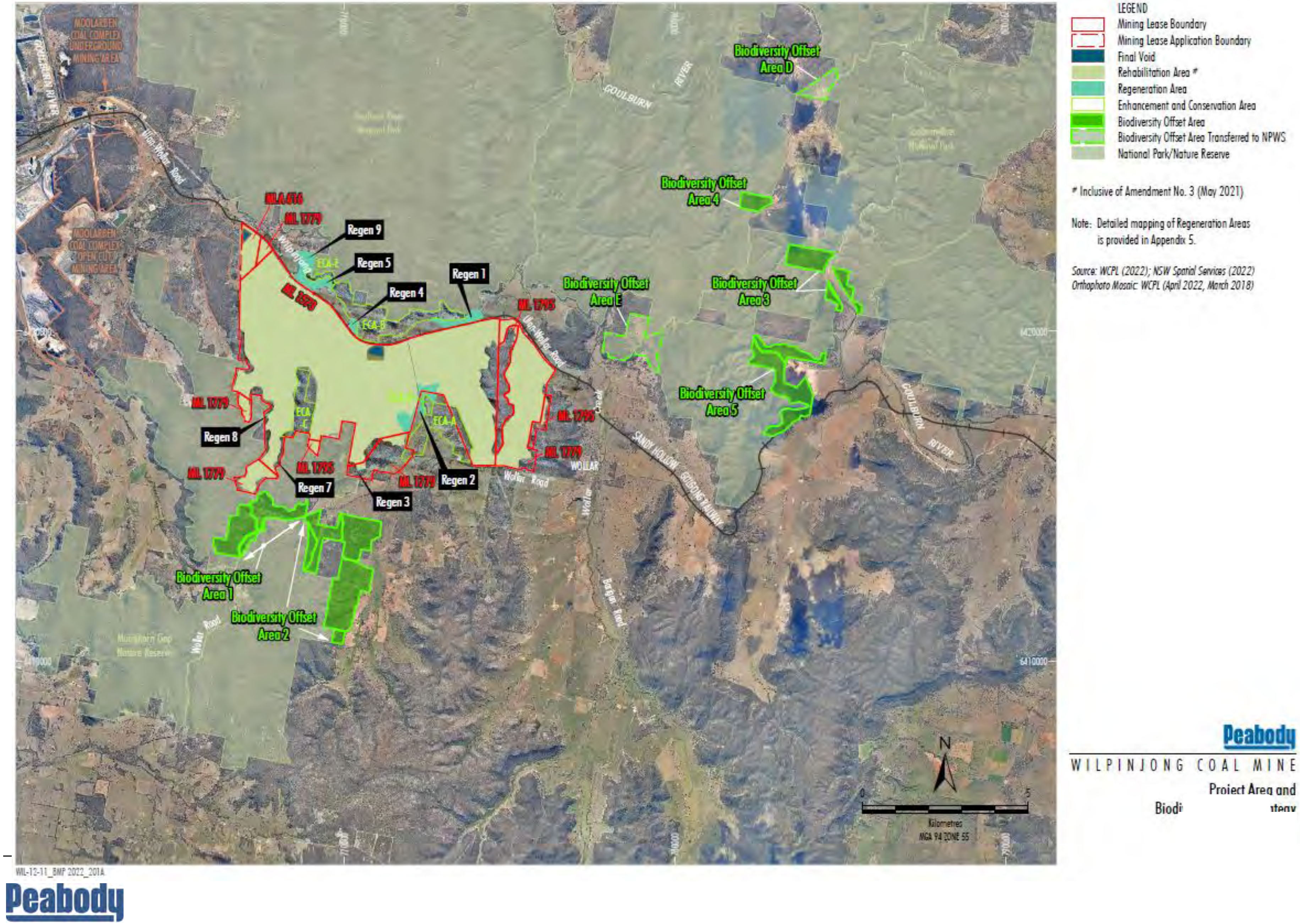
APPENDIX 5

BIODIVERSITY

Biodiversity Offset Strategy


LEGEND
Mining Lease Boundary
Mining Lease Application Boundary
Final Void
Rehabilitation Area #
Regeneration Area
Enhancement and Conservation Area
Biodiversity Offset Area
Biodiversity Offset Area Transferred to NPWS
National Park/Nature Reserve
Inclusive of Amendment No. 3 (May 2021)
Note: Detailed mapping of Regeneration Areas is provided in Appendix 5.
Source: WCPL (2022); NSW Spatial Services (2022)
Orthophoto Mosaic: WCPL (April 2022, March 2018)
Biodiversity Offset Area D
Biodiversity Offset Area 4
Biodiversity Offset Area 3
Biodiversity Offset Area E
Biodiversity Offset Area 5
Biodiversity Offset Area 1
Biodiversity Offset Area 2
Regen 1
Regen 2
Regen 3
Regen 4
Regen 5
Regen 7
Regen 8
Regen 9
MLA 616
ML 1779
ML 1573
ML 1795
ECA-A
ECA-B
ECA-C
ECA-E
WOLLAR
GOULBURN RIVER
SANDY HOLLOW - GULGONG RAILWAY
MOOLARBEN COAL COMPLEX UNDERGROUND MINING AREA
MOOLARBEN COAL COMPLEX OPEN CUT MINING AREA
Ulan-Wollar Road
Wollar Road
Wollar Creek
Bungaba Road
Munghorn Gap Nature Reserve
Kilometres
MGA 94 ZONE 55
WIL-12-11_BMP 2022_201A
Peabody
WILPINJONG COAL MINE
Project Area and

Biodiversity Reports

Review of BMP Management Schedule for 2022

Management Strategy	Objectives	2021	2022	2023	Comments 2022
Cultural Heritage Management	Cultural heritage items within the approved disturbance area, ECAs, Regeneration and Rehabilitation Areas are managed in accordance with the WCPL ACHMP (within DA boundaries) and Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW for areas elsewhere	• Continue implementation of WCPLs ACHMP, Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW and WCPLs GDP Process	• Continue implementation of WCPLs ACHMP, Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW and WCPLs GDP Process	• Continue implementation of WCPLs ACHMP, Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW and WCPLs GDP Process	• Implemented in 2022 (refer to Section 6.3 of the 2022 Annual Review
	Prevent unauthorised human access and exclude livestock from areas of native regeneration (unless being used as within management program i.e. crash grazing) to all Management Domains	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Annual & opportunistic inspections completed in 2022 • Inspections determined no further need for repairs • No livestock in sensitive areas
Fencing, Gates and Signage	Access to the Management Domains is retained for maintenance and safety purposes	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Annual & opportunistic inspections completed in 2022 • Inspections determined no further need for repairs • Adequate signage in place
Access Tracks	Reduce and rehabilitate unnecessary access tracks in all Biodiversity Offset Areas, ECAs and Regeneration Areas	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• No decommissioning of tracks required in 2022 (insitu tracks remaining are required for bush fire management) • One section of track within ECA-B needs repair due to wash outs, scheduled for repair in 2022

Management Strategy	Objectives	2021	2022	2023	Comments 2022
	Provide safe, unimpeded access for monitoring and maintenance, bushfire management, and asset protection in all Biodiversity Offset Areas, ECAs and Regeneration Areas	• Identify and map all access tracks required for safe and ongoing access, including tracks suitable for a CAT 1 tanker • Develop a repair and maintenance program for existing tracks that are proposed to remain • Seek relevant authorisation to enable construction of new access tracks (as required)	• Undertake annual and opportunistic access track inspection. Schedule and undertake necessary repairs	• Undertake annual and opportunistic access track inspection. Schedule and undertake necessary repairs	• No decommissioning of tracks required in 2022 (insitu tracks remaining are required for bush fire management) • One section of track within ECA-B needs repair due to wash outs, scheduled for repair in 2023
Waste Management	ECAs and Regeneration Areas are free of waste, disused buildings and redundant farm equipment	• Undertake annual and opportunistic waste inspections. Schedule and commission removal of all additional waste	• Undertake annual and opportunistic waste inspections. Schedule and commission removal of all additional waste	• Include disused building sites in annual and opportunistic inspections. Schedule and undertake necessary repairs	• Annual inspection completed in 2021, outstanding waste in ECA_B underwent partial removal during 2022 - due to be completed in 2023.
Erosion, Sedimentation and Soil Management	High risk erosion, sediment or soil risks are identified and mapped in all ECAs and Regeneration Areas	• Undertake annual and opportunistic erosion, sediment and soil inspections. Update GIS database with necessary changes. • Undertake repairs as necessary to a stabilise high risk areas.	• Undertake annual and opportunistic erosion, sediment and soil inspections. Update GIS database with necessary change. • Undertake repairs as necessary to a stabilise high risk areas.	• Undertake annual and opportunistic erosion, sediment and soil inspections. Update GIS database with necessary changes. • Undertake repairs as necessary to a stabilise high risk areas.	• In 2019 high resolution mapping of Wilpinjong Creek (erosion profiling) was completed. • In 2022 ongoing targeted tree planting along sections of Wilpinjong Creek within ECA_B, ECA_A and Regen Area 2. • 2022 planting in Regen 1, plantings along LDP19 Wilpinjong Creek. • Annual inspections completed in late 2022 to monitor high risk erosion areas e.g., ECB_B. Ongoing development of suitable remediation plan in 2022.

Management Strategy	Objectives	2021	2022	2023	Comments 2022
	Exclude livestock from areas of native regeneration in all Biodiversity Offset Areas, ECAs and Regeneration Areas (unless being used as within management program)	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Undertake annual and opportunistic security inspections (fences, gates and signage). Schedule and undertake necessary repairs	• Annual & opportunistic inspections completed in 2022 • Inspections determined no further need for repairs • No livestock in sensitive areas
Seed Collection and Propagation	All seed collectors are appropriately qualified and trained	• Confirm training records for engaged seed collectors	• Confirm training records for engaged seed collectors	• Confirm training records for engaged seed collectors	• Seed collecting methodology and supplier details formed part of the 2020 seed tendering contract process
	Local species are included in revegetation and rehabilitation seed mixes	• Identify available seed species • Species collected to align with BVT species list and as required for site rehabilitation	• Identify available seed species • Species collected to align with BVT species list and as required for site rehabilitation	• Identify available seed species • Species collected to align with BVT species list and as required for site rehabilitation	• WCPL has maintained an ongoing seed collecting and seed storage program since 2015 • During 2021, applicable BVT seed species were identified from WCPL's seed bank and approximately 5,000 seedlings were propagated at a local nursey in Wollar. Propagation of this seed batch continued into 2022.
	Locally sourced seed is available for revegetation and rehabilitation works within all Management Domains	• Implement Seed Collection Program	• Implement Seed Collection Program	• Implement Seed Collection Program	• See above • During 2022 the seed collecting program continued (refer to Section 8 of the Annual Review)
Habitat Augmentation	Habitat augmentation opportunities are identified and assessed	• Implement Habitat Augmentation Procedure and recommendations where applicable	• Implement Habitat Augmentation Procedure and recommendations where applicable	• Implement Habitat Augmentation Procedure and recommendations where applicable	• Ongoing refer to **Section 8** of the Annual Review

Revegetation and Regeneration	Increase overall native plant species richness in ECAs, Regeneration and Rehabilitation Areas	**ECA-B** Revegetation of local native over-storey and shrub species within poor condition areas **Regeneration Area 1** Opportunistic supplementary tree planting **Regeneration Area 9** Opportunistic supplementary tree planting	**ECA-B** Continue revegetation works of local species **Regeneration Area 1** Opportunistic supplementary tree planting **Regeneration Area 2** Opportunistic undertakings of revegetation works of local native over-storey and shrub species within poor condition areas **Regeneration Area 4** Opportunistic undertakings of revegetation works of native over-storey and shrub species in areas of no to low resilience **Regeneration Area 5** Opportunistic undertakings of revegetation works of native over-storey and shrub species in areas of no to low resilience **Regeneration Area 9** Opportunistic undertakings of revegetation works of native over-storey and shrub species in areas of no to low resilience Undertake annual and opportunistic revegetation and regeneration inspections.	Undertake annual and opportunistic revegetation and regeneration inspections. Schedule and undertake necessary maintenance including reapplication of seed or supplementary tree and shrub planting.	• ECA_B (2019 & 2020) and Regen (2021) have been replanted with tubestock species.

Management Strategy	Objectives	2021	2022	2023	Comments 2022
Weed Management	Noxious and environmental weeds are identified and mapped in all ECAs and Regeneration Areas	Undertake a detailed inspection of all Biodiversity Offset Areas, ECAs and Regeneration Areas and accurately map (GIS) noxious and environmental weeds	Undertake quarterly weed inspections. Update GIS database with necessary changes	Undertake quarterly weed inspections. Update GIS database with necessary changes	• ECA_A and ECA_B weed control incomplete due to access constraints caused by wet weather in 2022.
	A risk based weed management program is developed for all ECAs, Regeneration and Rehabilitation Management Domains	• Implement weed management program • Undertake weed inspections 1. Schedule and undertake necessary weed treatment	• Implement weed management program • Undertake weed inspections 2. Schedule and undertake necessary weed treatment	• Implement weed management program • Undertake weed inspections 3. Schedule and undertake necessary weed treatment	• Ongoing weed management assessments, based on annual and opportunistic inspections and Weed Management Plan developed by ELA (2020).

Wilpinjong Coal Mine
2022 Annual Biodiversity Monitoring Report

Wilpinjong Coal Pty Ltd

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DOCUMENT TRACKING

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Contents

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Abbreviations

Abbreviation	Description
BC Act	*Biodiversity Conservation Act 2016*
BCS	Biodiversity, Conservation and Science Directorate
BMP	Biodiversity Management Plan
BOA	Biodiversity Offset Area
BVT	BioMetric Vegetation Type
DNG	Derived native grassland
DPIE	Department of Planning, Industry and Environment
EC	Exotic Cover
ECA	Enhancement and Conservation Area
ELA	Eco Logical Australia Pty Ltd
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FL	Fallen Logs
LFA	Landscape Function Analysis
LGA	Local Government Area
LOI	Landscape Organisation Index
Microbat	Microchiroptera bat

Abbreviation	Description
ML	Mining Lease
MOP	Mine Operations Plan
MWRC	Mid-Western Regional Council
NGCG	Native Ground Cover Grass
NGCO	Native Ground Cover Other
NGCS	Native Ground Cover Shrub
NMC	Native Midstorey Cover
NOC	Native Overstorey Cover
NPWS	National Parks and Wildlife Service
NSR	Native Species Richness
NTH	Number of Trees with Hollows
OR	Overstorey Regeneration
OEH	Office of Environment and Heritage
PA	Project Approval
SSA	Soil Surface Assessment
SVS	Site Value Score
TARP	Trigger Action Response Plan
WCM	Wilpinjong Coal Mine
WCPL	Wilpinjong Coal Pty Ltd
WEP	Wilpinjong Extension Project
WSDSF	Western Slopes Dry Sclerophyll Forest
WSGW	Western Slopes Grassy Woodland

Executive Summary

Biodiversity monitoring was undertaken at the Wilpinjong Coal Mine (WCM) during 2022, under the methodology prescribed in the WCM Biodiversity Management Plan (BMP) (WCPL 2021). Monitoring was undertaken at established sites across the WCM Management Domains, including Biodiversity Offset Areas, Enhancement and Conservation Areas, Regeneration and Rehabilitation Areas. A series of reference sites were monitored to provide comparative results.

Reference sites were established in 2019 & 2020 in areas that conform to WCPL's targeted rehabilitation BioMetric Vegetation Types (BVTs), in accordance with Condition 36 of the Development Consent SSD 6764 for the Wilpinjong Extension Project (WEP). These sites have been established to provide comparative data for the approved Wilpinjong rehabilitation BVTs.

Vegetation monitoring was undertaken within the Rehabilitation Areas and Reference Sites in 2022. Most sites monitored in 2022 were assessed as being Moderate to Good/High with one site categorised as Low.

Landscape Function Analysis (LFA) monitoring was also undertaken within the Rehabilitation Areas and Reference Sites. Landscape Organisation Index (LOI) scores remained comparable to 2021 monitoring results. Infiltration and nutrient cycling scores are still consistently below the completion criteria, however improvements in these two measures was observed at two sites for infiltration and at three sites for nutrient cycling. Despite this, all rehabilitation sites monitored in 2022 recorded a <5% annual improvement from the previous monitoring period in at least one Soil Surface Assessment (SSA) measure and as such, review of the relevant Trigger Action Response Plan (TARP) is required.

Fauna monitoring recorded a total species richness of 127 species, comprising of 111 birds, five (5) mammals, two (2) reptiles, and nine (9) positively identified Microchiroptera (microbat) species. Seven (7) species (five (5) bird species and two (2) positively identified microbat species) listed as threatened under the NSW *Biodiversity Conservation Act 2016* and/or the Commonwealth *Environmental Protection and Biodiversity Act 1999* were observed across the Wilpinjong Management Domains during 2022 monitoring.

A series of recommendations have been provided to ensure the continual improvement of the monitoring program. Recommendations include re-evaluating the current LFA monitoring. As part of the required TARP review for LFA results, it is recommended that consideration is given to the management aims for which LFA monitoring seeks to evaluate, and the efficacy of the LFA method to inform the achievement of these aims. A range of alternative methods are proposed for consideration.

1. Introduction

Wilpinjong Coal Pty Ltd (WCPL), a wholly owned subsidiary of Peabody Energy Australia Pty Ltd (Peabody), operates the Wilpinjong Coal Mine (WCM) located in the western coalfields of NSW approximately 48 km north-east of Mudgee, within the Mid-Western Regional Council (MWRC) Local Government Area (LGA).

The WCM originally operated under Project Approval (PA) 05-0021, granted under Part 3A of the NSW Environmental Planning and Assessment Act 1979 on 1 February 2006. A series of modifications to PA 05-0021 were approved until it was superseded by Development Consent SSD-6764, granted on 24 April 2017 for the Wilpinjong Extension Project (WEP).

A Biodiversity Offset Strategy was developed and augmented by WCPL to offset impacts on threatened species, populations or communities listed under the NSW *Biodiversity Conservation Act 2016* (BC Act) and /or the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act) in accordance with SSD-6764. The strategy comprises more than 4,500 ha of Management Domains including:

- **Biodiversity Offset Areas (BOAs):** The BOAs comprise significant areas of largely undisturbed remnant vegetation and require minimal management to maintain ecological integrity. The BOAs are located next to the Goulburn River National Park and Munghorn Gap Nature Reserve with the aim that these parcels of land will be transferred to the National Parks Estate to be managed in perpetuity. Two BOAs, D and E (211 ha), were transferred in 2019 and are now under the management of the NSW National Parks and Wildlife Service (NPWS). Further biodiversity monitoring within BOAs D and E is no longer required. BOAs 1 – 5 (1,007 ha) were added to the monitoring program in winter 2018 and will be transferred into the National Parks Estate at a later date.
- **Enhancement and Conservation Areas (ECAs):** WCPL entered into a Voluntary Conservation Agreement (VCA) with the NSW Minister for the Environment for three parcels of land surrounding Mining Lease (ML) 1573 – ECAs A, B and C. These areas have been established for conservation purposes and enhanced through weed management, revegetation and pest control.
- **Regeneration Areas:** Established on areas of WCPL owned land next to the ML, these areas were predominately cleared agricultural land in which woodland vegetation will be established through natural regeneration and implementation of proactive management actions.
- **Rehabilitation Areas:** Rehabilitation of disturbed areas is undertaken on a progressive basis in accordance with the approved Mining Operation Plan (MOP). The Development Consent allows for rehabilitation to provide biodiversity offset credits if it can be demonstrated that the target vegetation communities have been established to fulfil the offset requirement aligning with the site's Performance and Completion Criteria.

The annual biodiversity monitoring program is implemented across all Management Domains in accordance with the WCM Biodiversity Management Plan (BMP) (WCPL 2021).

Eco Logical Australia (ELA) was engaged by WCPL to undertake biodiversity monitoring consistent with the requirements and methods outlined in the BMP. Monitoring includes:

- BioMetric vegetation monitoring (Gibbons et al 2009)
- Landscape stability monitoring using Landscape Function Analysis (LFA) (Tongway and Hindley 2004)
- Terrestrial fauna monitoring.

In accordance with Condition 36 of the Development Consent SSD-6764, WCPL must demonstrate that rehabilitation areas have reached performance and completion criteria to generate ecosystems credits to offset impacts from the WEP, for the following prescribed BVTs:

- HU547 – Fuzzy Box Woodland
- HU981 – Rough Barked Apple Woodland / HU732 – Yellow box Grassy Woodland
- HU824 – White Box-Black Cypress Pine Shrubby Woodland.

Further, in accordance with Condition 36 and 37 of the Development Consent SSD-6764, WCPL must demonstrate rehabilitation areas have reached performance and completion criteria to generate species credit requirements specific to the critically endangered *Anthochaera phrygia* (Regent Honeyeater):

- HU697 – Mugga Ironbark-Black Cypress Pine Open Forest
- HU732 – Yellow Box Grassy Woodland
- HU825 – Narrow-leaved Ironbark-Black Cypress Pine Grass Woodland.

1.1. Objective

The objective of the biodiversity monitoring program is to assess biodiversity across the Management Domains against the relevant Performance and Completion Criteria prescribed in the BMP (WCPL 2021). Monitoring results from the spring 2015 and autumn 2016 programs represent the baseline (Year 0) data for each monitoring site, with the 2022 results presented in this report representing Year 7 and Year 6 data for spring and autumn respectively. The Management Domain locations are listed in Table 1-1 and shown in Figure 1-1.

Table 1-1: WCPL Management Domains

Management Domain	Area (ha)	Location Description
BOA-1	201.12	Located to the south-west of ML 1573
BOA-2	417.48	Located to the south of the ML 1573
BOA-3	128.45	Located to the north-west of ML 1573, access via the Wollara Downs property
BOA-4	39.02	Located to the north-west of ML 1573, access via Mogo Road
BOA-5	221.24	Located to the west of ML 1573, access via the Wollara Downs property
ECA-A	177.32	Located to the south-east of ML 1573
ECA-B	216.38	Located to the north of ML 1573

Management Domain	Area (ha)	Location Description
ECA-C	96.23	Located in the south-east portion of ML 1573
Regeneration Area 1	28.12	Located adjacent to the eastern boundary of the approved disturbance area
Regeneration Area 2	59.94	Located on the western side of ECA-A
Regeneration Areas 3, 7 and 8	1.34	Located adjacent to the south and southwestern boundary of the approved disturbance area
Regeneration Area 4	6.53	Located on the north side of the mine, between the approved disturbance boundary and ECA-B
Regeneration Area 5	24.94	Located towards the western end of ECA-B
Regeneration Area 9	27.60	Located towards the western end of ECA-B
Rehabilitation Areas	Variable	Includes areas within the approved disturbance area for the mine, including active and future mining areas, infrastructure areas and rehabilitation of disturbed areas that is undertaken on a progressive basis in accordance with the approved WCPL MOP (WCPL 2020)

As noted previously, BOAs D and E (211ha) were transferred to the National Park Estate in 2019 and are now under the management of NPWS. Regeneration Area 6 was removed from the program in 2017 with approval under the WEP. ECA and Regeneration management domains were discontinued following the approval of the BMP (WCPL, 2021).

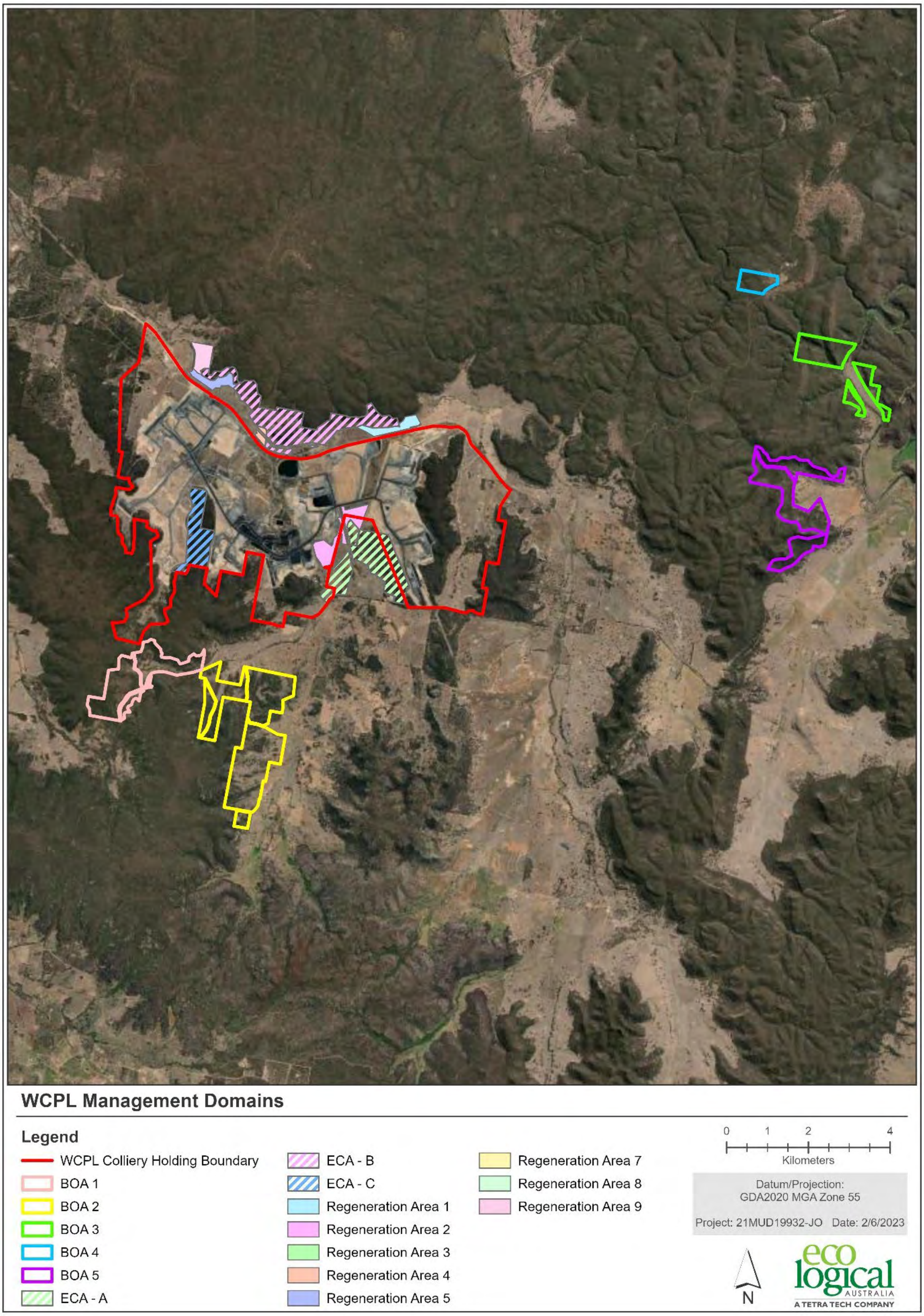


Figure 1-1: WCPL Management Domains

1.2. Assessment against Local Reference Site BVT Benchmarks and WCPL Performance Criteria

Revised Performance and Completion Criteria for the Rehabilitation Areas were developed by WCPL in and endorsed by the Biodiversity, Conservation and Science Directorate (BCS) in June 2021 which acknowledges local Reference Site benchmarks as preferential to broader benchmark data. Local Reference Site benchmarks were incorporated into the approved BMP (WCPL 2021). The 2022 monitoring data from the Rehabilitation Areas is assessed against these local Reference Site benchmarks and the rehabilitation performance and completion criteria as detailed in Table 12 of the BMP (WCPL 2021).

BOAs will continue to be monitored until transferred to NPWS, however, they are not comparable to the BMP Performance and Completion Criteria as these are specific to Rehabilitation Areas. BOAs are instead compared and monitored for resilience, with management actions to be implemented where poor resilience is determined, or improvements are not apparent.

2. Methodology

The 2022 biodiversity monitoring program was undertaken in accordance with the methods and survey techniques prescribed in the BMP (WCPL, 2021).

Weather conditions throughout the 2022 monitoring period are presented in **Appendix A**. Vegetation condition, class and coordinates for all monitoring sites are detailed in **Appendix B**.

2.1. Vegetation Monitoring

Autumn vegetation monitoring was undertaken between 26 May and 2 June 2022 by ELA ecologists David Allworth, Elise Keane, and Lachlan Metzler at two established monitoring sites and five reference sites. Spring vegetation monitoring was undertaken between 27 October and 2 November 2022 by ELA ecologists Cheryl O'Dwyer, Lachlan Metzler, and Tahnee Coull at three established monitoring sites and two reference sites. The locations of established and reference vegetation monitoring sites are illustrated in Figure 2-1 and Figure 2-2below. A further three reference sites were scheduled for spring vegetation monitoring, however, were inaccessible due to high water levels at Wilpinjong Creek.

The eight Rehabilitation Area sites that were seeded in 2020 were again monitored in June 2022 after being previously monitored in sFebruary 2022. The seeding of these sites was designed to establish areas as the target BVTs listed in the section above. Although establishment of BioMetric monitoring plots is not required until years 3 – 4 within the Rehabilitation Areas (as per Table 11 within the BMP [WCPL 2021]), vegetation monitoring was again undertaken at these sites to track early progress of these areas against the BVT performance criteria to determine success of seeded areas and aid in management decisions if necessary. Monitoring was undertaken between undertaken between 1 and 2 June 2022 by ELA ecologists Elise Keane and Lachlan Metzler, with the locations of monitoring sites shown in Figure 2-3**.**

Vegetation monitoring was undertaken utilising the BioMetric method of plot assessment prescribed in the BMP (WCPL, 2021). Permanent BioMetric plots, comprising a 20m x 20m (0.04ha) plot nested within a 20m x 50m plot, were surveyed at each monitoring site. Within each plot, the following data was collected:

- Native species richness (NSR), cover and abundance within the 20m x 20m plot
- Native overstorey cover (NOC) and native mid-storey cover (NMS) – at regular 5m intervals along 50m transect (10 points)
- Native ground stratum (grass, shrub, other) and exotic cover (EC) – at regular 1m intervals along 50m transect (50 points)
- Habitat features (number of trees with hollows (NTH), length of logs (FL)) and proportion of overstorey species regeneration – within 20m x 50m plot.

All vascular plant species were recorded and identified to the lowest taxonomic level possible, with samples of unknown species collected for further identification.

2.2. Landscape Function Analysis

Landscape Function Analysis (LFA) monitoring was undertaken at six (6) monitoring sites, including within four (4) WCPL Rehabilitation Areas and two (2) reference sites (Figure 2-2) in accordance with the methods prescribed in Tongway and Hindley (2004) and the BMP (WCPL, 2021).

At each LFA site, a 50 m transect line was established downslope between transect start and end markers. The majority of LFA transects directly correspond to the 50 m BioMetric transect of the respective monitoring site. However, at several sites, the LFA transect does not align with the BioMetric transect, particularly where the BioMetric transect is set across slope. Along each LFA transect, LFA attributes were assessed to monitor the Landscape Organisation Index (LOI) and Soil Surface Assessment (SSA).

2.2.1. Landscape Organisation Index (LOI)

The LOI characterises and maps the spatial patterns of resource loss or accumulation at a site. The LOI provides a proportion of the transect occupied by patches (landscape elements that are relatively permanent and provide stable, resource accumulating structures, such as trees, shrubs, grassy tussocks, ground cover, and logs). A higher LOI implies a more stable transect that is less prone to erosion, with a maximum LOI value of 1.00 indicating a transect that is completely covered by patches. The SSA is more in depth, providing an index (0-100) of Stability, Soil Infiltration and Nutrient Cycling for the whole of the landscape (transect). Table 13 in the BMP (WCPL, 2021) outlines the SSA attributes that contribute to each of these three indices (Table 2-1).

According to the LFA method, patches are long-term features that obstruct or divert water flow and/or collect/filter out material from runoff, and where there is evidence of resource accumulation. Inter-patches are zones where resources such as water, soil material and litter may be mobilised and freely transported either down slope when water is the active agent or down-wind when aeolian processes are active.

The following data was recorded for each patch/inter-patch along each LFA transect:

- Distance (m) from the start of the transect
- Patch width (cm)
- Patch/inter-patch identification.

The following patch types were defined and monitored across all LFA monitoring sites and monitoring periods:

- Bare soil
- Litter (including annual plants)
- Rock (>5 cm diameter)
- Logs (>10cm diameter)
- Ground cover (perennial)
- Shrub/tree
- Cryptogram
- Any combination of the above (e.g. ground cover – litter patch).

2.2.2. Soil Surface Assessment (SSA)

Each patch/inter-patch type identified in the landscape organisation data log was subject to an SSA. A subset of up to five occurrences of each patch/inter-patch type were monitored, and data relating to 11 Soil Surface Condition Indicators (SSCIs) were collected along the 50 m transect (Table 2-1)

Table 2-1: Soil Surface Condition Indicators used to determine the overall Soil Surface Analysis (see Table 13 BMP: WCPL, 2021)

SSCI	Description
Rain splash protection	Percentage cover of perennial vegetation to a height of 0.5 m. plus rocks > 2 cm and woody material > 1 cm in diameter or other long-lived, immoveable objects.
Perennial vegetation cover	Percentage perennial vegetation cover.
Litter	Percentage cover of annual grasses and ephemeral herbage (both standing and detached) as well as detached leaves, stems, twigs, fruit, dung, etc.
Cryptogam cover	Percentage cover of algae, fungi, lichens, mosses, liverworts and fruiting bodies of mycorrhizas.
Crust brokenness	Categorises soil crusts from 0-4 where 0 refers to 'no crust present' and 4 refers to an 'intact and smooth' soil crust.
Soil erosion type and severity	Categorises the aerial extent and severity of various erosion types from 'Insignificant' to 'Severe'.
Deposited materials	Categorises the extent and depth of deposited alluvial material
Soil surface roughness	Categorises the depth of surface depressions from 'smooth' to 'deep' depressions.
Surface nature (resistance to disturbance)	Categorises the soils capacity to resist disturbance based on the soils 'hardness' or 'brittleness'.
Slake Test	Categorises the soils stability when exposed to water
Texture	Categorises the soils water infiltration capacity from 'very slow' to 'high'

Baseline Data for the Slake Test and Texture SSCIs was used for the LFA analysis and was not assessed in the field in 2022. All other parameters were assigned a simple score in the field. Data was entered into the LFA calculation spreadsheets and used to calculate Soil Stability, Soil Infiltration and Nutrient Cycling indices.

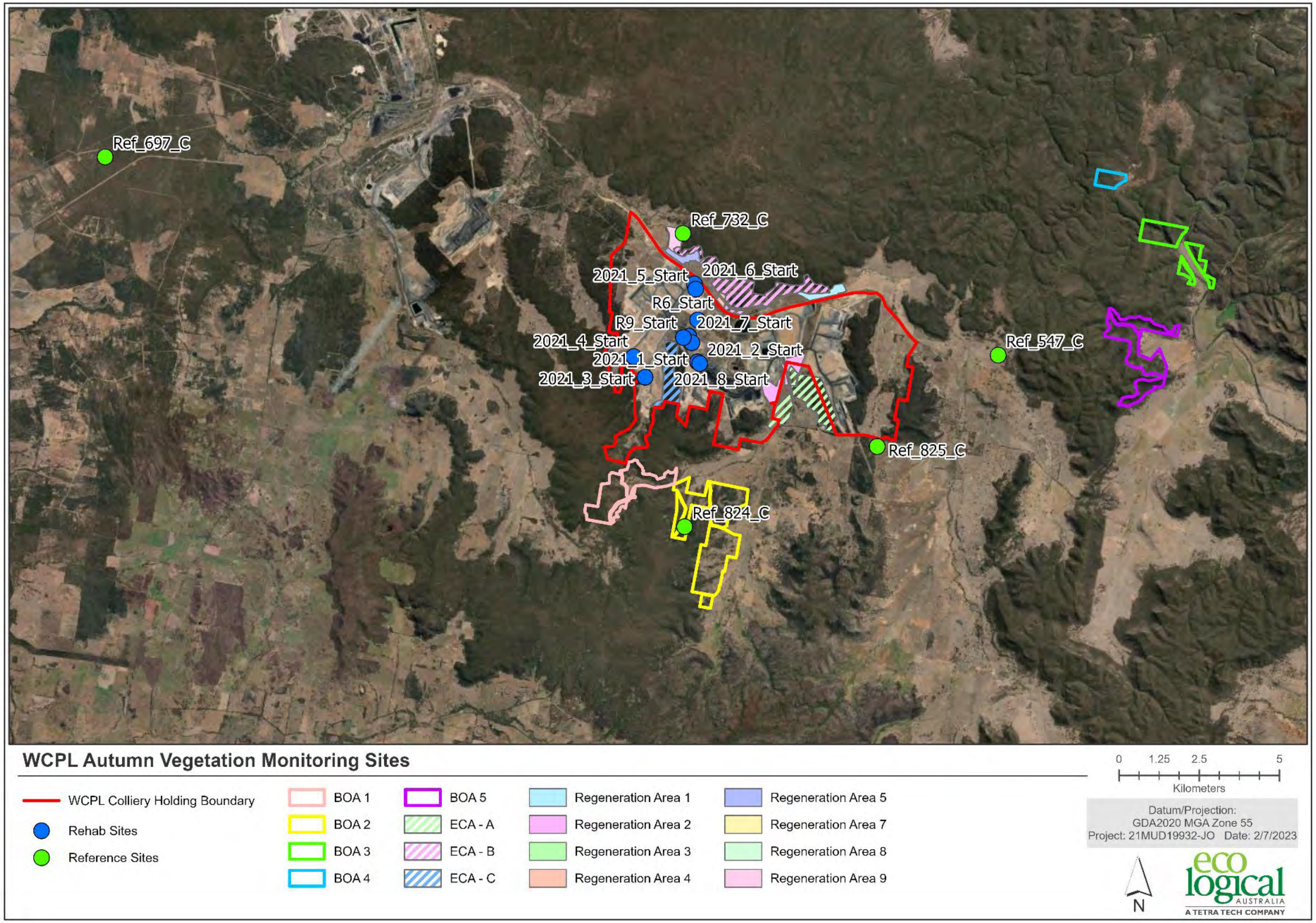


Figure 2-1: Autumn 2022 vegetation monitoring sites

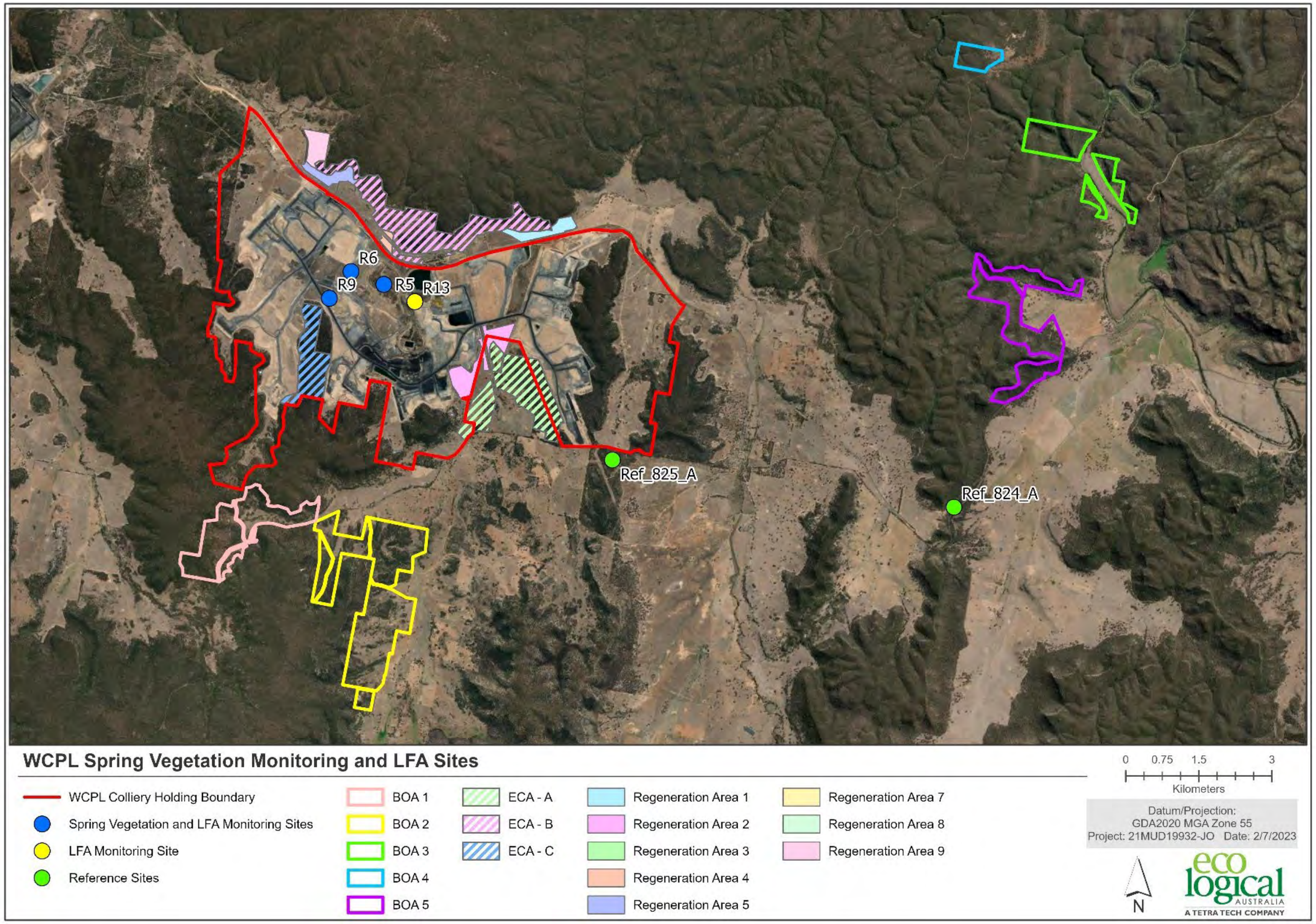


Figure 2-2: Spring 2022 vegetation and LFA monitoring sites

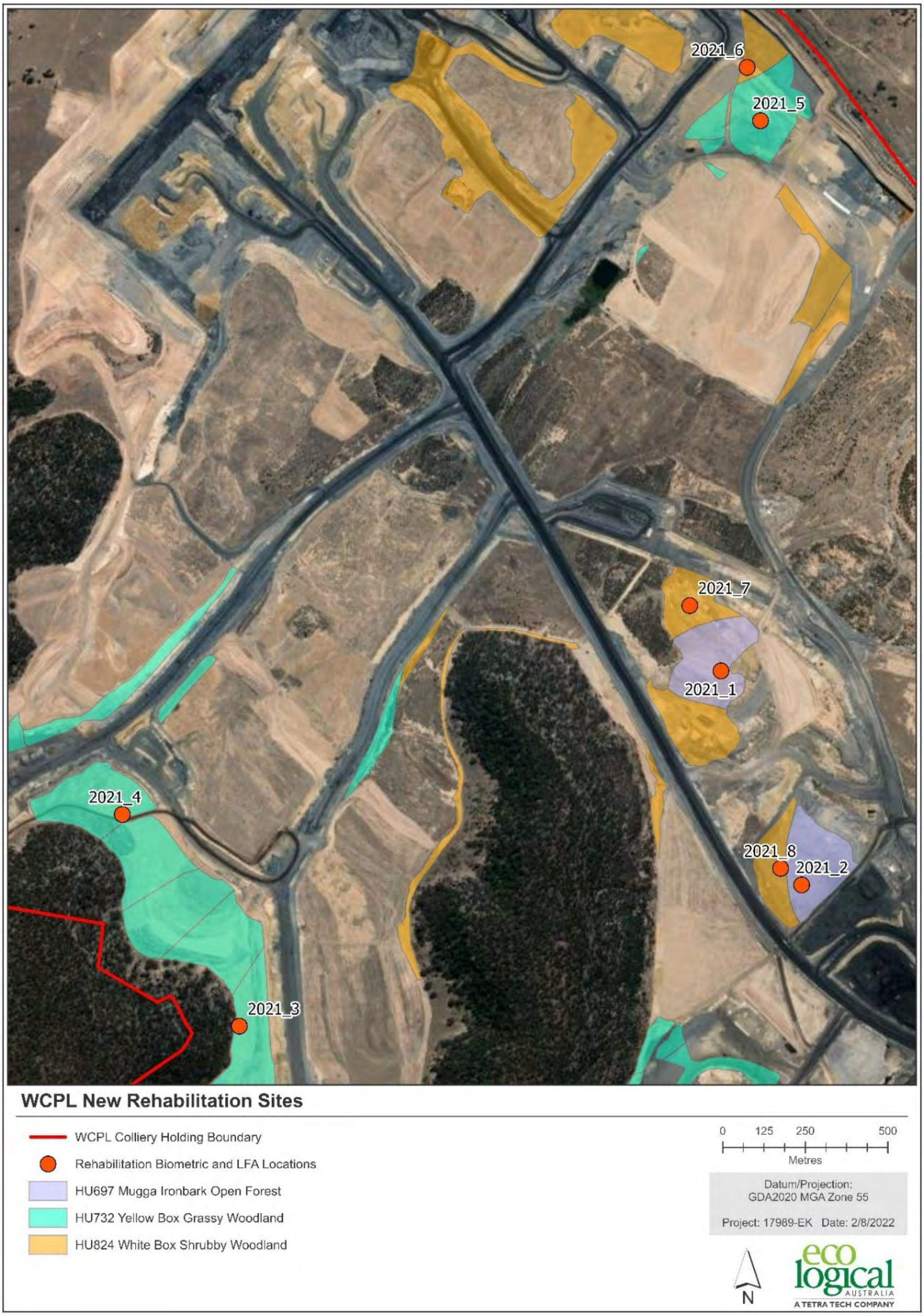


Figure 2-3: WCPL 2022 Rehabilitation Sites

2.3. Fauna Monitoring

Terrestrial fauna monitoring was undertaken across all Management Domains including:

- Bird Monitoring across three seasons (Summer, Winter, and Spring)
- Camera trapping in spring
- Microchiroptera (Microbat) monitoring in spring
- Nest box monitoring in spring.

Table 2-2 below outlines the methodology and survey effort for each target species per the methods prescribed within the BMP (WCPL, 2021).

Table 2-2: Fauna monitoring methods summary

Target Species	Methodology	Total Survey Effort
Birds	Bird census consisting of 10 minutes recording all birds seen/heard within 50 m radius of central plot point, and further 10 minutes recording all birds seen/heard within balance of a 2-ha plot. Call playback for the Critically Endangered Regent Honeyeater was played during surveying. Flowering Eucalypt and Mistletoe species were recorded using Survey123 to identify foraging sources specific to the Regent Honeyeater	80 total minutes per site (20 minutes per survey, per person, per site), over one morning and one afternoon.
Ground fauna (amphibians, mammals, reptiles)	Pit fall/funnel trap line of 30 m drift fence and five 20 L buckets/10 funnel traps spaced 5 m apart covering both sides of the drift fence. Infra-red cameras were installed on trees and large woody debris to monitor for ground fauna	Twice daily inspections of traps (morning and afternoon) for four nights (7 sites). Cameras were installed at five reference sites and two rehabilitation sites for four nights
Bats	Automated ultrasonic acoustic recording to identify all bat species occurring.	Recording for 2 nights (6pm – 6am)
All	Any sightings of fauna recorded whilst moving throughout the Project Area and located using a GPS.	Opportunistic
Mammals	Opportunistic collection of scats and observations of tree scratching's, animal tracks and paw prints.	Opportunistic

Above average rainfall causing localised flooding presented an ethical consideration to trapping of ground fauna in spring 2022. Therefore, it was decided to temporarily cease the ground fauna surveying using pit fall/funnel traps for the Spring 2022 monitoring period. Opportunistic fauna sightings, including fauna evidence such as scats and tracks, were also recorded, where identified, across all fauna monitoring sights. The locations of fauna monitoring sites are shown in the below in Figure 2-4**,** Figure 2-5, and Figure 2-6.

2.3.1. Bird Monitoring

Bird monitoring is undertaken across three seasons, summer, winter, and spring, to provide a comprehensive measure of bird presence. Winter bird surveys are undertaken specifically to target species that feed on the blossoms of winter-flowering eucalypts and lerps. Of the target winter-flowering eucalypt feed trees, only two species, *Eucalyptus albens* (White Box) and *Eucalyptus sideroxylon* (Mugga Ironbark), were recorded in flower. No mistletoe species were recorded in flower at any of the sites during the winter monitoring period.

Summer bird monitoring was undertaken at 19 bird monitoring sites between 21 and 25 February 2022 by ELA ecologists Thomas Kelly, Elise Keane, and Lachlan Metzler.

Winter bird monitoring was undertaken at 21 sites between 23 and 24 June and 27 and 29 July 2022 by ELA ecologists Tom Kelly, Rebecca Croake, and Tahnee Coull.

Spring bird monitoring was undertaken at 14 sites between 25 October and 3 November 2022 by ELA ecologists Elise Keane, Lachlan Metzler, and Tahnee Coull in combination with microbat monitoring.

2.3.2. Ground Fauna Monitoring

Ground fauna monitoring is undertaken in spring only and consisted of infra-red camera observations. Four infra-red motion sensitive Reconyx cameras were installed at two reference sites and two rehabilitation sites between 26 October and 2 November 2022. Ground trapping of fauna through the use of pitfall and funnel traps was not conducted in the 2022 spring monitoring period due to prevailing wet weather conditions.

2.3.3. Microbat Monitoring

Microbat monitoring is undertaken in Spring using ultrasonic acoustic recording devices. A total of eight (8) microbat monitoring sites were surveyed in spring 2022. Each detector was set to survey ultrasonic microbat calls passively for at least two, but up to four consecutive nights during the survey period. A total of 14 survey nights were completed during this survey.

Acoustic analysis was undertaken by microbat ecologist Greg Ford, with the analysis report provided in **Appendix C**.

2.3.4. Nest Box Monitoring

Nest boxes were monitored using a 12-metre-high pole and wireless hollow scope to investigate fauna presence or signs of use. The condition of the next box was also assessed. A total of 59 previously installed nest boxes were monitored within ECA B and Regeneration Areas 5 and 9.

The condition and usage of next boxes were divided into three categories:

- Fit for use
- In need of repair
- Unservicable.

Damage to nest boxes were also divided into three categories:

- Fallen off tree
- Missing roof
- Chewing present.

Nest box usage was determined by the presence of indicators such as nesting material, feathers, droppings, signs of chewing, scratching or a combination of these. An assessment of whether nest boxes had been currently or recently used was also made based on the nature and condition of the signs of use, including nest structure, age of droppings and the colour of leaves and plant material in the nest.

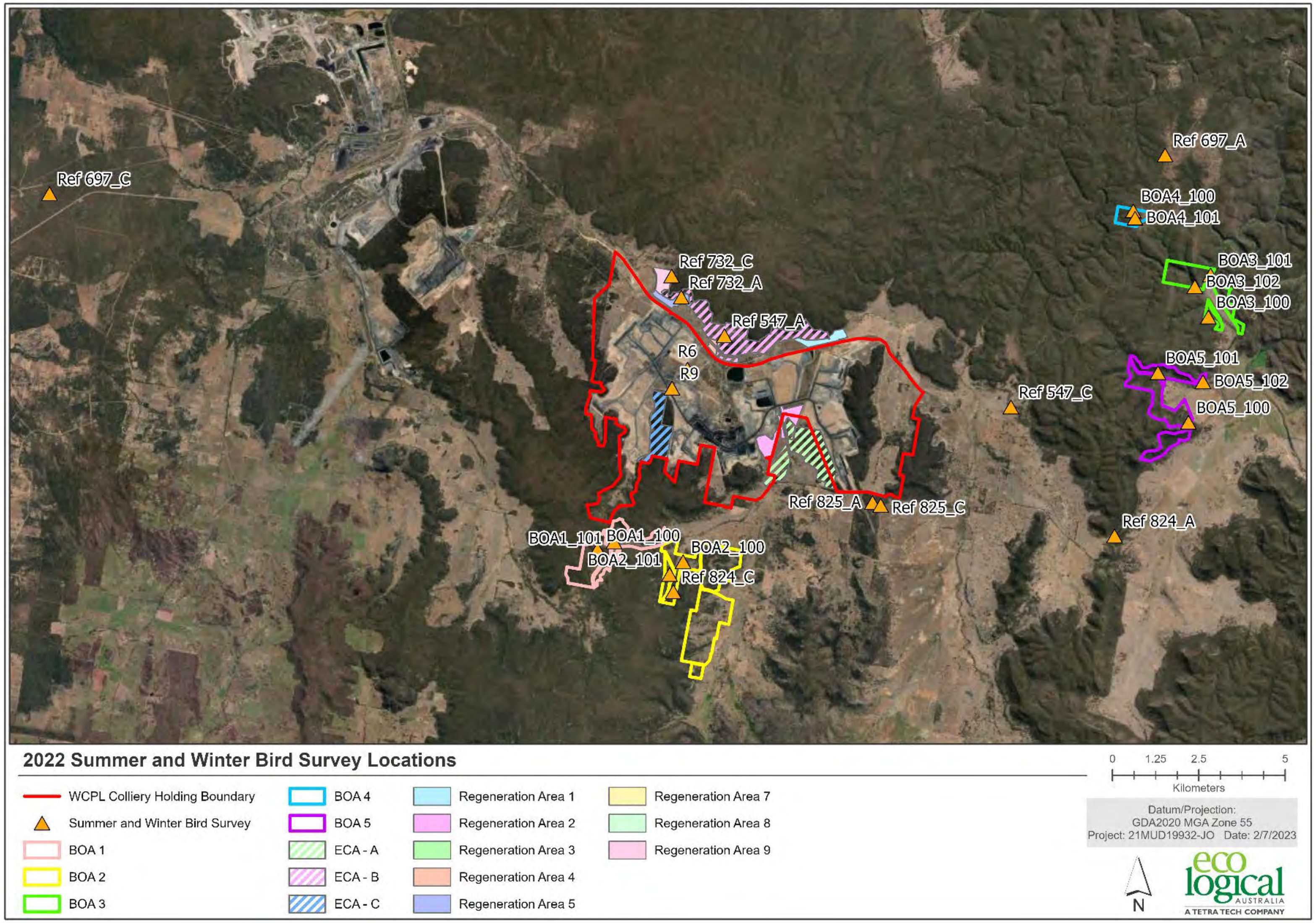


Figure 2-4: 2022 Summer, Autumn, and Winter Bird Locations

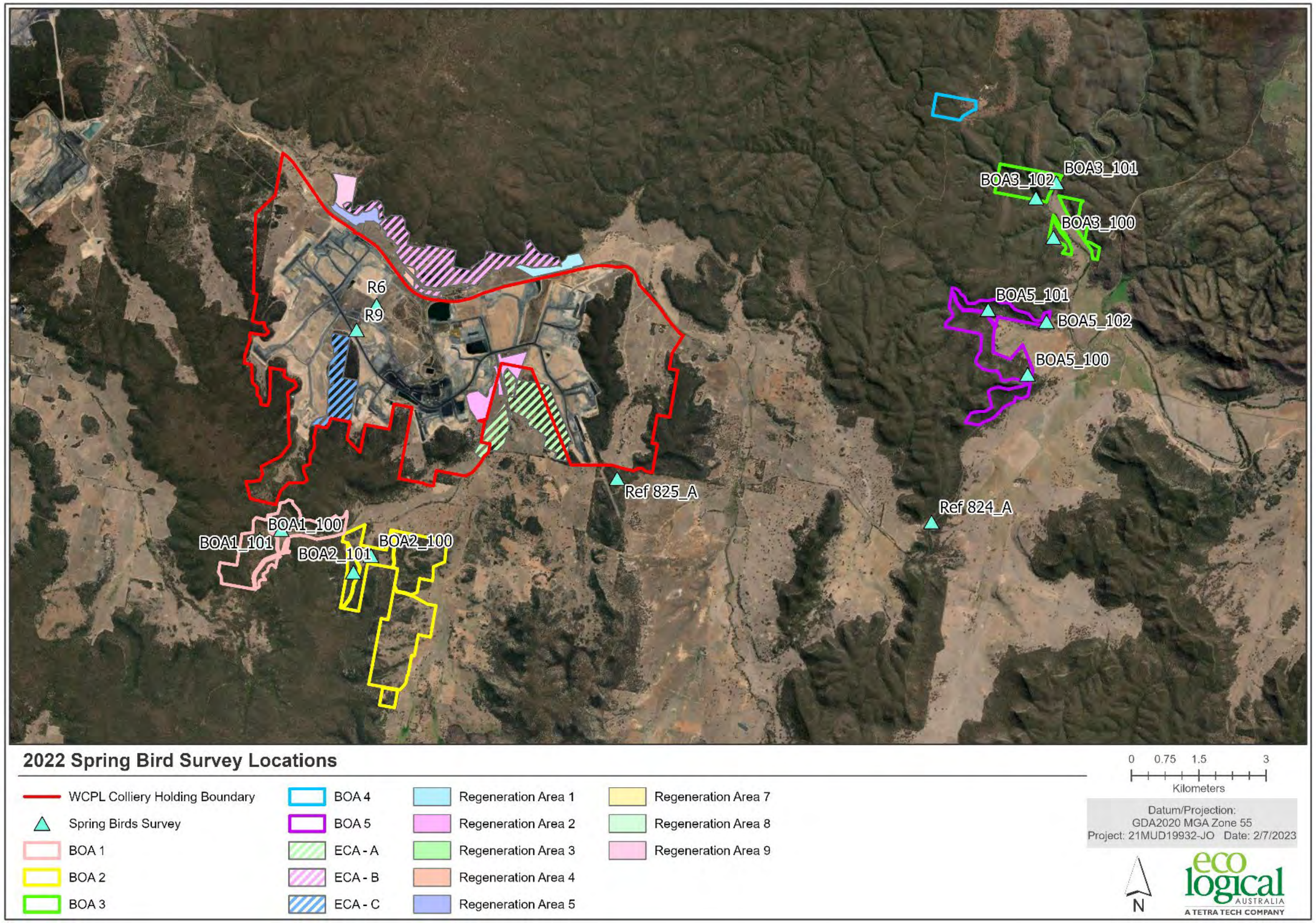


Figure 2-5: 2022 Spring Bird Survey Locations

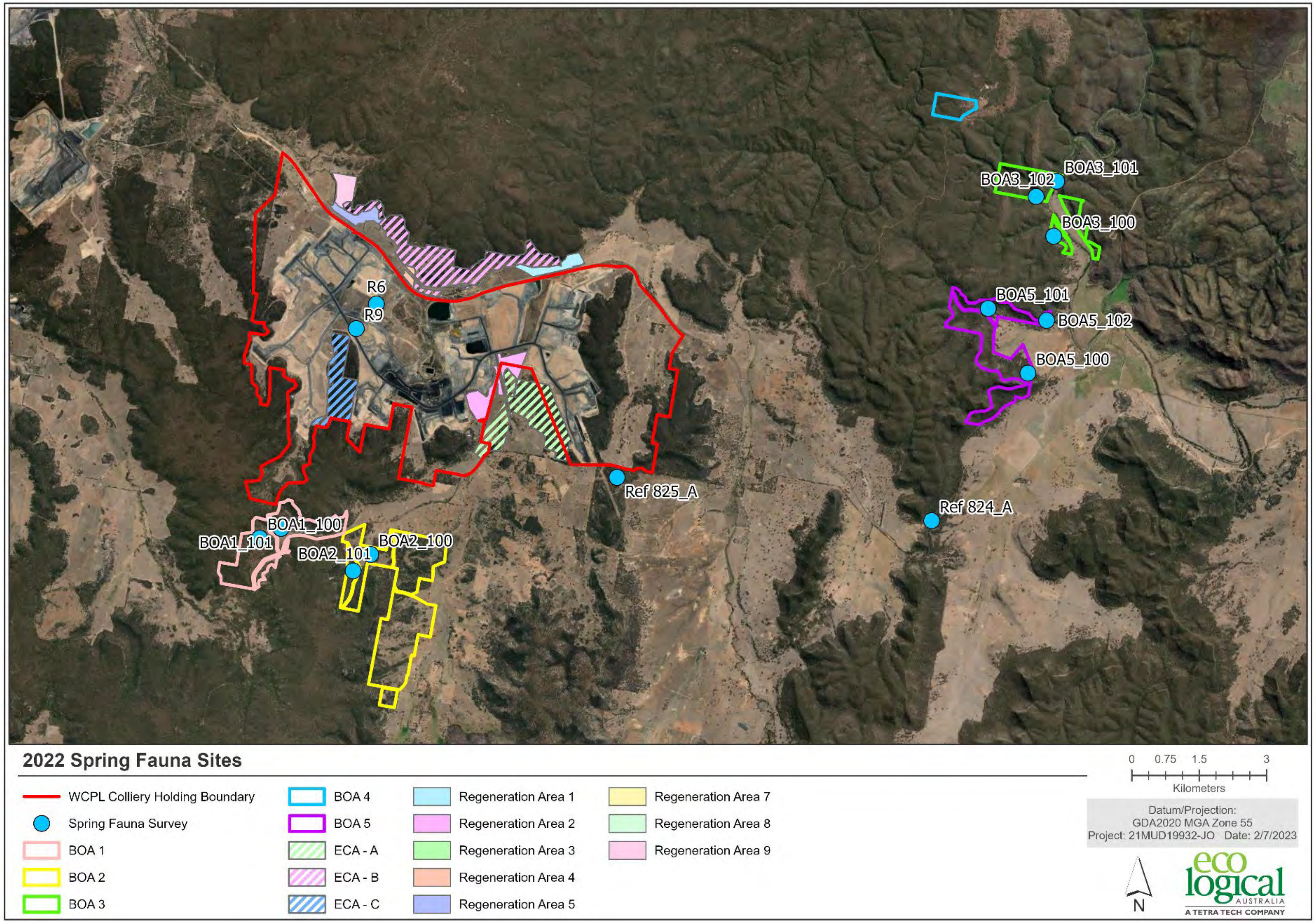


Figure 2-6: 2022 Spring Fauna Sites

3. Results and Discussion

The results of the 2022 biodiversity monitoring program are presented below.

3.1. Vegetation Monitoring

A total of 225 flora species were recorded across all vegetation and reference sites monitored during autumn (seven sites) and spring (five sites) 2022. Species recorded included 157 native species and 57 exotic species, with a further 11 species unable to be identified as either native or exotic as these species were only identified to genus. The full list of flora species recorded during the 2022 monitoring period is included in **Appendix E**.

3.1.1. Assessment against Rehabilitation BVT Benchmarks and WCPL Performance Criteria

Vegetation monitoring results for the Rehabilitation Areas were assessed against the WCPL Rehabilitation Performance Criteria and the Local Reference Site BVT Benchmarks (see **Appendix D**). A Site Value Score (SVS) was calculated for each site using the BioMetric Tool (NSW Department Environment Climate Change and Water, DECCW 2011) which combines the quality and quantity of native vegetation by measuring ten condition variables within a plot compared to the pre-European benchmarks for the BVT.

Table 3-1 and Table 3-2 present the individual site attribute and SVS for each 2022 rehabilitation monitoring site. Table 3-1 presents comparison of sites against the approved WCPL Performance Criteria and Table 3-2 presents comparison of sites against the Local Reference Site BVT Benchmarks. SVS which do not meet the BVT Benchmark Targets or Performance Criteria are highlighted in red – monitoring results from these sites trigger the Interim Rehabilitation Performance Criteria (Years 1 – 10) Trigger Action Response Plan (TARP) detailed in **Table 19** of the BMP (WCPL, 2021). Amber is not applied to the SVS as anything below the Benchmark Target or Performance Criteria is considered LOW. A colour coding system has been applied to all site attribute results.

- GREEN indicates site attributes that have met the relevant Benchmark Targets or Performance Criteria (indicating that no additional management intervention is required)
- AMBER indicates site attributes that have not met the relevant Benchmark Targets or Performance Criteria, but are within 50 - <100% of the targets
- RED indicates site attributes that are <50% of the relevant Benchmark Targets or Performance Criteria.

Table 3-1: Assessment against WCPL Rehabilitation Performance Criteria * for Rehabilitation Sites within their respective BVT

BVT	Season	Site	Vegetation Condition	SVS	Site attributes (% cover)									
					NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU824	Autumn	R6	Mod to Good – Good	57	22	14.2	5	6	2	4	62	0	0.25	0
	Spring	R6	Mod to Good – Medium	55	23	6	4	0	0	4	64	0	0	1
	Autumn	R9	High	71	27	18.5	1.5	8	0	16	54	0	0.33	25
	Spring	R9	High – Benchmark	83	24	22.5	3.5	0	0	26	40	0	1	25
Unclassified	Spring	R5[1]			44	20	6	12	2	14	34	0	0	0

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Midstorey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

*Rehabilitation Biometric Performance Criteria was approved by DPIE on June 2021, and is incorporated into the BMP (WCPL, 2021)

Table 3-2: Assessment against Local Reference Site BVT Benchmarks* for Rehabilitation Sites within their respective BVT

BVT	Season	Site	Vegetation condition	SVS	Site attributes (% cover)									
					NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU824	Autumn	R6	Mod to Good – Poor	40	22	14.2	5	6	2	4	62	0	0.25	0
	Spring	R6	Low	33	23	6	4	0	0	4	64	0	0	1
	Autumn	R9	Mod to Good – Medium	50	27	18.5	1.5	8	0	16	54	0	0.33	25
	Spring	R9	Mod to Good – Medium	53	24	22.5	3.5	0	0	26	40	0	1	25
Unclassified	Spring	R5[1]			44	20	6	12	2	14	34	0	0	0

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Midstorey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

*BVT Benchmarks are taken from Local Reference Sites and was approved by DPIE on June 2021, and is incorporated into the BMP (WCPL, 2021)

[1] Site R5 has no specified BVT and cannot be compared to any performance criteria

3.1.2. Reference Site BioMetric Assessment

BioMetric results for Reference Sites monitored during Autumn and Spring for 2022 are presented below (Table 3-3). Of the five References Sites designated for Spring monitoring, three of these (Sites 547_A, 697_A, and 732_A) were inaccessible due to high flood waters across Wipinjong Creek and were therefore not surveyed.

Table 3-3: 2022 Reference Site BioMetric Data

Season	Vegetation Community	Site	Site attributes (% cover)									
			NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH	OR	FL (m)
Autumn 2022	HU547	Ref_547_C	27	25.5	0	28	2	10	0	0	0	30
Autumn 2021	HU547	Ref_547_C	30	26	0	12	0	24	10	0	1	50
Autumn 2022	HU697	Ref_697_C	22	18	1.5	2	10	0	0	0	0	15
Autumn 2021	HU697	Ref_697_C	22	17	5	4	6	4	0	0	0.66	12
Autumn 2022	HU732	Ref_732_C	33	18	0	54	4	36	0	0	0	8
Autumn 2021	HU732	Ref_732_C	30	17.5	0	24	0	38	6	0	1	6
Autumn 2022	HU824	Ref_824_C	51	18	2	10	10	26	0	4	1	110
Autumn 2021	HU824	Ref_824_C	48	21.5	2.5	6	2	14	0	4	0	120
Autumn 2022	HU825	Ref_825_C	46	18	0.6	50	10	22	0	0	1	5
Autumn 2021	HU825	Ref_825_C	50	16.7	2	52	4	28	0	0	1	8
Spring	HU824	Ref_824_A	50	13.3	18.5	22	32	16	2	4	0.5	30
Spring	HU825	Ref_825_A	70	27.5	18.3	8	38	10	0	1	0.5	10

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Mid storey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

Monitoring of ECA and Regeneration sites are no longer required, therefore sites within these management domains were not surveyed in 2022. Under the revised BMP (WCPL, 2021), a new three-yearly rotational monitoring schedule was implemented for 2022, consisting of a representative subset of Reference Sites within each BVT that will undergo BioMetric monitoring across each monitoring period (shown above in Table 3-3 above). The up-to-date Biodiversity Monitoring Program is detailed in **Table 18** of the BMP (WCPL, 2021).

Assessment against Local Reference Site BVT Benchmarks

This is the second year comparing rehabilitation monitoring results against the approved Local Reference Site BVT benchmarks. Both R6 and R9 have progressed well against the Performance Criteria, with Site Value Scores improving across both sites in comparison to the 2021 monitoring period.

Rehabilitation Site R6 is still in relatively poor condition despite improvements to its Site Value Score, with several attributes not reaching 50% of the relevant Performance Criteria. Exotic cover was high (>60%) during both autumn and spring monitoring. St John's Wort (*Hypericum perforatum)* was recorded throughout R6 and should be a management priority.

Rehabilitation site R9 has maintained its progress towards the new criteria with five out of the nine attributes meeting the target values. Although exotic cover is less than the BVT criteria, it was still high in both autumn and spring monitoring (>40%) compared to the HU824 (White Box – Black Cypress Pine shrubby Woodland) reference sites, which had very low exotic species coverage (<2%) (Table 3-3). St John's Wort (*Hypericum perforatum)* was also recorded at R9 and should be managed accordingly.

3.1.3. Weeds

Weed species classified as priority weeds under the Central Tablelands Regional Strategic Weed Management Plan 2017-2022 (Central Tablelands Local Land Services 2017) were identified at several monitoring sites across the Management Domains. These priority weeds and their site locations are presented below in Table 3-4.

Table 3-4: Priority weeds recorded during 2022

Scientific Name	Common Name	State Priority Weed	Regional Weed	Priority	Sites recorded
Hypericum perforatum	St John's Wort		Y		R5, R6, R9, 2021_3, 2021_7, 2021_8
Opuntia sp.	Prickly Pear	Y	Y		Ref 824_A, Ref 825_A

3.2. Landscape Function Analysis

Landscape Organisation Index (LOI) is an output from the LFA. The LOI is a function of the proportion of a transect occupied by patches. Patches are areas of resource loss or gain, as a result of movement downslope, and are defined by soil surface elements including perennial vegetation cover, litter or large woody debris, or rocks, which help retain soil and resources are a site. A LOI value close to 100% (1.0) implies a transect can retain resources, which is an important characteristic of a self-sustaining ecosystem. Bare soil does not contribute to LOI.

A self-sustaining ecosystem is deemed to have been achieved when SSA scores of 50 or more are recorded (the LFA Completion Criteria, expected to be achieved by Year 10 of the management cycle). Incremental improvement toward that target is expected with each year of monitoring. Failure to achieve an increase of 5% in the annual LFA scores represents a trigger for implementation of the Landscape Stability LFA TARP described in **Table 21** of the BMP (WCPL, 2021). Comparative annual results have been colour-coded to provide a visual indicator, with green reaching or exceeding the incremental increase of 5% or more, and red showing an increase of less than 5% (or in some cases, a reduction from the previous year). Red colour-coded cells indicate the TARP needs to be implemented. Results maintained at or above the Completion Criteria (50%) have been coded green regardless of comparative incremental increases or decreases from previous monitoring periods.

The LOI and SSA scores calculated from Spring 2022 LFA monitoring are presented in Table 3-5 and Table 3-6 below. The results are presented as a comparison to 2021 LFA monitoring data to provide an assessment against the LFA completion criteria.

3.2.1. Rehabilitation Areas

Four LFA monitoring sites located within Rehabilitation Areas were monitored in 2022. The LOI and SSA scores for these sites are presented in Table 3-5.

Spring 2022 monitoring results show that the LOI has remained relatively constant between the current and 2021 monitoring periods, except for R13, with had a slightly lower LOI in 2022. The LOI is heavily influenced by climatic conditions and the associated generation of litter and plant cover. Therefore, the continuation of high LOI results across these four sites can be attributed to favourable seasonal conditions throughout 2022.

Table 3-5: LOI and SSA results for Rehabilitation Area transects

Site	Monitoring Season	Landscape Organisation Index (%)	Soil Surface Assessment		
			Stability	Infiltration	Nutrient cycling
R5	Spring 2022	0.85	49.2	31.7	29.4
	Spring 2021	0.86	51.4	29.6	26.1
		Annual incremental increase	-2.2	2.1	3.3
R6	Spring 2022	0.85	48.9	25.6	18.5
	Spring 2021	0.84	49.3	22.4	14.7
		Annual incremental increase	-0.4	3.2	3.8
R9	Spring 2022	1	50.3	26.1	23.1
	Spring 2021	0.98	50.3	29.5	23.9
		Annual incremental increase	0.0	-3.4	-0.8
R13	Spring 2022	0.87	44.5	30.9	27.9
	Spring 2021	0.95	48	30.7	25.5
		Annual incremental increase	-3.5	0.2	2.4

3.2.2. Reference Sites

LFA monitoring was undertaken at two Reference sites in 2022. The LOI and SSA scores for these sites are presented in Table 3-6. Three additional References Sites (Sites 547_A, 697_A, and 732_A) were scheduled for LFA monitoring in 2022, however these were inaccessible due to high flood waters across Wilpinjong Creek and were therefore not surveyed.

Both reference sites recorded high LOI scores (>0.98). Both sites are occupied with patches of perennial ground cover and litter and demonstrate a self-sustaining, stable landform. There is no previous data to provide a comparison due to the three-yearly rotational monitoring schedule implemented in 2022.

Table 3-6: LOI and SSA results for reference sites

Site	Monitoring Season	Landscape Organisation Index (%)	Soil Surface Assessment		
			Stability	Infiltration	Nutrient cycling
Ref 824_A	Spring 2022	0.98	47.6	31.8	28.1
Ref 825_A	Spring 2022	1	48.7	38.3	31.0

3.2.3. Discussion of LFA Monitoring Sites

All sites recorded relatively high LOI scores (≥ 0.85), indicating stable, functioning landform covered predominantly by perennial vegetation cover. High LOI scores are reflective of high perennial vegetation and litter ground cover across most sites, leading to a more stable landscape, less susceptible to erosion. Within each of the Management Domains, the dominant patch types were perennial groundcover and litter.

A year-on-year comparison of Stability, Nutrient Cycling and Infiltration scores are presented below in Figure 3-1 to Figure 3-3, with reference sites presented in Figure 3-4. No reference sites, and only one Rehabilitation site (R9) met the completion criteria target for Stability (50). The other three Rehabilitation sites (R5, R6, and R13) saw decreases in stability scores when compared to the previous monitoring period. Despite this, sites R5, R6, and R9 all had stability scores higher than those recorded at both reference sites. Additionally, as Figure 3-1 outlines below, stability scores have been subject to year-on-year fluctuation since the commencement of monitoring in 2015, ranging from 44-63.

No rehabilitation sites met the Completion Criteria for Nutrient Cycling or Infiltration. Since the commencement of monitoring, scores for both of these parameters have fluctuated generally within the 20 – 40 range but have remained well below of the completion criteria target of 50 (Figure 3-2 and Figure 3-3). These numbers are, however, largely consistent with the Nutrient Cycling and Infiltration scores measured at the reference sites, none of which met the completion criteria (Table 3-6**)**; Figure 3-4). Despite the overall declining trend of Infiltration and Nutrient Cycling indices for the rehabilitation sites, the target 5% annual increase was achieved at two sites for Infiltration (R5 and R6), and at three sites for Nutrient Cycling (R5, R6, and R13) (Table 3-5).

Infiltration is affected by litter decomposition, surface roughness and surface nature, whilst nutrient cycling is affected by perennial vegetation cover, litter cover, extent of litter decomposition, cryptogam cover and soil surface roughness. Whilst many LFA sites have moderate to dense cover of perennial vegetation (i.e. grasses) and/or high litter cover, there was limited litter decomposition observed and largely uniform soil micro topography. Additionally, across all sites there has been an increase in annual exotic vegetation cover, which is classified as litter in the LFA methodology (Tongway and Hindley 2004).

Nutrient Cycle and Infiltration scores are heavily influenced by litter and litter decomposition scores, which is in turn impacted by the high annual exotic cover. Whilst the Reference Sites were also below the benchmark for Nutrient Cycling and Infiltration scores, these scores were slightly higher than the Rehabilitation Sites.

Low scores recorded within the Rehabilitation sites may be due to the compacted soils on which the Rehabilitation Areas are located and relatively lower levels of perennial vegetation. Most sites have not yet met the Completion Criteria for Infiltration and Nutrient cycling across any monitoring year and exhibit an overall declining trend. Nutrient cycling scores at R6, R9 and R13 were similar to several reference sites monitored in 2021. Low nutrient cycling scores could be a result of seasonal changes, and as such, may not be the most appropriate measure to track site progression or inform management.

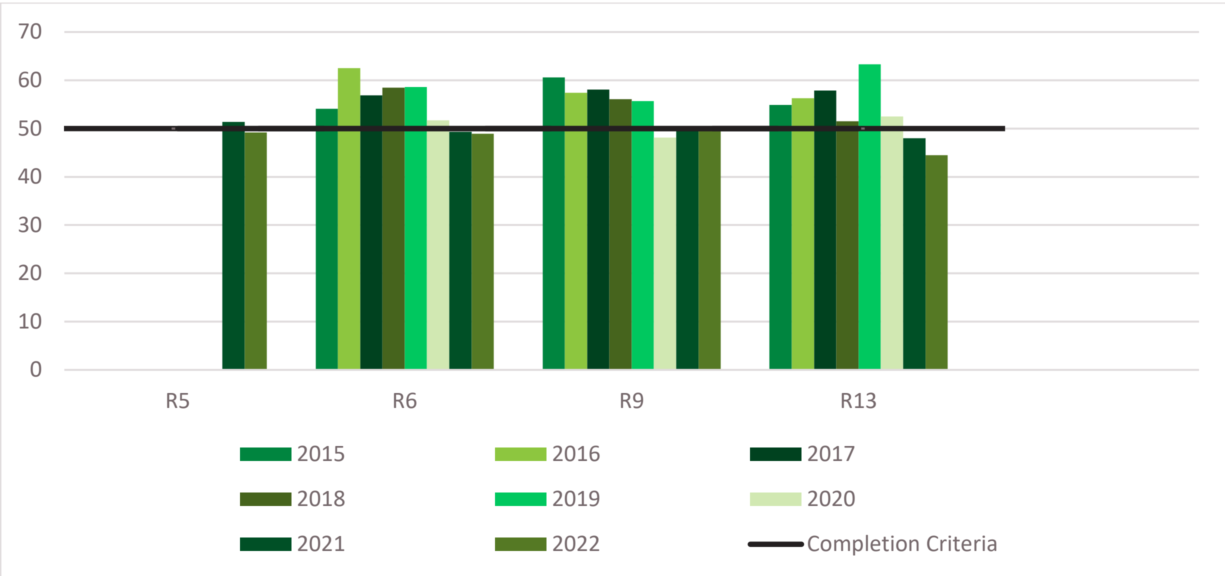


Figure 3-1: 2015-2022 Stability LFA scores for Rehabilitation Sites

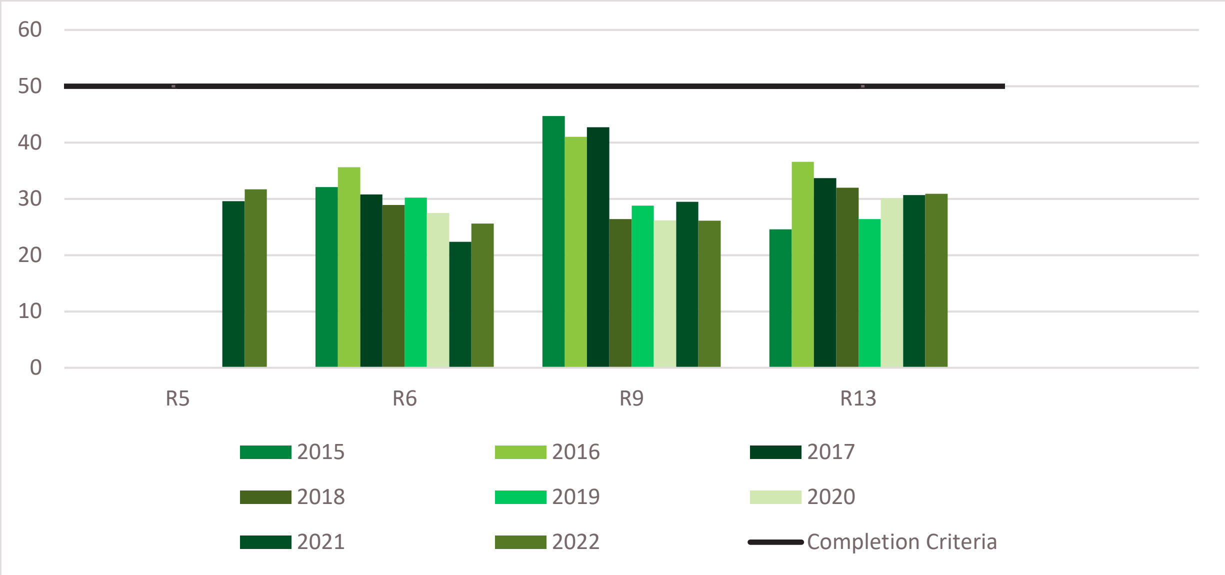


Figure 3-2: 2015-2022 Infiltration LFA scores for Rehabilitation Sites

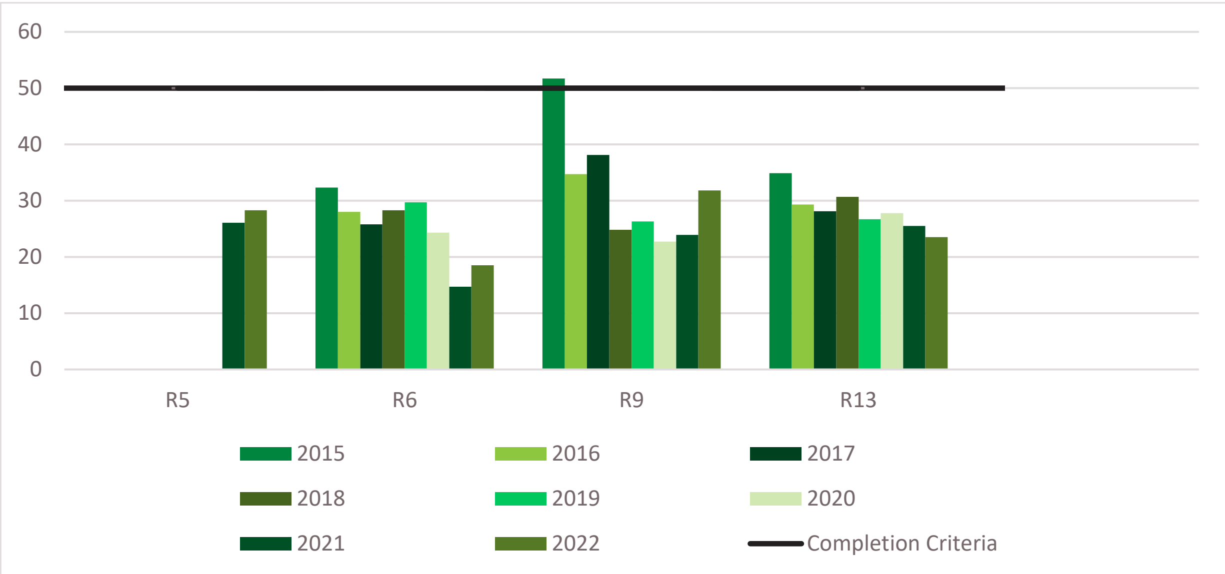


Figure 3-3: 2015-2022 Nutrients LFA scores for Rehabilitation Sites

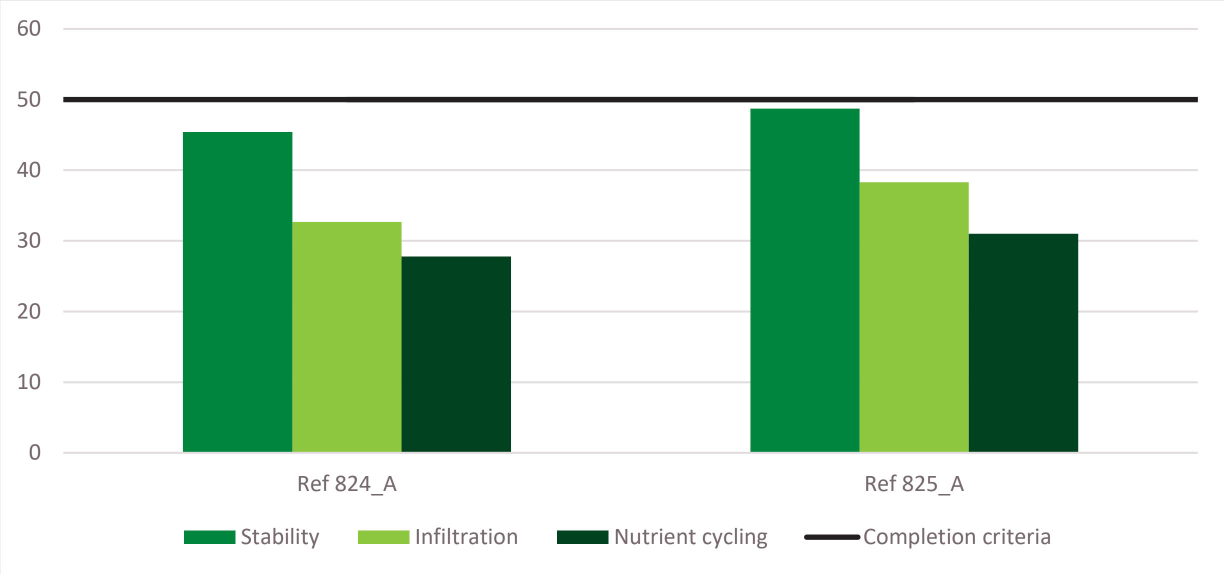


Figure 3-4: 2022 Reference Site LFA scores

3.2.4. Review of LFA results against Trigger Action Response Plan (TARP)

As per the updated BMP (WCPL, 2021), a Trigger Action Response Plan (TARP) is implemented if LFA scores are not incrementally improving towards the respective Completion Criteria. The TARP provides a plan to review and monitor these sites and increase remedial actions to address declining scores. As per the TARP, a review of these scores is required to be undertaken. It is recommended that this review include a consideration of the management aims for which the LFA monitoring seeks to address and the efficacy of the LFA method to inform the achievement of these aims.

3.3. Rehabilitation sites within 2020 seeded areas

Eight sites were established in February 2022 within Rehabilitation Areas which had been direct seeded during 2020, with seeding designed to establish these areas as the target BVTs listed in **Section 1** of this report. Vegetation monitoring consistent with the methods described in **Section 2** was undertaken at these sites during autumn in 2022 to determine ongoing progress of these areas since they were first monitored in February 2022, although establishment of BioMetric monitoring plots is not required until years 3 – 4 within the Rehabilitation Areas (as per **Table 11** within the BMP [WCPL, 2021]). LFA was not completed.

3.3.1. Vegetation Monitoring

A total of 124 flora species were recorded in Autumn 2022 monitoring across the eight Rehabilitation Area sites seeded in 2020. Species recorded included 60 native species and 54 exotic species, with a further 10 species unable to be identified as either native or exotic as these species were only identified to genus. Of these, two species are classified as overstorey species, four as midstorey species and the remainder are groundcover species. The full list of flora species is included in **Appendix E**.

Vegetation monitoring results for the 2020 Rehabilitation Areas were assessed against the Local Reference Sites BVT Benchmarks (Table 3-7) and the WCPL Rehabilitation Performance Criteria (Table 3-8) which are outlined in **Appendix D**. A SVS was calculated for each site using the BioMetric Tool (NSW

DECCW, 2011) which combines the quality and quantity of native vegetation by measuring ten condition variables within a plot compared to the pre-European benchmarks for the BVT. The colour coding system outlined in **Section 3.1.1** was utilised for this assessment.

Table 3-7: Rehabilitation Sites established in 2022 within 2020 seeded areas, assessment against Local Reference Site BVT Benchmarks

BVT	Site	Vegetation Condition	SVS	Site attributes (% cover)									
				NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU697	2021_1	Low	13	10	0	0	4	0	16	44	0	0	0
	2021_2	Low	17	16	0	0	0	0	10	42	0	0	0
HU732	2021_3	Mod to Good – Good	59	24	0	0	28	0	12	24	0	0	107
	2021_4	Mod to Good – Poor	42	19	0	0	0	0	0	24	0	0	71
	2021_5	Mod to Good – Poor	39	11	0	0	2	0	10	56	0	0	0
HU824	2021_6	Low	20	15	0	0	72	0	2	20	0	0	0
	2021_7	Low	15	17	0	0	8	0	10	56	0	0	0
	2021_8	Low	14	26	0	0	0	0	0	42	0	0	0

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Midstorey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

Table 3-8: Rehabilitation Sites established in 2022 within 2020 seeded areas, assessment against WCPL Rehabilitation Performance Criteria

BVT	Site	Vegetation Condition	SVS	Site attributes (% cover)									
				NSR	NOC	NMC	NGCG	NGCS	NGCO	EC	NTH (Count)	OR	FL (M)
HU697	2021_1	Low	17	10	0	0	4	0	16	44	0	0	0
	2021_2	Low	22	16	0	0	0	0	10	42	0	0	0
HU732	2021_3	Mod to Good – Good	59	24	0	0	28	0	12	24	0	0	107
	2021_4	Mod to Good – Poor	42	19	0	0	0	0	0	24	0	0	71
	2021_5	Mod to Good – Medium	46	11	0	0	2	0	10	56	0	0	0
HU824	2021_6	Low	33	15	0	0	72	0	2	20	0	0	0
	2021_7	Low	24	17	0	0	8	0	10	56	0	0	0
	2021_8	Low	22	26	0	0	0	0	0	42	0	0	0

SVS = Site Value Score, NSR = Native Plant Species Richness, NOC = Native Overstorey Cover, NMC = Native Midstorey Cover, NGCG = Native Ground Stratum Cover (grasses), NGCS = Native Ground Stratum Cover (shrubs), NGCO = Native Ground Stratum Cover (other), EC = Exotic Plant Cover, NTH = Number of Trees with Hollows, OR = Overstorey Regeneration and FL = Length of Fallen Logs

All rehabilitations sites within the HU732 (Yellow Box Grassy Woodland) target BVT met the Moderate to Good SVS under both the Local Reference Site BVT Benchmarks and the WCPL Performance Criteria. All three sites had NMC, NGCG and NGCS within the benchmark range, with one site also meeting the NSR and FL under the Local Reference Site BVT Benchmark. There was no tree cover recorded at any of these sites, which was expected as these areas were only seeded in 2020. The overstorey species *Acacia linearifolia* was recorded at each of the three sites, however, there were no eucalypt species recorded, despite *Eucalyptus punctata* being recorded at two sites during monitoring in summer 2022.

All rehabilitation sites within the target HU697 (Mugga Ironbark – Black Cypress Pine shrub/grass Open Forest) and HU824 (White Box – Black Cypress Pine Shrubby Woodland) BVTs scored Low for SVS under both the Local Reference Site BVT Benchmarks and the WCPL Performance Criteria. Most sites scored moderate to low when compared to the benchmark for NSR, and there was no NOC, NMC, NGCS, or FL recorded within these areas.

3.4. Fauna Monitoring

Fauna monitoring was undertaken during summer, winter, and spring in 2022 across 24 sites (19 in summer, 19 in winter and 14 in spring). A total species richness of 127 species were recorded in 2022 comprising of 111 birds, five mammals, two reptiles and nine positively identified microbat species.

There were nine (9) threatened species recorded during monitoring:

- Artamus cyanopterus cyanopterus (Dusky Woodswallow)
- Chalinolobus dwyeri (Large-eared Pied Bat)
- Chthonicola sagittata (Speckled Warbler)
- Climacteris picumnus victoriae (Brown Treecreeper (eastern subspecies))
- Daphoenositta chrysoptera (Varied Sittella)
- Miniopterus orianae oceanensis (Large Bent-winged Bat)
- Stagonopleura guttata (Diamond Firetail)
- Scoteanax rueppellii (Greater Broad-nosed Bat)
- Vespadelus troughtoni (Eastern Cave Bat).

A full list of all fauna species recorded during the 2022 monitoring program is included in **Appendix F.**

3.4.1. Bird Monitoring

Bird monitoring results and species richness across all management domains was comparable with previous monitoring years. A total of 111 species were recorded within summer, winter and spring monitoring for 2022, compared to 126 species recorded within 2021. Bird species richness across the BOAs has increased across most sites in 2022 compared to 2021 results as seen below in Figure 3-5, potentially attributable to good rainfall providing an abundance of feed and water sources.

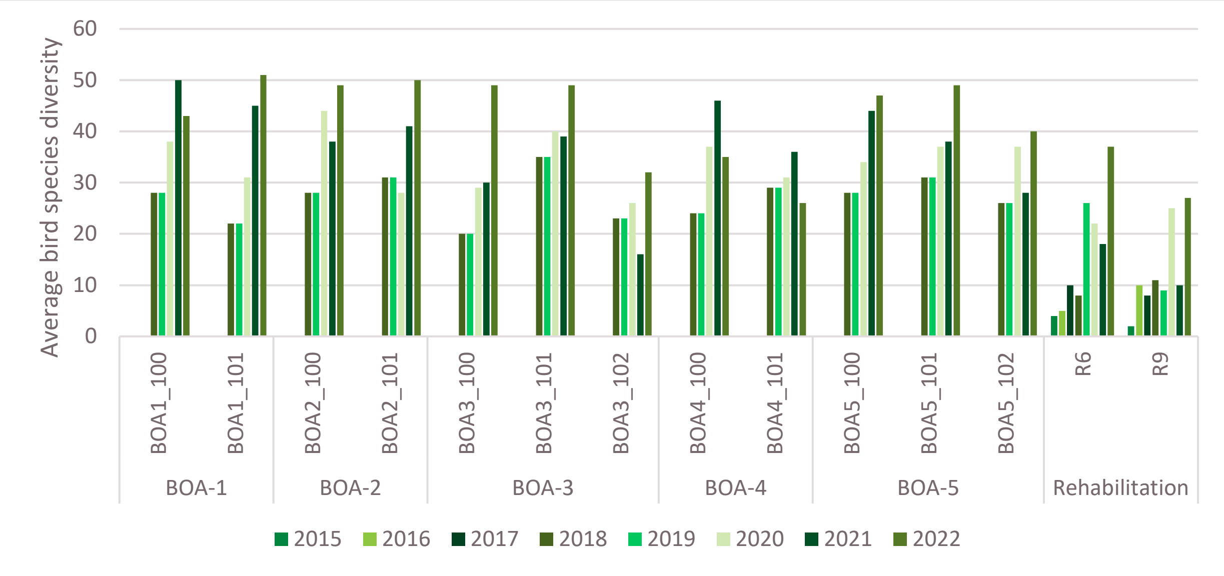


Figure 3-5: Average bird species richness

Rehabilitation Areas

There are two fauna sites within the Rehabilitation Areas, R6 and R9, both of which have developed a moderately dense shrub layer and developing canopy layer. Both sites recorded higher species richness counts in 2022 compared to 2021. This is a positive indication that increasing diversities of bird species will continue to be recorded across Rehabilitation Areas as suitable habitat continues to develop.

Chthonicola sagittata (Speckled Warbler) were recorded during surveys at both Rehabilitation sites. This species is listed as Vulnerable under the NSW BC Act.

The species richness results of bird monitoring within the Rehabilitation Areas are shown in Table 3-9.

Table 3-9: Rehabilitation Sites bird species richness

Season	Number of species recorded	
	R6	R9
Summer	15	15
Winter	16	16
Spring	26	16
Overall bird species richness	37	27

The survey methodology includes monitoring for flowering Eucalypt and Mistletoe species to provide an indication of habitat potential for the Regent Honeyeater. At site R6, *Eucalyptus punctata* (Grey gum) was flowering during summer monitoring and *Eucalyptus sideroxylon* (Red Ironbark) was flowering during winter monitoring, whilst at site R9, *Eucalyptus crebra* (Narrow-leaved Ironbark) was flowering during winter monitoring.

Outlined in

Table 3-10 are the nectivorous bird species (i.e. feed on nectar) that have been recorded on Rehabilitation Sites R6 and R9. These species are surrogate species to determine if the rehabilitation areas can support the critically endangered Regent Honeyeater as per section 6.3 of the BMP (2021).

Table 3-10: Nectivorous species recorded at Rehabilitation Sites R6 and R9

Rehabilitation site	Scientific name	Common Name
R6	*Caligavis chrysops*	Yellow-faced Honeyeater
	Lichenostomus penicillatus	White-plumed Honeyeater
	Acanthagenys rufogularis	Spiny-cheeked Honeyeatear
	Lichmera indistincta	Brown Honeyeater
	Lichenostomus leucotis	White-eared Honeyeater
	Gavicalis virescens	Singing Honeyeater
	Philemon corniculatus	Noisy Friarbird
R9	*Philemon corniculatus*	Noisy Friarbird
	Lichenostomus penicillatus	White-plumed Honeyeater
	Caligavis chrysops	Yellow-faced Honeyeater
	Philemon corniculatus	Noisy Friarbird

Reference Sites

Reference sites are located throughout the region in areas of remnant vegetation representing the five approved WCPL Rehabilitation BVTs, HU547, HU697, HU732, HU824 and HU825. Bird monitoring results within the reference sites is shown in Table 3-11.

Table 3-11: Reference Sites bird species richness

Season	Number of species recorded									
	Ref 547_A	Ref 547_C	Ref 697_A	Ref 697_C	Ref 732_A	Ref 732_C	Ref 824_A	Ref 824_C	Ref 825_A	Ref 825_C
Summer	*	22	*	18	*	22	*	29	*	32
Winter	15	*	24	*	12	*	13	*	21	*
Spring	*	*	*	*	*	*	23	*	20	*
Overall bird richness	15	22	24	18	12	22	30	29	28	32

Outlined in Table 3-12 are the nectivorous bird species that have been recorded throughout the WCPL reference sites. These species are surrogate species for the critically endangered Regent Honeyeater and show that the Reference Sites have the capacity to support this species as per section 6.3 of the BMP (2021).

Table 3-12: Nectivorous species recorded at the Reference Sites

Site	Scientific name	Common name
Recorded throughout the Reference Sites	*Climacteris picumnus victoriae*	Brown Treecreeper (eastern subspecies)
	Melithreptus brevirostris	Brown-headed Honeyeater
	Meliphaga lewinii	Lewin's Honeyeater
	Dicaeum hirundinaceum	Mistletoebird
	Philemon corniculatus	Noisy Friarbird
	Manorina melanocephala	Noisy Miner
	Anthochaera carunculata	Red Wattlebird
	Myzomela sanguinolenta	Scarlet Honeyeater
	Plectorhyncha lanceolata	Striped Honeyeater
	Lichenostomus leucotis	White-eared Honeyeater
	Melithreptus lunatus	White-naped Honeyeater
	Lichenostomus penicillatus	White-plumed Honeyeater
	Lichenostomus melanops	Yellow-tufted honeyeater
	Lichenostomus chrysops	Yellow-faced Honeyeater

Biodiversity Offset Areas

There are two fauna sites within BOA 1, both located within a woodland / forested area. The results of bird monitoring within BOA 1 are shown in Table 3-13.

Overall, both monitoring sites had a high species richness. *Climacteris picumnus victoriae* (Brown Treecreeper (eastern subspecies)), *Stagonopleura guttata* (Diamond Firetail) (winter), *Artamus cyanopterus cyanopterus* (Dusky Woodswallow) (summer), and *Glossopsitta pusilla* (Little Lorikeet) (winter and summer) were recorded in 2022, with all four species listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act). *Hirundapus caudacutus* (White-throated Needletail) was recorded during summer monitoring and is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Table 3-13: BOA 1 bird species richness

Season	BOA1_100	BOA1_101
Summer	27	31
Winter	18	32
Spring	25	29
Overall bird richness	43	51

There are two fauna sites within BOA 2, both located within woodland / forest habitat. The results of bird monitoring within BOA 2 are shown in Table 3-14.

Overall, both monitoring sites recorded similar and high species richness, with highest species richness observed in summer at both sites. *Climacteris picumnus victoriae* (Brown Treecreeper (eastern subspecies) (summer and spring), *Daphoenositta chrysoptera* (Varied Sittella) (spring), and *Chthonicola sagittata* (Speckled Warbler) (all 3 monitoring periods) were recorded in 2022. These species are all listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act).

Table 3-14: BOA 2 bird species richness

Season	BOA2_100	BOA2_101
Summer	37	32
Winter	22	26
Spring	27	21
Overall bird richness	49	50

There are three fauna sites within BOA 3, located within woodland / forest areas. The results of bird monitoring within BOA 3 are shown in Table 3-15**.**

Overall, site BOA3_100 and BOA3_101 had higher species richness in comparison to BOA3_102. *Climacteris picumnus victoriae* (Brown Treecreeper (eastern subspecies) (summer and winter), *Stagonopleura guttata* (Diamond Firetail) (summer), *Glossopsitta pusilla* (Little Lorikeet) (summer), and *Chthonicola sagittata* (Speckled Warbler) (summer) were recorded in 2022. These species are all listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act).

Table 3-15: BOA 3 bird species richness

Season	BOA3_100	BOA3_101	BOA3_102
Summer	33	37	22
Winter	17	21	18
Spring	25	17	13
Overall bird species richness	49	49	32

There are two fauna sites within BOA 4, located within woodland / forest areas. The results of bird monitoring within BOA 4 are shown in Table 3-16.

Overall, both monitoring sites recorded relatively high species richness. *Chthonicola sagittata* (Speckled Warbler) was recorded during summer surveys. This species is listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act).

Table 3-16: BOA 4 bird species richness

Season	BOA4_100	BOA4_101
Summer	26	15
Winter	19	20
Spring	*	*

Season	BOA4_100	BOA4_101
Overall bird species richness	35	26

*BOA4_100 and BOA4_101 were not surveyed in spring due to access issues

There are three fauna sites located within BOA 5, located within woodland / forest areas. The results of bird monitoring within BOA 5 are shown in Table 3-17**.**

Overall, all monitoring sites recorded high species richness. *Chthonicola sagittata* (Speckled Warbler) (winter and spring), *Climacteris picumnus victoriae* (Brown Treecreeper (eastern subspecies)) (all 3 monitoring periods), *Artamus cyanopterus cyanopterus* (Dusky Woodswallow) (spring), and *Glossopsitta pusilla* (Little Lorikeet) (winter) were recorded in 2022. These species are listed as Vulnerable under the NSW *Biodiversity Conservation Act 2016* (BC Act).

Table 3-17: BOA 5 bird species richness

Season	BOA5_100	BOA5_101	BOA5_102
Summer	31	25	19
Winter	25	18	23
Spring	19	28	21
Overall bird species richness	47	49	40

3.4.2. Microbat Monitoring

Microbat monitoring was undertaken in spring 2022 across all Management Domains. The microbat monitoring results are presented below, with the full ultrasonic analysis report in **Appendix C**.

A total of 201 call sequences were recorded during this survey. Of these, 143 (71.14%) were deemed useful, because these call profiles were of sufficient quality and/or length to enable positive identification of a bat species. The remaining 58 (28.86%) call sequences were either too short or were of low quality, thus preventing positive identification of bat species.

There were at least nine (9) and up to thirteen (13) species recorded during this survey. This includes up to four (4) species that are listed as Vulnerable under the NSW Biodiversity Conservation Act 2016 (BC Act) (**Table 3-18**). Based on the call profiles, two Vulnerable species under the BC Act were deemed to have been definitely present within the study area, including;

- *Chalinolobus dwyeri* (Large-eared Pied Bat)
- *Scoteanax rueppellii* (Greater Broad-nosed Bat)

Two (2) other threatened species which are also listed as Vulnerable under the BC Act could potentially be present within the study area. As outlined in Appendix C, potential calls are classified where the quality and structure of the call profiles are such that there is some / low probability of confusion with species that produce similar call profiles.

- *Miniopterus orianae oceanensis* (Large Bent-winged Bat)

- *Vespadelus troughtoni* (Eastern Cave Bat)

The activity levels and distribution of each threatened species recorded in the 2022 surveys varied. There were:

- Seventeen (17) potential calls attributed to the Large Bent-winged Bat were recorded at sites BOA 5 and REF824.
- Six (6) definite calls attributed to the BC and EPBC Act listed Large-eared Pied Bat. Large-eared Pied Bat calls were recorded at sites BOA5 and REF824.
- Twenty-five (25) potential calls (included in a species complex) for Eastern Cave Bat were recorded at sites, including BOA3, BOA5, and REF824.
- One (1) definite and two (2) potential calls attributed to Greater Broad-nosed Bat were recorded at site BOA5.

Compared to results across previous years, the number of sites that recorded calls, and the overall number of calls across all sites, dropped significantly (201 calls in 2022 compared to 1,316 calls in 2020 and 5,143 in 2021). Sites BOA2, R6 and R9 recorded zero microbat calls, whilst sites BOA3 and REF825 recorded 5 and 1 call respectively. During the deployment of anabats across the surveying period (25 Oct – 3 Nov), conditions were likely not favourable microbat surveying, with high winds and rainfall recorded over this period. BOA5 and REF824 recorded the majority of microbat calls, with 83 and 113 respectively.

Table 3-18: 2022 Spring monitoring microbat species and species combinations lists by site, as derived from ultrasonic call results for each WCPL offset survey site.

Species Name	Common Name	Survey site						
		BOA2	BOA3	BOA5	R6	R9	REF824A	REF825A
Austronomus australis	White-striped Free-tailed Bat	-	-	D	-	-	D	D
Chalinolobus dwyeri *[1]	Large-eared Pied Bat	-	-	D	-	-	D	-
Chalinolobus gouldii	Gould's Wattled Bat	-	-	D	-	-	D	-
Chalinolobus morio	Chocolate Wattled Bat	-	P	D	-	-	D	-
*Miniopterus orianae oceanensis**	Large Bent-winged Bat	-	P	P	-	-	P	-
Ozimops ridei	Ride's Free-tailed Bat	-	-	P	-	-	P	-
Ozimops planiceps	Southern Free-tailed Bat	-	-	D	-	-	D	-
Rhinolophus megaphyllus	Eastern Horseshoe Bat	-	-	D	-	-	D	-
*Scoteanax rueppellii**	Greater Broad-nosed Bat	-	-	D	-	-	-	-
Vespadelus pumilus	Eastern Forest Bat	-	P	P	-	-	-	-
Vespadelus regulus	Southern Forest Bat	-	-	D	-	-	D	-
*Vespadelus troughtoni**	Eastern Cave Bat	-	p	p	-	-	P	-
Vespadelus vulturnus	Little Forest Bat	-	D	D	-	-	D	-

D = Definitely recorded, P = Potentially recorded. *Listed as threatened under the BC Act and [1] listed as threatened under the EPBC Act

3.4.3. Ground Fauna Monitoring

Infra-red cameras and herpetological searches

Overall, ground fauna surveys within the Rehabilitation and Reference Sites recorded five mammal species and one reptile species (Appendix F and G). Rehabilitation site R9 had the greatest species richness and species count. One pest species was recorded on the rehabilitation sites, *Dama dama* (Fallow Deer) (**Table 3-19**). This species is listed as priority pest species in the region (LLS 2017) and should be managed accordingly. The reduction in number of survey sites (four down from seven) and survey nights (two down from four), was a likely factor in the overall reduction of pest species recorded on infra-red cameras in the 2022 monitoring period, in addition to reduced species abundance and species richness compared to 2021.

Table 3-19: Feral animal species recorded on infra-red cameras

Common Name	Scientific Name	R6	R9	Ref 824_A	Ref 825_A
Brown Hare	*Lepus europaeus*		1		
Fallow Deer*	*Dama dama*	3	4		

*Declared feral pest species (Local Land Services 2017)

Species richness and count across the rehabilitation sites and reference sites are shown below in **Figure 3-6** and **Figure 3-7**. A complete fauna species list is provided in **Appendix G.**

It should be noted that species count refers to the number of times the species was recorded on camera and is not an accurate estimation of population size.

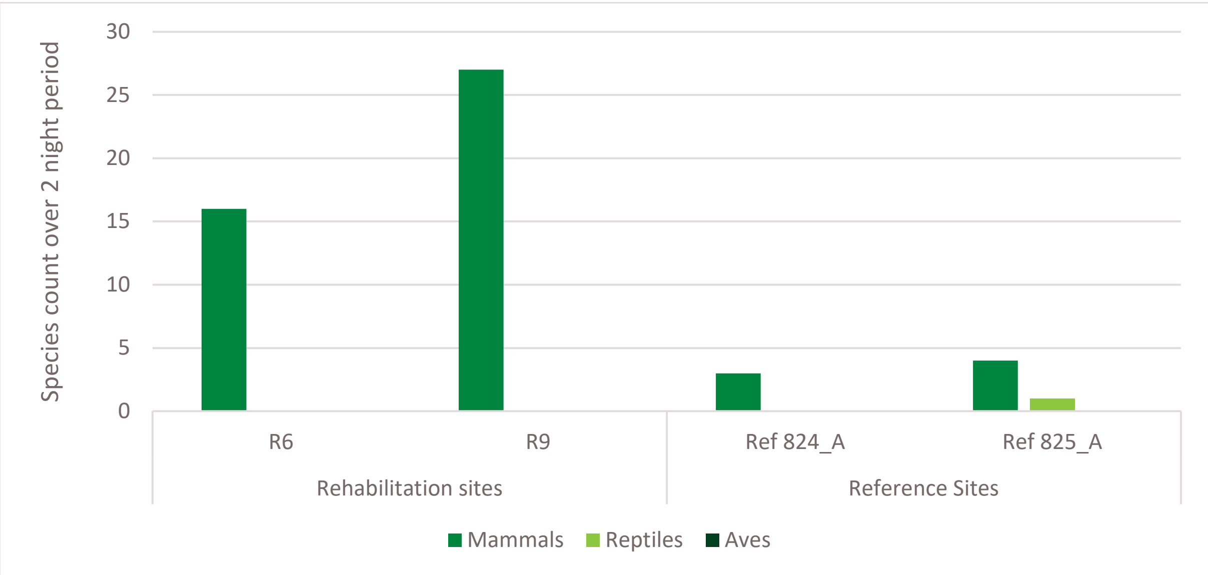


Figure 3-6: Fauna species richness for rehabilitation and reference sites

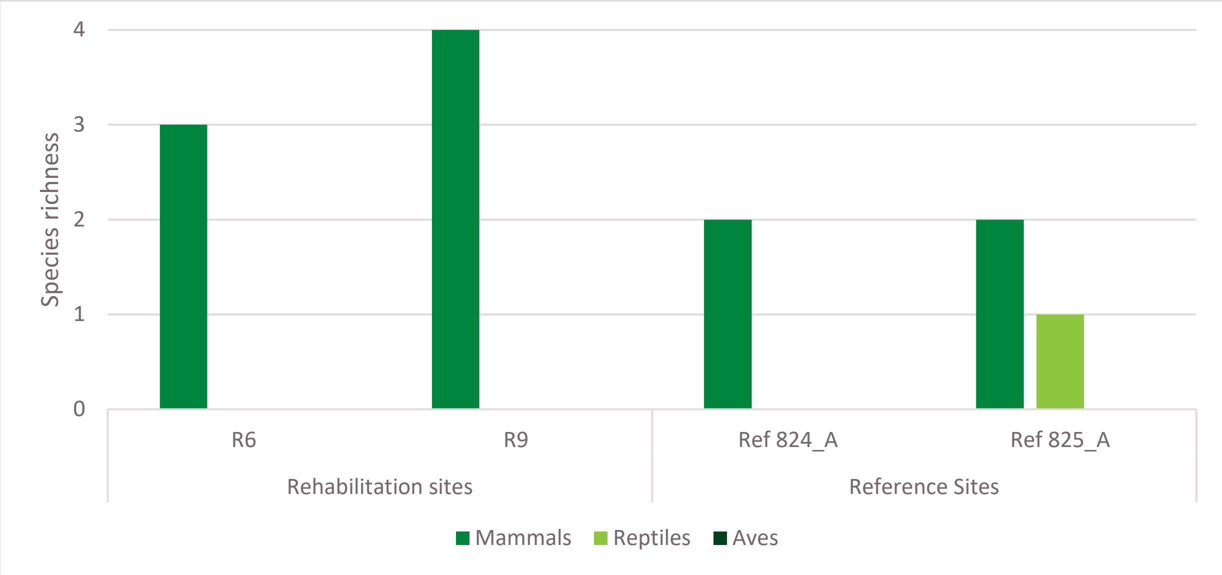


Figure 3-7: Fauna species count for rehabilitation sites and reference sites

3.4.4. Nest Box Monitoring

Sixty-nine nest boxes are situated throughout Regen 5, Regen 9, and ECA-B. Fifty-nine nest boxes were monitored in January 2023. Three boxes were unable to be located and a further ten couldn't be monitored due to the height and angle of the nest box entrance. Twenty-two boxes demonstrated signs of use; nine had fauna within them and sixteen contained nesting material and exhibited signs of use e.g chewings around entrance. All monitored nest boxes were deemed fit for use with future recommendations provided below.

Three fauna species were identified during January 2023 monitoring: *Trichosurus vulpecula* (Common Brushtail Possum), *Petaurus breviceps* (Sugar Glider) and *Apis mellifera* (European HoneyBee). The summarised results of the nest box monitoring are show in **Table 3-20**.

Table 3-20: January 2023 nest box monitoring results

Installation Area	Condition			Fauna present (%)	Signs of use		
	Fit (%)	Repair (%)	Unserviceable (%)		Nest / nesting material (%)	Chewing present (%)	Other (e.g. feathers, scats) (%)
ECA B	96	4	0	16	18	6	2
Regen 5	100	0	0	0	50	17	0
Regen 9	88	12	0	3	12	0	0

Recommendations

- Repairs are recommended for NB 5 which is falling away from the trunk and will need to be resecured
- NB 55 and 57 contain active beehives. It is recommended to leave in situ and replace with another box

- NB 4 (Treecreeper box) has its entrance towards the back of the nest box, facing the trunk. The nest box has been screwed too tightly to the trunk, making it difficult for fauna to access. It's recommended to loosen the nest box off the trunk to allow for adequate fauna entry.
- It's recommended to reinstate nest box numbers that are missing from N 53 and N 58.
    - N 53 coordinates (769807, 6421247)
    - N 58 coordinates (769848, 6421255)

4. Recommendations and Conclusion

4.1. BioMetric monitoring

BioMetric monitoring was undertaken within the BOA and Rehabilitation management domains, as well as selected Reference sites prescribed by the BMP during 2022. BOAs continued to be monitored, however they were not compared to the BMP Performance and Completion Criteria as these are specific to Rehabilitation Areas. ECA and Regeneration Area were not assessed in 2022.

When assessed against the WCPL Rehabilitation Performance Criteria, all rehabilitation sites are at or above the Moderate to Good SVS. When assessed against the local reference site benchmarks, site R9 was designated a Moderate to Good SVS. The remaining site (R6) recorded a low SVS score and low NOC and Or, as well a high exotic cover (64%). Weed management measures should be implemented accordingly.

4.2. Landscape Function Analysis monitoring

The LOI data captured during 2022 observed relatively high LOI scores (>0.85), with good cover of perennial vegetation cover. A higher LOI represents better site stability and less susceptibility to erosion. One Rehabilitation Area sites (R9) met the stability completion criteria, which indicates that stability is high and levels of erosion, with the majority of sites are low and consistent with previous monitoring seasons. Whilst the remaining three Rehabilitation Area sites did not meet the completion criteria for Stability, two sites (R5 and R6) were only slightly below the completion criteria score of 50. Moreover, the Stability scores fluctuate across monitoring years, and generally remain with range of the completion criteria. None of the Rehabilitation Area sites met the completion criteria for Infiltration and Nutrient cycling, however, this is consistent with previous year's results and the results from the two reference sites monitored in 2022. These results have triggered the relevant TARP and it is recommended that the TARP review include a consideration of the management aims for which LFA monitoring seeks to address and the efficacy of the LFA method to inform the achievement of these aims.

4.3. Rehabilitation sites within 2020 seeded areas

Continuing from Summer 2022 monitoring, all sites within the HU732 BVT met the Moderate to Good SVS, indicating that the sites are already in good condition with capacity for continued improvement. NMC and NGCS were within the benchmark range for all three sites, with two of the sites also meeting the NSR and FL benchmark. The rehabilitation sites within the HU697 and HU824 BVT did not improve from the previous year and recorded low SVS. Growth of Eucalypt seedlings remained low, with only two individuals recorded across all eight sites.

Overall, across the 2020 seeded rehabilitation areas, there was limited growth of overstorey and midstorey species recorded. Above average rainfall continued throughout 2022 from previous years, which likely provided good growing conditions for overstorey and midstorey seeds, however, it also provided ideal growing conditions for grasses groundcover species. This has likely resulted in the high cover of both native and exotic species, likely resulting in the suppression of young overstorey seedlings. It is not expected that overstorey species will be able to establish without intervention and replanting. It is recommended that scalping be undertaken to remove the weed seedbank that has established within the soil, followed by direct seeding and/or planting of tube stock.

4.4. Fauna monitoring

Fauna monitoring was undertaken across a range of sites during summer, winter and spring in 2022. The BOAs were monitored across all seasons in 2021. These areas are expected to be handed over to National Parks at an unknown date, and therefore monitoring will continue from herein until this occurs, from which monitoring will discontinue within these areas. Fauna monitoring was undertaken within the Rehabilitation and Reference areas during all seasons in 2022 and will continue to be monitored.

Bird monitoring results and species richness across all management domains was comparable with previous monitoring years. Both sites monitored within the rehabilitation areas recorded relatively high species richness counts, which is a positive indication that increasing diversity of bird species will continue to be recorded across Rehabilitation sites as suitable habitat continues to develop. A range of surrogate nectivorous bird species were recorded at both rehabilitation sites, indicating that the sites may function as suitable habitat for the Regent Honeyeater. In addition, one flowering eucalypt was recorded at one site in spring.

Only Infra-red cameras were utilised within the rehabilitation areas and reference sies in 2022. Overall species richness and abundance were higher within the rehabilitation sites compared to the reference sites. However, compared to the previous monitoring year, species richness and abundance were a lot lower, likely due to the reduced number of sites (4) and survey effort (2 nights) employed in 2022. Pitfall traps and funnels were not used in 2022 due to inclement weather during the monitoring period.

All nest boxes monitored during 2022 were deemed fit for use, with minor repairs recommended for two bat boxes (NB 4 and 5). There were three fauna species identified during monitoring, within ECA B and Regen 9 areas, with nest boxes across all monitoring areas showing signs of use.

4.5. Recommendation Summary

Table 4-1: Summary of recommendations

Monitoring	Comment	Recommendation
BioMetric monitoring		
Rehabilitation sites	SVS was at or above the Moderate to Good Vegetation Condition at site R9. Site R6 did not meet the SVS target against the local reference site BVT benchmarks	Continue monitoring as per the BMP, including flowering Eucalypt species within Biometric plots. Implement weed management measures accordingly.
Reference sites	Two sites were monitored during autumn 2022 monitoring. Following the approval of the BMP (WCPL 2021), reference sites began three yearly rotational monitoring schedule, with BVT Sites A monitored during spring 2022. Three sites were inaccessible due to weather.	Continue monitoring as per the BMP, including flowering Eucalypt species within Biometric plots.
Landscape Function Analysis (LFA)		
Rehabilitation sites	The LOI for Sites R5, R6, and R9 remained stable since 2021 monitoring. R13 saw a decrease in LOI in 2021, but	A review of the current LFA program is recommended to determine:

Monitoring	Comment	Recommendation
	still had a relatively high LOI score (87%), which was similar to sites R5 and R6. Site R9 met the completion criteria target for Stability. No sites met the completion criteria for Infiltration and Nutrient cycling in 2022.	- The management actions sought to be measured by LFA monitoring - The efficacy of the current LFA method to inform the achievement of these management actions. The use of remote sensing (e.g. LiDAR and Digital Elevation Models (DEMs)) can be used to assess slope, gradient and erosion at high resolution across rehabilitated areas in addition with erosion and stability transects which can mirror the BioMetric transects utilised for floristic monitoring.
2020 Seeded Rehabilitation Areas		
BioMetric Monitoring	Similar to the previous monitoring year, all sites within the HU732 BVT were at Moderate to Good Vegetation condition. The remaining sites within HU697 and HU824 recorded low vegetation condition. There were only two Eucalypt individuals recorded across all eight monitoring sites.	Due to the high cover of both native and exotic grasses, further eucalypt species are unlikely to establish without management intervention, such as scalping and reseeding or planting tube stock.
Fauna		
Bird Monitoring	Rehabilitation sites R6 and R9 continued to record relatively high species richness counts, compared to previous years. This provides a positive indication that increasing diversities of bird species will continue to be recorded across Rehabilitation sites as suitable habitat continues to develop. Bird species richness across the BOAs has fluctuated across monitoring years, with an increase in species richness across most monitoring sites in 2022.	Increasing bird species diversity and species richness recorded at Rehabilitation Area sites indicates that management actions are improving biodiversity and habitat. Monitoring should continue at these sites. With the WCPL rehabilitation BVTs and their respective Reference sites now approved, bird monitoring can focus on both Rehabilitation and Reference sites with more targeted methodology (such as 5-minute call playback) aimed at recording Regent Honeyeater and/or surrogate nectivorous species.
Ground Fauna	Species are limited to reptiles and occasional small marsupials.	The use of infra-red cameras and ground searches were used in 2022. It is recommended that these methods continue to be utilised, as they provided similar levels of species diversity compared to fauna trapping methods, despite such trapping methods not being implemented in 2022 due to weather. Additionally, reduced sites due to inclement weather will likely be a one off, with a normal number of sites being surveyed again in 2023.
Nest Box	Three fauna species were identified during 2021 monitoring (Common Brushtail Possum, Sugar Glider and European Honey Bee), with signs of	Continue to monitor to provide data on whether nest boxes are inhabited by resident fauna.

Monitoring	Comment	Recommendation
	fauna use also observed within other nest boxes.	
Microbat Monitoring	Nine (9) microbat species were definitely recorded during the survey, including two vulnerable species.	Microbat monitoring has been conducted on the rehabilitation areas for a number of years and has shown presence of a variety of bat species using the area, presumably as foraging habitat due to the relative immaturity of trees and lack of old growth hollows. Microbat monitoring at the rehabilitation sites is not a requirement of the BMP, and therefore a review of the program is recommended prior to the commencement of 2023 monitoring. However, it is recommended that future microbat monitoring and deployment of anabats is undertaken when weather conditions are favourable to ensure that surveying of microbat populations is representative.

5. References

Bureau of Meteorology 2021. Climate Statistics for Gulgong Post Office, Bureau of Meteorology, Commonwealth Government of Australia. Available at http://www.bom.gov.au/climate/averages/tables/cw_062013.shtml.

ELA 2021. Wilpinjong Coal Mine 2021 Annual Biodiversity Monitoring Report. ELA, Mudgee NSW.

ELA 2020. Wilpinjong Coal Mine 2020 Annual Biodiversity Monitoring Report. ELA, Mudgee NSW.

ELA 2019. Wilpinjong Coal Mine 2018 Autumn and Winter Summary Report. Prepared for Wilpinjong Coal Pty Ltd.

ELA 2018. Wilpinjong Coal 2018 Annual Works Program. ELA, Mudgee NSW

ELA 2017. Wilpinjong Coal 2016 Annual Biodiversity Monitoring Report. ELA, Mudgee NSW.

ELA 2016. Wilpinjong Coal Biodiversity Monitoring Program, Spring 2015. ELA, Mudgee NSW.

Erskine 2013. Opportunities and constraints of functional assessment of mined land rehabilitation. Australian Centre for Geomechanics, Perth.

Local Land Services Central Tablelands, 2017. Central Tablelands Regional Strategic Weed Management Plan 2017 – 2022.

Office of Environment and Heritage 2014. Biobanking Assessment Methodology. NSW OEH, Sydney.

Office of Environment and Heritage 2017. NSW Vegetation Information System: Classification. NSW OEH, Sydney.

Peabody Energy 2015. Wilpinjong Extension Project Environmental Impact Statement. Appendix E Biodiversity Assessment Report and Biodiversity Offset Strategy.

Reardon, T.B., McKenzie, N.L., Cooper, S.J.B., Appleton, B., Carthew, S. and Adams, M. (2014). A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian Free-tailed Bats Mormopterus (Chiroptera: Molossidae). Australian Journal of Zoology 62: 109 – 136

Spence-Bailey, L. M., Nimmo, D. G., Kelly, L. T., Bennett, A. F., and Clarke, M. F., 2010. Maximising trapping efficiency in reptile surveys: the role of seasonality, weather conditions and moon phase on capture success. Wildlife Research, 37, 104-115.

Tongway, D.J. and Hindley, N.L. 2005. Landscape Function Analysis: Procedures for monitoring and assessing landscapes with special reference to mine sites and rangelands. CSIRO Sustainable ecosystems, Canberra, ACT.

Wilpinjong Coal Pty Ltd 2017. Wilpinjong Coal Biodiversity Management Plan, August 2017. Peabody Energy Australia Pty Ltd, Brisbane.

Wilpinjong Coal Pty Ltd 2020. Wilpinjong Coal Biodiversity Management Plan, August 2020. Peabody Energy Australia Pty Ltd, Brisbane.

Wilpinjong Coal Pty Ltd 2021. Wilpinjong Coal Biodiversity Management Plan, June 2021. Peabody Energy Australia Pty Ltd, Brisbane.

Appendix A Weather Conditions

Table A – 1: 2022 Monthly mean and historical average weather conditions

Month	2022 Averages (WCPL)			Historical Averages – Wollar (Barrigan St)		
	Min Temp (°C)	Max Temp (°C)	Total Rainfall (mm)	Min Temp (°C)	Max Temp (°C)	Rainfall Mean (mm)
January	18.6	29.4	101.4	16.2	30.9	67.2
February	16.4	27.8	16	15.7	29.4	62.6
March	16.0	25.8	119.8	12.9	26.7	55.1
April	11.2	22.5	95	8.0	22.9	39.3
May	7.3	18.7	43.6	4.1	18.6	37.2
June	3.0	14.8	13	2.3	15.0	43.8
July	4.2	14.7	136.4	1.2	14.5	43.0
August	4.3	17.0	103.2	1.6	16.3	41.1
September	7.11	18.4	93.8	4.4	19.7	41.9
October	11.2	21.3	174.4	7.8	23.1	52.2
November	10.1	23.3	64	11.3	26.3	56.5
December	11.8	26.2	26.6	15.0	29.9	60.7

SOURCE: WCPL (2022 DATA); BUREAU OF METEOROLOGY, 2022 (HISTORICAL AVERAGES) TEMPERATURE DATA FROM GULGONG POST OFFICE WEATHER STATION NUMBER 62013. RAINFALL FROM WOLLAR (BARRIGAN ST) WEATHER STATION NUMBER 62032.

Table A – 2: Monthly Rainfall from 2013 – 2022 (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2013	73.6	54.2	61.4	12.2	17.4	77.9	20.8	6.6	33.0	8.8	78.6	27.6	472.1
2014	15.6	60.0	112.6	62.8	13.8	29.8	28.6	28.8	14.6	15.4	24.4	126.7	533.1
2015	127.6	11.6	9.4	108.4	42.8	42.8	38.0	53.8	7.8	61.0	59.0	118.4	680.6
2016	152.1	7.2	23.5	14.8	66.8	104.2	101.1	40.9	198.7	86.6	51.9	90.6	938.4
2017	27.8	34.2	146	23	32.4	10.4	5.8	25.2	3	28.4	92.6	102.6	531.4
2018	24.4	77	24.6	42.2	12.4	21.6	1.2	43.8	39.6	56.8	47.4	91.2	482.2
2019	54.8	7.4	108.8	0	17.6	10.6	2.6	10.2	23	5.6	22	3	265.6
2020	27.2	127	92	117	16	23.4	70	36.4	77.2	150.6	17.4	161.6	915.8
2021	52.6	126.6	159.8	1.8	9.4	84.4	66.8	25.4	44.2	40.8	249.2	81.4	942.4
2022	101.4	16	119.8	95	43.6	13	136.4	103.2	93.8	174.4	64	26.6	987.2
Historical Mean – Wollar (Barrigan St)	67.2	62.6	55.1	39.3	37.2	43.8	43.0	41.1	41.9	52.2	56.5	60.7	593.8

SOURCE: WCPL (2022 DATA) AND BUREAU OF METEOROLOGY, 2017 (HISTORICAL AVERAGES) WOLLAR (BARRIGAN ST) WEATHER STATION NUMBER: 62032.

Appendix B 2022 Biodiversity Monitoring Sites

Table B – 1: Autumn 2022 BioMetric Monitoring sites

Domain	Site	Management Domain	Condition	Keith Vegetation Class	Vegetation Community	Easting	Northing
Rehabilitation	R5	Rehabilitation	Rehabilitation	N/A	N/A	770234	6419256
	R6	Rehabilitation	Rehabilitation	WSDSF	N/A	769566	6419516
	R9	Rehabilitation	Rehabilitation	WSDSF	N/A	769120	6418969
Reference Sites	Ref 547_C	Reference site	Reference site	HU547		778934	778934
	Ref 697_C	Reference site	Reference site	HU697		751096	751096
	Ref 732_C	Reference site	Reference site	HU732		769183	769183
	Ref 824_C	Reference site	Reference site	HU824		769159	769159
	Ref 825_C	Reference site	Reference site	HU825		775163	775163

Table B – 2: Spring 2022 BioMetric monitoring sites

Domain	Site	Management Domain/Location	Condition	Keith Vegetation Class	Vegetation Community	Easting	Northing
Rehabilitation Area	R5	Rehabilitation Area	Rehabilitation – Grassland	N/A	N/A	770234	6419256
	R6	Rehabilitation Area	Rehabilitation – Grassland	WSDSF	N/A	769566	6419516
	R9	Rehabilitation Area	Rehabilitation – Grassland	WSDSF	N/A	769120	6418969
Reference Sites	Ref 824_A	Reference site	Reference site	HU824		781933	6414689
	Ref 825_A	Reference site	Reference site	HU825		774926	6415657

Table B – 3: LFA monitoring sites

Site	Management Domain	Easting	Northing	Zone	Type
R5	Rehabilitation Area	770234	6419256	55H	Biometric and LFA
R6	Rehabilitation Area	769562	6419517	55H	BioMetric and LFA
R9	Rehabilitation Area	769118	6418973	55H	BioMetric and LFA
R13	Rehabilitation Area	770872	6418901	55H	LFA
Ref 824_A	Reference site	781933	6414689	55H	BioMetric and LFA
Ref 825_A	Reference site	774926	6415657	55H	BioMetric and LFA

Table B – 4: Fauna monitoring sites

Area	Site ID	Coordinates		Management Zone	Vegetation Class	Survey		
		Easting	Northing			Fauna	Bats	Birds
BOA-1	BOA1_100	766963	6414300	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest		Y	Y
	BOA1_101	767441	6414516	Regeneration (moderate resilience)	Western Slopes Grassy Woodland			Y
BOA-2	BOA2_100	769440	6413937	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			Y
	BOA2_101	769050	6413570	Native vegetation (good resilience)	Western Slopes Grassy Woodland			Y
BOA-3	BOA3_100	784649	6421025	Native vegetation (good resilience)	Western Slopes Grassy Woodland		Y	Y
	BOA3_101	784714	6422246	Native vegetation (good resilience)	Western Slopes Grassy Woodland			Y
	BOA3_102	784258	6421909	Native vegetation (good resilience)	Dry Rainforest			Y
BOA-4	BOA4_100	782475	6424100	Native vegetation (good resilience)	Western Slopes Grassy Woodland			
	BOA4_101	782527	6423888	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			
BOA-5	BOA5_100	784073	6417976	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			Y
	BOA5_101	783192	6419415	Native vegetation (good resilience)	Western Slopes Grassy Woodland		Y	Y
	BOA5_102	784493	6419150	Native vegetation (good resilience)	Western Slopes Dry Sclerophyll Forest			Y
Rehabilitation	R6	769562	6419517	Rehabilitation - Woodland	Western Slopes Dry Sclerophyll Forest	Y	Y	Y
	R9	769118	6418973	Rehabilitation - Woodland	Western Slopes Dry Sclerophyll Forest	Y	Y	Y
Reference sites	Ref 824_A	6414688	781932	N/A	HU824	Y	Y	Y
	Ref 732_C	6422269	769182	N/A	HU732			Y
	Ref 824_C	6413073	769159	N/A	HU824			Y
	Ref 547_C	6418422	778934	N/A	HU547			Y
	Ref 697_C	6424600	751095	N/A	HU697			Y
	Ref 825_A	6415657	774926	N/A	HU825	Y	Y	Y
	Ref 825_C	6415573	775162	N/A	HU825			Y

Appendix C Microbat Ultrasonic Analysis Report

Microbat Call Identification Report

Prepared for ("Client"):	Eco Logical Australia
Survey location/project name:	2022 Wilpinjong Annual Monitoring
Survey dates:	25th October – 2nd November 2022
Client project reference:	21MUD-19932
Job no.:	ELA-2301
Report date:	21 February 2023

Methods

Data received

Balance! Environmental received a 2.3GB ZIP folder containing Anabat Swift full-spectrum ultrasonic acoustic files (WAV files) recorded at eight sites between 25th October and 3rd November 2022.

Call analysis and species identification

Call analysis was performed in *Anabat Insight* (Titley Scientific, Brisbane), with all WAV files first processed through a generic noise filter to exclude files with only non-bat noise. Files that passed the noise filter were then run through a Decision Tree Analysis to group and label similar calls based on zero-crossing analysis metrics (e.g. characteristic frequency (Fc), pulse duration (Dur) and time between pulses (TBC)). The Decision Tree also set aside any call files that contained fewer than three measurable pulses ("short calls").

Each Decision Tree group was reviewed manually to confirm or adjust species labels, with the "short call" group only reviewed if there were obvious species gaps or few identifiable calls for a site. Species identification was based on comparison of call spectrograms and derived metrics with those of regionally relevant reference calls and published call descriptions (Reinhold *et al.* 2001; Pennay *et al.* 2004).

The likelihood of species' presence on site was confirmed by referring to the *BatMap* application (Australasian Bat Society 2021) and other published distributional information (e.g. Churchill 2008; van Dyck et al. 2013).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Armstrong *et al.* (2020).

Results & Discussion

The noise filtration process found only 188 WAV files containing identifiable bat calls. Within those files, 201 individual bat calls were recognised, 143 of which were attributed positively to known species, while the remainder could not be reliably identified and were allocated to several "unresolved" species groups (see **Table 1**).

Given the low number of calls recorded throughout the survey, all calls from all nights at every successful site are presented in these results.

No bat calls were recorded at three sites – BOA2, R6 and R9 – and only one call was recorded at Ref_825_A.

At least nine and up to twelve species were detected across the study area (see **Table 1**).

Sample call spectrograms of each species and unresolved call-group are shown in **Appendix 1**.

Significant species

At least one and up to three "cave-dependent" threatened species were detected during the surveys:

- *Chalinolobus dwyeri*
  - recorded at two locations: BOA5 and Ref 824_A
  - only 6 calls in total
- *Miniopterus orianae oceanensis*
  - Sites BOA3, BOA5 and Ref 824_A
  - 17 calls that possibly belonged to *M. o. oceanensis* but could equally have come from *V. regulus* and/or *V. vulturnus*
  - Calls with "typical" *Vespadelus* characteristics (steep initial frequency sweep with sharply curved – "hooked" – characteristic section, or "body", and up-swept "tail") were allocated to *V. regulus* if characteristic frequency (Fc) was ~44-46 kHz, *V. regulus/V. vulturnus* if Fc~46-47 kHz and *V. vulturnus* when Fc~47-48.5 kHz
  - Calls in those frequency ranges that included pulses without "typical" features, especially if lacking the "hook" or with some evidence of a down-swept "tail", were allocated to the *Vespadelus* sp./*M. o. oceanensis* group.
- *Vespadelus troughtoni*
  - Sites BOA3, BOA5 and Ref 824_A
  - 17 calls that could be either *V. troughtoni* or *V. vulturnus* and another 8 calls that belonged to one of those species or *Chalinolobus morio*
  - "typical" *Vespadelus* calls with Fc ~47-48.5 kHz were allocated to *V. vulturnus*, whereas those with Fc~48.5-50.5 kHz were allocated to the undifferentiated species pair *V. troughtoni/V. vulturnus*
  - Calls in the latter frequency range but with mixed and/or atypical pulse shapes were allocated to the *Vespadelus* sp./*C. morio* group

Table 2 Bats recorded at the Wilpinjong monitoring sites, 25th October – 3rd November 2022. Number of calls allocated per species or unresolved group.

Site:	BOA3	BOA5				Ref 824_A		Ref 825_A		Species Total
Night:	26-Oct	28-Oct	29-Oct	30-Oct	31-Oct	25-Oct	26-Oct	25-Oct	26-Oct	
Positively identified calls										
Rhinolophus megaphyllus			1		2	7	8			18
Chalinolobus dwyeri				1	1	2	2			6
Chalinolobus gouldii		9	14	12	3	5	4			47
Chalinolobus morio		2	2	3			1			8
Scoteanax rueppellii		1								1
Vespadelus regulus			1			12	10			23
Vespadelus vulturnus	1	2		1	5	7	9			25
Austronomus australis					4		4		1	9
Ozimops planiceps				1	1	2	2			6
Unresolved calls										
C. gouldii / Ozimops ridei			2		1	1	2			6
C. gouldii / S. rueppellii				2						2
C. morio/Vespadelus pumilus	1	2		1						4
V. regulus / V. vulturnus				2		1	1			4
Vespadelus sp. / *Miniopterus orianae oceanensis*	2			4		5	6			17
V. vulturnus / V. troughtoni						9	8			17
V. vulturnus/V. troughtoni/C. morio	1	1		1	1	4				8
Nightly Total	5	17	20	28	18	55	57	0	1	201

References

Armstrong, K.N., Reardon, T.B., and Jackson, S.M. (2020). *A current taxonomic list of Australian Chiroptera.* Version 2020-06-09. http://ausbats.org.au/species-list/4593775065.

Australasian Bat Society (2021). *BatMap* - http://ausbats.org.au/batmap; Accessed 20/2/2022.

Churchill, S. (2008). Australian Bats. Jacana Books, Allen & Unwin; Sydney.

Pennay, M., Law, B., and Reinhold, L. (2004). Bat calls of New South Wales: Region based guide to echolocation calls of Microchiropteran bats. NSW Department of Environment and Conservation, Hurstville.

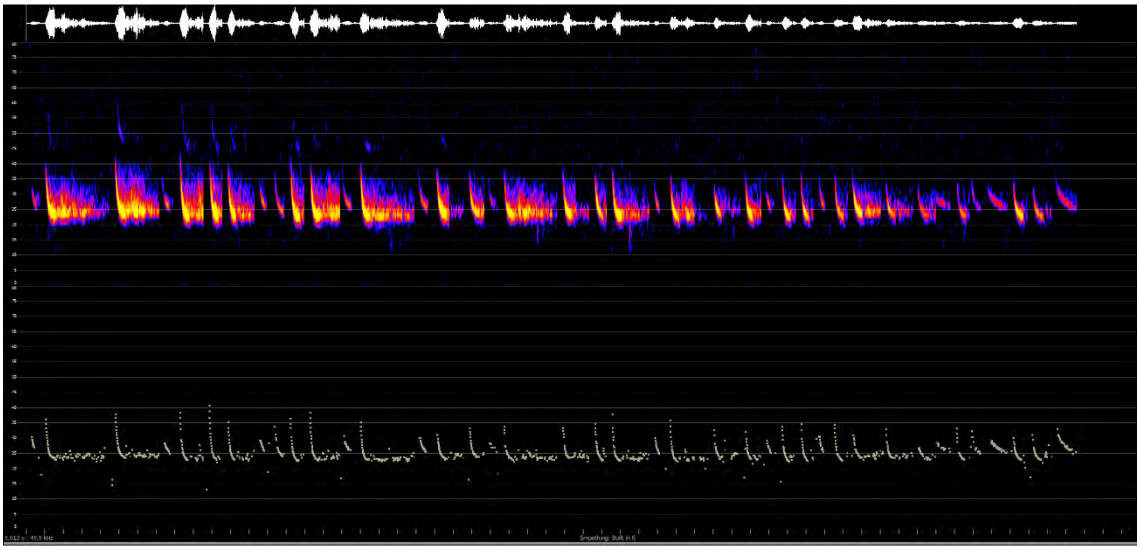
Reardon, T. (2003). Standards in bat detector based surveys. Australasian Bat Society Newsletter 20, 41-43.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). Key to the bat calls of south-east Queensland and north-east New South Wales. Department of Natural Resources and Mines, Brisbane.

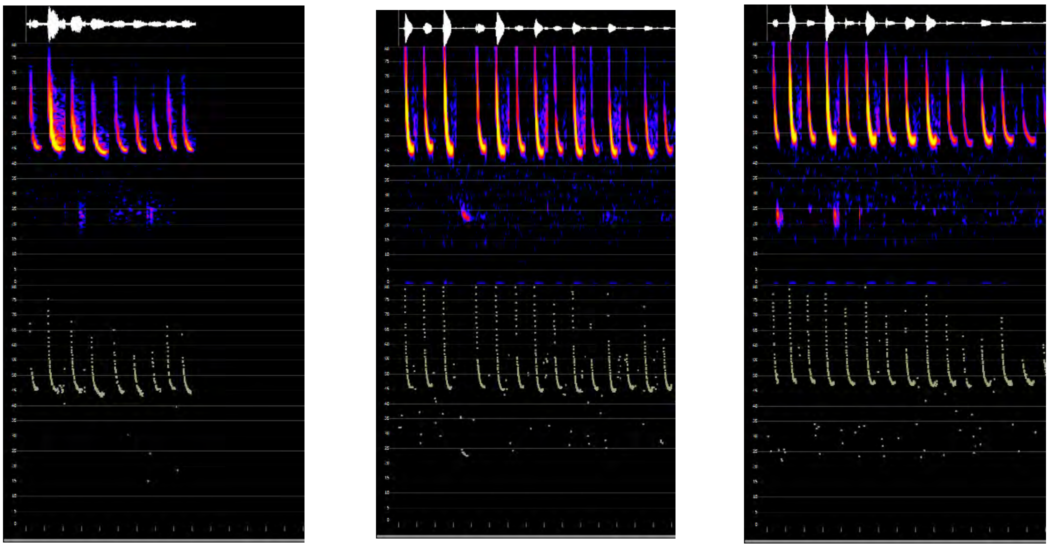
van Dyck, S., Gynther, I. and Baker, A. (ed.) (2013). Field Companion to the Mammals of Australia. New Holland; Sydney.

Appendix 1 Representative bat-calls from the Wilpinjong 2022 monitoring dataset.
X-axis (time)=10 msec per tick; time between pulses removed ("compressed")

Each image shows oscillogram (top), spectrogram (middle) and zero-crossing trace (bottom) for the chosen call sequence.



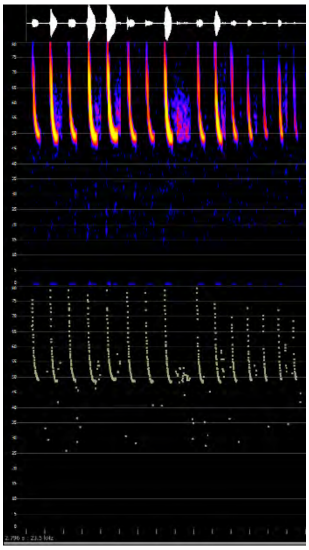
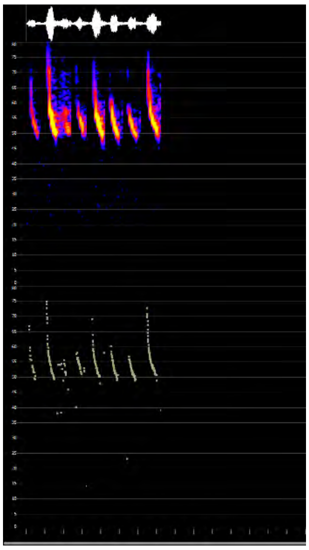
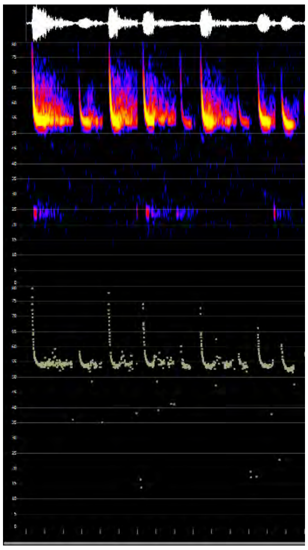
Chalinolobus dwyeri



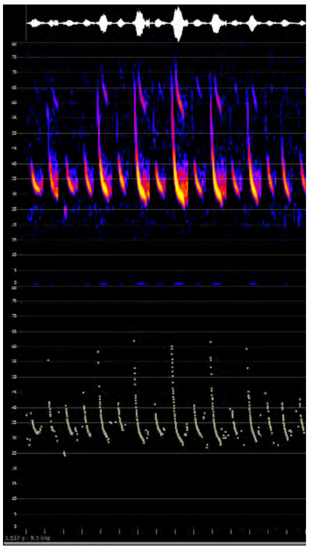
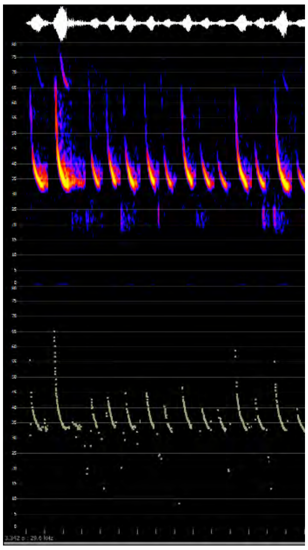
Possible *Miniopterus orianae oceanensis* (left); *Vespadelus regulus* (centre); *V. vulturnus* (right)

Appendix 1 Representative sonograms from the Wilpinjong 2022 monitoring dataset.
X-axis (time)=10 msec per tick; time between pulses removed ("compressed")

Each image shows oscillogram (top), spectrogram (middle) and zero-crossing trace (bottom) of the same call sequence.

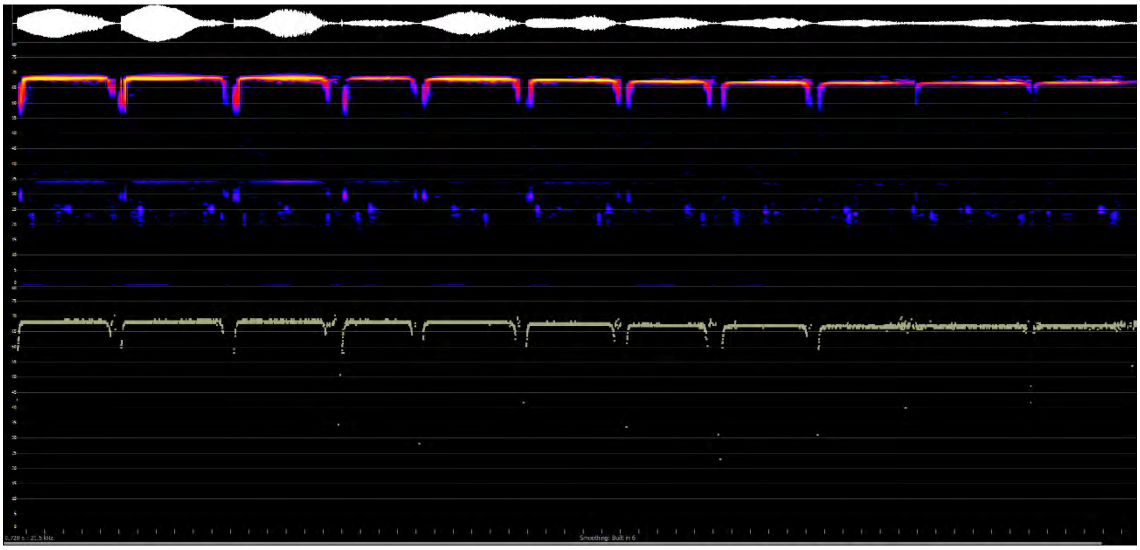
Possible *V. troughtoni* or *V. vulturnus* (left); *Chalinolobus morio* (centre); possible *V. pumilus* (right)

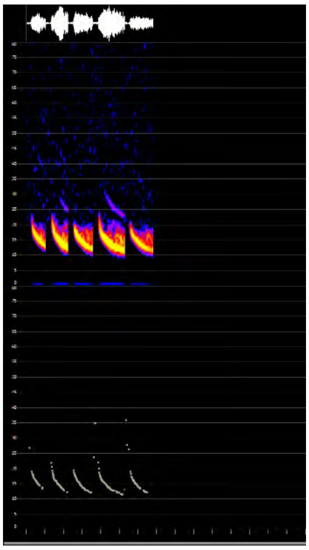
Chalinolobus gouldii (left); *Scoteanax rueppellii* (right)

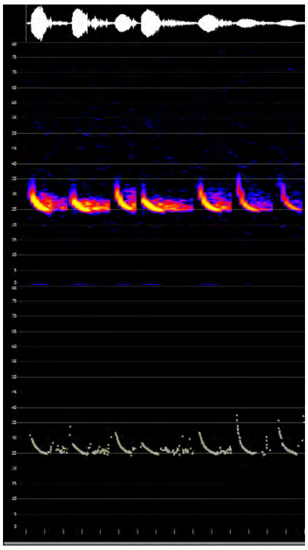
Appendix 1 Representative sonograms from the Wilpinjong 2022 monitoring dataset.
X-axis (time)=10 msec per tick; time between pulses removed ("compressed")

Each image shows oscillogram (top), spectrogram (middle) and zero-crossing trace (bottom) of the same call sequence.



Rhinolophus megaphyllus





Austronomus australis (left); *Ozimops planiceps* (right)

Appendix D BioMetric Performance and Completion Criteria (Rehabilitation monitoring)

Attribute (WCPL2021)	BVT	Native Plant Species Richness MIN-MAX (No.		Native Over Storey Cover MIN-MAX (%)[7]		Native Mid – Storey Cover MIN-MAX (%)		Native Ground Cover Grass MIN-MAX (%)		Native Ground Cover Shrubs MIN-MAX (%)		Native Ground Cover Other MIN-MAX (%)		Number of Trees with Hollows	Total Length Fallen Logs (m)	
Local Reference Site BVT Data (WCPL, 2021)	HU547	15-		15-26		0-6		4-58		0-2		2-34		0	38.22	
	HU732	17-		9-28		0-0.2		2-50		0-2		2-38		0	25	
	HU697	22-		17-23		1-13		4-12		0-14		0-20		0	38	
	HU824	27-		12.7-30.5		0.7-13.7		0-18		0-8		2-38		3	83.39	
	HU825	27-		16.5-27		0.4-7		0-52		0-12		0-34		1	58	
Completion Criteria		**1**		**1**		**1**		**1**		**1**		**1**		**0**	**0.5**	
Allowable Future Attribute Score Increases Relative to Benchmark (After OEH, 2014b, 2015)		**>50 %**		**>25<200%**		**>25<200%**		**>25<200%**		**>25<200%**		**>25<200%**		**N/A**	**>25%**	
WCPL Criteria	**BVT**	**Comp.**	**Perf.**	**Comp.**	**Perf.**	**Comp.**	**Perf.**	**Comp.**	**Perf.**	**Comp.**	**Perf.**	**Comp.**	**Perf.**		**Comp.**	**Perf.**
	HU547	7.5-22.5	3.75-11.25	3.75-52	1.88-52	1.25-100	1-100	1-100	0.5-100	0.5-20	0-10	0.5-68	0.25-68	NIL	9.56	4.78
	HU732	8.5-31	4.25-11.25	2.25-56	1.88-56	0.5-20	0-20	0.5-100	0.25-100	0.5-20	0-10	0.5-76	0.25-76		6.25	3.13
	HU697	11-25	5.50-12.5	4.25-46	2.13-46	2.5-100	1-100	1-24	0.5-24	1.25-20	1-10	0-40	0-40		9.5	4.75
	HU824	13.5-30.5	6.75-15.25	3.18-61	1.59-61	2.5-100	1-100	0-36	0-36	1.25-20	1-10	0.5-76	0.25-76		16.5	8
	HU825	13.5-26	6.75-13	4.13-54	2.06-54	2.75-100	1-100	0-104	0-104	1.25-60	1-30	0-68	0-68		14.5	7.25

Attribute (OEH, 2017)	Exotic Plant Cover (% of total cover)		[7] (% of over-storey species that are naturally regenerating)		Overall Site Value Score (OEH, 2015) (average of plots in vegetation zone)	
Completion Criteria	**1**		**0.5**		**16.93**	
Allowable Future Attribute Score Increases Relative to Benchmark (After OEH, 2014b, 2015)	**<45 %**		**25%**			
WCPL Criteria	**Com**	**Perf.**	**Comp.**	**Perf.**	**Comp.**	**Perf.**
All relevant BVTs	<45 %	<90%	To be determined based on number of OS species	No regeneration	17	7

[7] RELEVANT REGENT HONEYEATER HABITAT CRITERIA, IN CONCURRENCE WITH THE PRESENCE/ABSENCE MONITORING FOR MISTLETOE AND SURROGATE NECTIVORE BIRD SPECIES

COMP. = COMPLETION CRITERIA

PERF. = PERFORMANCE CRITERIA AT 10 YEARS AFTER LANDFORM ESTABLISHMENT

Appendix E Flora Species List

Family	Scientific name	Native/ Exotic
Amaranthaceae	*Alternanthera denticulata*	Native
Amaranthaceae	*Dysphania sp.*	Native
Amaranthaceae	*Dysphania pumilio*	Native
Amaranthaceae	*Enchylaena tomentosa*	Native
Anthericaceae	*Dichopogon fimbriatus*	Native
Anthericaceae	*Laxmannia gracilis*	Native
Apiaceae	*Anethum sp.*	Exotic
Apiaceae	*Daucus glochidiatus*	Native
Apiaceae	*Platysace sp.*	Native
Apocynaceae	*Gomphocarpus sp.*	Exotic
Araliaceae	*Hydrocotyle laxiflora*	Native
Asparagaceae	*Arthropodium sp.*	Native/exotic
Asteraceae	*Arctotheca calendula*	Exotic
Asteraceae	*Bidens pilosa*	Exotic
Asteraceae	*Bidens sp.*	Exotic
Asteraceae	*Bidens subalternans*	Exotic
Asteraceae	*Calotis cuneifolia*	Native
Asteraceae	*Calotis lappulacea*	Native
Asteraceae	*Carthamus lanatus*	Exotic
Asteraceae	*Cassinia quinquefaria*	Native
Asteraceae	*Cassinia sifton*	Native
Asteraceae	*Cassinia sp.*	Native
Asteraceae	*Cenchrus clandestinus*	Exotic
Asteraceae	*Chondrilla juncea*	Exotic
Asteraceae	*Chrysocephalum apiculatum*	Native
Asteraceae	*Chrysocephalum semipapposum*	Native
Asteraceae	*Cineraria lyratiformis*	Exotic
Asteraceae	*Cirsium vulgare*	Exotic
Asteraceae	*Conyza bonariensis*	Exotic
Asteraceae	*Conyza sp.*	Exotic
Asteraceae	*Cotula australis*	Native
Asteraceae	*Cymbonotus lawsonianus*	Native
Asteraceae	*Euchiton involucratus*	Native
Asteraceae	*Euchiton sp.*	Native

Family	Scientific name	Native/ Exotic
Asteraceae	*Euchiton sphaericus*	Native
Asteraceae	*Gamochaeta calviceps*	Exotic
Asteraceae	*Gamochaeta coarctata*	Exotic
Asteraceae	*Gamochaeta purpurea*	Exotic
Asteraceae	*Gamochaeta sp.*	Exotic
Asteraceae	*Hypochaeris radicata*	Exotic
Asteraceae	*Lactuca saligna*	Exotic
Asteraceae	*Lactuca serriola*	Exotic
Asteraceae	*Lactuca sp.*	Exotic
Asteraceae	*Podolepis sp.*	Native
Asteraceae	*Schkuhria pinnata*	Exotic
Asteraceae	*Senecio quadridentatus*	Native
Asteraceae	*Senecio sp.*	Native/exotic
Asteraceae	*Sigesbeckia orientalis*	Native
Asteraceae	*Solenogyne bellioides*	Native
Asteraceae	*Solenogyne dominii*	Native
Asteraceae	*Solenogyne sp.*	Native
Asteraceae	*Sonchus asper*	Exotic
Asteraceae	*Sonchus oleraceus*	Exotic
Asteraceae	*Stuartina muelleri*	Native
Asteraceae	*Taraxacum officinale*	Exotic
Asteraceae	*Vittadinia cuneata*	Native
Asteraceae	*Vittadinia sp.*	Native
Asteraceae	*Vittadinia muelleri*	Native
Asteraceae	*Xanthium spinosum*	Exotic
Boraginaceae	*Cynoglossum australe*	Native
Boraginaceae	*Cynoglossum sp.*	Native
Boraginaceae	*Echium plantagineum*	Exotic
Boraginaceae	*Heliotropium amplexicaule*	Exotic
Brassiaceae	*Brassicaceae sp.*	Native/exotic
Brassicaceae	*Capsella bursa-pastoris*	Exotic
Brassicaceae	*Lepidium africanum*	Exotic
Brassicaceae	*Lepidium bonariense*	Exotic
Brassicaceae	*Sisymbrium officinale*	Exotic
Cactaceae	*Opuntia sp.*	Exotic
Cactaceae	*Opuntia stricta*	Exotic

Family	Scientific name	Native/ Exotic
Campanulanceae	*Wahlenbergia communis*	Native
Campanulanceae	*Wahlenbergia gracilis*	Native
Campanulanceae	*Wahlenbergia sp.*	Native
Cannabaceae	*Celtis occidentalis*	Exotic
Carophyllaceae	*Paronychia brasiliana*	Exotic
Carophyllaceae	*Petrorharghia dubia*	Exotic
Caryophyllaceae	*Silene gallica*	Exotic
Caryophyllaceae	*Silene sp.*	Exotic
Casuarinaceae	*Allocasuarina gymnanthera*	Native
Casuarinaceae	*Allocasuarina verticillata*	Native
Chenopodiaceae	*Chenopodium album*	Exotic
Chenopodiaceae	*Chenopodium sp.*	Native/exotic
Chenopodiaceae	*Dysphania carinata*	Native
Chenopodiaceae	*Einadia hastata*	Native
Chenopodiaceae	*Einadia nutans*	Native
Chenopodiaceae	*Einadia polygonoides*	Native
Chenopodiaceae	*Einadia trigonos*	Native
Chenopodiaceae	*Salsola australis*	Native
Concolculaceae	*Convolvulus erubescens*	Native
Convolvulaceae	*Dichondra repens*	Native
Cupressaceae	*Callitris endlicheri*	Native
Cyperaceae	*Carex inversa*	Native
Cyperaceae	*Cyperaceae sp.*	Native/exotic
Cyperaceae	*Cyperus gracilis*	Native
Cyperaceae	*Cyperus sp.*	Native/exotic
Cyperaceae	*Gahnia aspera*	Native
Cyperaceae	*Lepidosperma laterale*	Native
Cyperaceae	*Schoenus apogon*	Native
Cyperaceae	*Schoenus sp.*	Native
Dilleniaceae	*Hibbertia riparia*	Native
Droseraceae	*Drosera hookeri*	Native
Ericaceae (Epacridoideae)	*Astroloma humifusum*	Native
Ericaceae (Epacridoideae)	*Leucopogon muticus*	Native
Ericaceae (Epacridoideae)	*Lissanthe strigosa*	Native
Ericaceae (Epacridoideae)	*Melichrus erubescens*	Native
Ericaceae (Epacridoideae)	*Styphelia triflora*	Native

Family	Scientific name	Native/ Exotic
Euphorbiaceae	*Euphorbia sp.*	Native/exotic
Euphorbiaceae	*Euphorbia drummondii*	Native
Fabaceae (Faboideae)	*Desmodium rhytidophyllum*	Native
Fabaceae (Faboideae)	*Desmodium varians*	Native
Fabaceae (Faboideae)	*Glycine clandestina*	Native
Fabaceae (Faboideae)	*Glycine tabacina*	Native
Fabaceae (Faboideae)	*Hardenbergia violacea*	Native
Fabaceae (Faboideae)	*Medicago polymorpha*	Exotic
Fabaceae (Faboideae)	*Medicago sp.*	Exotic
Fabaceae (Faboideae)	*Ornithopus compressus*	Exotic
Fabaceae (Faboideae)	*Pultenaea microphylla*	Native
Fabaceae (Faboideae)	*Swainsona galegifolia*	Native
Fabaceae (Faboideae)	*Trifolium arvense*	Exotic
Fabaceae (Faboideae)	*Trifolium repens*	Exotic
Fabaceae (Faboideae)	*Trifolium sp.*	Exotic
Fabaceae (Faboideae)	*Trifolium subterraneum*	Exotic
Fabaceae (Faboideae)	*Trifolium vesiculosum*	Exotic
Fabaceae (Mimosaceae)	*Acacia decora*	Native
Fabaceae (Mimosaceae)	*Acacia doratoxylon*	Native
Fabaceae (Mimosaceae)	*Acacia hakeoides*	Native
Fabaceae (Mimosaceae)	*Acacia implexa*	Native
Fabaceae (Mimosaceae)	*Acacia ixiophylla*	Native
Fabaceae (Mimosaceae)	*Acacia leucolobia*	Native
Fabaceae (Mimosaceae)	*Acacia linearifolia*	Native
Fabaceae (Mimosaceae)	*Acacia sp.*	Native
Fabaceae (Mimosaceae)	*Acacia spectabilis*	Native
Fabaceae (Mimosaceae)	*Acacia verniciflua*	Native
Geraniaceae	*Erodium botrys*	Exotic
Geraniaceae	*Erodium cicutarium*	Exotic
Geraniaceae	*Erodium crinitum*	Native
Geraniaceae	*Geranium molle*	Exotic
Geraniaceae	*Geranium solanderi*	Native
Goodeniaceae	*Goodenia hederacea*	Native
Goodeniaceae	*Goodenia ovata*	Native
Haloragaceae	*Gonocarpus tetragynus*	Native
Haloragaceae	*Haloragis heterophylla*	Native

Family	Scientific name	Native/ Exotic
Hypericaceae	*Hypericum gramineum*	Exotic
Hypericaceae	*Hypericum perforatum*	Exotic
Juncaceae	*Juncus sp.*	Native/exotic
Lamiaceae	*Marrubium vulgare*	Exotic
Lamiaceae	*Salvia verbenaca*	Exotic
Lobeliaceae	*Isotoma axillaris*	Native
Lomandraceae	*Lomandra filiformis*	Native
Lomandraceae	*Lomandra filiformis subsp. filiformis*	Native
Lomandraceae	*Lomandra glauca*	Native
Lomandraceae	*Lomandra multiflora*	Native
Lomandraceae	*Lomandra multiflora subsp. multiflora*	Native
Loranthaceae	*Amyema miquelli*	Native
Loranthaceae	*Amyema quandang var. quandang*	Native
Malvaceae	*Brachychiton populneus*	Native
Malvaceae	*Modiola caroliniana*	Exotic
Malvaceae	*Sida corrugata*	Native
Malvaceae	*Sida cunninghamii*	Native
Malvaceae	*Sida rhombifolia*	Exotic
Malvaceae	*Sida sp.*	Native/exotic
Myrtaceae	*Angophora floribunda*	Native
Myrtaceae	*Calytrix sp.*	Native
Myrtaceae	*Calytrix tetragona*	Native
Myrtaceae	*Eucalyptus albens*	Native
Myrtaceae	*Eucalyptus blakelyi*	Native
Myrtaceae	*Eucalyptus bridgesiana*	Native
Myrtaceae	*Eucalyptus conica*	Native
Myrtaceae	*Eucalyptus crebra*	Native
Myrtaceae	*Eucalyptus dealbata*	Native
Myrtaceae	*Eucalyptus fibrosa*	Native
Myrtaceae	*Eucalyptus melliodora*	Native
Myrtaceae	*Eucalyptus punctata*	Native
Myrtaceae	*Eucalyptus sideroxylon*	Native
Myrtaceae	*Eucalyptus sp.*	Native
Myrtaceae	*Sannantha cunninghamii*	Native
Oleaceae	*Notelaea sp.*	Native
Oxalidaceae	*Oxalis perennans*	Native

Family	Scientific name	Native/ Exotic
Oxalidaceae	*Oxalis sp.*	Native/exotic
Phormiaceae	*Dianella caerulea var. caerulea*	Native
Phormiaceae	*Dianella revoluta*	Native
Phormiaceae	*Dianella sp.*	Native
Phyllanthaceae	*Poranthera corymbosa*	Native
Phyllanthaceae	*Poranthera microphylla*	Native
Phytolaccaceae	*Phytolacca octandra*	Exotic
Pittosporaceae	*Bursaria spinosa*	Native
Plantaginaceae	*Linaria pelisseriana*	Native
Plantaginaceae	*Plantago debilis*	Native
Plantaginaceae	*Plantago lanceolata*	Exotic
Plantaginaceae	*Plantago varia*	Native
Plantaginaceae	*Veronica plebeia*	Native
Poaceae	*Austrostipa pubescens*	Native
Poaceae	*Echinochloa esculenta*	Exotic
Poaceae	*Anthosachne plurinervis*	Native
Poaceae	*Aristida ramosa*	Native
Poaceae	*Aristida vagans*	Native
Poaceae	*Arundinella nepalensis*	Native
Poaceae	*Austrostipa densiflora*	Native
Poaceae	*Austrostipa scabra*	Native
Poaceae	*Austrostipa scabra subsp. Scabra*	Native
Poaceae	*Austrostipa verticillata*	Native
Poaceae	*Bothriochloa macra*	Native
Poaceae	*Briza minor*	Exotic
Poaceae	*Bromus catharticus*	Exotic
Poaceae	*Bromus molliformis*	Exotic
Poaceae	*Bromus sp.*	Exotic
Poaceae	*Chloris truncata*	Native
Poaceae	*Chloris ventricosa*	Native
Poaceae	*Cymbopogon refractus*	Native
Poaceae	*Cynodon dactylon*	Native
Poaceae	*Cynodon sp.*	Native/exotic
Poaceae	*Dichanthium sericeum*	Native
Poaceae	*Digitaria ammophila*	Native
Poaceae	*Digitaria breviglumis*	Native

Family	Scientific name	Native/ Exotic
Poaceae	*Digitaria eriantha*	Exotic
Poaceae	*Digitaria parviflora*	Native
Poaceae	*Digitaria sp.*	Native/exotic
Poaceae	*Echinochloa crus-galli*	Exotic
Poaceae	*Echinopogon caespitosus*	Native
Poaceae	*Echinopogon ovatus*	Native
Poaceae	*Ehrharta erecta*	Exotic
Poaceae	*Eleusine sp.*	Exotic
Poaceae	*Eleusine tristachya*	Exotic
Poaceae	*Enneapogon gracilis*	Native
Poaceae	*Eragrostis brownii*	Native
Poaceae	*Eragrostis cilianensis*	Native
Poaceae	*Eragrostis curvula*	Exotic
Poaceae	*Eragrostis curvula var. Console*	Exotic
Poaceae	*Eragrostis leptostachya*	Native
Poaceae	*Eragrostis sp.*	Native/exotic
Poaceae	*Eriochloa procera*	Native
Poaceae	*Eriochloa sp.*	Native
Poaceae	*Erodium sp.*	Native/exotic
Poaceae	*Lachnagrostis filiformis*	Native
Poaceae	*Lolium perenne*	Exotic
Poaceae	*Lolium rigidum*	Exotic
Poaceae	*Microlaena stipoides*	Native
Poaceae	*Panicum effusum*	Native
Poaceae	*Paspalidium sp.*	Native
Poaceae	*Paspalum dilatatum*	Exotic
Poaceae	*Phalaris aquatica*	Exotic
Poaceae	*Poa labillardieri*	Native
Poaceae	*Poaceae sp.*	Native/exotic
Poaceae	*Rytidosperma caespitosum*	Native
Poaceae	*Rytidosperma pallidum*	Native
Poaceae	*Rytidosperma racemosum*	Native
Poaceae	*Rytidosperma sp.*	Native
Poaceae	*Setaria parviflora*	Exotic
Poaceae	*Setaria pumila*	Exotic
Poaceae	*Sporobolus creber*	Native

Family	Scientific name	Native/ Exotic
Poaceae	*Sporobolus elongatus*	Native
Poaceae	*Themeda australis*	Native
Poaceae	*Themeda triandra*	Native
Poaceae	*Urochloa panicoides*	Exotic
Polygonaceae	*Polygonum aviculare*	Exotic
Polygonaceae	*Rumex acetosella*	Exotic
Polygonaceae	*Rumex brownii*	Native
Portulacaceae	*Portulaca oleracea*	Native
Portulacaceae	*Portulaca oleracea*	Native
Primulaceae	*Lysimachia arvensis*	Exotic
Primulaceae	*Sonchus sp.*	Native/exotic
Proteaceae	*Hakea dactyloides*	Native
Proteaceae	*Persoonia linearis*	Native
Proteaceae	*Persoonia sp.*	Native
Pteridaceae	*Cheilanthes austrotenuifolia*	Native
Pteridaceae	*Cheilanthes sieberi*	Native
Ranunculaceae	*Clematis aristata*	Native
Rhamnaceae	*Rhamnaceae sp.*	Native/exotic
Rosaceae	*Rosa rubiginosa*	Exotic
Rubiaceae	*Asperula conferta*	Native
Rubiaceae	*Galium australe*	Native
Rubiaceae	*Galium propinquum*	Native
Rubiaceae	*Opercularia hispida*	Native
Rubiaceae	*Pomax umbellata*	Native
Sapindaceae	*Dodonaea viscosa*	Native
Scrophulariaceae	*Verbascum virgatum*	Exotic
Solanaceae	*Solanum brownii*	Native
Solanaceae	*Solanum campanulatum*	Native
Solanaceae	*Solanum cinereum*	Exotic
Solanaceae	*Solanum nigrum*	Exotic
Solanaceae	*Solanum prinophyllum*	Native
Solanaceae	*Solanum sp.*	Native/exotic
Stackhousiaceae	*Stackhousia viminea*	Native
Stylidiaceae	*Stylidium sp.*	Native
Thymelaeaceae	*Pimelea linifolia*	Native
Verbenaceae	*Verbena bonariensis*	Exotic

Appendix F Fauna Species list (Summer, Winter, and Spring 2022)

Scientific name	Common name	BC Act	EPBC Act
Aves			
Acanthagenys rufogularis	Spiny-cheeked Honeyeater		
Acanthiza chrysorrhoa	Yellow-rumped Thornbill		
Acanthiza lineata	Striated Thornbill		
Acanthiza nana	Yellow Thornbill		
Acanthiza pusilla	Brown Thornbill		
Acanthiza reguloides	Buff-rumped Thornbill		
Acanthorhynchus tenuirostris	Eastern Spinebill		
Accipter sp.	Collared Sparrowhawk		
Alectura lathami	Australian Brush-turkey		
Alisterus scapularis	Australian King-Parrot		
Anas gracilis	Grey Teal		
Anas superciliosa	Pacific Black Duck		
Anthochaera carunculata	Red Wattlebird		
Anthus novaeseelandiae	Australasian Grebe		
Aquila audax	Wedge-tailed Eagle		
Artamus cinereus	Black-faced Woodswallow		
Artamus cyanopterus	Dusky Woodswallow	V	
Artamus superciliosus	White-browed Woodswallow		
Cacatua galerita	Sulphur-crested Cockatoo		
Cacomantis flabelliformis	Fan-tailed Cuckoo		
Ceyx azureus	Azure Kingfisher		
Chenonetta jubata	Australian Wood Duck		
Chrysococcyx basalis	Horsefield's Bronze Cuckoo		
Cincloramphus mathewsi	Rufous Songlark		
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V	
Colluricincla harmonica	Grey Shrike-thrush		
Coracina novaehollandiae	Black-faced Cuckoo-shrike		
Coracina papuensis	White-bellied Cuckooshrike		
Corcorax melanorhamphos	White-winged Chough		
Cormobates leucophaea	White-throated Treecreeper		
Corvus coronoides	Australian Raven		
Coturnix ypsilophora	Brown Quail		
Cracticus nigrogularis	Pied Butcherbird		

Scientific name	Common name	BC Act	EPBC Act
Cracticus tibicen	Australian Magpie		
Cracticus torquatus	Grey Butcherbird		
Dacelo novaeguineae	Laughing Kookaburra		
Daphoenositta chrysoptera	Varied Sittella	V	
Dicaeum hirundinaceum	Mistletoebird		
Dromaius novaehollandiae	Emu		
Edolisoma tenuirostre	Common Cicadabird		
Egretta novaehollandiae	White-faced Heron		
Elanus axillaris	Black-shouldered kite		
Entomyzon cyanotis	Blue-faced Honeyeater		
Eolophus roseicapillus	Galah		
Eopsaltria australis	Eastern Yellow Robin		
Gallirallus philippensis	Buff-banded Rail		
Gavicalis virescens	Singing Honeyeater		
Geopelia placida	Peaceful Dove		
Gerygone olivacea	White-throated Gerygone		
Glossopsitta concinna	Musk Lorikeet		
Glossopsitta pusilla	Little Lorikeet	V	
Grallina cyanoleuca	Magpie-lark		
Haliaeetus leucogaster	White-bellied Sea-Eagle		
Hirundapus caudacutus	White-throated Needletail		V
Hirundo neoxena	Welcome Swallow		
Leucosarcia melanoleuca	Wonga Pigeon		
Lichenostomus chrysops	Yellow-faced Honeyeater		
Lichenostomus fuscus	Fuscous Honeyeater		
Lichenostomus leucotis	White-eared Honeyeater		
Lichenostomus melanops	Yellow-tufted Honeyeater		
Lichenostomus penicillatus	White-plumed Honeyeater		
Lichmera indistincta	Brown Honeyeater		
Malurus cyaneus	Superb Fairy-wren		
Manorina melanocephala	Noisy Miner		
Manorina melanophrys	Bell Miner		
Meliphaga lewinii	Lewin's Honeyeater		
Melithreptus brevirostris	Brown-headed Honeyeater		
Melithreptus lunatus	White-naped Honeyeater		
Menura novaehollandiae	Superb Lyrebird		

Scientific name	Common name	BC Act	EPBC Act
Merops ornatus	Rainbow Bee-eater		
Microeca fascinans	Jacky Winter		
Milvus migrans	Black Kite		
Myiagra inquieta	Restless Flycatcher		
Myiagra rubecula	Leaden Flycatcher		
Myzomela sanguinolenta	Scarlet Honeyeater		
Neochmia temporalis	Red-browed Finch		
Neophema pulchella	Turquoise Parrot	V	
Ocyphaps lophotes	Crested Pigeon		
Origma solitaria	Rockwarbler		
Oriolus sagittatus	Olive-backed Oriole		
Pachycephala pectoralis	Golden Whistler		
Pachycephala rufiventris	Rufous Whistler		
Pardalotus punctatus	Spotted Pardalote		
Pardalotus striata	Striated Pardalote		
Petrochelidon aerial	Fairy Martin		
Petrochelidon nigricans	Tree Martin		
Phaps chalcoptera	Common Bronzewing		
Philemon citreogularis	Little Friarbird		
Philemon corniculatus	Noisy Friarbird		
Platycercus elegans	Crimson Rosella		
Platycercus eximius	Eastern Rosella		
Plectorhyncha lanceolata	Striped Honeyeater		
Pomatostomus superciliosus	White-browed Babbler		
Psephotus haematonotus	Red-rumped Parrot		
Psophodes olivaceus	Eastern Whipbird		
Ptilonorhynchus violaceus	Satin Bowerbird		
Pyrrholaemus sagittatus	Speckled Warbler	V	
Rhipidura albiscapa	Grey Fantail		
Rhipidura leucophrys	Willie Wagtail		
Sericornis frontalis	White-browed Scrubwren		
Smicrornis brevirostris	Weebill		
Stagonopleura guttata	Diamond Firetail	V	
Strepera graculina	Pied Currawong		
Sturnus vulgaris	Common Starling		
Taeniopygia bichenovii	Double-barred Finch		

Scientific name	Common name	BC Act	EPBC Act
Taeniopygia guttata	Zebra Finch		
Todiramphus macleayii	Forest Kingfisher		
Todiramphus sanctus	Sacred Kingfisher		
Turnix varius	Painted Button-quail		
Vanellus miles	Masked Lapwing		
Zosterops lateralis	Silvereye		
Reptiles			
Pogona barbata	Eastern Bearded Dragon		
Chelodina longicollis	Eastern long-necked Turtle		
Mammals			
Dama dama	Fallow Deer		
Lepus europaeus	Brown Hare		
Macropus giganteus	Eastern Grey Kangaroo		
Notamacropus rufogriseus	Red-necked Wallaby		
Wallabia bicolor	Swamp Wallaby		
Austronomus australis	White-Striped Free-tailed Bat		
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Chalinolobus gouldii	Gould's Wattled Bat		
Chalinolobus morio	Chocolate Wattled Bat		
Miniopterus orianae oceanensis	Large Bent-winged Bat	V	
Ozimops planiceps			
Ozimops ridei			
Rhinolophus megaphyllus	Eastern Horseshoe Bat		
Scoteanax rueppellii	Greater Broad-nosed Bat	V	
Vespadelus pumilus	Lesser Broad-nosed Bat		
Vespadelus regulus	Southern Forest Bat		
Vespadelus troughtoni	Eastern Cave Bat	V	
Vespadelus vulturnus	Little Forest Bat		

Appendix G Ground Fauna List at Rehabilitation and Reference Sites

Site	Species	Scientific name	Total sightings over 2 nights	Priority pest species?
R6	Eastern Grey Kangaroo	*Macropus giganteus*	12	
	Fallow Deer	*Dama dama*	3	Y
	Red-necked Wallaby	*Notamacropus rufogriseus*	1	
R9	Eastern Grey Kangaroo	*Macropus giganteus*	10	
	Fallow Deer	*Dama dama*	5	Y
	Red-necked Wallaby	Notamacropus rufogriseus	11	
	Brown Hare	*Lepus europaeus*	1	
Ref 824_A	Red-necked Wallaby	Notamacropus rufogriseus	2	
	Unidentified rodent	N/A	1	
Ref 825_A	Eastern Grey Kangaroo	*Macropus giganteus*	2	
	Swamp Wallaby	*Wallabia bicolor*	2	
	Eastern Bearded Dragon	*Pogona barbata*	1	

2022 Stream Health Monitoring

Wilpinjong Coal Pty Ltd

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DOCUMENT TRACKING

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Abbreviations

Abbreviation	Description
ANZECC	Australian and New Zealand Environment and Conservation Council
AUSRIVAS	Australian River Assessment System
DO	Dissolved oxygen
EC	Electrical conductivity
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
EPL	Environment Protection Licence
LGA	Local Government Area
NP	National Park
RCE	Riparian, Channel and Environment
SHM	Stream Health Monitoring
SIGNAL2	Stream Invertebrate Grade Number Average Level
WCM	Wilpinjong Coal Mine
WCPL	Wilpinjong Coal Pty Ltd

Summary of Key Findings

Stream health monitoring was undertaken during spring 2022 within the catchments surrounding the Wilpinjong Coal Mine (WCM). A total of eight permanent sites were monitored along Wilpinjong, Wollar and Cumbo creeks, as well as two control sites located along Barigan Creek. Two sites along Wollar Creek were inaccessible at the time of surveying.

The monitoring results were largely consistent with previous years' results, with minor differences attributable to changes in macrophyte cover, likely due to the continued improved climatic conditions following three years of above average rainfall. Most sites recorded mid-range scores, typical of catchments in the region.

Water quality results were recorded for various parameters and differed markedly across most sites in comparison with previous years. Parameters were inside Australian and New Zealand Environmental and Conservation Council (ANZECC) guidelines at most sites for dissolved oxygen (DO) and were within or close at five sites for electrical conductivity (EC), likely as a result of increased stream flow from rainfall leading up to the monitoring period. Water quality results fluctuate considerably across monitoring years, during times of variable stream flow levels and at sites both upstream and downstream of the WCM licensed discharge point. As such, these results indicate that natural factors and fluctuating climatic conditions, rather than mining operations are the primary influences on water quality in the catchments surrounding the WCM.

Across all monitoring sites, a total of 17 macroinvertebrate Orders and 40 Families were recorded. Stream invertebrate grade number average level (SIGNAL2) scores were variable in 2022, with five sites showing improvements, and five declining in comparison to the 2021 SHM period. Despite this, it shows a continued improvement from 2021, and further showing recovery in habitat quality and availability recognised in the period from 2016 – 2019 due to prolonged drought conditions. In line with previous years, SIGNAL2 scores were <4.0 for all but four sites, which is indicative of severely disturbed systems. The overall temporal and spatial consistency of these macroinvertebrate results indicate that historical disturbances, combined with fluctuating climatic conditions within the catchments surrounding the WCM, are the main factors responsible for current stream health conditions.

The 2022 SHM was conducted under prevailing wet conditions in the lead up to and during the monitoring period. To ensure an accurate representation of water quality and macroinvertebrate community health, it is recommended that where practicable, future SHM be conducted several weeks following high rainfall and flooding events, to allow the survey sites and the wider catchment to return to baseline flow levels.

1. Introduction

1.1. Background

Wilpinjong Coal Pty Ltd (WCPL) are required to undertake annual stream health monitoring (SHM) to satisfy the updated requirement of Development Consent SSD 6764 Condition 29 & 30 (ii) (previously under Schedule 3, Condition 32 of WCPL's Project Approval (05-0021)) and the SHM criteria detailed in Appendix 2 of the Wilpinjong Water Management Plan (WCPL 2018). Eco Logical Australia (ELA) was engaged by WCPL to undertake SHM in the 2022 monitoring period.

1.2. Regional Overview

The Wilpinjong Coal Mine (WCM) is located in the Mid-Western Regional Council Local Government Area, approximately 45 km north-east of Mudgee. The mine is owned and operated by WCPL, a wholly owned subsidiary of Peabody Energy Australia.

The WCM is located at the headwaters of the Goulburn River which is a major tributary of the Hunter River catchment. Wilpinjong Creek is the main drainage channel within the WCM. It is an intermittent creek with a narrow floodplain that has a history of cattle grazing. The northern edge of the floodplain is bordered by the sandstone escarpments of Goulburn River National Park (NP). Wilpinjong Creek has three coal mines in its catchment, Moolarben, Ulan, and Wilpinjong, with the latter positioned furthest downstream. WCPL discharges water, treated by reverse osmosis, into Wilpinjong Creek at Environment Protection Licence (EPL) point 24 (EPL 24) directly adjacent to WCM.

Barigan Creek flows north through agricultural land as a tributary to Wollar Creek, joining south of the town of Wollar. Cumbo Creek flows north through land managed by WCPL, passing between Pit 3 and Pit 4, before joining Wilpinjong Creek north of the eastern pit area. Wilpinjong Creek continues to flow east, for approximately 4.5 km downstream where it joins Wollar Creek, which continues another 13 km through the Goulburn River NP before entering the Goulburn River.

1.3. Objectives

The ongoing SHM program for WCM is aimed to assist in determining the need for any maintenance and/or contingency measures. The objectives of annual SHM within Wilpinjong, Cumbo, Wollar and Barigan Creeks include:

- Survey of aquatic macroinvertebrate assemblages in spring if streamflow or ponded water is present and access to the creeks is safe, paired with in situ surface water quality sampling at each sampling site.
- An assessment of environmental condition at each site based on a variety of ecological indices.
- Comparisons of site indices against previous survey data to assess changes through time, and comparisons to trigger levels that would prompt further investigation.

2. Methodology

2.1. Survey overview

The 2022 SHM was undertaken by ELA ecologists Tom Kelly, Jack O'Sullivan and Elise Keane from 31 October to 2 November 2022. A total of eight permanent monitoring sites were surveyed along Wilpinjong, Cumbo and Wollar Creeks, along with two control sites at Barigan Creek established in 2020 (**Table 1**, **Figure 1**). All sites surveyed contained water suitable for macroinvertebrate sampling. Two survey sites along Wollar Creek, WO3 and WO4, were inaccessible due to wet and boggy conditions and therefore not surveyed in 2022.

Monitoring locations reflect a balance of sites both upstream and downstream of WCPL discharge point (EPL Point 24), as well as the various creeks (including external creeks) within the surrounding catchment. Photographs of each site are included at **Appendix A**.

Table 1: 2022 monitoring sites

Creek	Site	Upstream / Downstream*	Inundation Status	Easting	Northing
Wilpinjong Creek	WC1	Upstream	Wet	767680	6422970
	WC2	Upstream	Wet	768490	6422490
	WC6	Downstream	Wet	774580	6420860
	WC8	Downstream	Wet	775860	6420820
Cumbo Creek	CC1	Upstream	Wet	772710	6418130
	CC2	Upstream	Wet	772980	6418950
Wollar Creek	WO1	Upstream	Wet	777940	6418170
	WO2	Upstream	Wet	777780	6418950
	WO3**	Downstream	Wet	777790	6420100
	WO4**	Downstream	Wet	778030	6420596
Barigan Creek	BC1	Upstream	Wet	778704	6409493
	BC2	Upstream	Wet	779830	6403765

*Indicates Upstream / Downstream of WCPL discharge point EPL Point 24)

**Sites were not sampled during the 2022 monitoring period

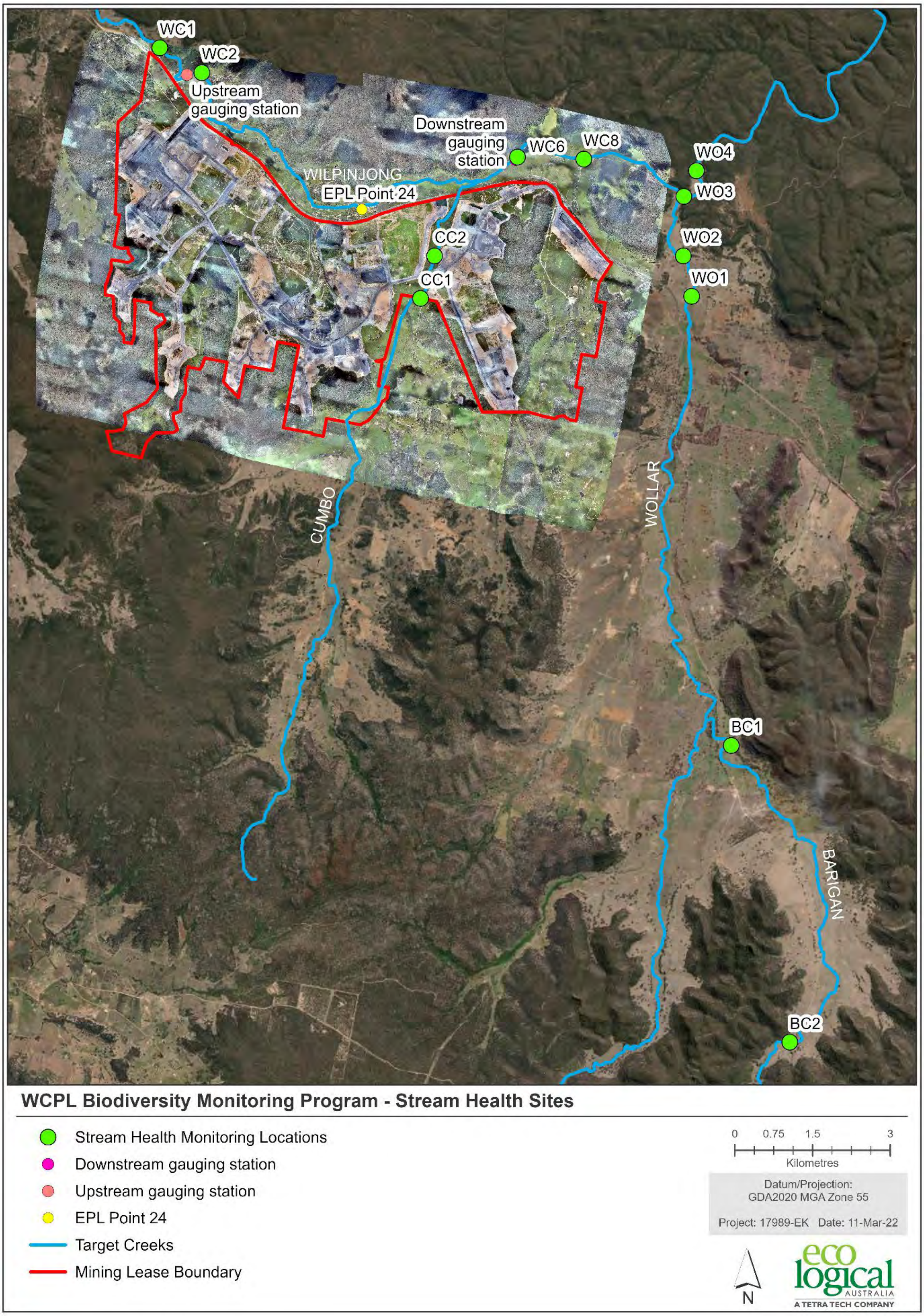


Figure 1: 2022 monitoring sites along Wilpinjong, Cumbo, Wollar and Barigan Creeks

2.2. Survey methods

2.2.1. Aquatic habitat assessment

Aquatic habitat assessments were based on the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI Fisheries 2013), which outlines the features important for fish habitat in freshwater, estuarine, and marine areas. Habitat assessments allow the significance of river reaches to be determined, regardless of whether target fish species are present permanently, or for brief periods of time.

Aquatic habitat variables (environmental data) were noted for each site, with observations made from the bank on the following characteristics:

- General signs of disturbance
- Habitat type
- Channel topography
- Current water level
- Bank and bed slope
- Degree of river shading
- Amount of detritus
- Macrophyte type and extent
- Riparian zone width
- Snags and large woody debris coverage
- Stream width and depth
- Surrounding land use
- Description of the natural substrate
- Extent of bank overhang
- Amount of trailing bank vegetation.

Riparian condition was assessed using a version of the Riparian, Channel and Environmental (RCE) inventory (Peterson 1992) that was modified for Australian conditions (Chessman *et al*. 1997). The modified RCE has 13 descriptors, each with a score from one (poor condition) to four (good condition).

Descriptors included width and condition of the riparian zone, surrounding land use, extent of bank erosion, stream width, water depth, occurrence of pools, riffles and runs, sub-stratum type, presence of snags and woody debris, in-stream and emergent macrophytes, algae, and barriers to fish passage. The total score for each site was derived by summing the score for each descriptor and calculating the result as a percentage of the highest possible score (up to 52).

Sites with a high RCE score indicate that the riparian zone is largely undisturbed, while those with a low score have undergone substantial modification. Based on the original classification established by Peterson (1992), site condition was rated as follows:

- Poor for RCE scores of 0-24%
- Fair for RCE scores of 25-43%

- Good for RCE scores of 44-62%
- Very Good for RCE scores of 63-81%
- Excellent for RCE scores of 82-100%.

RCE results from 2022 were compared with results from previous monitoring years dating to 2016, when RCE was introduced to the WCPL SHM program (**Section 4.1**).

2.2.2. Water quality

Complementing documented biological data, the following physicochemical parameters were measured at all sites:

- temperature
- dissolved oxygen (DO)
- electrical conductivity (EC)
- turbidity (NTU)
- pH.

Water quality results from 2022 were compared with previous year's results for DO, EC, turbidity and pH (**Section 4.2**). Results date back to 2006, however, not all parameters have results available for each year. Water quality parameters measured during surveys were compared with the ANZECC and ARMCANZ (2000) guidelines for the protection of aquatic environments. The ANZECC and ARMCANZ (2000) guidelines provide different ranges for upland and lowland streams, with upland streams being those above 150 m altitude. All sites surveyed for this project are considered upland stream sites.

2.2.3. Macroinvertebrate communities

Macroinvertebrate samples were collected at each site using the Australian Rivers Assessment System (AUSRIVAS) protocols (Turak *et al*. 2004). Three representative samples were collected at each site. Samples were collected from 10 m of representative edge, pool and/or riffle habitats using a standard AUSRIVAS kick net with 250 µm mesh. The net was bounced along the bottom to disturb resting invertebrates, and then rapidly passed again through the water column to collect the disturbed taxa. Edge habitats were defined as adjacent to the creek bank in areas of little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds and overhanging bank vegetation (Turak *et al*. 2004).

Macroinvertebrate samples were live-sorted in the field for a minimum of 40 minutes. If new taxa were collected in the period from 30 to 40 minutes, picking continued for 10 minutes. If no new taxa were found after the additional 10 minutes, sorting stopped. The maximum sorting time was 60 minutes. All picked animals were preserved in 70% ethanol solution and transferred to the laboratory for identification. Specific care was taken to ensure cryptic, fast-moving taxa were represented.

Macroinvertebrates were identified to family level, except for Copepoda, Ostracoda, Oligochaeta, Platyhelminthes, Hirudinea, Collembola, and Lepidoptera which were identified to order.

The Stream Invertebrate Grade Number - Average Level (SIGNAL2) is a biotic index that allocates a value to each macroinvertebrate family based upon their sensitivity to pollution. A macroinvertebrate family with a value of ten indicates high sensitivity, while a value of one indicates low sensitivity (i.e. high pollution tolerance) (Chessman *et al*. 1997). The SIGNAL2 score for the entire site is calculated by summing the SIGNAL2 grades for each family collected at that site and then dividing by the total number of families collected. SIGNAL2 scores are used to grade aquatic health into the following categories:

- SIGNAL2 Score > 6: Healthy Habitat
- SIGNAL2 Score 5-6: Mild Pollution
- SIGNAL2 Score 4-5: Moderate Pollution
- SIGNAL2 Score < 4: Severe Pollution.

Average SIGNAL2 scores for 2022 were compared with scores from previous years, dating back to 2006 (where available) (**Section 4.3**). SIGNAL2 scores from 2011 to 2013 (Landline Consulting 2011; 2012; 2013) were calculated using abundance weighting of macroinvertebrate taxa which resulted in slightly higher average SIGNAL2 scores for sites with relatively abundant macroinvertebrates. Whilst this method differs slightly from that undertaken in previous years, the results are largely consistent and valid for comparison.

2.3. Climate data

During the three days of the 2022 stream health monitoring period, the temperature was cool and below historical averages, with rainfall occurring on every day across the survey period totalling 29mm (**Table 2**). Rainfall was well above average in the preceding four months prior to monitoring, with total rainfall over this period almost three times the historical average for July-October (**Table 3**). Because of this consistent trend, there was a high availability of surface water for sampling.

Table 2: Temperature and rainfall data for the Spring 2022 monitoring period

Date	Min. temp (°C)	Max. temp (°C)	Rainfall (mm)
31 Oct 2022	11.6	24.6	18.8
1 Nov 2022	8.4	19	8.6
2 Nov 2022	6.3	14	1.6

Source: WCPL Weather Station Sentinex 34

Table 3: Temperature and rainfall preceding 2022 monitoring period

Month	2022 Averages (WCPL)			Historical Averages – Wollar (Barrigan St)		
	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)	Min. temp (°C)	Max. temp (°C)	Rainfall (mm)
January	18.6	29.4	101.4	16.2	30.9	67.2
February	16.4	27.8	16.0	15.7	29.4	62.6
March	16.0	25.8	119.8	12.9	26.7	55.1
April	11.2	22.5	95	8.0	22.9	39.3
May	7.3	18.7	43.6	4.1	18.6	37.2
June	3.0	14.8	13	2.3	15.0	43.8
July	4.2	14.7	136.4	1.2	14.5	43.0
August	4.3	17.0	103.2	1.6	16.3	41.1
September	7.11	18.4	93.8	4.4	19.7	41.9

Month	2022 Averages (WCPL)			Historical Averages – Wollar (Barrigan St)		
	Mean min. temp (°C)	Mean max. temp (°C)	Total Rainfall (mm)	Min. temp (°C)	Max. temp (°C)	Rainfall (mm)
October	11.2	21.3	174.4	7.8	23.1	52.2
November	10.1	23.3	64	11.3	26.3	56.5

Source: 2020 data from the WCPL Weather Station Sentinex 34, historical data from the BoM weather stations at Mudgee Airport (temp) and Wollar (Barigan St) weather station (rainfall)

Flow data from upstream and downstream gauging stations was not available for the 2022 monitoring period.

3. Results

3.1. Aquatic habitat assessment

Results of the habitat assessment, including water, substrate, vegetation, land use, and how these elements contribute to the RCE score are detailed below. A breakdown of how the 13 RCE parameters scored for each site is included in **Table 4.**

Table 4: Site results for the 13 RCE parameters

Descriptor	WC1	WC2	WC6	WC8	WO1	WO2	WO3 *	WO4 *	BC1	BC2	CC1	CC2
Land use pattern beyond immediate riparian zone	3	3	2	3	2	3	-	-	3	3	2	3
Width of riparian strip of woody vegetation	3	3	3	3	3	3	-	-	3	3	2	1
Completeness of riparian woody strip of vegetation	2	2	2	3	2	2	-	-	3	1	1	1
Vegetation of riparian zone within 10 m of channel	4	4	2	2	3	3	-	-	3	1	2	1
Stream bank	2	2	3	3	2	3	-	-	3	3	3	3
Bank undercutting	3	3	3	4	3	3	-	-	3	3	4	4
Channel form	2	3	3	3	3	3	-	-	3	3	2	3
Riffle/pool sequence	2	3	3	3	3	3	-	-	3	3	2	2
Retention devices in stream	1	1	1	1	4	3	-	-	2	2	1	1
Channel sediment accumulations	4	3	4	4	2	4	-	-	3	3	4	4
Stream bottom	1	2	2	1	3	1	-	-	2	2	2	1
Stream detritus	1	2	2	2	2	2	-	-	2	2	2	2
Aquatic vegetation	2	2	2	2	2	2	-	-	2	2	2	2
Total	30	33	32	34	34	35	-	-	35	31	29	28
Total %	57.7	63.4	61.5	65.4	65.4	67.3	-	-	67.3	59.6	55.8	53.8
Condition classification	G	VG	G	VG	VG	VG	-	-	VG	G	G	G

G = Good; VG = Very Good

* Sites WO3 and WO4 were not surveyed in 2022

All sites continue to record an RCE classification of 'Good' (five of ten sites) or 'Very Good' (five of ten sites), consistent with that recorded in 2021. WO3 and WO4, were not surveyed in 2022 due to site inaccessibility, therefore no RCE classifications were produced for these sites.

3.2. Water quality

The results of in situ water quality sampling for temperature, EC, DO, pH and Turbidity are detailed in **Table 5**. Water temperatures at the time of sampling ranged between 10.9°C and 20.3°C. Variation in water temperature generally reflected the time of day as well as the stream morphology of the monitoring sites, with samples collected later in the day (e.g. WC1) and/or from shallower profile streams (e.g. WC2) recording higher temperatures.

EC levels were greatly reduced across all sites in 2022 compared to the water quality results from 2021. The lowest EC recorded was at sites WC1 (105.7) and WC2 (105.9), with both sites located upstream of the WCPL discharge site. WC1, WC2, BC1 and BC2 were the only sites to record EC values within the ANZECC and ARMCANZ (2000) guidelines. The highest two EC values were recorded at CC1 (1222 µS/cm) and CC2 (1188 µS/cm), both of which are located within the WCPL mining lease, with the EC values at this site substantially higher than all other monitoring sites.

DO ranged between 83.1% saturation at BC1 to 129% saturation at WO2. Four sites were below, four sites within, and two sites above the recommended ANZECC and ARMCANZ (2000) guideline range. The pH at sites ranged between 6.48 at WC1 and 7.81 at CC2. All sites were within the ANZECC and ARMCANZ (2000) guidelines except WC1, which was narrowly below the guidelines. Turbidity ranged from 1.07 NTU at CC2, to 376 NTU at BC1 (**Table 5**). WC8 was the only site to fall within the recommended ANZECC and ARMCANZ (2000) guideline range for turbidity, with CC1 and CC2 falling below the guidelines and every other site exceeding the guidelines.

Table 5: Water Quality results

Variable	Guideline Range	WC1	WC2	WC6	WC8	WO1	WO2	WO3	WO4	BC1	BC2	CC1	CC2
Temperature (°C)	N/A	20.0	18.0	19.4	17.7	13.7	20.3	-	-	10.9	11.9	16.7	15.8
Conductivity (µS/cm)	30-350	105.7	105.9	700	763	354.7	501	-	-	227.5	184.9	1222	1188
DO (% saturation)	90-110	92.7	93.1	88.4	121.9	85.3	129	-	-	83.1	85	97.4	95.6
DO (mg/L)	N/A	8.05	8.42	7.8	11.13	8.49	11.18	-	-	8.75	8.72	9.06	8.77
pH	6.5-8.0	6.48	6.8	7.33	7.77	7.57	7.79	-	-	7.80	7.68	7.66	7.81
Turbidity (NTU)	2-25	55.29	70.71	40	9.4	226.5	104.1	-	-	376	152.83	1.5	1.07

3.3. Macroinvertebrate communities

A summary of macroinvertebrate results are presented in **Table 6**, with the full results for each site detailed in **Appendix B**. A total of 17 macroinvertebrate Orders/Classes and 40 Families were recorded during 2022 monitoring. Only one taxa was recorded across all 10 monitoring sites, this being Atyidae from the Order Diptera. Two other taxa were recorded across nine of the monitoring sites. Across individual sites, macroinvertebrate taxonomic richness ranged from 13 to 28, with CC1 recording the lowest level of richness and CC2 recording the highest richness. At the time of sampling, these sites had a variety of available micro-habitat for macroinvertebrates, including macrophytes, woody debris and riffles.

Pollution sensitivity ratings for each family/order were used to calculate the average SIGNAL2 score for each site. Where families/orders have no assigned SIGNAL2 sensitivity rating, they were not included in the averages, however, are still represented in results for taxa richness. Average SIGNAL2 scores range from 2.8 (severely disturbed) at CC2 to 5.0 (mildly disturbed) at CC1 and BC2 (**Table 6**). Six of the 10 sites had an average SIGNAL2 score of less than 4.0 (with two sites recording scores of 4.0) and as such, are classified as severely disturbed. This is the first time whereby a site has recorded a SIGNAL2 score of 5.0 across all monitoring periods, thereby categorising it into the mildly polluted category, however it still remains on the zone between moderately/mildly disturbed.

Section 6.2 of the WCPL Surface Water Management and Monitoring Plan (WCPL, 2018) outlines the following trigger condition for SHM:

- Minimum taxon richness: 15 taxa; and
- Minimum SIGNAL2 index: 3.0.

One site (CC1) scored below the minimum trigger conditions for both SIGNAL2 and taxa richness scores. Site WC2 also recorded a SIGNAL2 score below the trigger threshold but did not meet the threshold for taxa richness. Interestingly, sites BC2 and WC1 were below the thresholds for taxa richness, however recorded the highest SIGNAL2 scores across the 10 sites.

Table 6: SIGNAL2 scores for 2022 monitoring sites

Measure	BC1	BC2	CC1	CC2	WC1	WC2	WC6	WC8	WO1	WO2
Taxa richness	17	14	13	28	14	16	22	18	24	21
Average SIGNAL2 score	3.4	5.0	2.8	3.5	4.3	2.9	3.5	4.0	3.2	4.0
SIGNAL2 pollution condition	S	MI	S	S	M	S	S	M	S	M

S = Severe, M = Moderate, MI = Mild

4. Discussion

4.1. Aquatic habitat assessment

All sites recorded either 'Good' or 'Very Good' classifications for their RCE indices during 2022 monitoring. This puts them in the mid-range for riparian and channel habitat quality. Habitat conditions within Wilpinjong, Wollar, Cumbo and Barigan Creek sites were largely consistent with those recorded in previous years, both upstream and downstream of the WCPL licensed discharge point (**Figure 2**). Temporal differences were largely restricted to changes in macrophyte cover (*Aquatic vegetation*), however, as discussed above, this is not reflective of an overall deterioration in these sites (**Table 4**). Overall, RCE results are consistent across the monitoring period (2016 – 2022).

Lack of in-stream retention devices (*Retention devices in stream*) such as logs, and boulders were common at many sites, particularly after the heavy rainfall and flooding experienced in October, with scores of one or two recorded for this attribute. This is typical of streams in agricultural landscapes as large debris have generally been removed, and woody riparian vegetation that would provide fallen branches and logs is limited. In-stream retention devices help slow the movement of flow, which in turn reduces the waters erosive power and contributes to of the local area. Retention devices are also important for the accumulation of coarse particulate organic matter, an important energy source for macroinvertebrate communities.

Similarly, the stream bed structure (*Stream bank*, *Stream bottom* and *Stream detritus*) also scored low overall, due to lack of vegetation cover and the presence of loose and mobile sediments along the stream bed at most sites. This is typical in a highly modified agricultural landscape where sites have reduced bank stability leading to increased erosion and sedimentation.

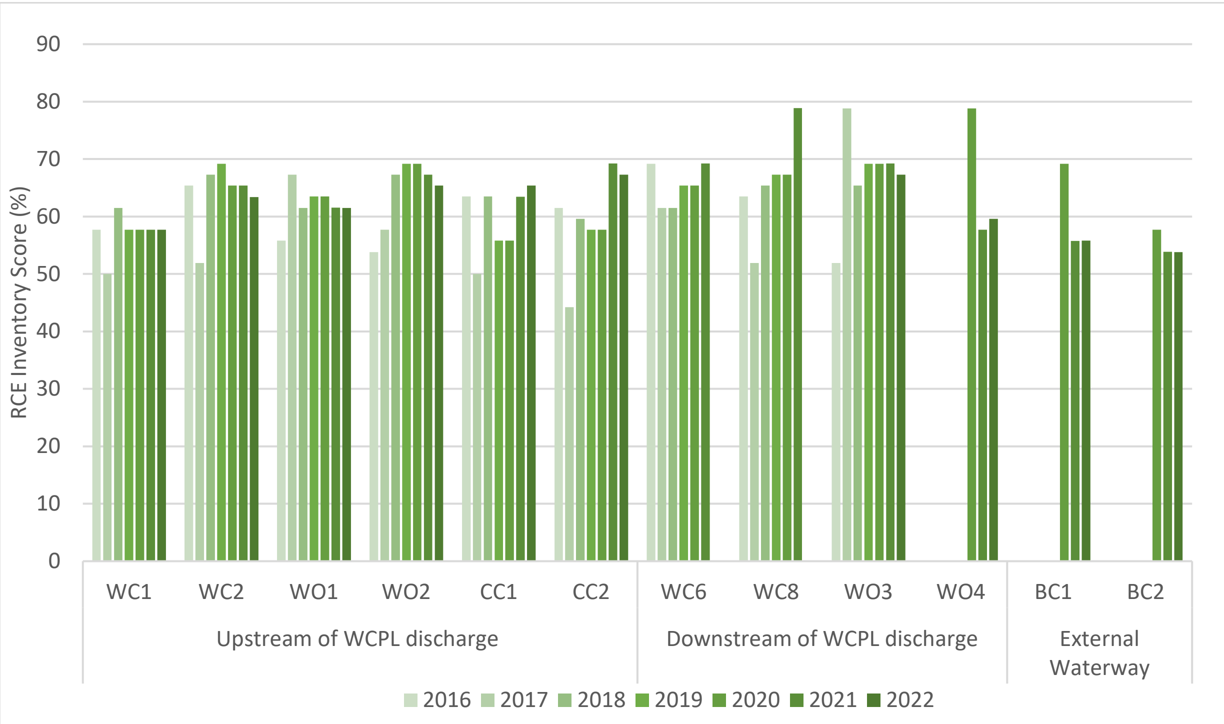


Figure 2: RCE scores across all sites and years

4.2. Water quality

Water temperature overall was cooler than previous years, with an average temperature of 16.4°C compared to 18.8°C in 2021. Fluctuation in water temperature at each site is expected to occur in line with ambient temperature, considering the generally shallow stream depth, minimal riparian shading and variable flow.

DO concentrations in 2022 were either close to, or within, the ANZECC and ARMCANZ (2000) guideline range across all sites, which is an increase from 2021. The rise in DO concentration from 2021 is likely due to the increased flow, turbulence, and mixing, resulting from high rainfall and flooding leading up to, and during, the 2022 SHM period. DO concentrations can fluctuate due to a range of factors including water temperature, organic and bacterial activity, water flow and circulation, and time of day. DO concentrations have fluctuated considerably across sites and years and, prior to this monitoring year, were consistently outside of ANZECC and ARMCANZ (2000) guidelines (**Figure 3**). These results have been recorded both upstream and downstream of the WCPL discharge point, as well as the two control sites located along Barigan Creek. This suggests DO concentrations and fluctuations may be a result of natural processes and are not linked to mining operations.

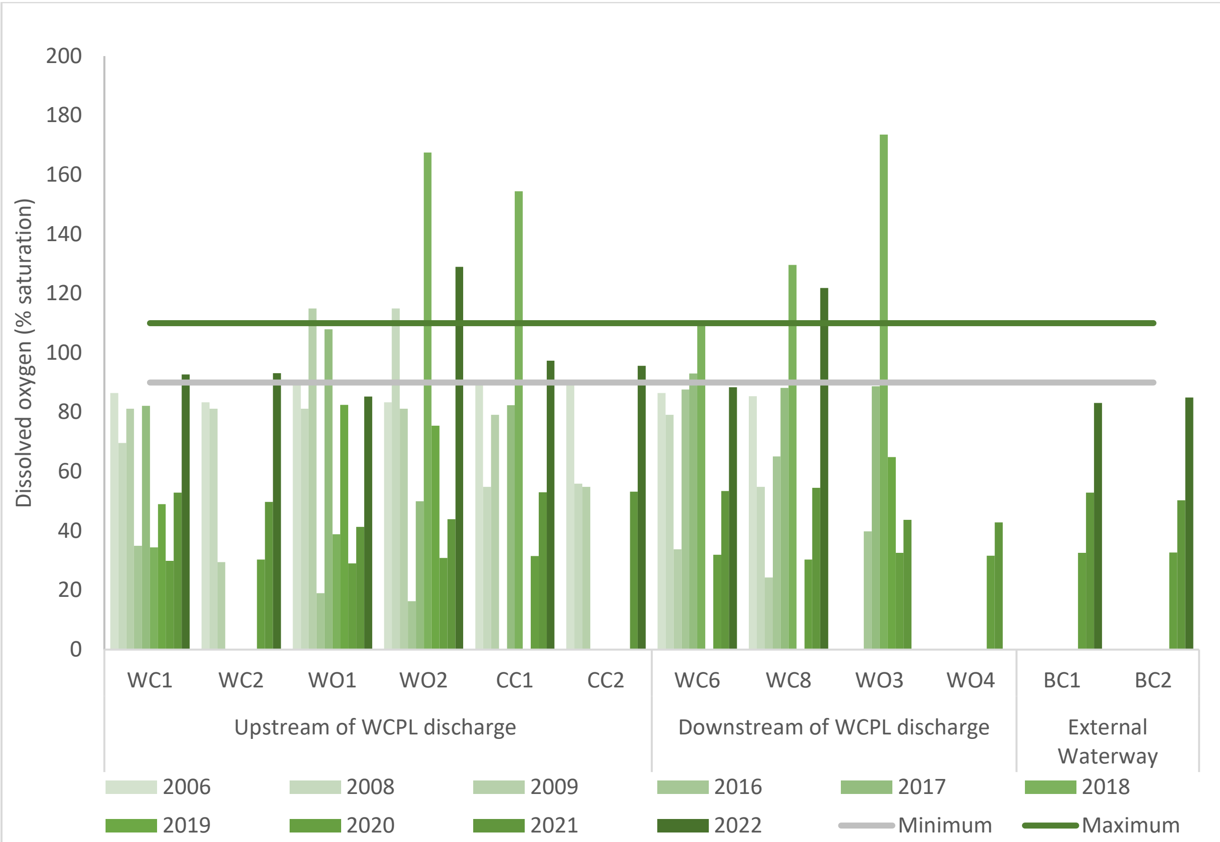


Figure 3: DO (% saturation) results across all sites and years

EC was greatly reduced across most sites compared to results recorded in 2021 and previous monitoring years, with four sites (WC1, WC2, BC1, and BC2) all falling within the recommended ANZECC guideline range (30-350 µS/cm) (**Figure 4**). This contrasts with previous years whereby EC concentrations at most sites have recorded values that consistently exceed the ANZECC guidelines, both upstream and downstream of the WCPL licensed discharge points. Despite the naturally occurring saline groundwater throughout the region (BIO-ANALYSIS 2015), the influx of freshwater from high rainfall totals in October 2022, and the rainfall experienced throughout the monitoring period itself, have likely led to dilution and a corresponding drop in EC levels throughout the catchment.

As was the case in previous monitoring years, EC concentrations recorded in 2022 showed a declining trend in EC values at sites further downstream along Wilpinjong and Wollar Creeks. These results indicate that naturally saline groundwater becomes more diluted as it travels downstream and interacts with an increasing proportion of runoff. EC levels recorded at control sites BC1 and BC2 during 2021 were generally lower than those recorded within Wilpinjong and Wollar Creeks, whilst Cumbo Creek sites (CC1 and CC2) recorded substantially higher EC values than all other sites. The increased in EC concentration that occurs between sites WC2 and WC6 is likely due to the high EC of Cumbo Creek water entering Wilpinjong Creek. EC then decreases downstream from this confluence and is potentially diluted further by the licenced discharge of RO water. Both Cumbo Creek sites (CC1 and CC2) have consistently recorded relatively high EC results across the ten-year monitoring period, and despite the drop in EC this year, is still well above the ANZECC guidelines.

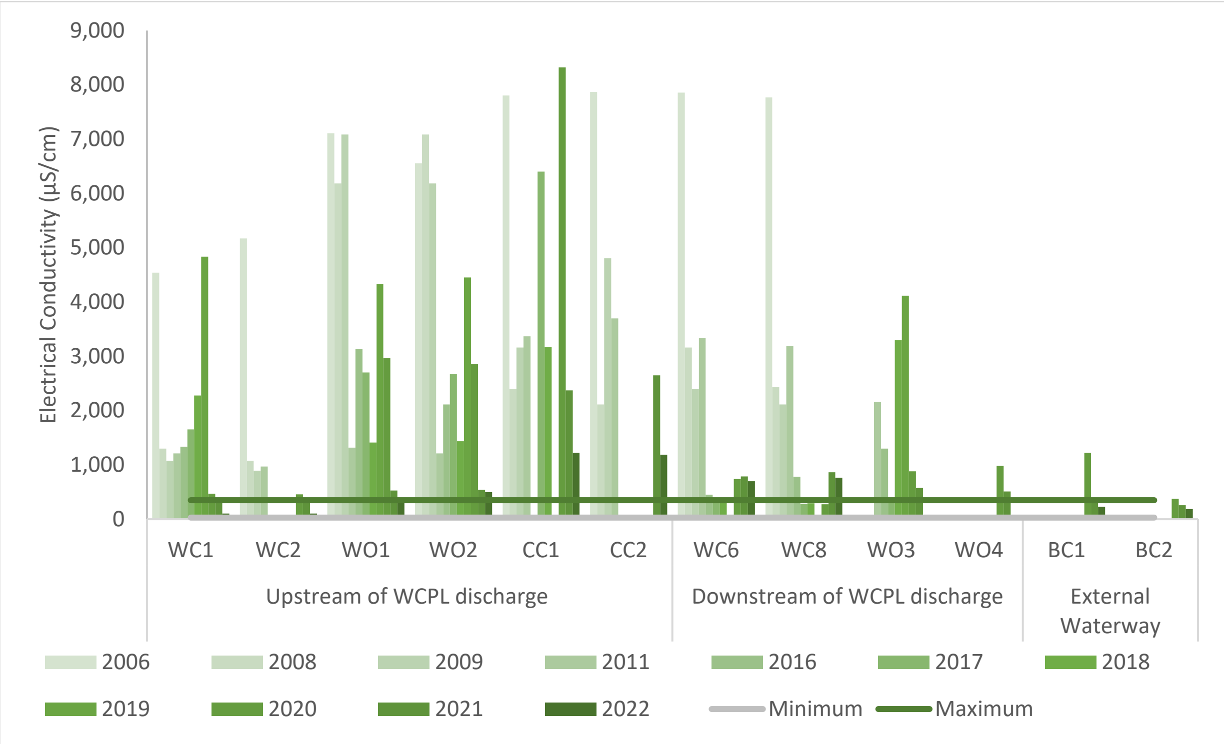


Figure 4: EC (µS/cm) results across all sites and years

Overall, turbidity was much higher compared to previous monitoring years, likely due to the higher amounts of sediment and organic matter caused by flooding and high rainfall, both before and during the 2022 monitoring period (**Figure 5**).

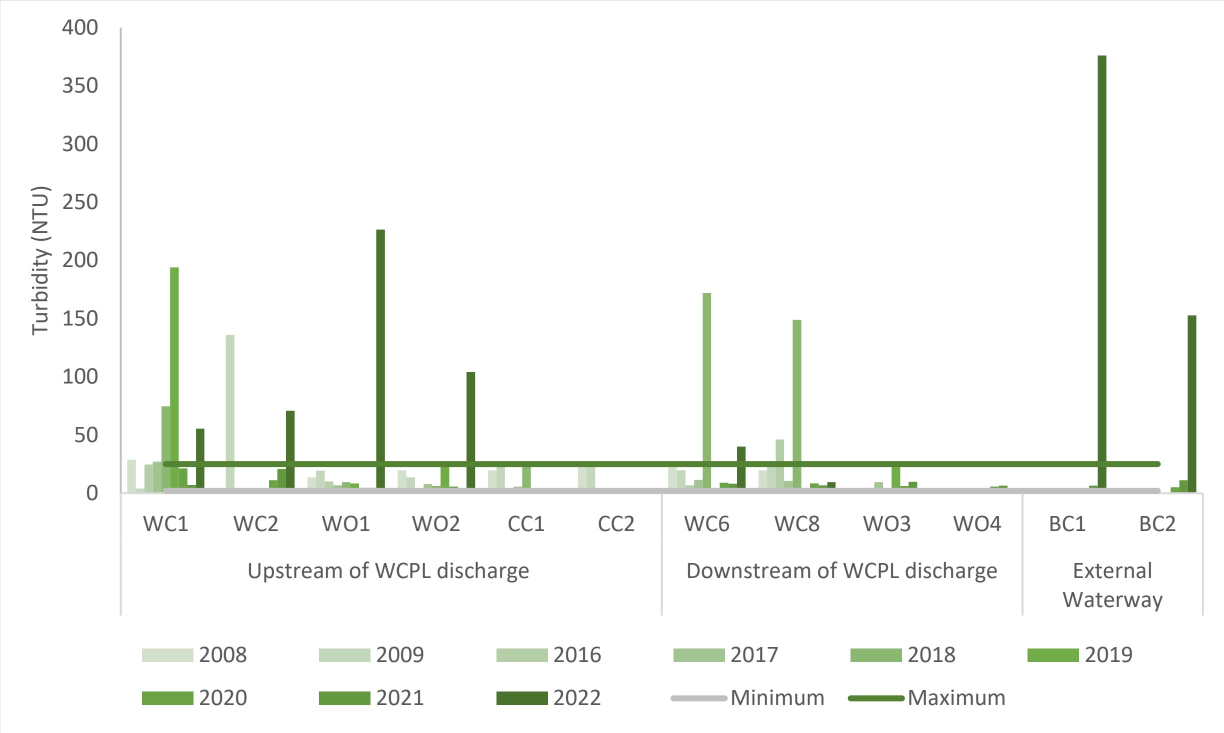


Figure 5: Turbidity (NTU) results across all sites and years

The pH results for all SHM sites monitored during 2022 were within or marginally outside of ANZECC guidelines. Across all sites and monitoring years, pH has remained highly consistent (**Figure 6**).

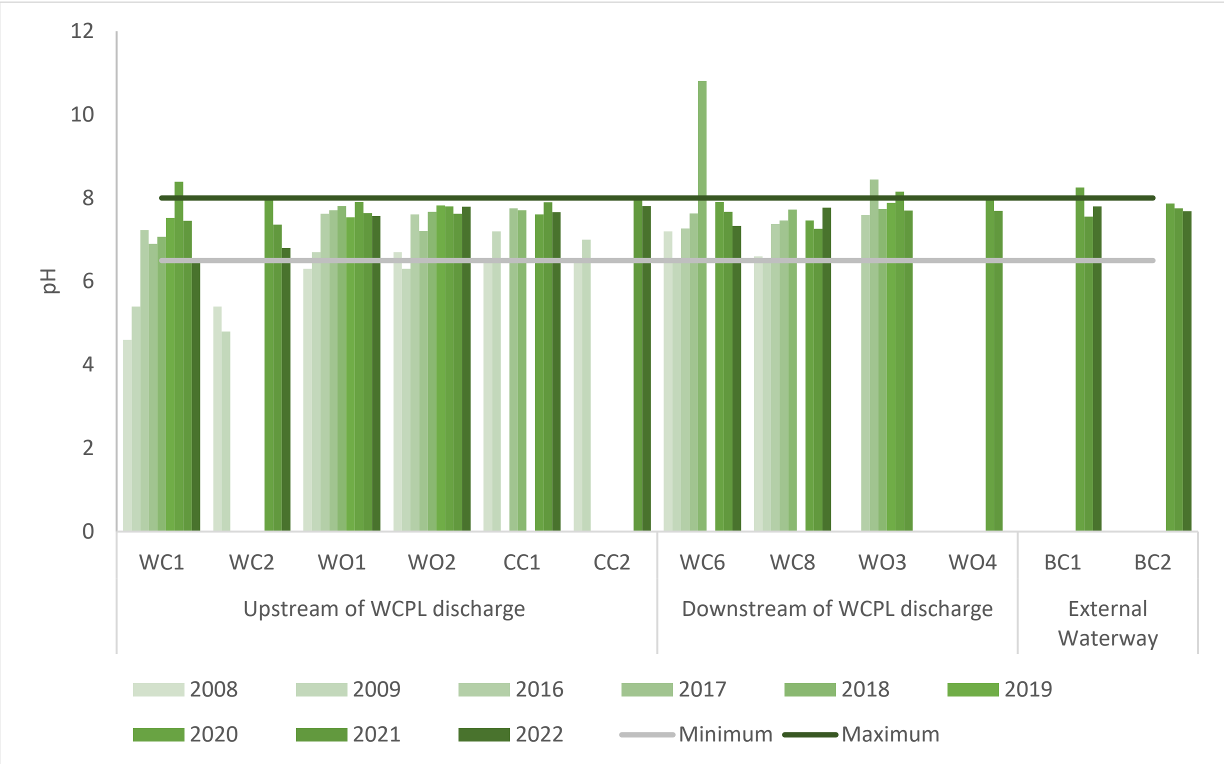


Figure 6: pH results across all sites and years

4.3. Macroinvertebrate communities

Across all monitoring years, the average SIGNAL2 score for each site except one (BC2) is <4.0 with these scores indicative of severely disturbed systems. These scores have been consistently recorded during periods of variable surface water flow and availability and at sites both upstream and downstream of the WCM, including the two control sites located in the external Barigan Creek. Such results therefore reflect the overall disturbed nature of the catchment, largely attributable to historical agricultural and land use practices.

SIGNAL2 scores differed across sites in 2022, with four sites increasing, five sites decreasing and one site remaining the same (**Figure 7**). Site CC1 scored below the minimum trigger conditions for SIGNAL2 and Taxa richness, which should trigger an investigation into the cause of this as outlined in the WCPL SWMMP (WCPL, 2018). However, it is likely that the prevailing climatic conditions during monitoring (i.e. high rainfall and water levels throughout the catchment) have strongly influenced the score, and therefore it is recommended that subsequent monitoring under closer to average rainfall conditions be conducted before investigations are warranted.

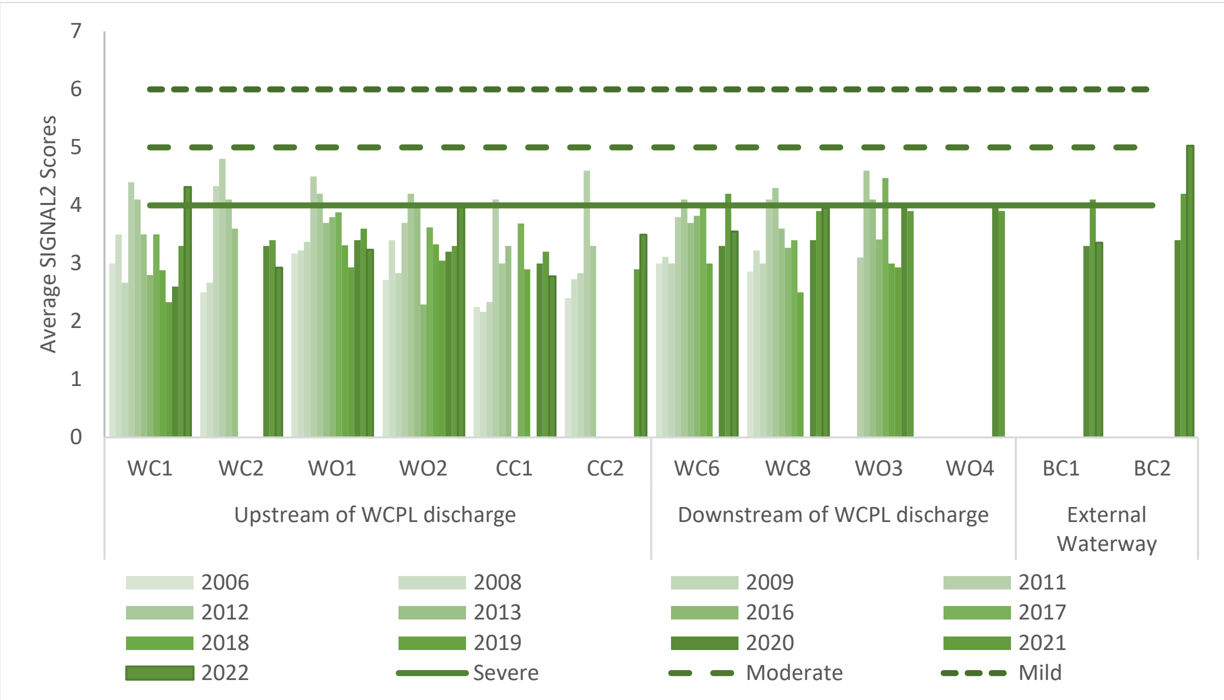


Figure 7: Average SIGNAL2 macroinvertebrate scores across all sites and years

5. Conclusions and recommendations

A total of eight permanent sites along Wilpinjong, Wollar and Cumbo Creeks were sampled in 2022, along with two control sites at Barigan Creek. Two sites in 2022 (WO3 and WO4), were inaccessible due to flood damaged roads, and were therefore not sampled. Due to the above-average rainfall preceding the monitoring period in 2022, all the other sites were easily accessible with sufficient water levels for sampling.

The habitat condition at all 10 sites were classified as either good or very good, which places the sites in the mid-range of aquatic habitat scores, typical of catchments in the surrounding region. Overall, aquatic habitat results have remained largely consistent across survey years, with differences primarily relating to changes in stream bed macrophyte and groundcover, because of fluctuating water levels due to heavy rainfall and flooding, in response to climatic conditions. There is the capacity to improve instream habitat through the re-introduction of logs and boulders as instream retention devices, particularly after the widespread flooding events that occurred during 2022. These works would also help limit downstream erosion and can be tied in with ongoing revegetation and rehabilitation works along Cumbo and Wilpinjong Creeks.

Water quality results showed considerable improvement compared to recent years, with several sites falling within the ANZECC and ARMCANZ (2000) guidelines for either DO, EC, or both metrics. This is likely due to increased rainfall in the months leading up to the monitoring period, causing increased flow, mixing and turbulence in the three creeks surveyed and throughout the catchment. Despite this, results for both parameters have fluctuated considerably across years and across varying stream flow levels, at sites both upstream and downstream of the WCPL licensed discharge point. It is likely that the guidelines for these measures are not appropriate at the local and/or regional catchment level. Water quality results overall, indicate that natural variables, rather than mining operations are the main factors which influence water quality in the sampled catchments.

A total of 17 macroinvertebrate Orders and 40 Families were recorded across all sites. SIGNAL2 scores showed varying trends across sites and at both upstream and downstream of the WCPL licensed discharge point in 2022, with five sites experiencing increases and five experiencing decreases, in SIGNAL2 scores. Taxa richness was also variable across the 10 sites, and was often not related to SIGNAL2 scores (i.e. BC2 and CC2). In line with previous years, SIGNAL2 scores were <4.0 for all but four sites, indicative of severely disturbed sites. One site, CC1, scored below the minimum trigger conditions for both SIGNAL2 and taxa richness scores, however, due to the prevailing climatic conditions in the lead up to, and during the SHM period, it is recommended that the site be re-sampled during normal conditions.

6. References

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Vol. 1 The Guidelines.*

BIO-ANALYSIS (2015). *Wilpinjong Coal Project Aquatic Ecosystem Assessment.* Report to Wilpinjong Coal Pty Ltd.

Bureau of Meteorology (BoM). 2022. *Climate Data Online – Mudgee Airport and Wollar (Barigan St)*: http://www.bom.gov.au/climate/data/index.shtml

Chessman, B.C., Growns, J.E., Kotlash, A.R. 1997. *Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL2 biotic index: application to the Hunter River System, New South Wales*. Marine and Freshwater Research, 48:159 – 172.

Department of Primary Industries (DPI). 2013. Policy and guidelines for fish habitat conservation and management.

Landline Consulting. 2011. Wilpinjong Coal Mine Stream Health Monitoring Aquatic Macroinvertebrate Survey. Prepared for Wilpinjong Coal Pty Ltd.

Landline Consulting. 2012. Wilpinjong Coal Mine Stream Health Monitoring Aquatic Macroinvertebrate Survey. Prepared for Wilpinjong Coal Pty Ltd.

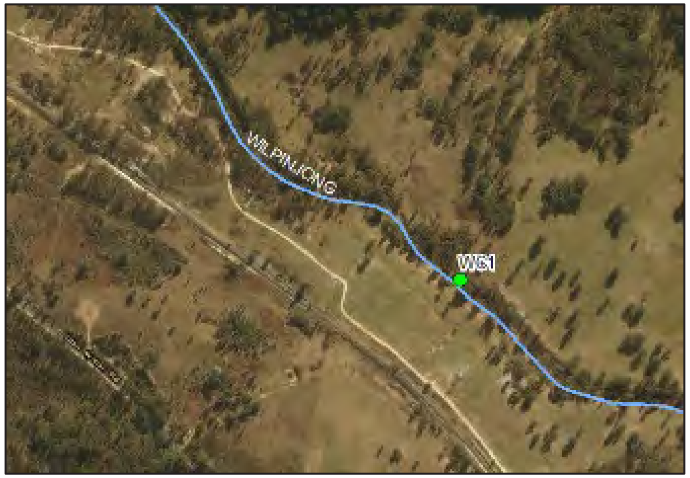
Landline Consulting. 2013. Wilpinjong Coal Mine Stream Health Monitoring Aquatic Macroinvertebrate Survey. Prepared for Wilpinjong Coal Pty Ltd.

Peterson R.C. 1992. The RCE: A Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology, 21: 295 – 306.

Turak, E., Waddell N., Johnstone G. 2004. New South Wales (NSW) Australian River Assessment System (AUSRIVAS) – Sampling and Processing Manual. Department of Environment and Conservation, Sydney

Wilpinjong Coal Pty Ltd 2018. Wilpinjong Coal Surface Water Management Plan. (WI-ENV-MNP-0040).

Appendix A Site Photos




Site WC1 (from left to right: site location, upstream, downstream (01/11/2022))


Site WC2 (from left to right: site location, upstream, downstream (01/11/2022))

Site WC6 (from left to right: site location, upstream, downstream (01/11/2022))

Site WC8 (from left to right: site location, upstream, downstream (31/10/2022))


Site WO1 (from left to right: site location, upstream, downstream (02/11/2022))


Site WO2 (from left to right: site location, upstream, downstream (31/10/2022))


Site CC1 (from left to right: site location, upstream, downstream (01/11/2022))


Site CC2 (from left to right: site location, upstream, downstream (01/11/2022))


Site BC1 (from left to right: site location, upstream, downstream (02/11/2022))


Site BC2 (from left to right: site location, upstream, downstream (02/11/2022))

Appendix B Macroinvertebrate data

Order/Class	Family	SIGNAL2	BC1	BC2	CC1	CC2	WC1	WC2	WC6	WC8	WO1	WO2
Acarina	Hydrachnidae	6										1
Coleoptera	Curculionidae	2						1				
	Dytiscidae	2	10	4		8	5	6	5	18	8	3
	Gyrinidae	4	14	3		1		4		2	3	4
	Haliplidae	2				4						
	Hydrophilidae	2							2			1
	Hygrobiidae	1	2						2		1	2
	Psephenidae	6				1						
	Scirtidae	6	8	9		3	18	7	6		13	6
Collembola		1					1		1			
Copepoda		N/A			2	6		3	1		1	2
Decapoda	Atyidae	3	3	3	1	6	5	9	7	4	11	4
Diptera	Ceratopogonidae	4	5	1	1		1		4		3	
	Chironomidae	3	21	4	3		47	28	23	122	25	15
	Dixidae	7				13						
	Dolichopodidae	3			2	1						
	Sciomyzidae	2			2							
	Simuliidae	5	12			1	14		7	29		44
	Tabanidae	3	1		1				1		1	
	Tipulidae	5			6	3	1	3	1		1	

Order/Class	Family	SIGNAL2	BC1	BC2	CC1	CC2	WC1	WC2	WC6	WC8	WO1	WO2
Ephemeroptera	Baetidae	5	5	1		1	1		4	34	25	31
	Caenidae	4								13	1	1
	Leptophlebiidae	8	9	54		1	1			21	8	24
Gastropoda	Physidae	1	5		7	11		1	3	11	11	21
Hemiptera	Corixidae	2	8			29		83	1	19	10	1
	Micronectidae	2	90		1	7			26	62	38	34
	Naucoridae	2									1	
	Nepidae	3							1			
	Notonectidae	1	4			4		15		3	15	6
	Pelidae	2									1	
	Veliidae	3			1						3	
Hirudinea		1				2						
Lepidoptera		2		1								
Odonata	Aeshnidae	4		1		1						
	Austrocordulidae	10				1						
	Coenagrionidae	2				11		2	0	3		2
	Gomphidae	5					1					
	Platycnemididae	3				3						
	Pseudocorduliidae	3	1	1		1	6	3	1	1		
Oligochaeta		2	2		3	1	4	3	3		1	
Ostracoda		N/A			2	3		1			2	
Platyhilmenthes		2				1		2	2	5		
Plecoptera	Gripopterygidae	8		9								
Trichoptera	Calamoceratidae	7										3

Order/Class	Family	SIGNAL2	BC1	BC2	CC1	CC2	WC1	WC2	WC6	WC8	WO1	WO2
	Hydroptilidae	4				1				2		
	Leptoceridae	6		2		1				16	6	6
	Philopotamidae	8		2			4		5	23	1	4

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Wilpinjong Coal Mine
2022 Channel Stability Monitoring

Wilpinjong Coal Pty Ltd

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Abbreviations

Abbreviation	Description
ARI	Average Recurrence Interval
BEHI	Bank Erosion Hazard Index
BoM	Bureau of Meteorology
CSM	Channel Stability Monitoring
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
EY	Exceedances per Year
IFD	Intensity-Frequency-Duration
LHB	Left Hand Bank
ML	Mining Lease
RHB	Right Hand Bank
WCM	Wilpinjong Coal Mine
WCPL	Wilpinjong Coal Pty Ltd

Summary of Key Findings

Channel stability monitoring (CSM) was completed by Eco Logical Australia (ELA) on behalf of Wilpinjong Coal Pty Ltd (WCPL) between 13 February and 15 February 2023, to be included in the 2022 annual monitoring for WCPL. Monitoring was not undertaken in 2022 due to access limitation from inclement weather conditions. The CSM program aims to provide quantitative and qualitative measures of channel stability along Wilpinjong and Cumbo Creeks. Monitoring was undertaken across a total of 59 permanent monitoring locations, including 49 on Wilpinjong Creek and 10 on Cumbo Creek. Consistent with previous monitoring, methods included surveying the designated reach of each monitoring site (approximately 100 m) and completing the Bank Erosion Hazard Index (BEHI) assessment, along with visual and photographic comparative assessment with data from previous years.

CSM results in 2022 were largely consistent with previous years, indicating the unchanged nature of the target creeks. For Wilpinjong Creek, BEHI ratings remained unchanged at all 49 sites, whilst for Cumbo Creek, ratings remained unchanged at all 10 sites. All sites showed a continued increase in both in-stream and bank vegetation ground cover, as well as water levels and stream flow. This follows on from the increases in vegetation cover observed in 2020 and 2021, which has that ensured consistency in BEHI scores across all sites from the previous year.

Identified historical erosion points were monitored in 2022, with most sites experiencing continued active erosion in 2022. The 2022 CSM program was undertaken following above average rainfall in the preceding 12-month period, including the occurrence of significant rainfall events with the potential to cause erosion. An Intensity-Frequency-Duration (IFD) table was generated for the Wilpinjong catchment using the Bureau of Meteorology (BoM) 2016 Rainfall IFD Data system and detailed rainfall data from the WCPL Meteorological Station. There was a rainfall event that exceeded the 1 in 5-year rainfall event generally accepted as likely to cause erosive scouring, which occurred on 3 July. Furthermore, sustained, above average rainfall through the months of July-October likely exacerbated a rainfall event that occurred on 20 October, which lead to major stream flow velocities recorded within both Wilpinjong and Cumbo Creeks.

Overall, erosion points continue to require ongoing monitoring, and additional revegetation and remediation works are recommended to allow for channel bank stability. In particular, reshaping and contouring of the bank, followed by revegetation is recommended at multiple erosion points, including E1, E3, E4, E6, E9 and E11.

The results of the 2022 CSM support conclusions made in previous monitoring and assessments that ongoing mining operations are not causing stability issues within the target creek systems. Both Wilpinjong and Cumbo Creeks are typical of ephemeral creek systems in agricultural landscapes of the surrounding region, with channel stability issues within these creeks reflecting historical disturbances and land use practices, rather than contemporary mining operations.

1. Introduction

1.1. Background

Eco Logical Australia (ELA) was engaged by Wilpinjong Coal Pty Ltd (WCPL) to undertake annual channel stability monitoring (CSM) along Wilpinjong and Cumbo Creeks. CSM is required to satisfy Schedule 3, Condition 30 (d, iii) of the WCPL Development Consent (SSD 6764), and the CSM criteria detailed in Appendix 2 (Surface Water Management Plan) of the Wilpinjong Water Management Plan (WCPL 2018).

1.2. Regional overview

The Wilpinjong Coal Mine (WCM) is located in the Mid-Western Regional Council Local Government Area, approximately 45 km north-east of Mudgee. The mine is owned and operated by WCPL, a wholly owned subsidiary of Peabody Energy Australia.

The WCM is located at the headwaters of the Goulburn River which is a major tributary of the Hunter River catchment. Wilpinjong Creek is the main drainage channel within the WCM. It is an intermittent creek with a narrow floodplain that has a history of cattle grazing. The northern edge of the floodplain is bordered by the sandstone escarpments of the Goulburn River National Park (NP). Wilpinjong Creek has three coal mines in its catchment, Moolarben, Ulan and Wilpinjong, with the latter positioned furthest downstream. WCPL discharges treated mine water into Wilpinjong Creek, treated by reverse osmosis, at a licensed discharge point (EPL24) directly adjacent to WCM.

Cumbo Creek flows north through land managed by WCPL, passing between Pit 3, Pit 2, Pit 7 and Pit 4, before joining Wilpinjong Creek north of the eastern pit area. Wilpinjong Creek continues to flow east, for approximately 4.5 km downstream where it joins Wollar Creek, which continues another 13 km through the Goulburn River NP before entering the Goulburn River.

1.3. Previous channel stability assessments

A baseline channel stability assessment of Wilpinjong and Cumbo Creeks was undertaken in 2005 as part of the Environmental Impact Statement (EIS) for the Wilpinjong Coal Project (WCPL 2005) to characterise the existing condition of the Wilpinjong and Cumbo Creek stream channels prior to mining. The Wilpinjong Creek survey included 49 sites and extended 12.5 km from the upstream gauging station to the confluence with Wollar Creek to the east. The Cumbo Creek survey included ten sites and extended 3 km from the southern boundary of the Mining Lease (ML) 1573 north to the confluence with Wilpinjong Creek.

The baseline surveys concluded both Wilpinjong and Cumbo Creeks have been affected by pre-mining land management practices dominated by sheep and cattle grazing. These land management practices involved the clearing of riparian vegetation on both creeks to maximise grazing areas and stock access to drinking water. The clearing of this vegetation is likely to have contributed significantly to bank instability. Disturbance from burrowing animals, both native (e.g. *Vombatus ursinus* (Common Wombats)) and introduced (e.g. *Oryctolagus cuniculus* (European Rabbit)), is also likely to have contributed to this instability.

Subsequent annual CSM has been undertaken in 2011, and 2014-2020, to assess the ongoing stability of the Wilpinjong and Cumbo Creeks during operational mining. Barnson (2017) developed a proforma to assist in the assessment of creek stability at each survey location and to enable comparisons to be made between annual survey periods. Annual CSM reports have concluded that overall riparian health is poor, with erosion and bank stability issues present, typical of historically cleared agricultural catchments. Consistent site stability ratings in recent years are associated with prolonged drought conditions, resulting in minimal stream flow and reduced vegetation cover. Data collected by annual CSM to date has indicated that mining activities are not contributing to further channel stability issues in Wilpinjong and Cumbo Creeks.

1.4. Objectives

This report details the findings from the 2022 CSM program and includes a comparison of the regeneration progress of both Wilpinjong and Cumbo Creeks against previous monitoring conducted since 2011.

The CMS program aims to provide qualitative measures of stream bed and bank erosion and channel instability along Wilpinjong and Cumbo Creeks.

The key objectives of the 2022 CSM program are to:

- Evaluate erosional or depositional features of the creek banks
- Record the details of permanent monitoring sites with written descriptions and photographs
- Assess the stability of Wilpinjong and Cumbo Creeks using a rapid assessment methodology
- Compare visual channel stability at each of the permanent monitoring sites against previous monitoring records.

2. Methodology

2.1. Field survey – Channel stability monitoring and comparative assessment

The field survey was conducted by ELA ecologists Elise Keane and Jack O'Sullivan over three days between 13 February and 15 February 2023, to be included in the 2022 annual monitoring for WCPL. Monitoring was not undertaken in 2022 due to access limitation from inclement weather conditions.

A total of 59 permanent monitoring locations were surveyed (49 on Wilpinjong Creek and 10 on Cumbo Creek; Figure 1). Consistent with previous monitoring, surveys involved surveying the designated reach of each site (approximately 100 m) and completing the Bank Erosion Hazard Index (BEHI) assessment. BEHI assessment involves scoring a site on eight quantitative categories outlined below and in in Appendix A.

The eight BEHI indicators of channel stability that were used to evaluate erosion at each site include:

- Bank Height (m)
- Bank Angle (°)
- Percentage of Bank Height with a Bank Angle greater than 80°
- Evidence of Mass Wasting (% of Bank)
- Unconsolidated Material (% of Bank)
- Streambank Protection (% of Streambank covered in plant roots, vegetation, logs, branches, rocks, etc.)
- Established Beneficial Riparian Woody – Vegetation Cover
- Stream Curvature Descriptor

The BEHI indicators produce an activity rating that classifies each location from 'Highly Unstable', indicating the drainage line is experiencing severe ongoing erosion, to 'Highly Stable', indicating the drainage line is highly stable in function and form. This rating system enables any deterioration or improvement in bank stability to be detected over time. The classification system is detailed below in Table 1.

Table 1: BEHI score ranges for each rating class

Rating	BEHI Score
Highly Stable	0-25
Moderately Stable	26-35
Stable	36-45
Unstable	46-55
Moderately Unstable	56-65
Highly Unstable	66-85

Field notes and photographs were taken to allow qualitative assessment through comparisons between monitoring periods. This process included written site descriptions using the previous monitoring report (ELA 2021) to make comparisons *in situ*, as well as taking upstream and downstream photographs at each of the permanent monitoring sites. Site descriptions are provided in Section 3 and copies of site photos are provided in Appendix B. Comparisons of the monitoring site photographs (2011-2022[2023]) has been made by referring to previous reports prepared by Barnson (2017) and ELA (2018-2021).

Previously established erosion points along Wilpinjong Creek were also assessed (Figure 2). These are in areas with moderate to severe erosion and are monitored to determine the presence and extent of on-going erosion. Management issues and threatened species were recorded opportunistically throughout the surveys, to highlight areas where management intervention is needed.

2.2. Rainfall and Flood Analysis

During 2022 there were several rainfall events likely to have influenced erosion in the target creeks. Flow data indicates that water volume levels moving through the system in 2022 were higher compared to those recorded in 2021 (Figures 3 – 5). Lower than average rainfall and drought conditions were recorded between 2017 and 2019, followed by increases in 2020 and 2021, which were maintained into 2022.

The intensity and amount of rainfall can result in flooding, and this influences erosion by way of scouring, slumping and surface destabilisation within rural creeks. The amount and rate of erosion is influenced by vegetation cover, topography, climatic factors and soil characteristics, along with the amount of rainfall and precipitation intensity.

An Intensity-Frequency-Duration (IFD) table was generated for the Wilpinjong catchment, using the Bureau of Meteorology (BoM) 2016 Rainfall IFD Data system. The process of determining IFD is known as frequency analysis and is an important part of hydrological design procedures. The IFD table was compared against the Wilpinjong rainfall data. Rainfall data for the 2022 monitoring period was collected from the WCPL Meteorological Station, Sentinex 34. Data was provided in 15 minute and hourly increments, as well as daily totals. This data was examined against the IFD table to determine the Average Recurrence Interval (ARI) or rarity of rainfall events over the 12-month period, to determine if any rainfall events would impact creek stability or result in erosion.

Figure 1: Channel stability monitoring locations along Wilpinjong Creek and Cumbo Creek

Figure 2: Significant erosion locations along Wilpinjong Creek

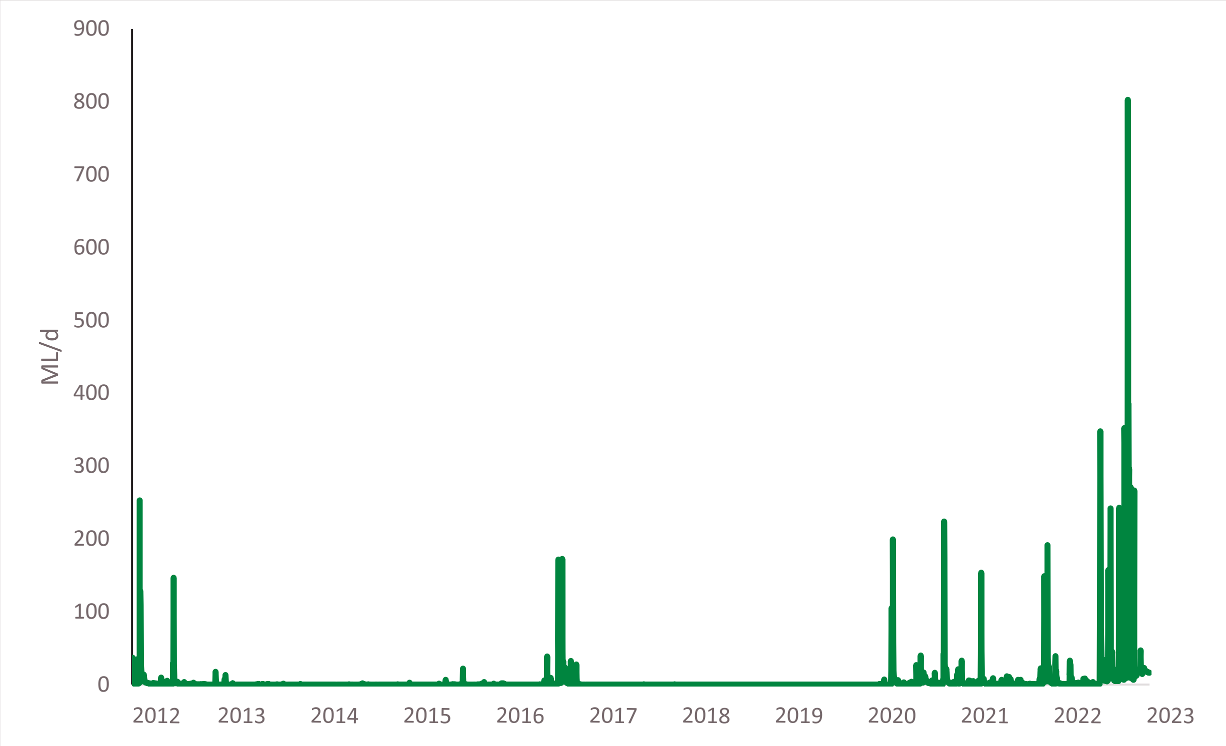

Figure 3: Wilpinjong Creek stream flow upstream of the WCPL mine discharge point EPL 24

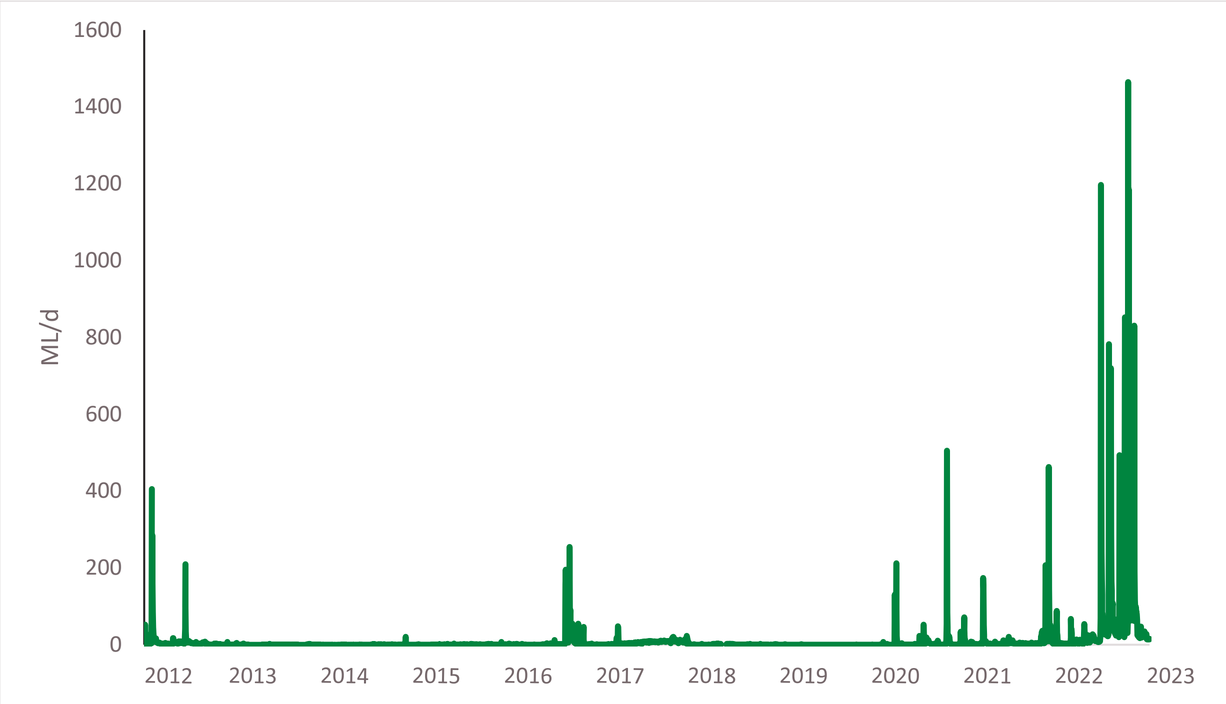

Figure 4: Wilpinjong Creek stream flow downstream of the WCPL mine discharge point EPL 24

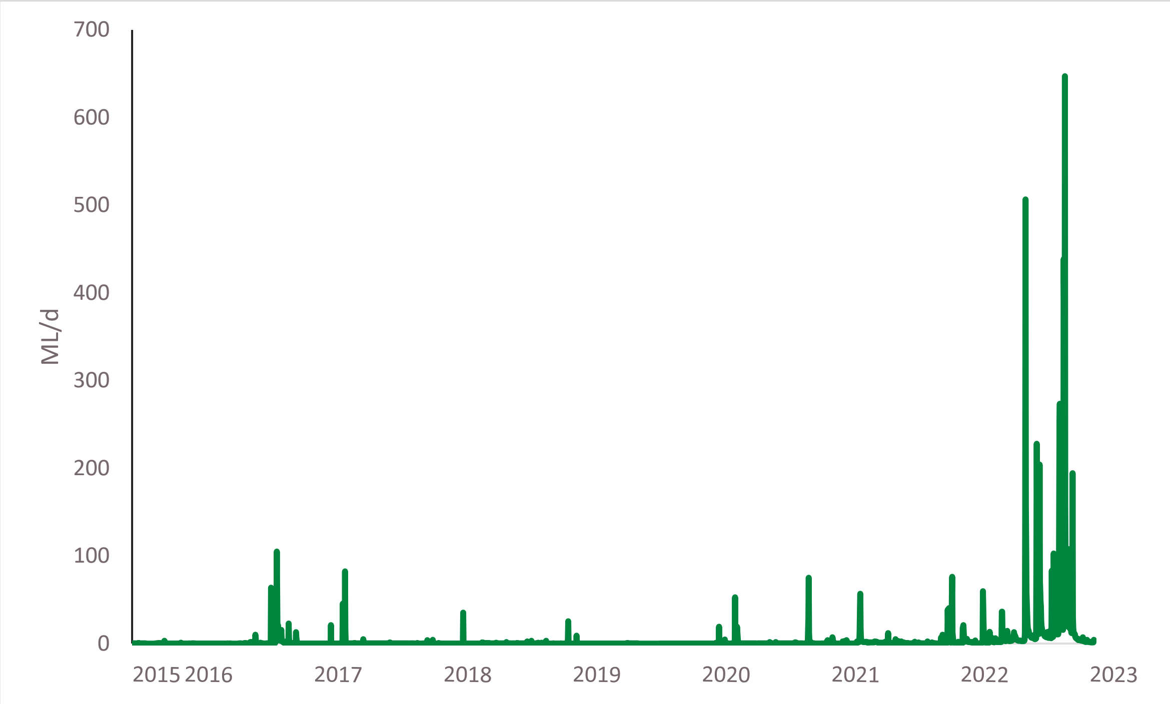

Figure 5: Cumbo Creek stream flow downstream of WCPL mine discharge point EPL 24

3. Results

3.1. Channel Stability Monitoring

The results of the BEHI assessments completed at sites along Wilpinjong Creek are presented below in Table 2, with results from Cumbo Creek sites presented in

Table 3. Site descriptions and comparison notes can be found in Table 4. A range of priority weed species listed within the Central Tablelands Regional Strategic Weed Management Plan 2017-2022 (LLS 2017) were recorded, as well as priority pest animal species listed within the Central Tablelands Regional Strategic Pest Animal Management Plan 2018-2023 (LLS 2018), the locations of which are shown in Figure 6.

Table 2: BEHI data for Wilpinjong Creek

Site	Bank (L/R)	Bank Height (m)	Bank Face Length	BEHI Indicator								Total	Rating
				1	2	3	4	5	6	7	8		
WCk1	L	4	10	5	2	5	0	2.5	2.5	7.5	5	29.5	Mod Stable
WCk2	R	3.5	9	5	2	5	0	2.5	5	10	0	29.5	Mod Stable
WCk3	L	3	12	5	2	2.5	5	7.5	10	12.5	5	49.5	Unstable
WCk4	L	3.5	7	5	4	7.5	7.5	7.5	10	12.5	0	54	Unstable
WCk5	L	3	7	5	2	2.5	5	5	2.5	7.5	0	29.5	Mod Stable
WCk6	L	3	6	2.5	2	2.5	0	2.5	2.5	7.5	2.5	22	Highly Stable
WCk7	L	2.5	6	2.5	2	2.5	0	0	2.5	7.5	0	17	Highly Stable
WCk8	L	5	12	7.5	2	0	0	0	0	15	2.5	27	Mod Stable
WCk9	R	2	9	2.5	2	7.5	5	2.5	10	15	2.5	47	Unstable
WCk10	R	1.5	15	2.5	0	0	0	0	0	15	2.5	20	Highly Stable
WCk11	R	1.5	18	0	0	0	0	2.5	0	10	2.5	15	Highly Stable
WCk12	R	2	12	2.5	2	0	0	2.5	2.5	12.5	5	27	Mod Stable
WCk13	L	4	8	5	4	0	0	2.5	0	10	5	26.5	Mod Stable
WCk14	L	1.8	7	2.5	2	0	0	0	0	12.5	0	17	Highly Stable
WCk15	L	1.8	6	2.5	2	2.5	0	2.5	2.5	10	2.5	24.5	Highly Stable
WCk16	L	2	7	2.5	2	5	0	2.5	0	7.5	0	19.5	Highly Stable
WCk17	R	1.8	4	2.5	2	0	0	0	0	15	2.5	22	Highly Stable
WCk18	R	2.5	5	2.5	2	5	2.5	0	0	15	2.5	29.5	Mod Stable
WCk19	L	2	4	2.5	2	2.5	2.5	0	2.5	15	0	27	Mod Stable
WCk20	L	1.8	5	2.5	2	5	7.5	2.5	7.5	12.5	0	39.5	Stable
WCk21	R	1.3	5	0	2	2.5	2.5	0	2.5	15	2.5	27	Mod Stable
WCk22	R	1.6	8	2.5	2	0	7.5	2.5	12.5	12.5	2.5	42	Stable
WCk23	R	2.5	12	2.5	2	0	2.5	7.5	12.5	15	5	47	Unstable
WCk24	R	1.7	10	2.5	0	2.5	0	2.5	7.5	15	2.5	32.5	Mod Stable
WCk25	L	1.7	7	2.5	2	2.5	7.5	5	10	15	2.5	47	Unstable
WCk26	L	3.5	10	5	2	7.5	7.5	5	10	15	2.5	54.5	Unstable
WCk27	R	2.8	5	2.5	6	7.5	7.5	7.5	10	15	2.5	58.5	Mod Unstable

Site	Bank (L/R)	Bank Height (m)	Bank Face Length	BEHI Indicator								Total	Rating
				1	2	3	4	5	6	7	8		
WCk28	L	2.5	5	2.5	2	7.5	5	5	7.5	12.5	2.5	44.5	Stable
WCk29	L	3.6	8	5	2	7.5	5	5	10	15	2.5	52	Unstable
WCk30	R	2.8	12	2.5	2	0	0	2.5	2.5	12.5	2.5	24.5	Highly Stable
WCk31	R	3	6	2.5	4	5	5	5	7.5	15	2.5	46.5	Unstable
WCk32	R	3.2	7	5	4	7.5	5	5	7.5	15	2.5	51.5	Unstable
WCk33	L	3.2	6	5	4	7.5	7.5	5	10	10	5	54	Unstable
WCk34	R	2.4	6	2.5	4	5	2.5	0	0	15	5	34	Mod Stable
WCk35	R	2.2	13	2.5	2	2.5	7.5	7.5	7.5	15	2.5	47	Unstable
WCk36	R	2	15	2.5	2	0	5	2.5	2.5	15	2.5	32	Mod Stable
WCk37	R	2	12	2.5	2	2.5	7.5	5	7.5	15	2.5	44.5	Stable
WCk38	L	3.1	6	5	2	2.5	0	0	0	10	5	24.5	Highly stable
WCk39	L	3.2	7	5	4	2.5	5	7.5	10	15	2.5	51.5	Unstable
WCk40	R	3.2	14	5	2	0	7.5	10	12.5	15	0	52	Unstable
WCk41	R	2.8	8	2.5	2	2.5	0	0	0	15	0	22	Highly Stable
WCk42	R	3.8	6	5	4	7.5	5	10	12.5	12.5	2.5	59	Mod Unstable
WCk43	L	3.1	5	5	4	7.5	2.5	0	0	15	2.5	36.5	Stable
WCk44	R	1.7	3	2.5	2	2.5	0	0	0	15	2.5	24.5	Highly Stable
WCk45	L	3.2	7	5	2	2.5	0	0	2.5	7.5	5	24.5	Highly Stable
WCk46	R	2.2	5	2.5	4	5	2.5	2.5	2.5	10	2.5	31.5	Mod Stable
WCk47	R	2.2	6	2.5	2	2.5	5	2.5	7.5	12.5	0	34.5	Mod Stable
WCk48	L	2.7	8	2.5	2	2.5	2.5	2.5	2.5	12.5	2.5	29.5	Mod Stable
WCk49	L	3.8	10	5	4	2.5	0	5	7.5	10	2.5	36.5	Stable

Table 3: BEHI data for Cumbo Creek

Site	Bank (L/R)	Bank Height (m)	Bank Face Length	BEHI Indicator								Total	Rating
				1	2	3	4	5	6	7	8		
CCk1	L	1.8	10	2.5	0	0	0	0	0	15	0	17.5	Highly Stable
CCk2	R	1.3	8	0	2	2.5	5	2.5	7.5	15	5	39.5	Stable
CCk3	L	0.4	2	0	0	0	0	0	0	15	2.5	17.5	Highly Stable
CCk4	R	1	13	0	0	0	0	0	0	15	2.5	17.5	Highly Stable
CCk5	R	1	8	0	0	0	0	2.5	2.5	15	2.5	22.5	Highly Stable
CCk6	R	1.8	10	2.5	2	2.5	0	0	2.5	15	2.5	27	Mod Stable
CCk7	R	0.5	2	0	2	2.5	0	0	0	15	2.5	22	Highly Stable
CCk8	L	2	15	2.5	0	0	0	0	0	15	2.5	20	Highly Stable
CCk9	L	0.7	2	0	2	2.5	0	0	0	15	2.5	22	Highly Stable
CCk10	L	0.7	4	0	2	2.5	0	0	0	15	2.5	22	Highly Stable

Table 4: Monitoring site descriptions – Wilpinjong Creek and Cumbo Creek

Site	Upstream	Downstream
Wilpinjong Creek		
WCk1	• Water level is lower than 2021, with water running over wall and then pooling • Increase in *Phragmites australis* (Common reed) on channel bank • No further dieback of *Angophora floribunda* (Rough-barked Apple) since 2021 • Good groundcover on bank, with *Themeda triandra* (Kangaroo grass), *Echinopogon ovatus* (Forest hedgehog grass) and *Microlaena stipoides* (Weeping grass)	• Increase cover of *Phragmites australis* in channel and on bank • Bare soil patches, erosion appears stabilised • Ponding water
WCk2	• Increase in vegetation within the channel, including *Juncus* sp., and *Phragmites australis* • Ponding water in channel • Minimal localised erosion, currently appears stable • Debris washed up from high flow events, sitting approximately 1.2m high against tree	• Good vegetation cover on banks, some bare soil on RHB • Erosion is stabilised • Ponding water • Increased cover of channel vegetation including *Phragmites australis*
WCk3	• Veg cover in channel is similar to 2021, with *Phragmites australis* and *Juncus* sp. • Vegetation cover on banks is similar to 2021 • Ponding water in creek •	• Vegetation cover in channel similar to 2021, with *Phragmites australis* and *Juncus* sp. present • Vegetation cover on banks similar to 2021 • Erosion appears stable
WCk4	• Increase in vegetation in channel, with *Phragmites australis* continuing to grow • Good vegetation on banks • Water ponding • Active erosion on left hand bank (LHB) continues, with evidence of undercutting and mass wasting	• LHB erosion active in past year, with undercutting and mass wasting • Vegetation in channel has increased, with *Phragmites australis* and *Juncus* sp. present • Litter trap along fence line • New fence across channel has broken following high flow events
WCk5	• *Phragmites australis* present in channel • LHB erosion active with mass wasting evident. Some bare soil patches on bank from erosion • Vegetation on banks is good	• Good vegetation cover in channel with *Phragmites australis* present • Bank vegetation cover good, with mixed grasses including *Themeda triandra* • Litter trap against trees from high flow events • Minor localised erosion on LHB from animal tracks

Site	Upstream	Downstream
	• *Eucalyptus blakelyi* (Blakely's Red Gum) regeneration in channel	
WCk6	• *Phragmites australis* in channel • Good vegetation on bank • Eucalypt regeneration on bank • Small *Rubus fruticosus* species aggregate (Blackberry) on LHB	• Good vegetation cover in channel and on banks • Ponding water • Large *Rubus fruticosus* species aggregate on RHB and small *Rubus fruticosus* species aggregate along LHB • No further dieback of *Angophora floribunda* observed • Fallen tree on RHB is creating litter trap • European carp present in channel
WCk7	• *Phragmites australis* present in channel • Good vegetation cover on banks • Regeneration of *Eucalyptus blakelyi* on banks • Large woody debris (LWD) creating litter trap	• *Phragmites australis* present in channel, with an increase in cover compared to 2021 • Good vegetation cover on bank, with groundcover on LHB contributing to stabilisation • Regeneration of *Angophora floribunda* and *Eucalyptus blakelyi* on banks
WCk8	• Increase in *Phragmites australis* cover in channel and edge of channel • Water ponding • Good vegetation cover on banks	• Good vegetation cover on banks • Increased cover of *Phragmites australis* on edge of channel • Ponding water in channel • Some debris from high flow events •
WCk9	• Erosion on right hand bank (RHB) has been active in past year, currently appears stable • High cover of *Phragmites australis* in channel • Debris washed up into trees from high flow events	• High cover of *Phragmites australis* in channel • Good vegetation cover on upper and lower bank • Erosion on RHB has been active within the past year, currently appears stable
WCk10	• High cover of *Phragmites australis* in channel and on bank • Water reduced to slow flow over road • Eucalyptus regeneration on RHB	• Good vegetation cover on bank • High cover of *Phragmites australis* and *Juncus* sp. in channel • Debris from high flow events washed up onto trees on RHB • Slow flow of water
WCk11	• High vegetation cover in channel and on banks with *Phragmites australis, Arundinella nepalensis* (Reedgrass), and *Austrostipa verticillata* (Slender bamboo grass) present • *Cyperaceae* sp. in channel	• Wombat burrow on bench on RHB • High cover of *Phragmites australis* in channel • Regeneration of *Eucalyptus blakelyi* in channel
WCk12	• Young *Allocasuarina* species on LHB	• Increase in *Phragmites australis* cover in channel

Site	Upstream	Downstream
	• Good vegetation cover on both banks • Increase in *Phragmites australis* cover in channel	• Debris washed up on RHB from high flow events • *Hypericum perforatum* (St John's Wort) present in low abundance • Regeneration of *Angophora floribunda* and *Eucalyptus blakelyi* on RHB
WCk13	• Good vegetation cover on banks, with an increase in cover of *Phragmites australis* on the edge of the channel • Debris washed up from high flow events in channel • Ponding water	• Litter trap on LHB • Good vegetation cover on LHB • Some dieback of *Eucalyptus blakelyi* on RHB, is dropping lots of leaves • Regeneration of *Eucalyptus blakelyi* on LHB •
WCk14	• Ponding water • Debris washed up against base of tree from high flow events • High cover of *Phragmites australis* in channel and on the edge of the channel • Good groundcover on banks • Regeneration of *Eucalyptus blakelyi* on RHB	• Ponding water in channel • High cover of *Phragmites australis* in channel and on edge of channel • Good ground cover on bank • Regeneration of *Eucalyptus blakelyi* on LHB
WCk15	• High cover of *Phragmites australis* in channel • Good vegetation cover on banks, which is stabilising LHB	• Bank stable with good vegetation cover • High cover of *Phragmites australis* in channel • Ponding water • Minor debris wash up
WCk16	• Ponding with low flow • Increase cover of *Phragmites australis* on the edge of the bank • *Juncus* sp. on LHB • Good vegetation cover on banks	• Low water flow • Increased cover of *Phragmites australis* on edge of bank • Good vegetation cover on bank • Litter trap at base of tree
WCk17	• Highly vegetated with *Phragmites australis* in channel and extended onto bank	• Dense vegetation of *Phragmites australis* in channel at similar cover to 2021 monitoring, is preventing access to point • *Eucalyptus blakelyi* regeneration on RHB
WCk18	• Good vegetation cover on bank • *Phragmites australis* on edge of channel • Water ponding • Erosion on RHB has been active over past year, with some mass wasting • European carp (*Cyprinus carpio*) present	• *Phragmites australis* present in channel downstream • Good vegetation cover on banks, *Phragmites australis* has extended to upper bank • Water ponding • Erosion on RHB has been active in past year • *Hypericum perforatum* is present in small abundance

Site	Upstream	Downstream
WCk19	• High vegetation cover on bank, including *Lomandra confertifolia* (Mat-rush) and *Themeda triandra* • Minor erosion from animal tracks on LHB, currently appears stable • *Phragmites australis* channel edge • Water ponding	• Good vegetation cover on bank, including *Lomandra confertifolia* and *Themeda triandra* • *Phragmites australis* in channel • Ponding water • Bare patches present on LHB, with minor erosion, currently appears stable • Vegetation cover on banks has increased • Some debris has washed up onto LHB post high flow events
WCk20	• *Phragmites australis* in channel • Mass wasting has occurred on LHB over past year, for approximately 50 m upstream from point • Good vegetation cover on lower bank and upper bank • Bare soil present mid bank on LHB from erosion	• Good cover of *Phragmites australis* in channel • Vegetation cover on banks similar to 2021, with good cover on bank which is stabilising bank. Species include *Lomandra confertifolia* and *Themeda triandra* • Regeneration of *Angophora floribunda*
WCk21	• Vegetation cover on banks similar to 2021, dominated by *Lomandra confertifolia* • *Phragmites australis* in channel • Regeneration present on RHB • Water ponding on crossing	• Good vegetation cover on banks including *Phragmites australis* • *Angophora floribunda* regeneration on RHB • Water across road • High cover of *Phragmites australis* in channel • Erosion on RHB has stabilised
WCk22	• Good vegetation cover in channel and on LHB • No riparian tree cover on LHB with only a small riparian zone on RHB • Regen present RHB • *Phragmites australis* present in channel	• Erosion on RHB has been active over the past year but currently appears stable • Minimal vegetation cover on RHB • No riparian tree cover • High cover of *Phragmites australis* in channel and good vegetation cover on LHB
WCk23	• High cover of *Phragmites australis* in channel • Minor erosion on LHB, however there is good vegetation cover and regeneration is occurring • Erosion and patches of bare soil on RHB, erosion is currently stable	• High cover of *Phragmites australis* in channel • Vegetation cover on RHB is similar to 2021 monitoring, and erosion appears to have stabilised • *Rubus fruticosus* species aggregate present • Minor debris from high flow events
WCk24	• Sediment fencing is creating a litter trap for debris from high flow events • Increase In vegetation cover on lower bank on RHB • High cover of *Phragmites australis* in channel with *Juncus* sp. on edge of channel	• Sediment fencing is catching debris from high flow events • High cover of *Phragmites australis* in channel • Increase in vegetation cover on lower RHB

Site	Upstream	Downstream
WCk25	• Bank well vegetated, with *Verbena bonariensis* (Purpletop) dominating • High *Phragmites australis* cover in channel • Eucalypt regeneration on LHB • *Hypericum perforatum* present	• High cover of *Phragmites australis* in channel • Bare soil patches on LHB • Erosion has been active over the past year • Good vegetation cover on the upper banks, mainly native grasses • *Hypericum perforatum* present
WCk26	• Good vegetation cover on bank and in channel • *Phragmites australis* in channel and extending to upper bank • *Rubus fruticosus* species aggregate present on LHB	• LHB continues to erode, with evidence of wasting and run off • High cover of *Phragmites australis* in channel • LHB mostly bare due to erosion • High grass cover on upper bank
WCk27	• High cover of *Phragmites australis* in channel • RHB continues to erode, currently appears stable • Good vegetation cover on upper banks •	• RHB wasting has occurred, currently appears stable • High *Phragmites australis* cover in channel • Patches of bare soil on RHB • Debris washed up on RHB from high flow events
WCk28	• Mass wasting on LHB, bank has collapsed • Good vegetation cover on banks • High cover of *Phragmites australis* in channel • Regeneration at top of LHB	• High cover of *Phragmites australis* in channel • LHB steep with evidence of erosion over the past year • Vegetation cover on upper bank similar to last year • Erosion on RHB currently appears stable
WCk29	• Regeneration of *Angophora floribunda* on LHB • Large *Rubus fruticosus* species aggregate present on LHB • High cover of *Phragmites australis* in channel • No further erosion around exposed tree root	• Signs of recent erosion on LHB, currently appears stable • Vegetation on banks is a mix of grasses including *Themeda triandra* • High cover of *Phragmites australis* in channel • Debris washed up on LHB from high flow events
WCk30	• High cover of *Phragmites australis* in channel • Extensive wombat burrows on RHB, decreasing bank veg cover • Regeneration of *Angophora floribunda* on both banks • RHB dominated by *Lomandra confertifolia*	• Good cover of *Phragmites australis* in channel • Vegetation cover is similar to 2021, with *Lomandra confertifolia* dominating RHB • *Rubus fruticosus* species aggregate on LHB • Regeneration of *Angophora floribunda* and *Eucalyptus blakelyi* on RHB • Water ponding in channel, with no flow
WCk31	• Erosion on RHB continues with undercutting, is currently stable • High cover of *Phragmites australis* in channel • Vegetation cover on banks is similar to 2021 • Water flowing in channel	• *Phragmites australis* in channel and extending to banks • Debris from flow events present • Minor erosion on RHB, is currently stable • Regeneration of Eucalypts on RHB

Site	Upstream	Downstream
WCk32	• High cover of *Phragmites australis* in channel • RHB steep leading to exposed roots. Erosion is currently stable • Bare patches mid bank on RHB, good vegetation cover on upper and lower bank • Very large *Rubus fruticosus* species aggregate at top of RHB which extends to the lower bank	• Evidence of further erosion on RHB, currently appears stable • *Phragmites australis* in channel • RHB dominated by grasses, with cover similar to 2021
WCk33	• Vegetation is similar to 2021, with *Lomandra confertifolia* on bank • High cover of *Phragmites australis* in channel • Erosion has occurred on LHB over past year, currently appears stable • Water ponding in channel, with water level preventing access to LHB	• LHB active erosion, exposed root system with active wasting around it and patches of bare soil • Upper LHB has good vegetation cover • Good vegetation cover on RHB, dominated by *Lomandra confertifolia* • Lots of wombat burrows on RHB • Water ponding • Two trees have fallen on LHB, with one over the channel • High cover of *Phragmites australis* in channel
WCk34	• Ponding water • High cover *Phragmites australis* in channel • Some localised erosion along animal tracks • Minor erosion on RHB, vegetation is stabilising bank	• Channel vegetation remains high with dense cover of *Phragmites australis* in channel • Minor erosion on RHB over the past year with some bare patches • Overall good vegetation cover on LHB, including grasses and rushes
WCk35	• In channel veg remains high, with *Phragmites australis* present • RHB bare patches and active erosion with mass wasting, currently appears stable • Good vegetation cover on LHB and top of RHB	• Vegetation cover on RHB is similar to 2021 monitoring, and is dominated by grasses • *Rubus fruticosus* species aggregate in channel • Erosion on RHB has been active over the past year • Good vegetation cover on LHB • No tree cover in riparian zone • Good cover of *Phragmites australis* in channel
WCk36	• *Phragmites australis* present in channel • Bare patches and minor erosion on both banks, currently appears stable • RHB vegetation includes a mix of *Verbena bonariensis* and native grasses	• RHB erosion appears stable with good vegetation cover • Similar vegetation cover in channel to 2021 monitoring • No tree cover in riparian zone, with closest trees 100m downstream • Both banks dominated by *Verbena bonariensis* and grasses
WCk37	• Increase in groundcover on RHB	• Increase in vegetation cover, mainly grasses

Site	Upstream	Downstream
	• Bare soil has decreased on RHB, however there is still evidence of mass wasting • Large pile of debris from high flow events with *Phragmites australis* growing on it • LHB remains well vegetated with minor lateral erosion	• Some minor erosion on RHB over past year, but increase in vegetation cover has stabilised the bank • High cover of Macrophytes and *Juncus* sp. • Some debris present on RHB • Regeneration of Eucalypts on LHB •
WCk38	• Vegetation on banks is similar to 2021 • *Phragmites australis* on edge of channel on LHB • Ponding water • *Rubus fruticosus* species aggregate present on LHB •	• Rush species present on edge of bank • Tree has fallen and is over channel • Good vegetation cover on both banks • *Rubus fruticosus* species aggregate on LHB
WCk39	• Vegetation similar to 2021 • *Cyperaceae* sp. on edge of channel • Slow flow of water • Erosion continues to occur on LHB with evidence of run off, currently appears stable • Regeneration of Eucalypt species on both banks	• Vegetation cover on banks and in channel is similar to 2021 • Erosion on LHB has been active in past year, currently appears stable • Upper LHB is steep, however vegetation cover is assisting with stabilising • Regeneration of Eucalypts on RHB • *Rubus fruticosus* species aggregate on RHB
WCk40	• Vegetation cover on banks and in channel similar to 2021 • Regeneration of *Eucalyptus blakelyi* on both banks • LHB erosion remains stable • RHB mostly bare with unconsolidated materials • Macrophytes and *Juncus* sp. in channel • Ponding water	• Vegetation cover is similar to 2021 • Rushes and sedges present in channel • RHB bare patches with unconsolidated material • Regeneration occurring on both banks
WCk41	• RHB exposed tree roots, however vegetation cover is good and is assisting with bank stabilisation • RHB stock tracks and hoof prints • Macrophytes and *Juncus* sp. in channel • Water ponding	• Banks well vegetated • Macrophytes present within the channel • Water ponding • Stag on LHB has fallen • RHB erosion remains stable
WCk42	• Veg in channel and on banks similar to 2021 • Pugging from cattle on RHB and cattle present on LHB • LWD on LHB trapping debris from high flow events • RHB steep but appears stable	• Erosion on RHB has been active in past year, with undercutting under root system continuing • Debris on RHB from flow events • Macrophytes in channel

Site	Upstream	Downstream
		• LHB is well vegetated with regeneration of Eucalypts present
WCk43	• Vegetation in channel similar to 2021, with high cover of Macrophytes • Good vegetation cover on banks • Bare patches on LHB from erosion, currently appears stable	• Good vegetation cover in channel • LWD in channel with debris from flow events • LHB continues to be stable with good vegetation cover stabilising bank • Water flowing
WCk44	• Increase in vegetation cover on bank, bare patch on RHB is now well vegetated • *Verbena bonariensis* dominating upper banks • Exposed root system on RHB is consistent with 2021 post flow events • Slow flow of water in channel • LHB appears stable	• Vegetation cover has increased on RHB • *Phragmites australis* in channel • Lower banks dominated by *Cyperaceae* species • Water pooling • LHB exposed steep bank appears stable due to good vegetation cover
WCk45	• Vegetation cover is similar to 2021 • Water flowing in channel • LHB stable with vegetation cover improving stability • *Eucalyptus blakelyi* and *Eucalyptus melliodora* (Yellow Box) regeneration on both banks	• Vegetation cover similar to 2021, with high vegetation cover on both banks • Debris on LHB from flow events • *Rubus fruticosus* species aggregate on LHB • Regeneration of *Eucalyptus melliodora* on RHB • *Juncus* sp., Cyperaceae species and Macrophytes on edge of channel and lower bank
WCk46	• Vegetation cover in channel and on banks similar to 2021 • Water flowing in channel • Large *Rubus fruticosus* species aggregate on LHB • Animal tracks on RHB causing localised erosion •	• High vegetation cover on both banks, including *Juncus* and Cyperaceae species on RHB • Very slow flow of water • Fallen tree from LHB across channel, causing litter trap • LHB continues to be stabilised due to vegetation cover • RHB has minor erosion on steep sections following rainfall, currently appears stable
WCk47	• Vegetation cover is similar to 2021 • Erosion has continued on RHB, is currently stable • Regeneration of *Eucalyptus blakelyi* and *Angophora floribunda* on both banks • LHB is steep but stable with good groundcover • RHB good groundcover on lower bank, including *Lomandra confertifolia* and *Arundinella nepalensis* • Fence has broken	• Macrophyte habitat in channel has remained similar to 2021 • Groundcover has continued to stabilise both banks • Slow flow of water • Debris washed up from flow events

Site	Upstream	Downstream
WCk48	• Vegetation cover is similar to 2021, with good cover on both banks • Animal tracks on LHB causing localised erosion • Active erosion and undercutting under tree root on LHB, currently appears stable • Water flowing in channel	• Macrophyte habitat on edges of channel • Water flowing • Good vegetation cover on both banks with some unconsolidated material on RHB where water has flowed onto bank • LHB erosion currently stable
WCk49	• Vegetation cover on banks is similar to 2021 • LHB vegetation cover is stabilising bank • RHB lateral erosion is currently stable • *Rubus fruticosus* species aggregate on LHB • Water flowing in channel • Sediment and unconsolidated material present in channel	• Water flowing • Good vegetation cover on banks assisting with stabilising • RHB some minor erosion and bare soil due to high flow events
Cumbo Creek		
CCk1	• Vegetation cover in channel similar to 2021 • Vegetation cover on banks is similar to 2021 and is dominated by *Verbena bonariensis* and *Plantago lanceolata* (Lamb's Tongues), with native grasses also present. • Some regeneration of Eucalypts present	• Vegetation cover on bank and in channel is similar to 2021 • Bank dominated by *Verbena bonariensis* and *Plantago lanceolata*
CCk2	• Vegetation cover in channel has increased • Bank dominated by *Verbena bonariensis* and *Juncus* sp. • Erosion on bank has stabilised	• Good vegetation cover in channel and on LHB • Bare soil on RHB, erosion currently appears stable • Feral pig tracks along RHB • Cyperaceae species in channel • *Verbena bonariensis* dominating bank
CCk3	• Road to causeway continues to erode • Water lightly flowing over causeway • Increase in in stream vegetation, including *Cyperaceae* species • Good vegetation cover on banks, with a mix of native and exotic grasses	• Vegetation cover in channel has increased • Bank dominated by *Juncus* sp. and Cyperaceae species • No riparian tree cover
CCk4	• Good groundcover in channel and on banks	• Large *Rosa rubiginosa* on RHB • Site remains stable with good vegetation cover • Channel vegetation cover is high, including *Juncus* sp. and Cyperaceae species

Site	Upstream	Downstream
	• Bank vegetation is dominated by *Plantago lanceolata* and *Verbena bonariensis*, with *Sporobolus creber* (Western Rat-tail Grass) also present in high abundance • Small amount of *Hypericum perforatum* • *Rosa rubiginosa* (Sweet Briar) in channel	• Old debris washed up from high flow events
CCk5	• Groundcover on banks is similar to 2021, dominated by *Plantago lanceolata* and *Cynodon dactylon* (Couch), with small amounts of *Hypericum perforatum* also present • Bare ground on RHB	• Vegetation cover is similar to 2021 • Upper bank dominated by *Plantago lanceolata, Paspalum dilatatum* and *Cynodon dactylon*, with small amounts of *Hypericum perforatum* also present
CCk6	• Channel vegetation cover has increased, and is almost completely vegetated • Upper banks dominated by *Lomandra filiformis* (Wattle Mat-rush)	• Channel vegetation cover has increased • Vegetation cover on banks is similar to 2021
CCk7	• High increase in vegetation cover in channel and on bank • Stagnant water, not flowing • *Paspalum dilatatum* (Paspalum) dominating banks with *Juncus* sp. also present	• Ground cover increased on banks and in channel • Banks dominated by *Paspalum dilatatum* and *Verbena bonariensis* • Water stagnant, not flowing
CCk8	• High cover of *Phragmites australis* in channel • Vegetation on bank is dominated by *Paspalum dilatatum* and *Verbena bonariensis* with *Sporobolus creber* also present in high abundance • Small amount of *Hypericum perforatum* present on LHB	• High vegetation cover in channel, with *Phragmites australis, Juncus* sp., and Cyperaceae present • Good vegetation cover on banks, including *Paspalum dilatatum, Verbena bonariensis* and *Sporobolus creber* present •
CCk9	• Vegetation cover is similar to 2021, with Cyperaceae species in channel and mixed native and exotic grasses on bank	• Vegetation cover is similar to 2021 • Erosion has been stabilised by vegetation cover • Bank is dominated by grasses
CC10	• Vegetation cover is similar to 2021, with bank dominated by a mix of native and exotic grasses and Cyperaceae species • Water ponding	• Vegetation is similar to 2021, and is dominated by grasses, Cyperaceae and sedges • LHB erosion is currently stable • Water ponding

Figure 6: Location of listed weeds and feral animals along Wilpinjong Creek and Cumbo Creek

3.2. Rainfall and Flood Analysis

The total catchment area of Wilpinjong Creek upstream of the project area (from the upstream gauging station) was calculated to be 81 km^2, with the downstream catchment calculated to be 175 km^2. The Cumbo Creek catchment area (upstream of the confluence with Wilpinjong Creek) was calculated to be 70 km^2 (Barnson 2017). Both creeks are ephemeral in nature, with flow through the system limited only after prolonged and/or intense rainfall events. Information relating to the velocities of flow versus scouring potential of soils within each creek is somewhat limited. It is generally accepted that well vegetated creek banks and beds will not scour during minor storm events (i.e. a 1 in 5-year rainfall event). There were multiple significant rainfall events recorded throughout the year, as detailed in the following section.

IFD tables and graphs were produced via the BoM 2016 Rainfall IFD Data system for:

- Frequent and Infrequent events – the annual exceedance probability (AEP) provided as a percentage (Table 5 and Figure 7)
- Very frequent events – with the number of times an event is likely to occur or be exceeded within any given year (Table 6 and Figure 8)

Table 5: Rainfall depths (mm) for durations and Annual Exceedance Probabilities (AEP) for frequent and infrequent events

	Annual Exceedance Probability (AEP)						
Duration	**63.20%**	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**
15 min	12.2	13.5	17.8	20.8	23.9	28.3	31.8
30 min	16.3	18.1	23.8	27.9	32.0	37.7	42.3
45 min	18.7	20.7	27.2	31.9	36.5	42.9	47.9
1 hour	20.4	22.6	29.7	34.7	39.7	46.4	51.7
1.5 hour	22.9	25.3	33.2	38.8	44.3	51.6	57.3
2 hour	24.7	27.4	35.9	41.9	47.8	55.6	61.7
3 hour	27.7	30.7	40.2	46.8	53.4	62.2	69.0
4.5 hour	31.1	34.5	45.3	52.8	60.2	70.3	78.2
6 hour	33.9	37.6	49.5	57.8	66.0	77.4	86.4
9 hour	38.4	42.7	56.6	66.2	75.9	89.8	101
12 hour	42.1	46.9	62.4	73.3	84.3	100	114
18 hour	47.9	53.5	71.8	84.9	98.3	118	135
24 hour	52.4	58.7	79.3	94.2	110	133	153

SOURCE: BOM DESIGN RAINFALL DATA SYSTEM (2016) AVAILABLE AT: http://www.bom.gov.au/water/designRainfalls/revised-ifd/

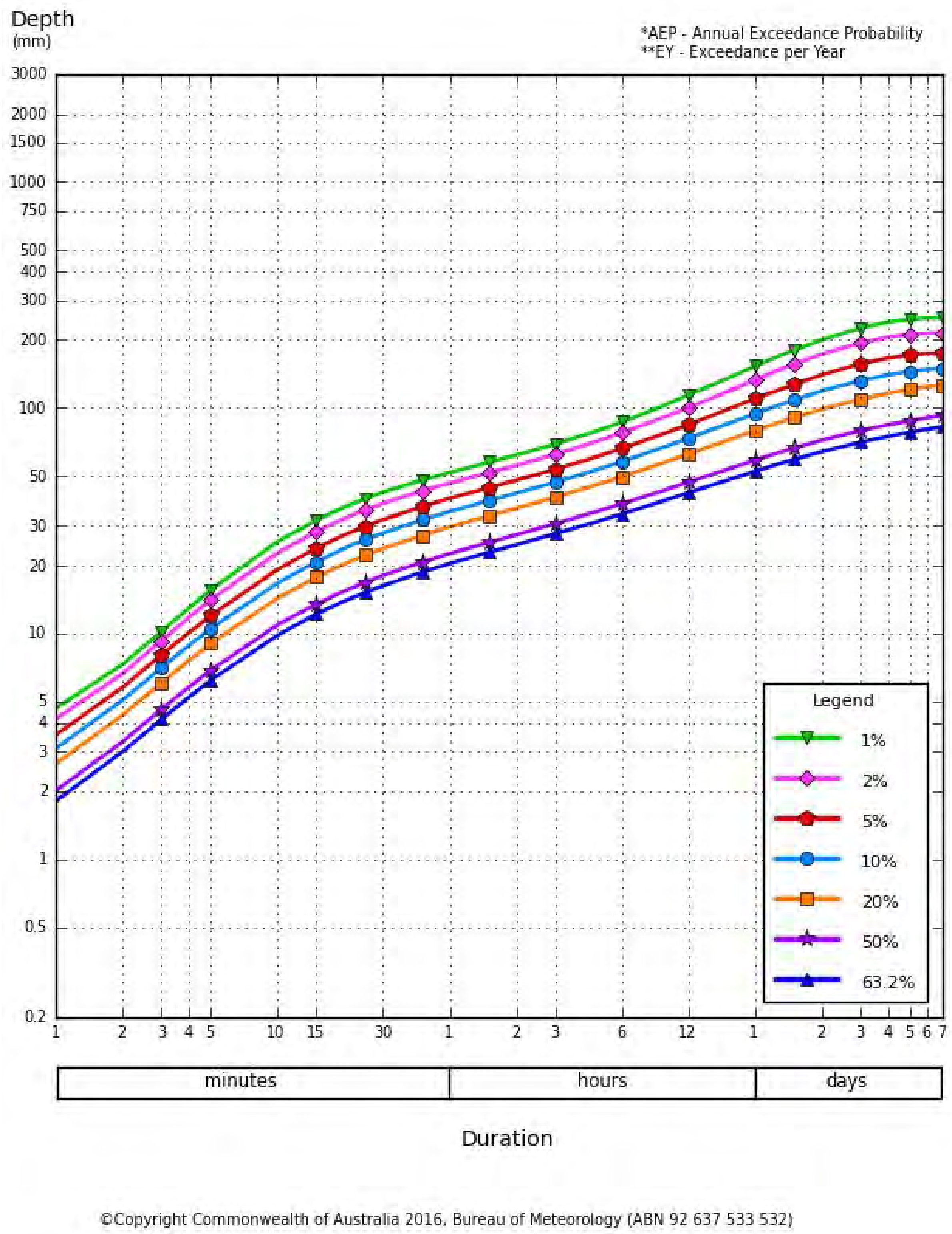

Figure 7: Rainfall depth for durations and Annual Exceedance Probabilities (AEP) for frequent and infrequent events

Table 6: Rainfall depth (mm) for durations and Exceedance per Year (EY) for very frequent events

	Exceedance per Year (EY)							
Duration	**12EY**	**6EY**	**4EY**	**3EY**	**2EY**	**1EY**	**0.5EY**	**0.2EY**
15 min	4.53	5.37	6.85	7.92	9.46	12.2	15.0	18.1
30 min	6.36	7.46	9.38	10.8	12.8	16.3	20.1	24.3
45 min	7.56	8.79	10.9	12.5	14.7	18.7	23.0	27.8
1 hour	8.46	9.78	12.1	13.8	16.1	20.4	25.1	30.3
1.5 hour	9.80	11.3	13.8	15.6	18.2	22.9	28.1	33.9
2 hour	10.8	12.4	15.1	17.0	19.8	24.7	30.4	36.6
3 hour	12.3	14.1	17.1	19.2	22.3	27.7	34.0	41.0
4.5 hour	14.0	15.9	19.3	21.7	25.1	31.1	38.3	46.2
6 hour	15.2	17.4	21.1	23.7	27.4	33.9	41.7	50.5
9 hour	17.1	19.6	23.8	26.8	31.1	38.4	47.4	57.7
12 hour	18.6	21.3	26.0	29.3	34.0	42.1	52.1	63.6
18 hour	20.7	23.8	29.2	33.1	38.5	47.9	59.4	73.2
24 hour	22.3	25.7	31.7	35.9	41.9	52.4	65.1	80.8

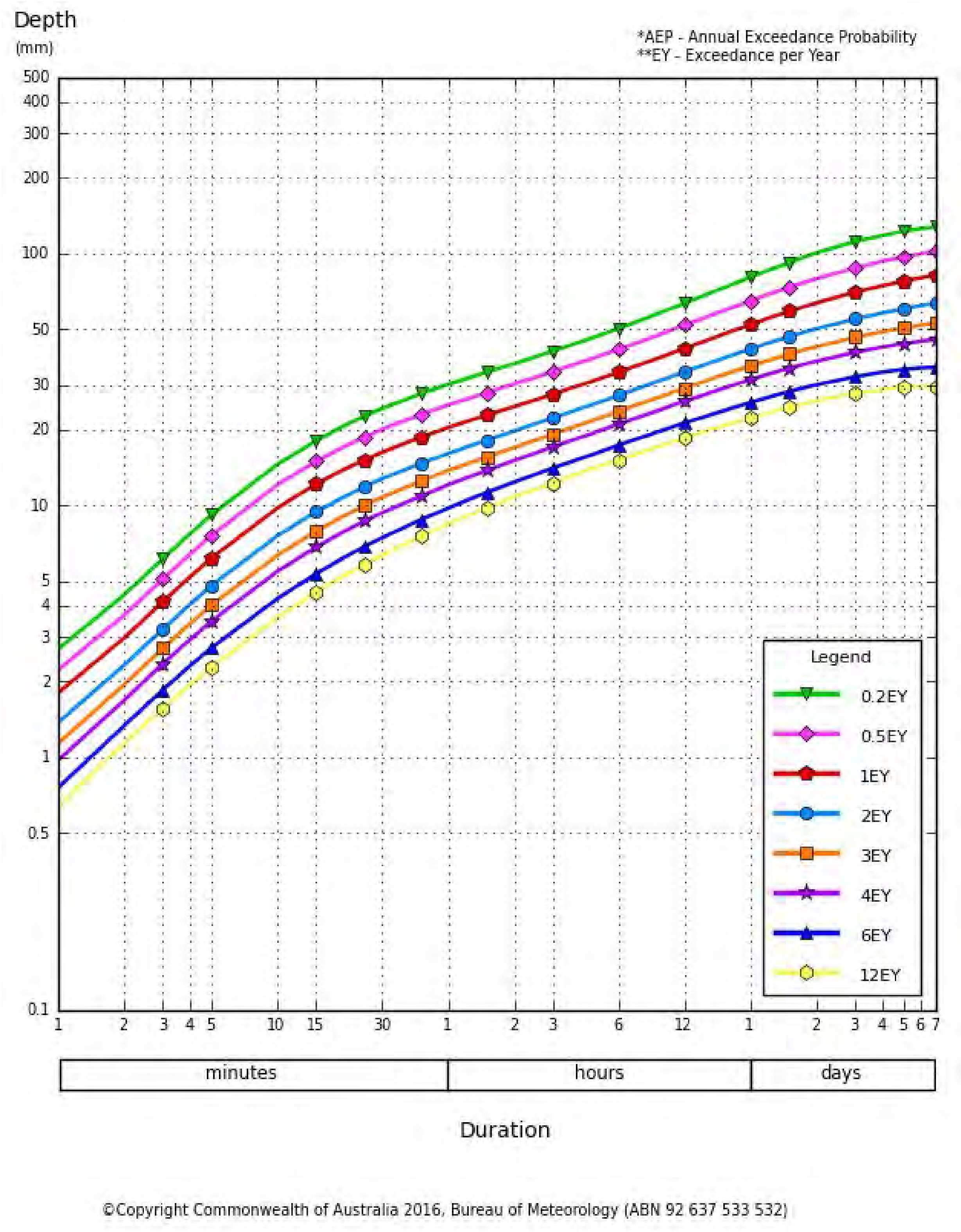

Figure 8: Rainfall depth for durations and Exceedance per Year (EY) for very frequent events

The total rainfall for the reporting period of 1 January to 31 December 2022 was calculated to be 987.2 mm, with 134 days of recorded rainfall. This annual total is greater than the previous three years, which recorded 265.6 mm, 915.8 mm, and 942.4 for 2019, 2020 and 2021 respectively. Total rainfall for the 2022 period is also above the historical mean for the region (593.8 mm as per the BoM), indicating the 2022 period was wetter than preceding years and the long-term average, like 2020 and 2021. Monthly rainfall data, provided by WCPL, is presented in Appendix C.

In review of the available 15-minute rainfall data for 2022 against the durations and AEP, the following was recorded:

- One event exceeded the 63.2% AEP. This event recorded 13.6 mm of rain between 17:00 – 17:15 on 20 October 2022.

In review of the daily rainfall data for 2022, one 63.2% AEP was recorded on 7 March 2022 with 73.8 mm over a 24-hour period.

Analysis of Exceedance per Year (EY) for very frequent events in respect to 15-minute rainfall durations, shows that 19 rainfall events were recorded above the 12 exceedances per year (greater than 4.53 mm). Of these events there were:

- Seven 12EY events
- Three 6EY events
- One 4EY event
- Five 3EY events
- Two 2EY events
- One 1EY event

On inspection of the calculated hourly rainfall data for 2022, there were 48 rainfall events recorded that fell above the 12 exceedance events per year (greater than 8.46 mm). Of these events there was:

- Nine 12EY events
- 19 6EY events
- Four 4EY events
- Three 3EY events
- Three 2EY events
- Five 1EY events
- Five 0.5EY events

The five 0.5EY events corresponds to a 1 in 2-year storm event. The five 0.5EY events correspond to a 1 in 2-year storm event. These events occurred on 1 January, 5 March, and 20 October 2022, with 25.4 mm of precipitation recorded within a one-hour period on 7 January, between 25.8 mm and 26.6 mm of precipitation recorded within a one-hour period on 5 March, and between 25.8 mm and 26.2 mm of precipitation recorded within a one-hour period on 20 October. Major increases in stream flow were recorded during the 20 October event, which is further outlined below in Table 8.

Analysis of EY for daily duration noted 12 rainfall events that fell above the 12 exceedance events per year. Of these events there was:

- Four 6EY events

- Two 4EY events
- One 3EY event
- Four 2EY events
- One 0.5EY event

Of the daily duration exceedance events listed above, one of these events occurred during successive days and equate to an expected exceedance of 96-hour rainfall duration equal to 0.5 exceedances per year (0.5EY event), corresponding to a 1 in 2-year storm event. This rainfall event was as follows:

- 3 – 5 July 2022 = 109 mm

The flow velocity of both Wilpinjong and Cumbo Creek after this significant rainfall event is detailed in Table 7 (based on flow data provided by WCPL, shown above in Figure 3 to Figure 5.

Table 7: Recorded stream flow post significant rainfall event in July 2022

Date	Upstream Cumbo Creek	Upstream Wilpinjong Creek	Downstream Wilpinjong Creek
		ML/d	
3 July	148.13	93.40	69.82
4 July	506.52	347.78	1196.98
5 July	157.88	243.11	516.14

The highest flow velocity of both Wilpinjong and Cumbo Creek was recorded between 20 – 23 October, where a 48 hr 2EY event between 7 – 8 October was followed by a 24 hr 2EY event on 20 October. The flow velocity after these rain events is detailed in Table 8 (based on flow data provided by WCPL, shown above in Figure 3 to Figure 5.

Table 8: Recorded stream flow post significant rainfall event in October 2022

Date	Upstream Cumbo Creek	Upstream Wilpinjong Creek	Downstream Wilpinjong Creek
		ML/d	
20 October	438.49	802.70	1464.49
21 October	342.76	491.05	1313.31
22 October	109.28	306.06	404.09
23 October	647.20	384.43	1184.73

Between double and triple the amount of rainfall was recorded for the four months leading up to, and including October, in 2022. This sustained, above average rainfall likely contributed to the high flow velocity recorded in the 20 October rainfall event due to high water saturation of the surrounding catchments that feed Wilpinjong and Cumbo Creeks.

The sustained above average rainfall in the lead up to October, with between double and triple the amount of rainfall recorded compared to historical means from July to October 2022

Durations of 15-min, hourly and daily levels were all recorded above the expected exceedances predicted in a 12-month period. Additionally, there was one event above the expected exceedance of 96 hr total rainfall.

4. Discussion and Recommendations

Of the 49 sites surveyed along Wilpinjong Creek, 34 sites recorded scores in the stable range, whilst 15 sites recorded scores in the unstable range (Table 2). The lowest scoring sites (all Moderately Unstable) were WCk27 and WCk42, both of which have scored Moderately Unstable since 2018 and 2017 respectively. These sites were typified by mass sediment wasting, high cover of unconsolidated material, less than 50% streambank protection and limited to no riparian woodland.

The western section of Wilpinjong Creek (incorporating WCk1 to WCk16) contains good areas of natural regeneration, with overall moderate to good riparian woodland vegetation and habitat present. There was some regeneration of *Eucalyptus sp.* recorded along the banks. Overall groundcover remained similar in 2022 compared to 2021, with stream vegetation cover of *Phragmites australis* (Common Reed) remaining consistent.

The middle section of Wilpinjong Creek (incorporating sites WCk17 to WCk44) is characterised by cleared adjacent paddocks and narrow, scattered riparian woodland (where present). Widespread historic clearing in this section of the creek has a pronounced influence on the channel stability scores, with unstable BEHI scores consistently recorded for *Established Beneficial Riparian Woody Vegetation Cover*. There was a slight increase in groundcover at some sites (although not impacting the overall score), which has assisted in stabilising erosion. A high cover of *Phragmites australis* within the channel was recorded at most sites.

The eastern section of Wilpinjong Creek (incorporating sites WCk45 to WCk49) is characterised by a relatively steep and narrow valley, which has resulted in a straight channel with an overall high bank height. All sites within this section are stable, with most sites in a moderately stable condition, in part due to the high groundcover on the banks which is assisting in stabilising the steep bank form erosion.

Of the ten sites surveyed along Cumbo Creek, all were in the Stable range, with most sites Highly Stable (

Table 3). The reach of Cumbo Creek is characterised by a shallow meandering channel with low stable banks. The adjacent paddocks have been historically cleared with only very sparse riparian vegetation woodland remaining. Despite the lack of woody riparian vegetation, the creek remains in a stable condition, primarily due to high groundcover. Groundcover species can assist in providing mid and upper bank sections with greater protection from scour, as they slow water flow close to the bank (Abernathy and Rutherford 1999).

4.1. Multi-year comparisons

Following on from the baseline channel stability assessment of Wilpinjong and Cumbo Creeks undertaken in 2005 as part of the WCPL EIS (WCPL 2005), annual monitoring has been undertaken during 2011, and 2014 – 2022. Annual monitoring since 2011 shows that the channel stability has remained relatively constant, both upstream and downstream of WCM. The following sections compare 2022 results to the results of previous monitoring years detailed above.

4.1.1. Site stability scores

Site channel stability data in the form of BEHI scores are available from 2016 – 2022 for direct comparison. Site stability ratings (based on BEHI scores) for Wilpinjong Creek sites are presented in

Table 9, with Cumbo Creek ratings presented in Table 10. Differences in ratings were only noted as 'Improved' or 'Declined' where a trend was observed over two consecutive years. If no differences were observed over three consecutive years (inclusive of 2022), the ratings were determined to be unchanged, indicating a consistent stability rating for that site. For Wilpinjong Creek, only one rating improved (WCk32) and remained unchanged at all other sites. For Cumbo Creek, ratings remained unchanged at all sites.

All sites within both Wilpinjong Creek and Cumbo Creek recorded unchanged differences in stability in 2022, largely due to the maintained vegetation growth following sustained, high rainfall conditions from 2020 through to 2022. Ten (10) sites recorded stability improvements and five sites recorded declines along Wilpinjong Creek between 2021 and 2022, however, these will be assessed in the next monitoring period to determine any three yearly differences. The mostly consistent results from 2016 to 2022 at Cumbo Creek reflects the overall stable nature of this creek, with most sites classified as Highly Stable.

Table 9: Wilpinjong Creek site stability scores 2016-2022 comparison

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	Difference
WCk1	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk2	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk3	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk4	Highly Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Unstable	Unstable	Unstable	Unchanged
WCk5	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Highly Stable	Moderately Stable	Unchanged
WCk6	Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk7	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk8	Stable	Stable	Stable	Unstable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk9	Unstable	Stable	Stable	Unstable	Stable	Stable	Unstable	Unchanged
WCk10	Highly Stable	Highly Stable	Moderately Stable	Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk11	Moderately Stable	Highly Stable	Highly Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk12	Moderately Stable	Highly Stable	Highly Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk13	Stable	Moderately Stable	Stable	Stable	Highly Stable	Highly Stable	Moderately Stable	Unchanged
WCk14	Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk15	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Unchanged
WCk16	Highly Stable	Moderately Stable	Moderately Stable	Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk17	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk18	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk19	Unstable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk20	Unstable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Stable	Unchanged
WCk21	Unstable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	Difference
WCk22	Moderately Unstable	Stable	Stable	Stable	Stable	Stable	Stable	Unchanged
WCk23	Moderately Unstable	Stable	Stable	Stable	Unstable	Unstable	Unstable	Unchanged
WCk24	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Moderately Stable	Unchanged
WCk25	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk26	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk27	Stable	Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Stable	Unchanged
WCk28	Unstable	Stable	Stable	Stable	Stable	Stable	Stable	Unchanged
WCk29	Unstable	Stable	Stable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk30	Stable	Moderately Stable	Highly Stable	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
WCk31	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk32	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Unstable	Unstable	Improved
WCk33	Moderately Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk34	Unstable	Unstable	Unstable	Unstable	Stable	Stable	Moderately Stable	Unchanged
WCk35	Stable	Moderately Stable	Stable	Stable	Stable	Stable	Unstable	Unchanged
WCk36	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk37	Stable	Stable	Stable	Stable	Unstable	Unstable	Stable	Unchanged
WCk38	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Highly stable	Unchanged
WCk39	Stable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged
WCk40	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unchanged

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	Difference
WCk41	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Unchanged
WCk42	Highly Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Unstable	Moderately Stable	Unchanged
WCk43	Not surveyed	Unstable	Unstable	Unstable	Unstable	Unstable	Stable	Unchanged
WCk44	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Highly Stable	Unchanged
WCk45	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Highly Stable	Unchanged
WCk46	Stable	Moderately Stable	Moderately Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk47	Stable	Moderately Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk48	Stable	Stable	Stable	Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
WCk49	Stable	Stable	Stable	Unstable	Stable	Stable	Stable	Unchanged

Table 10: Cumbo Creek site stability scores 2016-2022 comparison

Site	2016 Rating	2017 Rating	2018 Rating	2019 Rating	2020 Rating	2021 Rating	2022 Rating	Difference
CCK1	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK2	Moderately Stable	Stable	Stable	Stable	Stable	Stable	Stable	Unchanged
CCK3	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK4	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK5	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK6	Moderately Stable	Highly Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Moderately Stable	Unchanged
CCK7	Not surveyed	Moderately Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK8	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK9	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged
CCK10	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Highly Stable	Unchanged

4.1.2. Photographic comparisons

Photographic comparisons of sites across 2018 – 2022 monitoring are included in Appendix B. Photos taken from 2011 and 2014 – 2017 monitoring were also compared, however are not included in this report due to formatting constraints.

Comparisons indicate that there has been little observable change in the overall morphology of the stream. The level of groundcover on the banks has either remained consistent or increased slightly compared to 2021, after a clear increase in vegetation cover was recorded in 2020 compared to previous years. This is due to the sustained, above average rainfall that has occurred since 2020 (Appendix C). The high cover of *Phragmites australis* recorded within the channels and onto the adjacent banks was also maintained in 2022.

Water levels within Wilpinjong Creek were slightly higher in 2022 compared to 2021, with Wilpinjong Creek flowing retaining water and flowing throughout the majority of its reach at the time of monitoring. Water levels within Cumbo Creek were overall similar to 2021. Vegetation cover, particularly in stream vegetation, has increased within both Wilpinjong and Cumbo Creeks. *Verbena bonariensis* (Purpletop), which dominated the banks in 2021, particularly at Cumbo Creek, has decreased in cover, and has been replaced by a mix of native and exotic grasses.

The high vegetation cover and water levels visible in the site photos were observed both upstream and downstream of the WCPL water discharge location and are attributable to the above average rainfall experienced in the region over the past three years.

4.2. Erosion points

Table 11 provides photos of the significant erosion points along Wilpinjong and Cumbo Creeks (see Figure 2 above). These sites were identified as having moderate to severe historical erosion and the potential for continued erosion during times of downstream and lateral flow. Overall, further progression of erosion was seen at most points in 2022, although all were stable at the time of monitoring. Site E2 contained rills which are continuing to form on the exposed bare soil, with mass wasting also occurring. Sites E3 and E4 showed soil run off and evidence of mass wasting post high rainfall events. Site E6 showed active erosion with minor undercutting. Site E7 displayed evidence of undercutting, rilling, and mass wasting. Site E9 displayed signs of recent erosion. Site E10 showed evidence of mass wasting and bank collapse and Site E11 displayed further undercutting and rilling within the past year.

Table 11: Significant erosion points and suggested remediation works

Erosion point	Image	Notes / suggested works
E1 (768557, 6422438)		Mass wasting has occurred at top of bank. Reshaping and contouring of bank and revegetation (**Section 4.3**).
E2 (768469, 6422527)		Rills continue to form on exposed bare soil. Mass wasting has occurred, with erosion point spreading to edge of track. Revegetation and mulching (**Section 4.3**).

Erosion point	Image	Notes / suggested works
E3 (768558, 6422432)		Evidence of mass wasting at top of bank, and soil run off from rainfall events. Reshaping and contouring of bank and revegetation (**Section 4.3**).
E4 (768614, 6422382)		Mass wasting evident at top of bank, with soil run off from rainfall events. Reshaping and contouring of bank and revegetation (**Section 4.3**).
E6 (772166, 6420287)		Erosion has been active over past year, with minor undercutting. Western side of erosion point has had soil run off, with vegetation cover through the middle of the gully likely preventing further high soil run off. Reshaping and contouring of bank and revegetation (**Section 4.3**).

Erosion point	Image	Notes / suggested works
E7 (772431, 6420352)		Undercutting and rilling evident. Appears stable with some mass wasting since 2021. Revegetation (**Section 4.3**)
E8 (773014, 6420339)		Road continues to be stable, despite high rainfall. Minor erosion including undercutting on banks on both sides of the road. Continue to monitor rill.
E9 (773397, 6420376)		Water depth in channel prevented access to erosion point, with observations made from the opposite bank. Appears to have sign of erosion over past year, with a tree fallen approximately 20 m upstream from erosion point. Reshaping and contouring of bank and revegetation (**Section 4.3**).

Erosion point	Image	Notes / suggested works
E10 (773772, 6420328)		Has continued to erode, with mass wasting and further collapse of bank. Revegetation and mulching (**Section 4.3**)
E11 (771670, 6419956)		Undercutting has continued, and rills continue to form. Evidence of rainfall from rainfall events. Debris present from high flow events. Reshaping of bank, revegetation and mulching (**Section 4.3**).

4.3. Revegetation and remediation

Revegetation works were completed in 2019 by WCPL on a 1.6 km section of Wilpinjong Creek, approximately between sites WCk25 and WCk27 (see Figure 1). Revegetation was undertaken on both sides of the creek using tubestock of local native species listed in Table 12.

Further revegetation work was completed in 2020 along approximately 1.9 km of Cumbo Creek and 1 km of Wilpinjong Creek using tubestock of species listed in Table 12. Revegetation condition assessments were carried out in September and October 2020 for Wilpinjong and Cumbo Creeks. Wilpinjong Creek returned an average survival rate of 57% whilst Cumbo Creek had a survival rate of 88% (Skillset Land Works 2020). It was determined that good survival rates were influenced by the above average rainfall, although sections with lower tubestock survival rates may have been impacted by grazing pressure from native and exotic fauna. Revegetation monitoring is ongoing.

Additional revegetation work is recommended to target most of the erosion points, except for E8. Riparian vegetation can assist in stabilising banks and slowing surface runoff (Abernathy and Rutherford 1999). Sites E1, E3, E4, E6 and E9 have very steep, high banks which continue to erode, from minor activity to gully retreat and further root exposure. As these banks become higher, and the bank angle becomes greater, they continue to erode. Therefore, it is recommended that these banks are initially reshaped, to reduce the bank angle, before undertaking revegetation works. Meanwhile, with site E2 showing evidence of rilling, the application of mulch to the bank sides (including hydro-mulch) is recommended to assist stabilisation until vegetation establishes, along with the installation of coarse-rock, large-woody debris, coir logs and/or hay bale check dams to reduce water flow in designated erosion points. Mulching is also recommended for sites E2, E10, and E11 before revegetation works to assist in stabilisation. Temporary fencing works in all areas will also assist in excluding native and introduced fauna from revegetation and remediation areas.

Table 12: Native species used for Wilpinjong Creek and Cumbo Creek revegetation works

Scientific Name	Common Name
Native trees	
Angophora floribunda	Rough-barked Apple
Casuarina cunninghamiana	River Sheoak
Eucalyptus blakelyi	Blakely's Red Gum
Eucalyptus melliodora	Yellow Box
Native shrubs	
Acacia decora	Western Silver Wattle
Acacia floribunda	Gossamer Wattle
Acacia implexa	Hickory Wattle
Native ground cover	
Lomandra spp.	Mat-rush

4.4. Exclusion of livestock

Livestock (cattle) access to the riparian zone continues to impact on the overall stability and riparian health of Wilpinjong Creek. While the increase in vegetation in the surrounding area has reduced the impact of stock grazing there was evidence of stock presence observed within the eastern section of Wilpinjong Creek (incorporating sites WCk41 to WCk46), as well as the far-western section (incorporating sites WCk1 to WCk4) during 2022 monitoring. Excluding stock from the riparian zone in these areas is recommended to improve creek stability and health and assist natural regeneration.

5. Conclusion

The channel stability of both Wilpinjong and Cumbo Creeks is characteristic of ephemeral systems in agricultural landscapes, and consistent with other creeks in the surrounding region. Both creek systems exhibit characteristic channel stability issues associated with agricultural landscapes including:

- Historically cleared and degraded riparian vegetation and the presence of exotic species, including Regional Priority Weeds such as *Rubus fruticosus* species aggregate, *Rosa rubiginosa* and *Hypericum perforatum*.
- Lateral gully-erosion at several locations, as a result of increase runoff velocity occurring perpendicular to the creek line from adjacent cleared paddocks.
- Continued livestock access contributing to bank instability, reducing in-stream and riparian vegetation and hampering natural regeneration.
- Other introduced and native fauna (e.g. European Rabbit and Common Wombat) burrowing within the riparian zone.

The 2022 period recorded rainfall levels that were above the historical average, which has maintained or led to increases in groundcover, which in turn has maintained the channel stability of both Wilpinjong and Cumbo Creeks. Despite there being an increase in water flowing throughout the system during 2022 compared to 2021, there was limited further impact on stability at CSM sites, mostly contributed to the maintained vegetation growth on the channel banks. Further erosion was observed at erosion monitoring points, as a result of the high water flow and/or rainfall intensity. Flow both upstream and downstream of the WCM was similar to 2021.

Erosion and bank stability issues within the Wilpinjong and Cumbo Creeks are the result of historic agricultural practices within the riparian zone, including widespread clearing and direct stock access to the bank and channel. There is no evidence that mining activities are adversely impacting the channel stability of the target creeks surrounding the WCM.

6. References

Abernathy, B. and Rutherford, I.D. 1999. *Guidelines for stabilising streambanks with riparian vegetation.* Cooperative Research Centre for Catchment Hydrology.

Barnson 2017. *Wilpinjong and Cumbo Creek Stability Assessment, 2016*. Prepared for Wilpinjong Coal Mine.

Eco Logical Australia 2018. *Wilpinjong Coal Mine – 2017 Channel Stability Monitoring Report*. Prepared for Wilpinjong Coal Pty Ltd.

Eco Logical Australia 2019. *Wilpinjong Coal Mine – 2018 Channel Stability Monitoring Report*. Prepared for Wilpinjong Coal Pty Ltd.

Eco Logical Australia 2020. *Wilpinjong Coal Mine – 2019 Channel Stability Monitoring Report*. Prepared for Wilpinjong Coal Pty Ltd.

Eco Logical Australia 2021. *Wilpinjong Coal Mine – 2020 Channel Stability Monitoring Report*. Prepared for Wilpinjong Coal Pty Ltd.

Eco Logical Australia 2022. *Wilpinjong Coal Mine – 2021 Channel Stability Monitoring Report*. Prepared for Wilpinjong Coal Pty Ltd.

Local Lands Services 2017. *Central Tablelands Regional Strategic Weed Management Plan 2017-2022.* Local Land Services, State of New South Wales.

Local Land Services 2018. *Central Tablelands Regional Strategic Pest Animal Management Plan 2018-2023*. Local Land Services, State of New South Wales.

Skillset Land Works 2020. *Cumbo Creek Section 1 and 2 Revegetation Condition Assessment September 2020.* Prepared for Wilpinjong Coal Pty Ltd

Skillset Land Works 2020. *Wilpinjong Creek Revegetation Condition Assessment October 2020.* Prepared for Wilpinjong Coal Pty Ltd

Wilpinjong Coal Pty Limited 2005. *Wilpinjong Coal Project Environmental Impact Statement*. Prepared by Resource Strategies Pty Ltd for Wilpinjong Coal Pty Limited.

Wilpinjong Coal Pty Limited 2018. *Wilpinjong Coal Water Management Plan (Appendix 2 – Surface Water Management Plan) WI-ENV-MNP-0006.*

Appendix A – BEHI Assessment Scoring

Indicator	Measure	Score
1. Bank Height (m)	0 - 1.5	0
	1.5-3	2.5
	3-4.5	5
	4.5-6	7.5
	6+	10
2. Bank Angle (°)	0-20	0
	21-60	2
	61-80	4
	81-90	6
	91-120	8
	> 120	10
3. Percentage of Bank Height with a Bank Angle Greater than 80°	0-10	0
	11 to 25	2.5
	26-50	5
	51-75	7.5
	76-100	10
4. Evidence of Mass Wasting (% of Bank)	0-10	0
	11 to 25	2.5
	26-50	5
	51-75	7.5
	76-100	10
5. Unconsolidated Material (% of Bank)	0-10	0
	11 to 25	2.5
	26-50	5
	51-75	7.5
	76-100	10
6. Streambank Protection (% of Streambank covered by plant roots, vegetation, logs, branches, rocks, etc.)	0-10	15
	11 to 25	12.5
	26-50	10
	51-70	7.5
	70-90	2.5
	90-100	0
7. Established Beneficial Riparian Woody – Vegetation Cover	0-10	15
	11 to 25	12.5

Indicator	Measure	Score
	26-50	10
	51-70	7.5
	70-90	2.5
	90-100	0
8. Stream Curvature Descriptor	Meander	5
	Shallow Curve	2.5
	Straight	0
Site Ratings (totals)	Highly Stable	0-25
	Mod Stable	26-35
	Stable	36-45
	Unstable	46-55
	Mod Unstable	56-65
	Highly Unstable	66-85

Appendix B – Site Photo Comparisons

WCK 1


Figure B - 1: 2022 upstream


Figure B - 2: 2021 upstream


Figure B - 3: 2020 upstream


Figure B - 4: 2019 upstream


Figure B - 5: 2018 upstream


Figure B - 6: 2022 downstream


Figure B - 7: 2021 downstream


Figure B - 8: 2020 downstream


Figure B - 9: 2019 downstream


Figure B - 10: 2018 downstream

WCK 2

Figure B - 11: 2022 upstream

Figure B - 12: 2021 upstream

Figure B - 13: 2020 upstream

Figure B - 14: 2019 upstream

Figure B - 15: 2018 upstream

Figure B - 16: 2022 downstream

Figure B - 17: 2021 downstream

Figure B - 18: 2020 downstream

Figure B - 19: 2019 downstream

Figure B - 20: 2018 downstream

WCK 3


Figure B - 21: 2022 upstream


Figure B - 22: 2021 upstream


Figure B - 23: 2020 upstream


Figure B - 24: 2019 upstream


Figure B - 25: 2018 upstream


Figure B - 26: 2022 downstream


Figure B - 27: 2021 downstream


Figure B - 28: 2020 downstream


Figure B - 29: 2019 downstream


Figure B - 30: 2018 downstream

WCK 4

Figure B - 31: 2022 upstream

Figure B - 32: 2021 upstream

Figure B - 33: 2020 upstream

Figure B - 34: 2019 upstream

Figure B - 35: 2018 upstream

Figure B - 36: 2022 downstream

Figure B - 37: 2021 downstream

Figure B - 38: 2020 downstream

Figure B - 39: 2019 downstream

Figure B - 40: 2018 downstream

WCK 5

Figure B - 41: 2022 upstream

Figure B - 42: 2021 upstream

Figure B - 43: 2020 upstream

Figure B - 44: 2019 upstream

Figure B - 45: 2018 upstream

Figure B - 46: 2022 downstream

Figure B - 47: 2021 downstream

Figure B - 48: 2020 downstream

Figure B - 49: 2019 downstream

Figure B - 50: 2018 downstream

WCK 6

Figure B - 51: 2022 upstream

Figure B - 52: 2021 upstream

Figure B - 53: 2020 upstream

Figure B - 54: 2019 upstream

Figure B - 55: 2018 upstream

Figure B - 56: 2022 downstream

Figure B - 57: 2021 downstream

Figure B - 58: 2020 downstream

Figure B - 59: 2019 downstream

Figure B - 60: 2018 downstream

WCK 7


Figure B - 61: 2022 upstream


Figure B - 62: 2021 upstream


Figure B - 63: 2020 upstream


Figure B - 64: 2019 upstream


Figure B - 65: 2018 upstream


Figure B - 66: 2022 downstream


Figure B - 67: 2021 downstream


Figure B - 68: 2020 downstream


Figure B - 69: 2019 downstream


Figure B - 70: 2018 downstream

WCK 8

Figure B - 71: 2022 upstream

Figure B - 72: 2021 upstream

Figure B - 73: 2020 upstream

Figure B - 74: 2019 upstream

Figure B - 75: 2018 upstream

Figure B - 76: 2022 downstream

Figure B - 77: 2021 downstream

Figure B - 78: 2020 downstream

Figure B - 79: 2019 downstream

Figure B - 80: 2018 downstream

WCK 9

Figure B - 81: 2022 upstream

Figure B - 82: 2021 upstream

Figure B - 83: 2020 upstream

Figure B - 84: 2019 upstream

Figure B - 85: 2018 upstream

Figure B - 86: 2022 downstream

Figure B - 87: 2021 downstream

Figure B - 88: 2020 downstream

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WCK 10

Figure B - 91: 2022 upstream

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WCK 11

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WCK 12

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Figure B - 140: 2018 downstream

WCK 15

Figure B - 141: 2022 upstream

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Figure B - 150: 2018 downstream

WCK 16

Figure B - 151: 2022 upstream

Figure B - 152: 2021 upstream

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Figure B - 159: 2019 downstream

Figure B - 160: 2018 downstream

WCK 17

Figure B - 161: 2022 upstream

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WCK 18

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WCK 19


Figure B - 181: 2022 upstream


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Figure B - 190: 2018 downstream

WCK 20

Figure B - 191: 2022 upstream

Figure B - 192: 2021 upstream

Figure B - 193: 2020 upstream

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Figure B - 195: 2018 upstream

Figure B - 196: 2022 downstream

Figure B - 197: 2021 downstream

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Figure B - 199: 2019 downstream

Figure B - 200: 2018 downstream

WCK 21


Figure B - 201: 2022 upstream


Figure B - 202: 2021 upstream


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WCK 22

Figure B - 211: 2022 upstream

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WCK 23


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Figure B - 236: 2022 downstream

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Figure B - 240: 2018 downstream

WCK 25

Figure B - 241: 2022 upstream

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WCK 26


Figure B - 251: 2022 upstream


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WCK 27

Figure B - 261: 2022 upstream

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Figure B - 266: 2022 downstream

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Figure B - 268: 2020 downstream

Figure B - 269: 2019 downstream

Figure B - 270: 2018 downstream

WCK 28

Figure B - 271: 2022 upstream

Figure B - 272: 2021 upstream

Figure B - 273: 2020 upstream

Figure B - 274: 2019 upstream

Figure B - 275: 2018 upstream

Figure B - 276: 2022 downstream

Figure B - 277: 2021 downstream

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Figure B - 279: 2019 downstream

Figure B - 280: 2018 downstream

WCK 29

Figure B - 281: 2022 upstream

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WCK 30

Figure B - 291: 2022 upstream

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Figure B - 319: 2019 downstream

Figure B - 320: 2018 downstream

WCK 33

Figure B - 321: 2022 upstream*

Figure B - 322: 2021 upstream

Figure B - 323: 2020 upstream

Figure B - 324: 2019 upstream

Figure B - 325: 2018 upstream

Figure B - 326: 2022 downstream*

Figure B - 327: 2021 downstream

Figure B - 328: 2020 downstream

Figure B - 329: 2019 downstream

Figure B - 330: 2018 downstream

*Photos taken from oppostie bank due to inaccessibility

WCK 34

Figure B - 331: 2022 upstream

Figure B - 332: 2021 upstream

Figure B - 333: 2020 upstream

Figure B - 334: 2019 upstream

Figure B - 335: 2018 upstream

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WCK 35

Figure B - 341: 2022 upstream

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WCK 38

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WCK 43

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WCK 44


Figure B - 431: 2022 upstream


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WCK 45


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WCK 46


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WCK 48


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WCK 49


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CCK1

Figure B - 491: 2022 upstream

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Figure B - 495: 2018 upstream

Figure B - 496: 2022 downstream

Figure B - 497: 2021 downstream

Figure B - 498: 2020 downstream

Figure B - 499: 2019 downstream

Figure B - 500: 2018 downstream

CCK2

Figure B - 501: 2022 upstream

Figure B - 502: 2021 upstream

Figure B - 503: 2020 upstream

Figure B - 504: 2019 upstream

Figure B - 505: 2018 upstream

Figure B - 506: 2022 downstream

Figure B - 507: 2021 downstream

Figure B - 508: 2020 downstream

Figure B - 509: 2019 downstream

Figure B - 510: 2018 downstream

CCK 3


Figure B - 511: 2022 upstream


Figure B - 512: 2021 upstream


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CCK 4

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CCK 5


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CCK 6

Figure B - 541: 2022 upstream

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CCK 7


Figure B - 551: 2022 upstream


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CCK 8

Figure B - 561: 2022 upstream

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Figure B - 567: 2021 downstream

Figure B - 568: 2020 downstream

Figure B - 569: 2019 downstream

Figure B - 570: 2018 downstream

CCK 9

Figure B - 571: 2022 upstream

Figure B - 572: 2021 upstream

Figure B - 573: 2020 upstream

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Figure B - 575: 2018 upstream

Figure B - 576: 2022 downstream

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Figure B - 579: 2019 downstream

Figure B - 580: 2018 downstream

CCK 10

Figure B - 581: 2022 upstream

Figure B - 582: 2021 upstream

Figure B - 583: 2020 upstream

Figure B - 584: 2019 upstream

Figure B - 585: 2018 upstream

Figure B - 586: 2022 downstream

Figure B - 587: 2021 downstream

Figure B - 588: 2020 downstream

Figure B - 589: 2019 downstream

Figure B - 590: 2018 downstream

Appendix C – Monthly Rainfall Data

Table C - 1: Monthly rainfall from 2014-2022 (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2014	15.6	60.0	112.6	62.8	13.8	29.8	28.6	28.8	14.6	15.4	24.4	126.7	533.1
2015	127.6	11.6	9.4	108.4	42.8	42.8	38.0	53.8	7.8	61.0	59.0	118.4	680.6
2016	152.1	7.2	23.5	14.8	66.8	104.2	101.1	40.9	198.7	86.6	51.9	90.6	938.4
2017	27.8	34.2	146	23	32.4	10.4	5.8	25.2	3	28.4	92.6	102.6	531.4
2018	24.4	77	24.6	42.2	12.4	21.6	1.2	43.8	39.6	56.8	47.4	91.2	482.2
2019	54.8	7.4	108.8	0	17.6	10.6	2.6	10.2	23	5.6	22	3	265.6
2020	27.2	127	92	117	16	23.4	70	36.4	77.2	150.6	17.4	161.6	915.8
2021	52.6	126.6	159.8	1.8	9.4	84.4	66.8	25.4	44.2	40.8	249.2	81.4	942.4
2022	101.4	16	119.8	95	43.6	13	136.4	103.2	93.8	174.4	64	26.6	987.2
Historical Mean	67.2	62.6	55.1	39.3	37.2	43.8	43.0	41.1	41.9	52.2	56.5	60.7	593.8

SOURCE: WCPL WEATHER STATION SENTINEX 34, AND BUREAU OF METEOROLOGY, 2022 (HISTORICAL AVERAGES) WOLLAR (BARRIGAN STREET) WEATHER STATION NUMBER: 62032

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