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Black cockatoo habitat assessment for the Worsley Bauxite Alumina Project

Prepared for S32 Ltd

September 2023

Final

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Version history

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EXECUTIVE SUMMARY

South32 Ltd (South32) operates the Worsley Bauxite Alumina Project (the Project), located in the south-west of Western Australia (WA). Including the Boddington Bauxite, Mine (BBM) near Boddington and the Worsley Refinery (the Refinery) near Collie, WA. In February 2023, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by South32 to undertake a black cockatoo habitat assessment for the Project in the areas surrounding the Primary Assessment Area (PAA) of the BBM (the study area). The purpose of the assessment is to gain an understanding of the suitability of habitat for the 3 black cockatoo species within the study area.

Phoenix undertook black cockatoo habitat assessments over 2 weeks in May 2023. Two teams surveyed half hectare and one-hectare quadrats each throughout the study area, located in a variety of habitat types. Field teams measured all trees within the quadrat, recording all eucalypts that had a diameter at breast height (DBH) of 500 mm or more (or DBH of 300 mm or more for *E*. *wandoo* and *E*. *accedens)* as potential habitat trees (PHT). Trees were recorded on a GPS and checked for the presence of hollows, noting any evidence of hollow use. Field teams recorded opportunistic evidence (sightings, calls and foraging evidence) of black cockatoos, as well as disturbances to assess habitat quality.

Nine fauna habitats were surveyed including:

- Blackbutt woodland on lower slopes (BB)
- Marri and/or Jarrah on lower slopes (DL)
- E. rudis woodlands which may include Jarrah, Marri, Banksia and/or Wandoo (FG)
- Jarrah, Marri and/or Allocasuarina (JC)
- Jarrah and/or Marri on slopes (JM)
- Melaleuca shrublands on seasonally wet valley floors (MS)
- Melaleuca, E. rudis woodlands on seasonally wet floors (MW)
- Heath and/or perched heath (PH)
- Wandoo woodlands (WO).

Forest Red-tailed Black Cockatoo was the most frequently and widespread observed species, detected across 36 of the sampled sites and 4 distinct areas were identified as having higher concentration of activity:

- State forest along the western and south-western boundary of the study area
- Quindanning Block – immediately east of Saddleback Mine
- Mooradung Nature Reserve
- Northern part of the study area.

Carnaby's Cockatoo evidence was observed much less frequently, being recorded at 5 sites. Sightings, calls or foraging evidence of Carnaby's Cockatoo occurred centrally and in the northern part of the study area. A single opportunistic record of Baudin's Cockatoo was recorded during the survey at site Q089.

A Baudin's Cockatoo single foraging location was recorded during the survey.

A total of 138.5 ha was surveyed totalling 3,918 PHT and 903 hollows.

The data from the field survey was used to determine mean PHT density and used to extrapolate the total number of PHT across all sampled habitat types of the study area. The desktop survey estimated a total of 2,166,950 PHT over the entire 164,184 ha of the study area. Given the relatively small proportion of the total study area that was surveyed (0.08% of the study area or 0.16% of remnant vegetation within the study area), the field survey estimate of 2,369,625 supports the desktop survey estimate, although the true number of PHT across the study area could vary. The highest density of PHT per hectare, with a mean value of 34 (±7) was the WO habitat. WO was the second highest

surveyed habitat type, with a total of 41.5 ha surveyed (first being JM, 50 ha surveyed). Most other habitat types were dominated by or included Jarrah and Marri (DL, FG, BB, JC, JM, and MW). These habitat types return relatively high mean PHT densities DL 24 ±9, n = 119 PHT per hectare, FG 32 ±7, n = 48, BB 29 ±2, n = 117, JC 22 ±4, n = 476, JM 29 ±2, n = 1,456 and MW 16 ±3, n = 48 PHT per hectare. Most of these habitats were sampled over large areas including JM over 50 ha (albeit only 0.12% of the total habitat type across the study area) and JC over 22.5 ha (0.23% of the total habitat type).

None of the 903 hollows recorded were observed to be occupied by any wildlife species. Hollow Density was highest in WO habitat, with a mean hollow density per hectare of 8 ±3, n = 327. The JM habitat had the second highest density of hollows of 7 ±3, n = 352. Given the composition of the habitats, it is unsurprising that PH had the lowest mean density of hollows of 2 ±1, n = 6. Habitats that consist mostly of Jarrah and Marri had relatively consistent hollow densities ranging from 4 ±1, n = 6 and 16 (FG and BB) to 6 ±1, n = 47 (MS). It is important to consider that only a small proportion of the total habitat has been sampled (0.08% of the study area or 0.16% of remnant vegetation within the study area), therefore the mean values may differ from the true values.

Chewing around hollows both historic (old) and recent provided evidence of hollow use, and scarring provided evidence of potentially suitable hollows used by other species. The data collected from the field survey regarding evidence of hollow use falls entirely within predicted high breeding value habitat for Carnaby's Cockatoo, predominantly high breeding habitat value for Forest Red-tailed Black Cockatoo (FRTBC) and in low value breeding habitat for Baudin's Cockatoo. The desktop survey did not identify any records of breeding evidence for Baudin's Cockatoo within the study area.

Evidence of hollow use aligns with the desktop records for 3 black cockatoo roosting areas, confirmed Carnaby's Cockatoo breeding areas and unspecified black cockatoo breeding records (Figure 5 1). Based on the field survey results, 5 distinct areas appear to have a higher potential to support a breeding area, however these require further investigation to confirm whether or not black cockatoos are using these for breeding:

- the north-west corner, which is between a confirmed and unconfirmed Carnaby's Cockatoo breeding area (DBCA)
- a patch within north-east section of the study area
- central area – close to known confirmed breeding area
- Quindanning Block
- southern boundary of the study area.

Disturbance was abundant throughout the study area and has likely already reduced the availability of foraging and breeding habitat. Despite the disturbance evident, most of the impacts of these disturbances do not immediately reduce the availability of foraging habitat, PHT or hollows. Habitat critical to survival includes areas occupied by cockatoos, consists of nests, feeding and roosting locations and has natural vegetation (specifically Marri, Jarrah and Wandoo) connecting different patches of habitat (DEC 2007). For this reason, the study area has recorded high quality foraging scores for all 3 species of black cockatoo, however localised variation is likely to exist and these may be validated individually through assessment of forage species presence, density and evidence.

In summary, the field survey reflects the desktop survey estimates of PHT density, habitat quality and suitability for 3 species of black cockatoos. The estimated number of PHT across the study area from the desktop survey was 2,166,950 compared to 2,369,625 in this field survey (noting 91% of the PHT associated with this field survey are estimated). While the evidence of hollow use follows the patterns of the desktop results for black cockatoo breeding, breeding use throughout the study area is still not well understood. Given that opportunistic black cockatoo evidence was relatively widespread between sites, and that the habitat quality of the study area is high, the study area represents critical habitat for all 3 black cockatoo species.

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Description
BB	Blackbutt woodland on lower slopes
BBM	Boddington Bauxite, Mine
BoM	Bureau of Meteorology
CBME	contingency bauxite mining envelope
CD	Conservation Dependent
CL	Cleared Land
DBCA	Department of Biodiversity, Conservation and Attractions
DBH	Diameter at breast height
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DL	Marri/Jarrah on lower slopes
EMA	Extended Mining Areas
EPA	Environmental Protection Authority
EPBC	The Environment Protection and Biodiversity Conservation Act 1999
ESA	Environmentally Sensitive Areas
FG	*E. rudis* woodlands which may include Jarrah, Marri, Banksia and/or Wandoo
FRTBC	Forest Red-tailed Black Cockatoo
IBRA	Interim Biogeographic Regionalisation of Australia
JC	Jarrah, Marri and/or Allocasuarina
JM	Jarrah and/or Marri on slopes
MS	Melaleuca shrublands on seasonally wet valley floors
MW	Melaleuca, *E. rudis* woodlands on seasonally wet floors
NES	National Environmental Significance
OS	species otherwise in need of special protection
PAA	Primary Assessment Area
PH	Heath and/or perched heath
PHT	Potential habitat trees
SP	Specially protected
TEC	Threatened ecological community
WA	Western Australia
WO	Wandoo woodlands

1 INTRODUCTION

South32 Ltd (South32) operates the Worsley Bauxite Alumina Project (the Project), located in the south-west of Western Australia (WA). Including the Boddington Bauxite, Mine (BBM) near Boddington and the Worsley Refinery (the Refinery) near Collie, WA (Figure 1-1).

In February 2023, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by South32 to undertake a black cockatoo habitat assessment for the Project in the areas surrounding the Primary Assessment Area (PAA) of the BBM (the study area) (Figure 1 1). The purpose of the assessment is to gain an understanding of the suitability of habitat for the 3 black cockatoo species within the study area.

Three species of black cockatoo are present in the south-west of WA. All 3 species are protected under state (Biodiversity Conservation Act 2016; [BC Act]) and federal (Environmental Protection and Biodiversity Conservation Act 1999 [EPBC Act]) legislation:

- Carnaby's Cockatoo (Zanda latirostris) – Endangered (EN) (EPBC and BC Acts)
- Baudin's Cockatoo (Zanda baudinii) – EN (EPBC and BC Acts)
- Forest Red-tailed Black Cockatoo (Calyptorhynchus banksii naso) (FRTBC) – Vulnerable (VU) (EPBC and BC Acts).

All 3 species have been recorded within South32's projects from 1982-2023 with the FRTBC the most common of the 3, accounting for approximately half of all individuals observed and Carnaby's Cockatoo the second most prevalent species (Biostat 2020; South32 2020).

The study area is located mainly in the Shire of Boddington (76.2%) and partly in the Shires of Williams, Wandering and Collie (17.0%, 5.6% and 1.2% respectively) and the Northern Jarrah Forest Botanical Province as defined by EPA (2016b).

1.1 BACKGROUND

Worsley Alumina currently has a proposal under assessment by the EPA for a mining expansion within the Boddington Region and has other Extended Mining Areas (EMA) with conditional approval under Ministerial Statement 719. As part of the Environmental Impact Assessment process for the proposed expansion, several offset Implementation Plans have been prepared to support the Biodiversity Offset Plan. Offset Implementation Plan No. Four relates specifically to the supply and installation of black cockatoo artificial hollows. In addition, Worsley has a requirement to undertake Biodiversity Investigations as a pre-cursor to gaining access to the EMA's and these investigations include determining the suitability of habitat for the 3 black cockatoo species.

An estimated 654 high potential and actively used (confirmed) black cockatoo breeding hollows are located within the Project Area (referred to as the PAA in the Environmental Review Document). Based on this estimation, activities described within the PAA will potentially disturb up to 65 'confirmed black cockatoo breeding habitat trees' i.e., trees with hollows and evidence to suggest breeding activity and trees with suitable hollows but no evidence of breeding activity (henceforth 'breeding trees'). Hollows large enough for utilisation by black cockatoos are estimated to take 100–200 years to develop in trees impacted by fire, fungi, invertebrates, or those that are decaying or dead (DPaW 2013). Worsley Alumina has committed to avoiding >90% of confirmed black cockatoo breeding trees within the PAA and will provide artificial hollows as compensation for the residual loss (estimated to be 65 hollows) associated with the removal of black cockatoo breeding trees at a ratio of at least 3:1 and therefore has proposed to install a minimum of 200 artificial breeding hollows.

1.2 SCOPE OF WORK

The objectives of which are to determine:

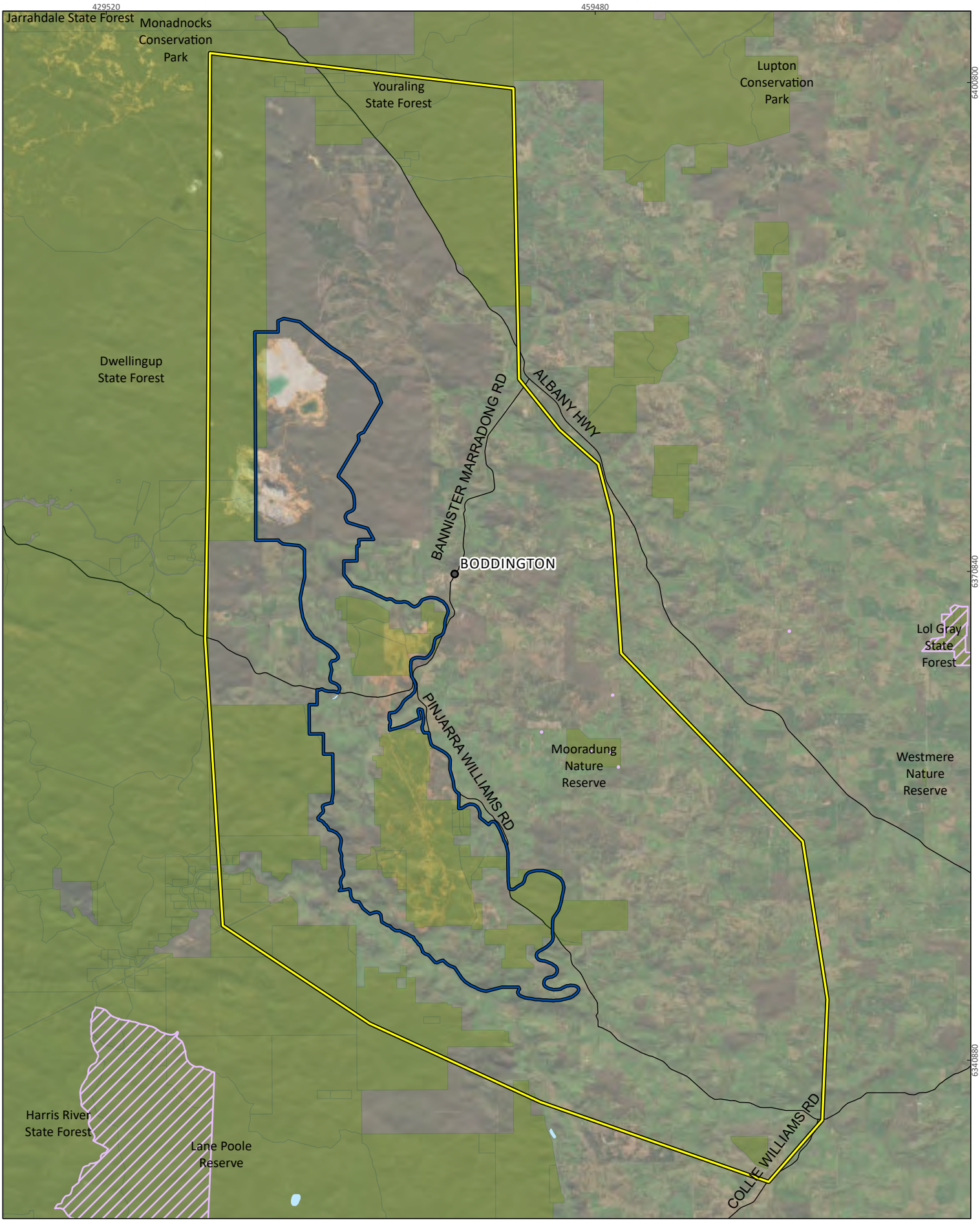
- the habitat quality available for the 3 Western Australian species of Black Cockatoo
- the density of potential habitat trees in the area
- appropriate locations for the placement of the artificial hollows.

The scope of work is therefore to undertake:

- a desktop study – where habitat condition, suitability, and density of potential habitat trees is estimated and where consideration is given to the known logging history of the area
- a field survey – to be completed over a representative area(s) to verify the habitat quality and density of habitat trees estimated in the desktop study.

1.3 STUDY AREA

The study area surrounds current operations at the BBM, the PAA and additional areas to the north, and is approximately 164,184 ha in size. (Figure 1-1).



S32
Worsley Mine Expansion

Project No	1562
Date	15/06/2023
Drawn by	BK
Map author	KF

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Kilometers

1:299,600 (at A4) GDA 1994 MGA Zone 50

- Study area
- PAA
- DBCA managed land
- Lakes
- Environmentally sensitive areas
- Roads

Figure 1-1
Project location and study area

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2 LEGISLATIVE CONTEXT

The protection of flora and fauna in WA is principally governed by three acts:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- State *Biodiversity Conservation Act 2016* (BC Act)
- State *Environmental Protection Act 1986* (EP Act).

The BC Act came into full effect on 1 January 2019 and replaced the functions of the *Wildlife Conservation Act 1950* (WC Act).

2.1 COMMONWEALTH

The EPBC Act is administered by the Federal Department of Climate Change, Energy, the Environment and Water (DCCEEW). The EPBC Act provides for the listing of Threatened flora, Threatened fauna and Threatened Ecological Communities (TECs) as matters of National Environmental Significance (NES). Under the EPBC Act, actions that have, or are likely to have, a significant impact on a matter of NES, require approval from the Australian Government Minister for the Environment through a formal referral process. Key threats and habitat critical to the survival of EPBC Act Threatened species are usually defined in the conservation advice and/or recovery plan for the species.

Conservation categories applicable to Threatened and fauna species under the EPBC Act are as follows:

- Extinct (EX)[1] – there is no reasonable doubt that the last individual has died
- Extinct in the Wild (EW) – taxa known to survive only in captivity
- Critically Endangered (CR) – taxa facing an extremely high risk of extinction in the wild in the immediate future
- Endangered (EN) – taxa facing a very high risk of extinction in the wild in the near future
- Vulnerable (VU) – taxa facing a high risk of extinction in the wild in the medium-term
- Conservation Dependent (CD)[1] – taxa whose survival depends upon ongoing conservation measures; without these measures, a conservation dependent taxon would be classified as Vulnerable, Endangered or Critically Endangered.

2.2 STATE

2.2.1 Threatened and Priority species

In WA, the BC Act provides for the listing of Threatened fauna species (Government of Western Australia 2018a, b)[2] in the following categories:

- Critically Endangered (CR) – species facing an extremely high risk of extinction in the wild in the immediate future[3]
- Endangered (EN) – species facing a very high risk of extinction in the wild in the near future[3]

[1] Species listed as Extinct and Conservation Dependent are not matters of NES and therefore do not trigger the EPBC Act.

[2] The *Wildlife Conservation (Specially Protected Fauna) Notice 2018* and the *Wildlife Conservation (Rare Flora) Notice 2018* have been transitioned under regulations 170, 171 and 172 of the *Biodiversity Conservation Regulations 2018* to be the lists of Threatened, Extinct and Specially Protected species under Part 2 of the BC Act.

[3] As determined in accordance with criteria set out in the ministerial guidelines.

- Vulnerable (VU) – species facing a high risk of extinction in the wild in the medium term future[3].

Species may also be listed as specially protected (SP) under the BC Act in one or more of the following categories:

- species of special conservation interest (conservation dependent fauna, CD) – species with a naturally low population, restricted natural range, of special interest to science, or subject to or recovering from a significant population decline or reduction in natural range
- migratory species (Mig.), including birds subject to international agreement
- species otherwise in need of special protection (OS).

The Department of Biodiversity, Conservation and Attractions (DBCA) administers the BC Act and also maintains a non-statutory list of Priority fauna. Priority species are still considered to be of conservation significance – that is they may be Threatened – but cannot be considered for listing under the BC Act until there is adequate understanding of threat levels imposed on them. Species on the Priority fauna lists are assigned to one of four Priority (P) categories, P1 (highest) – P4 (lowest), based on level of knowledge/concern.

2.2.2 Critical habitat

Under the BC Act, habitat is eligible for listing as critical habitat if it is critical to the survival of a Threatened species or a TEC and its listing is otherwise in accordance with the ministerial guidelines.

2.2.3 Other significant fauna

Under the EPA's environmental factor guidelines, fauna may be considered significant for a range of reasons other than listing as a Threatened or Priority species or ecological community.

In addition to listing as Threatened or Priority, EPA (2016a) identifies the following:

In addition to listing as Threatened or Priority, EPA (2016b) identifies the following attributes that constitute significant fauna:

- species with restricted distribution
- species subject to a degree of historical impact from threatening processes
- providing an important function required to maintain the ecological integrity of a significant ecosystem.

3 EXISTING ENVIRONMENT

3.1 INTERIM BIOGEOGRAPHIC REGIONALISATION OF AUSTRALIA

The Interim Biogeographic Regionalisation of Australia (IBRA) classifies Australia's landscapes into large 'bioregions' and 'subregions' based on climate, geology, landform, native vegetation and species information (DoEE 2016). The study area is located in the Northern Jarrah Forest subregion (JF1) of the Southwest bioregion (Figure 3-1) which is characterised as Jarrah-Marri forest over laterite gravels and Wandoo-Marri over clay soils. Agonis shrublands are situated on Eluvial and alluvial deposits. Other Shrublands rich in species diversity occur over Mesozoic sediment in the Warm Mediterranean climate (Williams & Mitchell 2001)

3.2 LAND SYSTEMS AND SURFACE GEOLOGY

DPIRD undertakes land system mapping for WA using a nesting soil-landscape mapping hierarchy (Schoknecht & Payne 2011). While the primary purpose of the mapping is to inform pastoral and agricultural land capability, it is also useful for informing biological assessments. Under this hierarchy, land systems are defined as areas with recurring patterns of landforms, soils, vegetation and drainage (Payne & Leighton 2004). The study area intersects 6 land systems (Table 3-1; Figure 3-2).

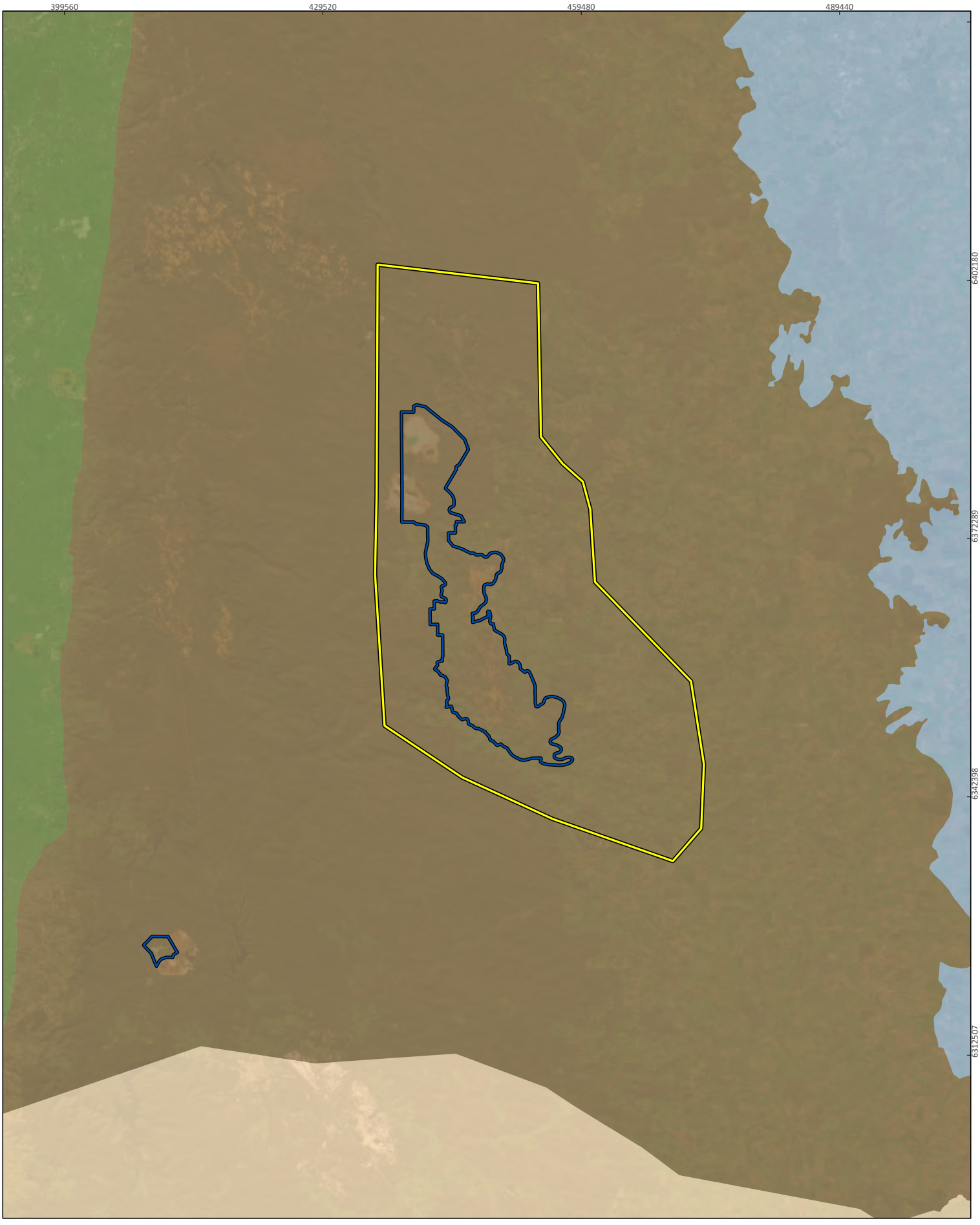
Table 3-1 Land systems and extent in study area

Land system	Description	Area (ha)	% of study area
Darling Plateau System	Lateritic plateau. Duplex sandy gravels, loamy gravels and wet soils. Jarrah-Marri-Wandoo forest and woodland.	41,236	25
Dryandra System	Gently undulating granitic terrain, in the central Zone of Rejuvenated Drainage, with deep sandy duplex, loamy duplex and brown loamy earth.	354	0.2
Marradong Upland System	Plateau remnants, in the central Eastern Darling Range, with sandy-gravel, loamy gravel, grey deep sandy duplex and loamy duplex. Jarrah-Marri-Wandoo forest and woodland.	71,494	44
Murray Valleys System	Western Darling Range from the Avon Valley to Harvey. Deeply incised valleys with Red loamy earths, shallow duplexes and rock outcrop and Jarrah-Marri-Wandoo forest and woodland with mixed shrubland.	1,866	1
Quindanning System	Deep granitic valleys, in the northern and central Eastern Darling Range, with deep sandy duplex soils, shallow sand, loamy duplex and bare rock. Marri-Wandoo-York Gum-Jam woodland.	4,7015	28.8
Wundowie System	Intact undulating lateritic terrain with minor rock outcrops in the northeastern Darling Range. "Buckshot" gravels, duricrust and some deep sands vegetated by Jarrah forest.	2,219	1

According to the Surface Geology of Australia 1:1,000,000 scale, Western Australia database (Stewart *et al.* 2008), the study area intersects 9 geological formations (Table 3-2; Figure 3-2).

Table 3-2 Surface geology of the study area, extent by deposit type

Surface geology	Abbreviation	Description	Area (ha)	% of study area
Alluvium	Qa	Channel and flood plain alluvium; gravel, sand, silt, clay, locally calcreted	3,619	2
Amphibolite	Aty	Amphibolite, mafic schist, mafic rock intercalated with granite, para-amphibolite; metabasalt, metagabbro, metapyroxenite and metadolerite; Youanmi Terrane	5,176	3.15
Colluvium	Qrc	Colluvium, sheetwash, talus; gravel piedmonts and aprons over and around bedrock; clay-silt-sand with sheet and nodular kankar; alluvial and aeolian sand-silt-gravel in depressions and broad valleys in Canning Basin; local calcrete, reworked laterite	3,862	2.35
Felsic Intrusives	Aq	Undifferentiated felsic intrusive rocks, including monzogranite, granodiorite, granite, tonalite, quartz monzonite, syenogranite, diorite, monzodiorite, pegmatite. Locally metamorphosed, foliated, gneissic. Local abundant mafic and ultramafic inclusions	89,125	54
Felsic volcanic rocks and porphyry	Afs	Plagiophyric dacite, felsic lavas and pyroclastics	2,958	2
Ferruginous duricrust	Czl	Pisolitic, nodular or vuggy ferruginous laterite; some lateritic soils; ferricrete; magnesite; ferruginous and siliceous duricrusts and reworked products, calcrete, kaolinised rock, gossan; residual ferruginous saprolite	43,711	27
Gneiss, granulite, migmatite	An	Banded granitic gneiss (monzogranitic to granodioritic), quartzofeldspathic gneiss with mafic bands, migmatite, granofels, mafic and felsic granulites, hypersthene-plagioclase-quartz granulite; schist, pelitic or mafic granofels	14,921	9
Pelitic and volcanic sedimentary rocks	Ass	Pelite, siltstone, greywacke, grit, pyroclastics	250	0.15
Sand plain	Cza	Sand or gravel plains; quartz sand sheets commonly with ferruginous pisoliths or pebbles, minor clay; local calcrete, laterite, silcrete, silt, clay, alluvium, colluvium, aeolian sand	560	0.35



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Study area
PAA

Region, subregion

Avon Wheatbelt,Katanning
Jarrah Forest,Northern Jarrah Forest
Jarrah Forest,Southern Jarrah Forest
Swan Coastal Plain,Perth

Figure 3-1
Study area in relation to IBRA bioregions and subregions

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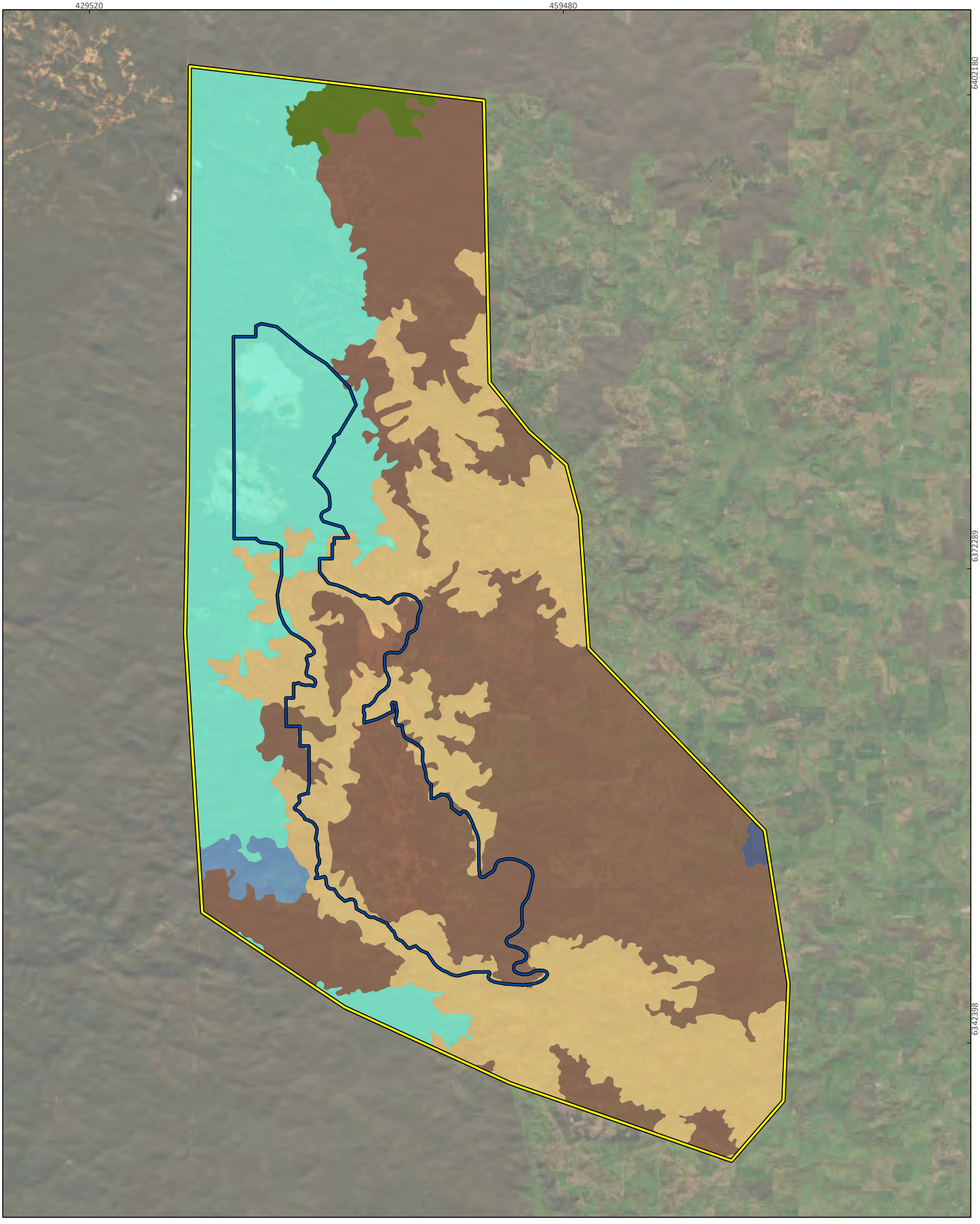

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Kilometers

1:309,000 (at A4) GDA 1994 MGA Zone 50

Study area
PAA

Land system
- Darling Plateau System
- Dryandra System
- Marradong Upland System
- Murray Valleys System
- Quindanning System
- Wundowie System

Figure 3-2
Land systems in the study area

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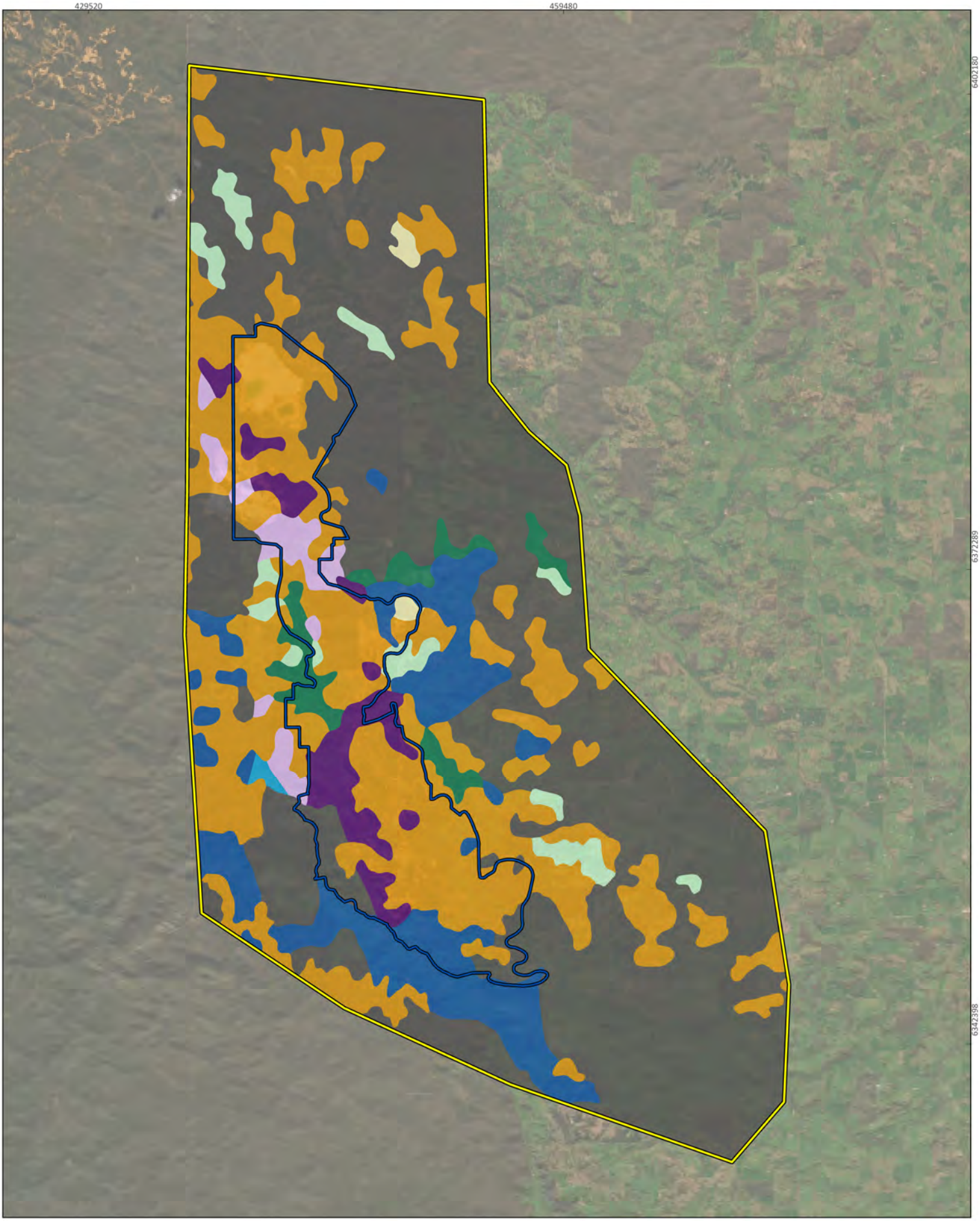

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Map author	KF

0 5 10
Kilometers

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- Study area
- PAA

Surface geology

- Afs
- Ag
- An
- Ass
- Aty
- Czl
- Czs
- Qa
- Qrc

Figure 3-3
Surface geology in the study area

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3.3 CLIMATE AND WEATHER

The climate of the Northern Jarrah Forest subregion is described as Warm Mediterranean (Williams & Mitchell 2001). The nearest Bureau of Meteorology (BoM) weather station with comprehensive data collection and recent historic climate data is Wandering (no. 010917), Latitude: 32.67°S Longitude 116.67°E), located 23 km east of the study area.

Wandering records the highest mean maximum monthly temperature (33°C) in January (lowest in July 15.8°C) and the lowest minimum mean monthly temperature (4°C) in August (highest in January, 13.8°C) (BoM 2023) (Figure 3-4).

Daily mean temperatures at Wandering preceding the surveys were beginning to decrease over the proceeding months. During the survey period, daily minimum temperatures were lower than the mean minimum of 4.7 degrees and ranged from -1.5 to 11.6 degrees (BoM 2023). The daily maximum temperatures during the survey period were much less variable than the minimum temperatures, ranging from 15.5 to 22.4 degrees (BoM 2023), and the monthly average high temperature was 19.4 degrees (Figure 3-4).

Records from Wandering show relatively high total rainfall for the months preceding the survey period (March, 90.6 mm and April, 97.2 mm). While March and April had considerably high total rainfall, the mean rainfall was much lower at 20 mm and 28.8 mm respectively. Indicating that March and April likely received a small number of days with very high amounts of rain. Total rainfall for the month of May was substantially lower, with a total rainfall of only 4.4 mm. During the survey period, rain occurred once (24/05/2023) and only 1.8 mm of rain was recorded in Wandering (Figure 3-4).

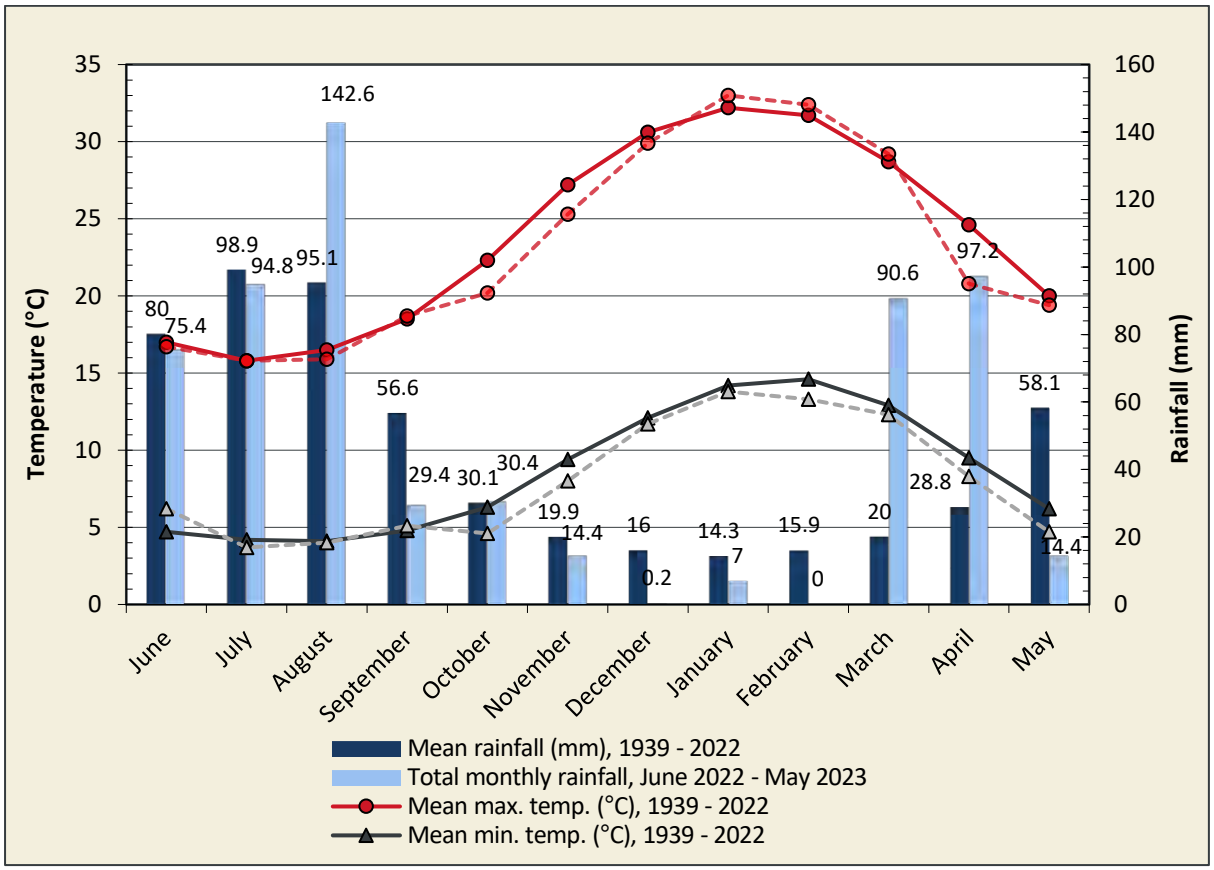


Figure 3-4 **Annual climate and weather data for Wandering (no. 010917) and mean monthly data for the 12 months preceding the survey (BoM 2023)**

3.4 LAND USE

Northern Jarrah Forest is predominantly native forest, improved pasture grazing, conservation estate, dry land agriculture, forest plantations and mining. There are also areas of rural residential estates, road easements, powerlines, and urban residential estates.

The study area is compromised of a variety of different land uses including, forest plantations, agriculture, conservation estate and mining.

3.5 CONSERVATION RESERVES AND ESAS

Multiple conservation reserves and ESA are located close to the study area and within the study area (Table 3-3). These have been listed below (Figure 1-1). These areas are likely to be used by black cockatoo species utilising nearby resources.

Table 3-3 Reserves and ESAs in proximity to the study area

Name/ ID	Distance from study area	Purpose
O 148 25	Inside study area	Timber reserve
O 147 25	Inside study area	Timber reserve
O 148 25	Inside study area	Timber reserve
O 171 25	Inside study area	Timber reserve
O 69 25	Intersecting study area	Timber reserve
O 160 25	6 km east of study area	Timber reserve
R 4596	6 km west of study area	Timber and parklands
R 43202	Inside study area	Protection and use of geodetic survey mark
Moonadnocks Conservation Park	10 km north of study area	Conservation and alumina refinery use
Lane Poole Reserve	Intersecting most of the south-western boundary of the study area	Conservation, recreation and the enjoyment of the natural environment
Lavender Nature Reserve	Inside study area	Conservation of flora and fauna
Mooradung Nature Reserve	Inside study area	Conservation of flora and fauna
Dwellingup State Forest	Intersecting most of the western boundary of study area	State forest
Jarradale State Forest	<2 km from study area	State forest
Youraling State Forest	Intersection north-east boundary of study area	State forest
Harris River State Forest	Intersecting south-west boundary of study area	State forest
14339	8 km south-west of study area	ESA
19947	Inside study area	ESA
19949	Inside study area	ESA
19953	Inside study area	ESA
19954	Inside study area	ESA
19956	Inside study area	ESA
19964	9 km north-east of study area	ESA

4 METHODS

The black cockatoo habitat assessment survey was conducted in accordance with relevant survey guidelines and guidance, including:

- EPA Environmental Factor Guideline: Terrestrial fauna (EPA 2016b)
- EPA Technical Guidance: Terrestrial fauna surveys (EPA 2016d)
- Referral guidelines for 3 WA Threatened black cockatoo species Carnaby's Cockatoo (Zanda latirostris), Baudin's Cockatoo (Zanda baudinii) and the Forest Red-tailed Black- cockatoo (Calyptorhynchus banksii naso) (DAWE 2022).

4.1 DESKTOP REVIEW

Searches of several biological databases were undertaken to identify and prepare lists of significant flora, vegetation and fauna that may occur within the study area. A literature search was conducted for accessible reports for biological surveys conducted within 20 km of the study area to build on the lists developed from the database searches.

- DBCA Threatened and Priority Fauna Database (DBCA 2023)
- Atlas of living Australia (ALA 2023)
- Carnaby's Cockatoo unconfirmed breeding areas (DBCA 2019c)
- Carnaby's Cockatoo unconfirmed roost areas (DBCA-051) (DBCA 2018b)
- Carnaby's Cockatoo confirmed breeding areas (DBCA 2019c)
- Carnaby's Cockatoo confirmed roost areas (DBCA-051) (DBCA 2018a)
- Black cockatoo breeding sites buffered (~1km radius) (DBCA 2019a)
- Black cockatoo roosting sites buffered (~1km radius) (DBCA 2019b)
- Newmont habitat tree and nest box monitoring (unpublished data)
- Phoenix internal database (Phoenix 2023b)
- Black cockatoo habitat, and flora and vegetation assessments of the Quindanning potential offset site Phoenix (Phoenix 2015)
- Biological survey for Albany Highway Realignment 63.4–66.87 SLK (Solus Road Project)(Phoenix 2019).

In addition to database searches, the desktop review also included habitat mapping, foraging habitat value determination and breeding habitat value determination (Phoenix 2023a). The findings in the desktop review have been summarised in Phoenix (2023c). Where relevant, the desktop review sections will be included to support fieldwork findings.

4.1.1 Habitat mapping

The following spatial datasets are used to determine habitat type and extent within the study area:

- Mattiske vegetation mapping (Mattiske 2020)
- Land Systems (geology, landform, soils, vegetation) (Payne & Leighton 2004)
- Heddle et al. (1980) vegetation complexes(Mattiske & Havel 1998)
- Native vegetation extent (DPIRD_005) (extent of clearing and regrowth) (DPIRD 2020)
- Previous vegetation and habitat mapping (Phoenix jobs 1097, 1231, 1294, 1337, 1482, 1506; various amounts of overlap and ground-truth detail, some from Mattiske etc.)

- Drinking habitat (water features, streams/pools/dams) (DPIRD 2022; Geoscience Australia 2020)
- Dieback Risk Areas (DRA).

The habitat datasets were combined to create a single layer containing all boundaries and non-redundant fields from previous mapping of habitat, vegetation type and extent.

Fauna habitat codes as applied by Phoenix (Phoenix 2021, 2023a) based on Mattiske vegetation mapping (Mattiske 2020) for available areas of the study area formed the basis of habitat types. The Mattiske vegetation mapping formed the majority of the study area. The fauna habitat codes were extrapolated to the remainder of the study area based on vegetation descriptions of datasets used.

Where detailed surveys of potential habitat trees have been carried out previously (Phoenix 2021), the number of trees were calculated and then converted to density (trees per ha) and extrapolated to polygons that haven't previously been surveyed, to map estimated habit tree density across the whole area.

4.1.2 Foraging habitat determination

To the extent possible, data from the above layers are used to apply the Foraging quality scoring tool from the black cockatoo referral guidelines (DAWE 2022a) for each of the 3 species, to each polygon distinguished in any of the previously mapped habitat areas, including Heddle vegetation types, comprising the whole study area.

Accordingly, each habitat within the study area was assessed for black cockatoo species using the foraging habitat quality scoring tool in the guidelines to determine the quality of foraging habitat present for each species. The scoring tool considers the following:

- Presence of feeding evidence
- Vegetation present in the surrounding area, i.e. within 12 km, including proximity to any breeding habitat, roosting sites or watering points
- Presence of disease, such as dieback (Phytophthora spp.) or Marri canker.
- DAWE (2022c) states that the scoring tool for foraging habitat quality assessment should be applied once to the entire impact area of a proposed action, except where the impact area includes more than one location.

4.1.3 Breeding habitat determination

Breeding habitat value determination followed the methods adopted by Phoenix (2021) where the following criteria were used (where it has been assumed that all remnant vegetation provides foraging habitat, including rehab of age >6 year; and whereby all potential breeding habitat is either within foraging habitat or within very close proximity to foraging habitat, i.e. within 6km of foraging resource):

- High – vegetation complex/vegetation type or fauna habitat has been recorded within the JAF01 to contain trees with confirmed breeding trees, or trees with breeding evidence close to water and foraging habitat
- Medium – vegetation complex/vegetation type or fauna habitat has been recorded within the JAF01 to contain trees with breeding evidence, but no confirmed breeding
- Low – contains trees (dominant or otherwise) known to be used by black cockatoos within the JAF01 for breeding above the DoEE (2017) potential habitat tree criteria (> 300/500mm)
- None – vegetation complex/vegetation type or fauna habitat contains no trees known to support breeding.

4.2 FIELD SURVEY

4.2.1 Site selection

Survey locations were determined using the desktop review habitat mapping (Phoenix 2023c). Of the 12 remnant habitat types identified in the desktop review, 9 were sampled during the survey (Table 4-1; Figure 4-1). Due to limitations outlined in section , some of the less abundant habitat types were not able to be surveyed Table 4-1. Quadrats were identified to cover a substantial extent of the study area, as well as a variety of habitat types. At each site, a 0.5 or one-hectare quadrat was used to measure all PHT within the quadrat and record any hollows present (4.3.2). A total of 172 sites were surveyed totalling 138.5 ha.

Table 4-1 Summary of number of survey sites per habitat

Habitat code	Habitat description	Number of sites surveyed	% of study area
BB	Blackbutt woodlands on lower slopes	4	0.20%
CL	Cleared land	0	43.60%
DL	Marri/Jarrah on lower slopes	6	0.80%
DM	Dam/Open Water Body	0	<0.1%
FG	*E. rudis* woodlands which may include Jarrah, Marri, *Banksia* or Wandoo. Riparian community	2	0.9%
FG/DL	Mosaic of Marri and/or Jarrah on lower slopes and E. rudis riparian community	0	<0.1%
JB	Jarrah and/or Marri valley floors/swamp	0	0
JC	Jarrah/Marri/Allocasuarina	27	6.10%
JM	Jarrah/Marri on slopes	66	24.70%
ML	Mallee	0	<0.1%
MS	Melaleuca shrublands on seasonally wet valley floors	11	1.60%
MW	Melaleuca, E. rudis woodlands on seasonally wet valley floors	2	1.00%
PH	Heath and/or perched heath	3	0.30%
WO	Wandoo woodlands	51	14.20%
PL, PL - Ag	Palntations	0	4.60%
RE	Rehabilitation	0	2.00%
Total		172	100%

4.2.2 Habitat assessment

Breeding habitat for WA's 3 Threatened black cockatoo species consists of woodland or forest; however, they will also breed in areas of former woodland or forest habitats which consist of now fragmented patches of habitat and/or isolated trees (DAWE 2022). Breeding habitat includes species that have suitable nest hollows for breeding or have a sufficient diameter at breast height (DBH) to develop a nest hollow (DAWE 2022). Depending on tree species, the minimum suitable DBH ranges between 300 mm (*Eucalyptus accedens* (Powderbark Wandoo), *Eucalyptus salmonophloia* (Salmon Gum) and *Eucalyptus wandoo* (Wandoo)) and 500 mm (all other species). Known breeding tree species

in the Northern Jarrah Forest bioregion include *Corymbia calophylla* Marri, *E. marginata* Jarrah, E. *rudis* Flooded Gum, *E. diversicolor* Karri, E. *megacarpa* Bullich, and *E. patens* Blackbutt.

At each quadrat, all PHTs were recorded, including any hollows present (4.2.2.2), as well as habitat assessments (4.2.2.1) and opportunistic sightings (4.2.3). These indicators, as well as site observations and the desktop review results, can be used to score the habitat foraging quality (DAWE 2022).

4.2.2.1 Site description

Site descriptions included dominant vegetation types, signs of disturbance such as weeds, vehicle tracks, logging, and fire history, soil type and depth, rock type, leaf litter abundance etc., to determine the quality of habitat at each location.

4.2.2.2 PHT and hollow records

The recording of habitat trees was used to extrapolate and estimate the density of habitat trees over the study area where practical. Density was calculated by mean PHT and hollows per hectare of each habitat type.

The location of all PHT trees for black cockatoo species was recorded using the GIS Pro on iPhone or iPad tablets. Tree species identifications were conducted in the field using tree descriptors (such as fruit/nuts, bark, and photographs. Trees that met the required DBH measurement were inspected for hollows and were assessed for any suitability of nesting and/or roosting. The number of hollows at each tree was recorded and if evidence of usage was observed. Evidence of breeding does not confirm a black cockatoo breeding events, as these may be signs of prospecting or may have been created by other species of parrots e.g. galahs, however they do indicate a suitable hollow. The following evidence of breeding was noted at each potentially suitable hollow:

- chewing (fresh)
- chewing (old)
- scarring below hollow
- presence of black cockatoos pairs in or very close to a hollow.

4.2.3 Opportunistic observations of black cockatoo species

Opportunistic observations of black cockatoos and secondary evidence such as foraging, roosts or feathers were recorded.

4.2.4 Survey timing

The field survey was undertaken 15th to 26th May 2023.

4.2.5 Survey personnel

The personnel involved in the surveys are listed in Table 4-2. At any one time during the survey period, 2 teams of 2 were completing the survey simultaneously.

Table 4-2 Survey personnel

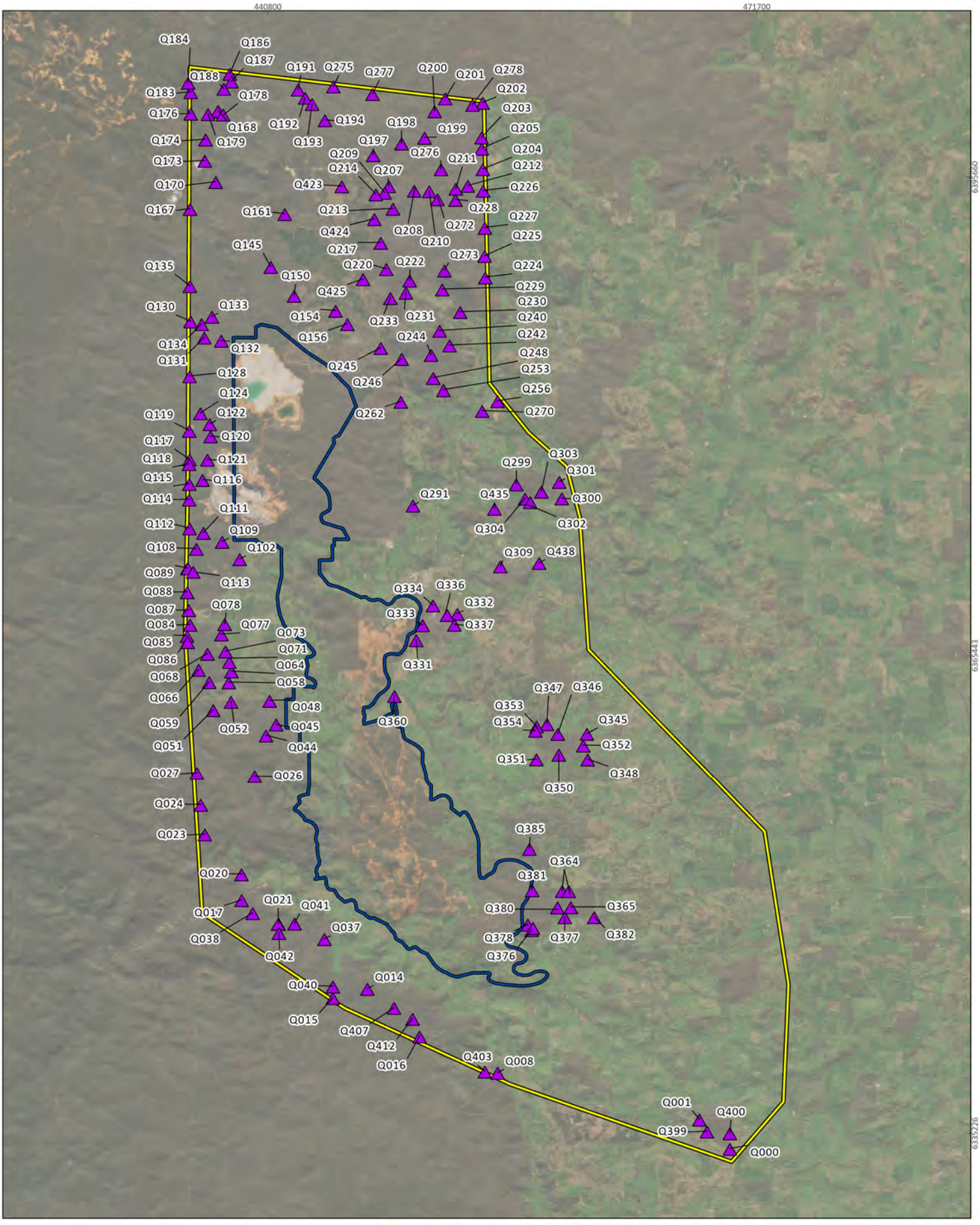
Name	Qualifications	Role
Anna Jacks	BSc Env. Science, Env. Biol. (Hons)	Project Management and Field Survey

Name	Qualifications	Role
Kerryn Fox	MSc Wildlife Health and Cons., BSc Cons. Wildlife Biol. and Marine Biol.	Field Survey
Paula Strickland	MSc Tropical Biol. and Cons., BSc Zoology and Cons. Biol.	Field Survey
Brendan Thomson	BSc Env. Management and Planning	Field Survey
Patrick Williams	MSc, BSc Cons. Wildlife Biol. and Marine and Freshwater Biol.	Field Survey
Sarah Woodiss-Field	BSc Cons. Biol. and Zoology	Field Survey

4.2.6 Analysis

After completion of the field survey, the raw data was reviewed, checked for quality assurance and used for analysis. Potential habitat trees were totalled for each habitat type and used to calculate the mean number of PHT per hectare in each habitat type. By using the mean PHT value for each habitat type to multiply across the entire extent of each habitat type within the study area, PHT within the entire study area could be calculated. The same method was applied to calculate the mean number of hollows in each habitat type and extrapolated across the entire study area. Mean values for both PHT and hollows were calculated, as well as standard errors to account for sample bias. Habitat quality was determined using the foraging scoring tool outlined in the referral guidelines (DAWE 2022) accounting for the recorded disturbances throughout the study area.

Given that the survey sites did not fall in the PAA, no separate PAA analysis has been included. This information was then used to extrapolate and estimate the number of PHT and hollows over the entire study area. Where habitat types were not able to be surveyed, no extrapolations of PHT or hollows were possible.



S32
Worsley Mine Expansion

Project No	1562
Date	26/06/2023
Drawn by	BK
Map author	KF

0 5 10
Kilometers

1:309,000 (at A4) GDA 1994 MGA Zone 50

Study area
PAA
Survey sites

Figure 4-1
Survey sites

PHOENIX ENVIRONMENTAL SCIENCES

5 RESULTS

5.1 DESKTOP RECORDS

The study area is within the modelled distribution for Carnaby's Cockatoo (*Zanda latirostris*; EN), Baudin's Cockatoo (*Zanda baudinii*; EN), and Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*; VU). Specifically, it is also within the modelled breeding range for Carnaby's Cockatoo and FRTBC (DAWE 2022) and is at the northern extent of the southern breeding range of the Baudin's Cockatoo. A thorough review of black cockatoo breeding and breeding habitat quality within the PAA was previously undertaken (Phoenix 2023a).

The desktop review identified records of all 3 black cockatoo species within the desktop search extent. Records occur throughout the study area with the highest concentration being in and around the Saddleback mine area, Boddington Gold Mine area, and north and west of the Boddington Gold Mine (Figure 5-1a-c). Black cockatoo records are scattered in the eastern part of the desktop search area and are sparse within the southern part of the desktop search area.

Forest red-tailed black cockatoo records are the most common species, with most records consisting of direct sightings. One record of breeding occurs approximately 12 km west of the study area from within a natural nesting hollow (Phoenix 2023b), and at least 3 records of breeding occur within south-eastern portion of the PAA (Phoenix 2023b).

Carnaby's cockatoo is well represented within the desktop search area, with the majority of records within the northern half. Two records of breeding are known from withing the study area from natural nest hollows. Confirmed and unconfirmed breeding sites mapped by DBCA suggest that more breeding sites are known within and immediately north-west of the study area, however their known breeding range is thought to extend as far as Dongara to the north, south-east to Hopetown, and south-west to Margaret River (DAWE 2022b). At least 3 confirmed records of breeding within the study area occur approximately 2 – 5 km east of the Newmont Gold Mine (Biostat 2021). Documented roost sites for Carnaby's cockatoo primarily occur on the swan coastal plain and eastern and western periphery of the Jarrah forest (Figure 5-1a-c) with the closest confirmed roost site being on the eastern edge of the study area. It is likely more roost sites occur within less populated areas of the desktop search area.

Baudin's cockatoo has the fewest records within the desktop search area, however records of this species are evenly distributed within the desktop search area. At least 2 records of breeding occurs within the study area, one fledgling was observed within the southern portion of the PAA and one approximately 5 km west of the PAA (Biostat 2021). Known breeding areas for Baudin's cockatoo occur south of Collie; it is thought this species breeds in higher rainfall areas (DAWE).

Habitat surveys undertaken in the PAA by Phoenix (Phoenix 2021) comprising of 180 one hectare quadrats in 2021 recorded 7 trees with suitable hollows containing evidence of breeding such as chew marks around the hollow entrance, however breeding has not been confirmed. Of these, 4 are located within close proximity to each other and if confirmed, may represent a breeding area.

An additional 10 breeding locations from unspecified species are recorded within the PAA (S32 monitoring data) (Figure 5-1a-c)., many of which are located in a DBCA Timber Reserve O 25 171. According to DBCA black cockatoo roost sites spatial dataset (DBCA 2019b), roosts are relatively common throughout the swan coastal plain and along the periphery of the forest areas in the south-west. Concentrations of roost sites appear in developed areas (e.g. Perth metro area, Bunbury, Dunsborough and Margaret River), however it is likely observations of roosts are higher in developed areas due to higher rates of reporting rather than roosts not occurring in un-developed areas.

5.2 HABITATS

A total of 12 habitat types were identified in the study area consisting of native and remnant vegetation (Table 5-1). Collectively, these occupy 49.7% of the study area, with the remaining 50.3% comprising of cleared land (43.6%), rehabilitation (2.1%), plantation (4.6%), and dams/water (<0.01). Of the 12 habitats, Jarrah and Marri on slopes is the most common (24.7%), followed by Wandoo woodland (14.2%). A further 5 habitats contain Jarrah and/or Marri as a dominant species (along with other species) and/or on differing topologies such as a valley. Other habitat types include perched heath (typically around granite outcrops), Mallee, Melaleuca, and/or Flooded Gum valley floors, and Blackbutt woodlands (a e -1; Figure -2).

Evidence of breeding of all 3 black cockatoo species occurs within the desktop search area, with FRTBC being the most common. Breeding habitat value was determined during the desktop review (Phoenix 2023a) and found the following key components:

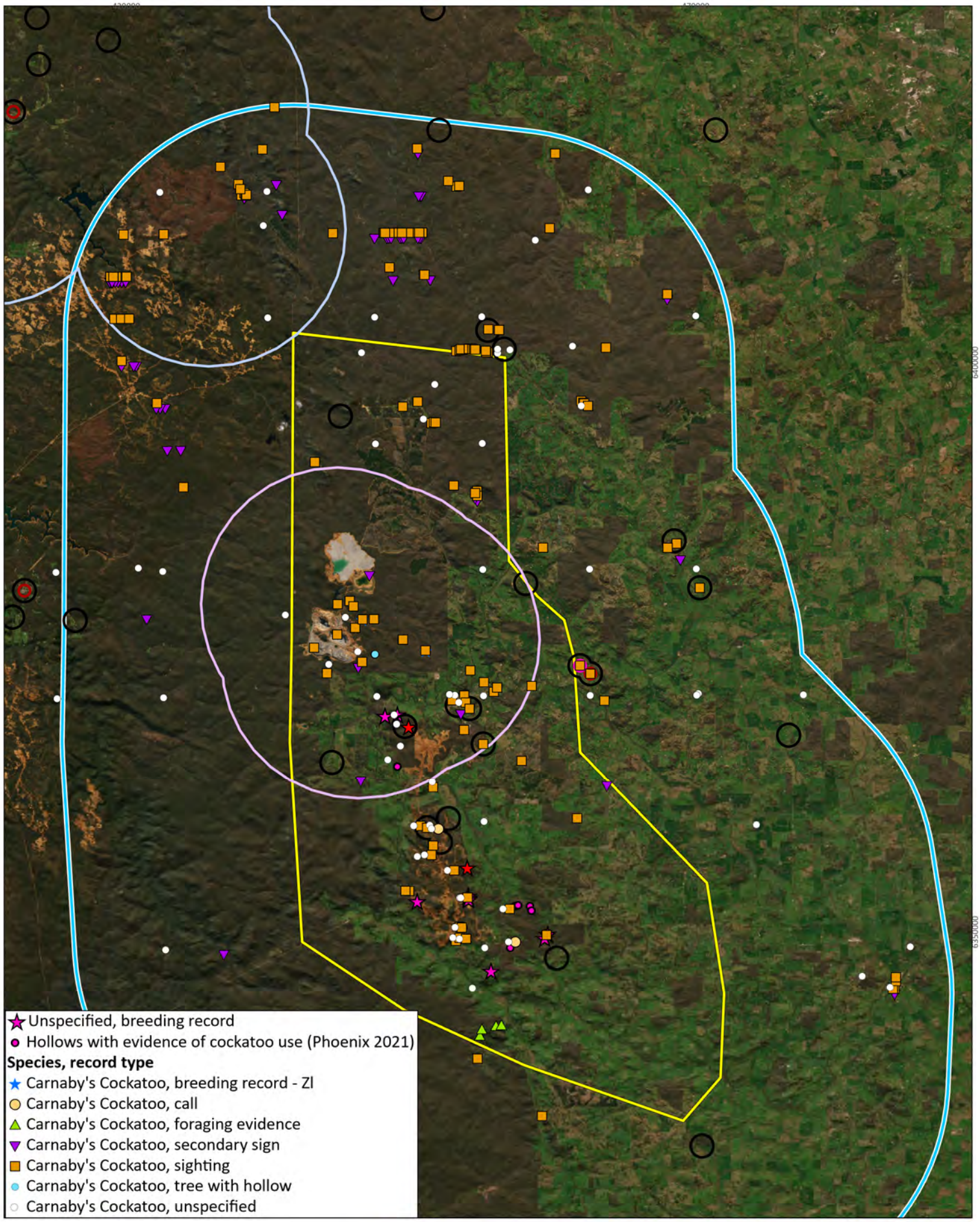
- Approximately 78,472.40 ha (47.8%) of the study area is considered to have breeding potential for Carnaby's Cockatoo, of which 74,960 ha is considered high value
- Baudin's Cockatoo breeding habitat within the study area comprises of 76,782 ha of low value habitat
- FRTBC breeding habitat occupies 76,782.10 ha within the study area, of which 51,730.70 ha is considered high value breeding habitat

Carnaby's Cockatoo and FRTBC are well known to breed within the study area.

Table 5-1 Extent and description of each fauna habitat in the study area and predicted PHT density

Fauna habitats (Biostat 2021)	Extent in study area (ha)	% of study area	Extent within the PAA*	PHT density within the PAA (stem/ha)*	Estimated no. of PHTs within the study area
Blackbutt woodlands on lower slopes (BB) Blackbutt woodland on lower slopes (BB)	321	0.2%	0.4%	41	13,205
Cleared Land (CL)	71,60	43.6%	20.9%	0	0
Marri and/or Jarrah on lower slopes (DL)	1,254	0.8%	1.5%	23	28,710
Dam/Open Water Body (DM)	5	<0.1%	0.2%	0	0
E. rudis woodlands which may include Jarrah, Marri, *Banksia* or Wandoo. Riparian community (FG)	1,500	0.91%	2.4%	29	43,070
Mosaic of Marri and/or Jarrah on lower slopes and *E. rudis* riparian community (FG/DL)	5	<0.1%	0%	0^	TBC
Jarrah and/or Marri valley floors/swamps (JB)	18	<0.1%	0%	0^	TBC
Jarrah, Marri and/or Allocasuarina (JC)	9,918	6.1%	17.7%	24	234,064
Jarrah and/or Marri on slopes (JM)	40,541	24.7%	12.0%	3	1,216,230
Mallee (ML)	16	<0.1%	<0.1%	15	236
Melaleuca shrublands on seasonally wet valley floors (MS)	2,563	1.6%	0.5%	8	20,504
Melaleuca, E. rudis woodlands on seasonally wet floors (MW)	1,690	1.0%	0	0^	TBC
Heath and/or perched heath (PH)	525	0.3%	0.4%	0	0
Plantations (PL, PL - Ag)	7,505	4.6%	0.8%	0	0
Rehabilitation (RE)	3,491	2.1%	10.8%	0	0
Wandoo woodlands (WO)	23,22	14.2%	9.2%	26	610,931
Total	164,184	100%	100%	n/a	2,166,950

- * Phoenix (2021); ^ habitat type not present in PAA therefore not assessed in Phoenix (2021)



S32
Worsley Mine Expansion

Project No	1562
Date	20/07/2023
Drawn by	AJ
Map author	AJ

0 7.5 15
Kilometers

1:429,300 (at A4) GDA 1994 MGA Zone 50

- Study area
- Desktop study area
- Carnaby's Cockatoo confirmed breeding areas
- Carnaby's Cockatoo unconfirmed breeding areas
- Carnaby's Cockatoo unconfirmed roost sites (DBCA 051)
- Carnaby's Cockatoo confirmed roost sites (DBCA 050)
- Black Cockatoo roost sites (DBCA_064)

Figure 5-1a

Desktop records of Carnaby's Cockatoos

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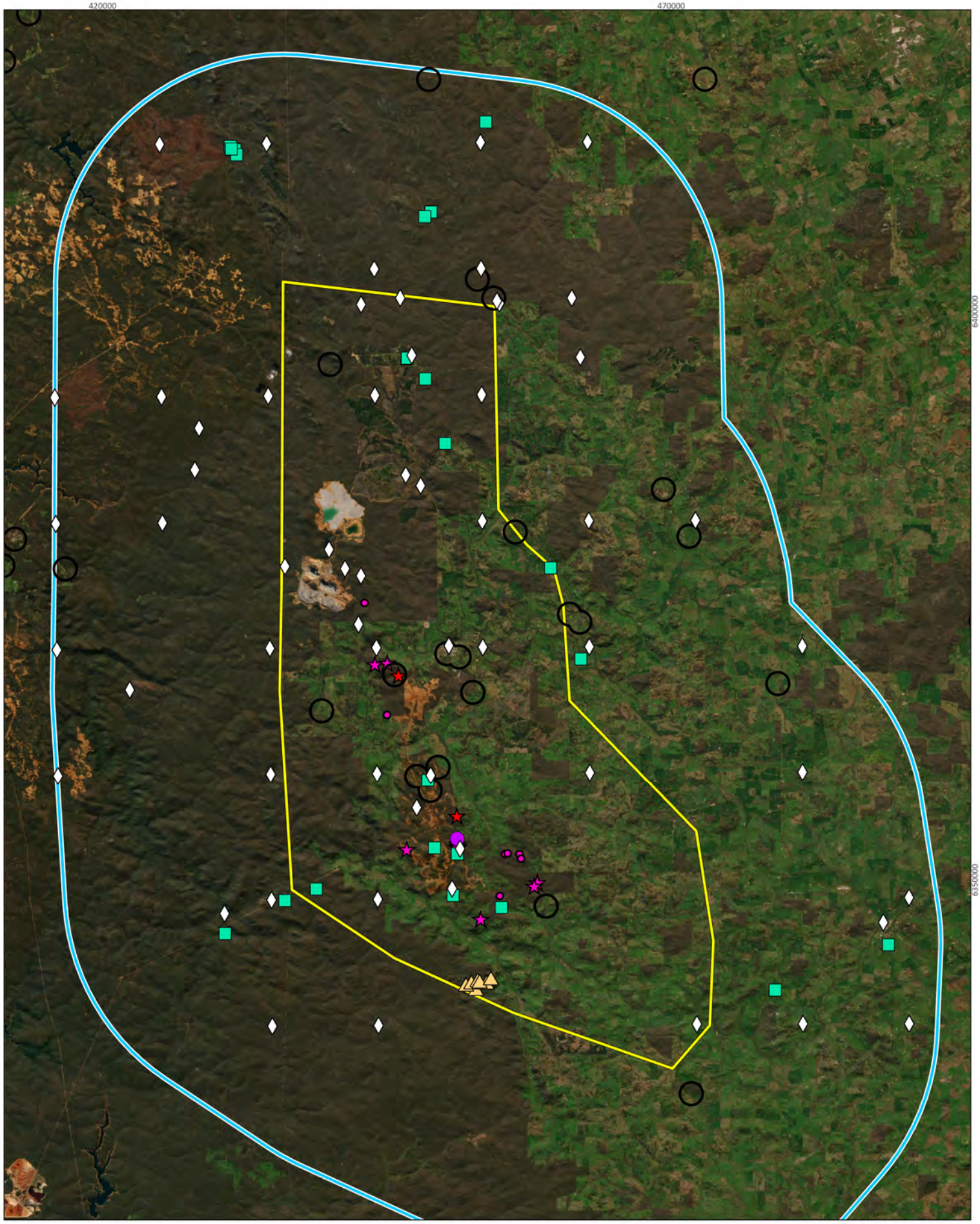


S32
Worsley Mine Expansion

Project No	1562
Date	20/07/2023
Drawn by	AJ
Map author	AJ

0 7.5 15
Kilometers

1:429,300 (at A4) GDA 1994 MGA Zone 50

- Study area
- Desktop study area
- Black cockatoo roost sites (DBCA_064)
- Unspecified, breeding record
- Hollows with evidence of cockatoo use (Phoenix 2021)

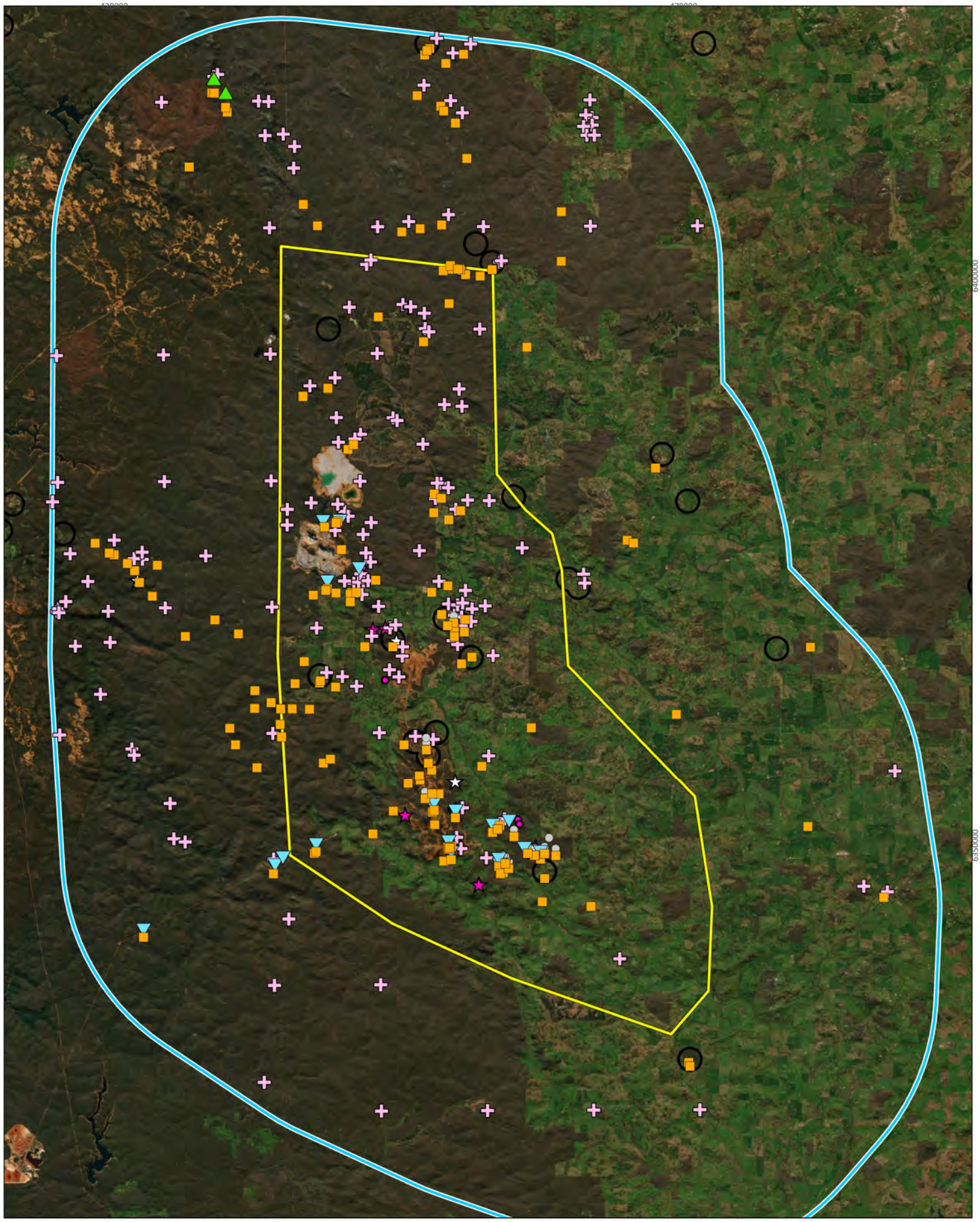
Species, record type

- Baudin's Cockatoo, call
- Baudin's Cockatoo, foraging evidence
- Baudin's Cockatoo, sighting
- Baudin's Cockatoo, unspecified

Figure 5-1b

Desktop records of Baudin's Cockatoos

PHOENIX ENVIRONMENTAL SCIENCES



S32
Worsley Mine Expansion

Project No	1562
Date	20/07/2023
Drawn by	AJ
Map author	AJ

0 7.5 15
Kilometers

1:429,300 (at A4) GDA 1994 MGA Zone 50

- Study area
- Desktop study area
- Black cockatoo roost sites (DBCA_064)
- Hollows with evidence of cockatoo use (Phoenix 2021)
- Unspecified, breeding record

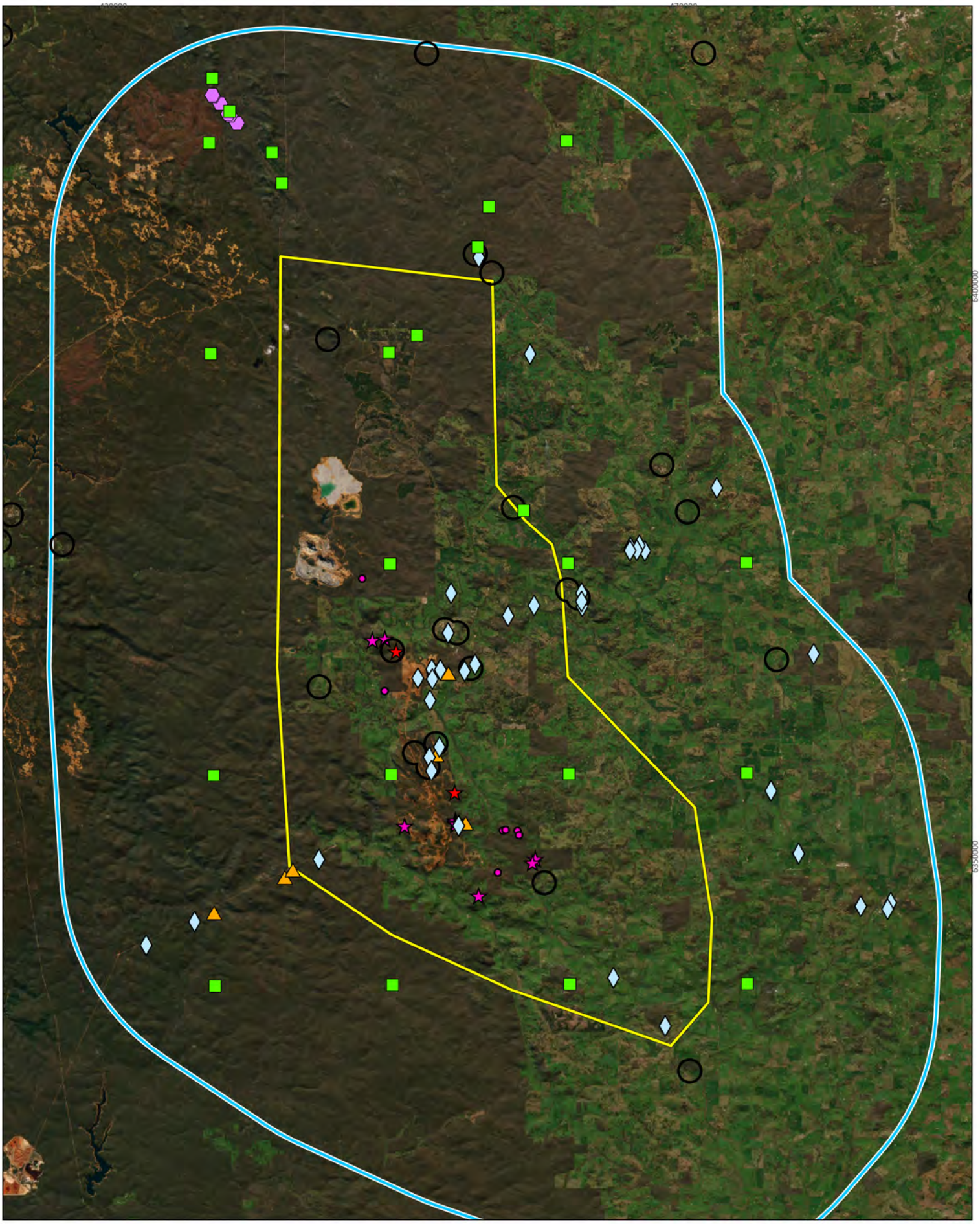
Species, record type

- Forest Red-tailed Black Cockatoo, unspecified
- Forest Red-tailed Black Cockatoo, breeding record
- Forest Red-tailed Black Cockatoo, call
- Forest Red-tailed Black Cockatoo, foraging evidence
- Forest Red-tailed Black Cockatoo, secondary sign
- Forest Red-tailed Black Cockatoo, sighting

Figure 5-1c

Desktop records of Forest Red-tailed Black Cockatoos

PHOENIX ENVIRONMENTAL SCIENCES



S32
Worsley Mine Expansion

Project No	1562
Date	21/08/2023
Drawn by	AJ
Map author	AJ

0 7.5 15
Kilometers

1:429,300 (at A4) GDA 1994 MGA Zone 50

- Study area
- Desktop study area
- Black cockatoo roost sites (DBCA_064)
- Unspecified, breeding record
- Hollows with evidence of cockatoo use (Phoenix 2021)

Species, record type

- White-tailed black cockatoo, foraging evidence
- White-tailed black cockatoo, secondary sign
- White-tailed black cockatoo, sighting
- White-tailed black cockatoo, unspecified

Figure 5-1d

Desktop records of white-tailed black cockatoos (*Zanda* sp.)

PHOENIX ENVIRONMENTAL SCIENCES

5.2.1 Habitat quality assessment

5.2.1.1 Foraging

Based on the known values within the study area, the habitat scoring tool (DAWE 2022) suggests that the study area is of high quality for all 3 species of black cockatoo (Table 5-2, Figure 5-3). Carnaby's and Forest Red-tailed Black Cockatoos scored the highest due to the presence of foraging, breeding and roosting records throughout the study area. Baudin's Cockatoo achieved a slightly lower score given the lack of breeding records and the known range of breeding (DAWE 2022) not within 12 km of the study area. Given the above, we can extrapolate from the areas of native vegetation within the study area, that approximately 81,576 ha of high quality native foraging habitat is present. Low quality foraging habitat comprising of rehabilitation occupies 3,491 ha of the study area, which when mature, produces forage resources which may be a valuable source of nutrition. Exotic foraging habitat in the form of Plantations, ie. Pine, Blue Gum, occupy 7,505 ha of the study area and the remaining 71,612 ha is cleared land which is of negligible foraging value, however there may still isolated foraging plant species present.

Dieback is known from the area, therefore all sites may be potentially affected.

All of the major vegetation types within the study area contain known forage species (Mattiske 2020), including primary forage species such as are Marri (Corymbia calophylla), Jarrah (Eucalyptus marginata), Banksia spp., and Allocasuarina fraseriana.

Table 5-2 Indicative foraging habitat quality scoring for the remnant native vegetation in the study area based on desktop data

Attribute	Baudin's cockatoo	Carnaby's cockatoo	Forest Red-tailed black cockatoo
Starting score	**10**	**10**	**10**
Foraging potential	- 0	- 0	- 0
Connectivity	- 0	- 0	- 0
Proximity to breeding	- 0 to 2	- 0	- 0
Proximity to roosting	- 0	- 0	- 0
Impact from significant plant disease	- 0 to 1	- 0 to 1	- 0 to 1
Total score	**7-10**	**9-10**	**9-10**

5.2.1.2 Breeding

Evidence of breeding of all 3 black cockatoo species occurs within the desktop search area (Figure 5-1), with Forest Red-tail Black Cockatoo being the most common. Breeding habitat value determination implemented by Phoenix (2021) takes into account vegetation structure (contains PHTs) and whether confirmed records or evidence of breeding were present.

Approximately 78,472 ha (47.8%) of the study area is considered to have breeding potential for Carnaby's Cockatoo, of which 74,960 ha is considered high value (Table 5-3, Table 5-4). Carnaby's Cockatoo are known to breed primarily in Wandoo and Marri, however nesting hollows in other species such as Jarrah and Flooded Gum have been recorded (Phoenix 2015b). Given Jarrah/Marri and Wandoo habitats dominate the remnant vegetation within the study area, the majority of remnant vegetation within the study area is considered high value breeding habitat for this species (Figure 5-4).

Baudin's Cockatoo breeding habitat within the study area comprises of 76,782 ha of low value habitat (Table 5-3, Table 5-4). The number of Baudin's Cockatoo breeding records compared to Carnaby's and Forest Red-tailed Black Cockatoos within the desktop search area is very low, indicating breeding may occur, however because it is outside of the known and predicted breeding area (DAWE 2022b) the habitat is considered low value.

Forest Red-tailed Black Cockatoo breeding habitat occupies 76,782.10 ha within the study area, of which 51,730.70 ha is considered high value breeding habitat (Table 5-3, Table 5-4). As with Carnaby's Cockatoo, this species is well known to breed within the area, however is a more opportunistic breeding species throughout the year with a larger known breeding range.

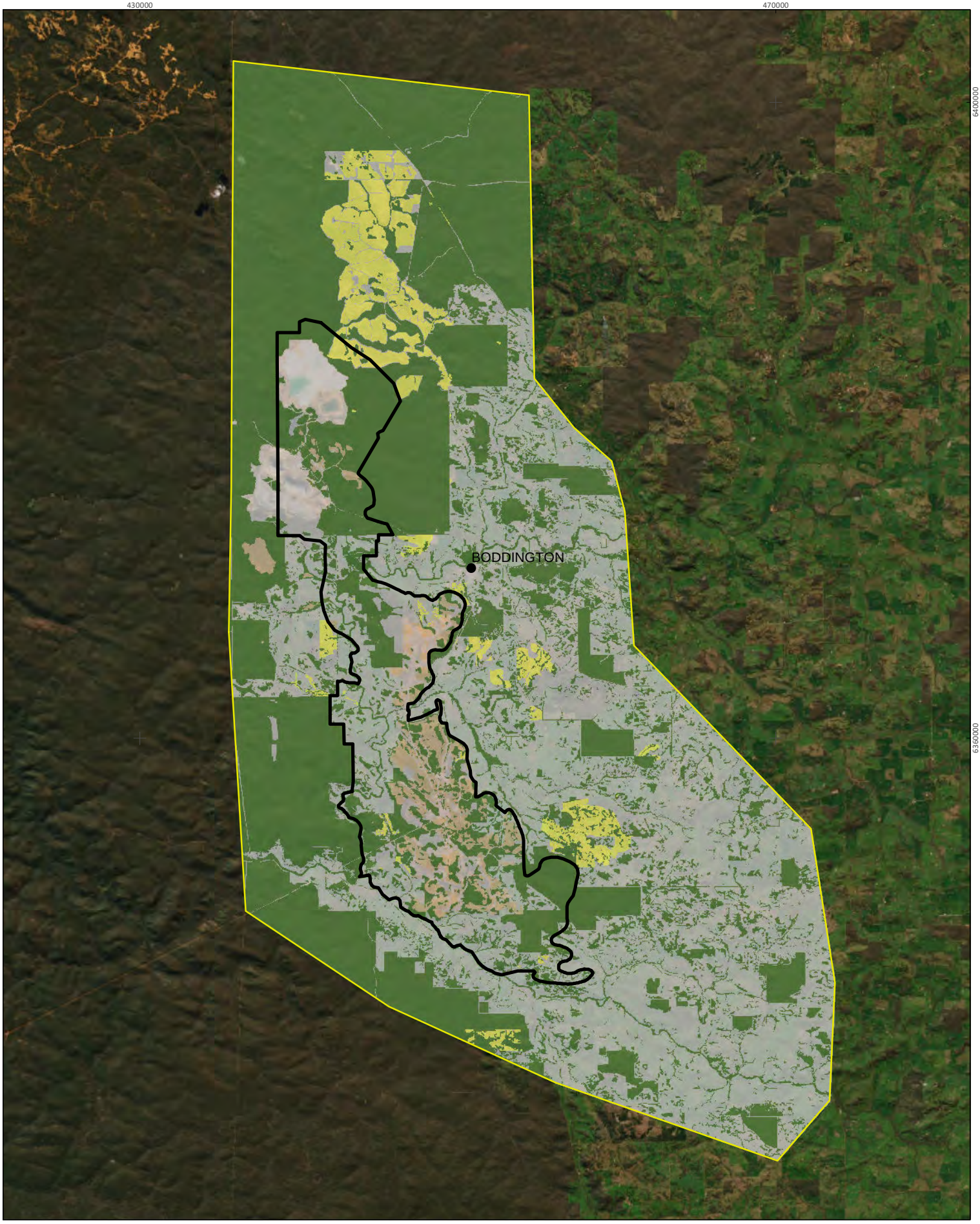
A total of 15 nest boxes installed 13 km of the Newmont Gold Mine, monitored since 2012 have not recorded evidence of breeding. Three of these are located within 200 – 400 m of a confirmed Carnaby's natural nest hollow, and a further 6 within 1.5 km of a confirmed breeding location. The confirmed Carnaby's nest has had a low breeding usage, with only one breeding attempt (in 2018) being made in that hollow since 2012 (Newmont monitoring data).

Table 5-3 Summary of extent of breeding habitat values within the study area

Breeding value/species	Carnaby's cockatoo	Baudin's cockatoo	Forest red-tail cockatoo
High	74,960 ha	0	51,731 ha
Medium	1,822 ha	0	0
Low	1,690 ha	76,782 ha	25,051 ha
Total breeding value (H, M, & L)	**78,472 ha**	**76,782 ha**	**76,782 ha**
n/a – may contain isolated trees breeding trees	85,711 ha	87,402 ha	87,402 ha

Table 5-4 Predicted breeding habitat value and extent within the study area

Fauna habitats (Biostat 2021)	CC	BC	FRTBC	Extent within study area
Blackbutt woodland on lower slopes (BB)	M	L	L	32
Cleared Land (CL)	n/a	n/a	n/a	71,60
Marri and/or Jarrah on lower slopes (DL)	H	L	H	1,254
Dam/Open Water Body (DM)	n/a	n/a	n/a	5
E. rudis woodlands which may include Jarrah, Marri, Banksia or Wandoo. Riparian community (FG)	M	L	L	1,495
Mosaic of Marri and/or Jarrah on lower slopes and E. rudis riparian community (FG/DL)	M	L	L	5
Jarrah and/or Marri valley floors/swamps (JB)	H	L	H	18
Jarrah, Marri and/or Allocasuarina (JC)	H	L	H	9,918
Jarrah and/or Marri on slopes (JM)	H	L	H	40,541
Mallee (ML)	n/a	n/a	n/a	16
Melaleuca shrublands on seasonally wet valley floors (MS)	n/a	n/a	n/a	2,563
Melaleuca, E. rudis woodlands on seasonally wet floors (MW)	L	n/a	n/a	1,690
Heath and/or perched heath (PH)	n/a	n/a	n/a	525
Plantations (PL, PL - Ag)	n/a	n/a	n/a	7,505
Rehabilitation (RE)	n/a	n/a	n/a	3,491
Wandoo woodlands (WO)	H	L	L	23,229
Total				**164,184**



S32
Worsley Mine Expansion

Project No	1562
Date	23-May-23
Drawn by	AJ
Map author	AJ

0 6 12
Kilometers

1:307,204 (at A4) GDA 1994 MGA Zone 50

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Study area
PAA

foraging habitat quality

igh ua i
Low quality
Exotic foraging habitat
none

Figure 5-3

Foraging habitat within the study area

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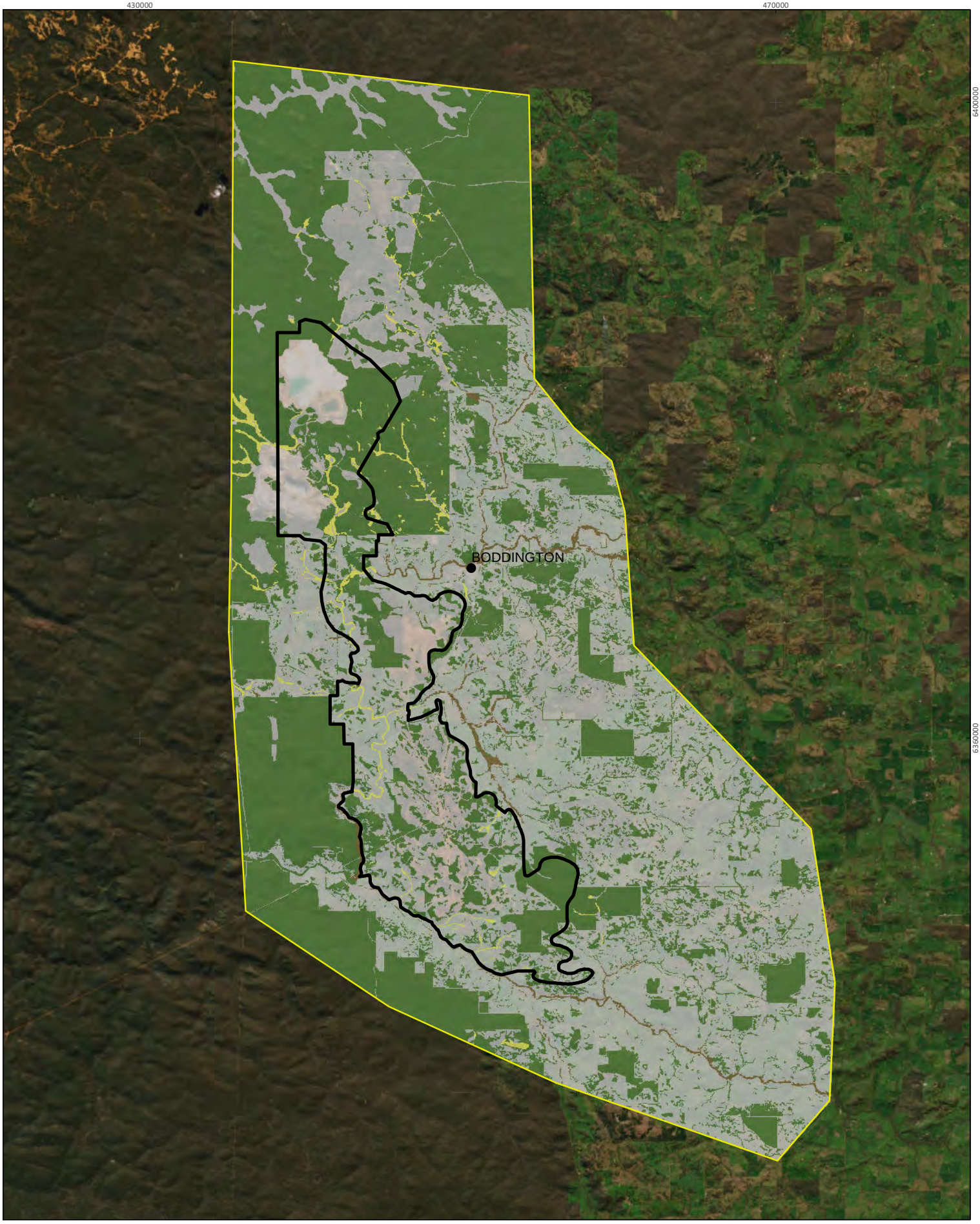

S32
Worsley Mine Expansion

Project No	1562
Date	23-May-23
Drawn by	AJ
Map author	AJ

0 6 12
Kilometers

1:307,204 (at A4) GDA 1994 MGA Zone 50

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Study area
PAA

Breeding value

High
Medium
Low
n/a

Figure 5-4a

Carnaby's Cocaktoo breeding habitat within the study area

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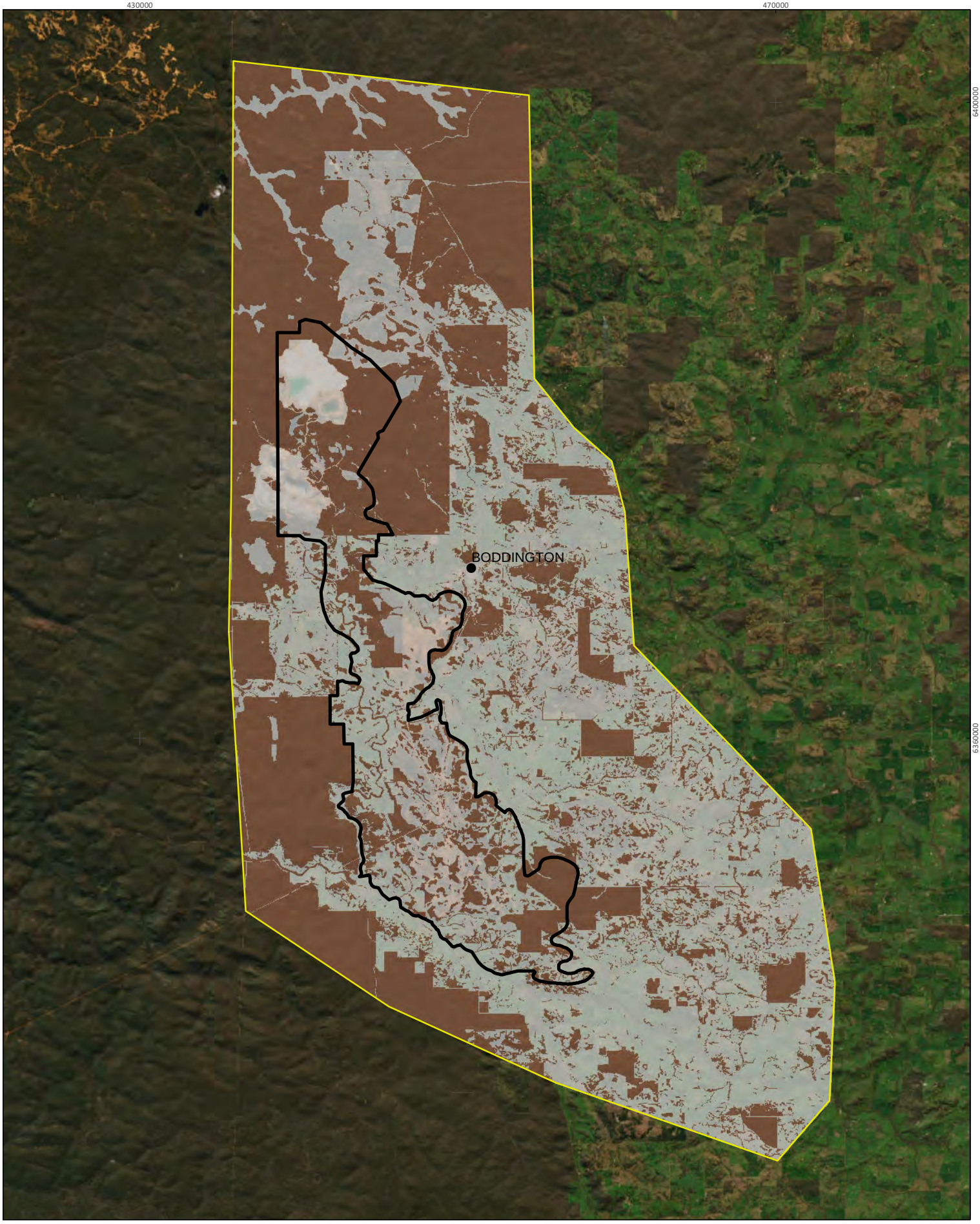

S32
Worsley Mine Expansion

Project No	1562
Date	23-May-23
Drawn by	AJ
Map author	AJ

0 6 12
Kilometers

1:307,204 (at A4) GDA 1994 MGA Zone 50

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Study area
PAA

Bredding habitat value

Low
n/a

Figure 5-4b

Baudin's Cocaktoo breeding habitat within the study area

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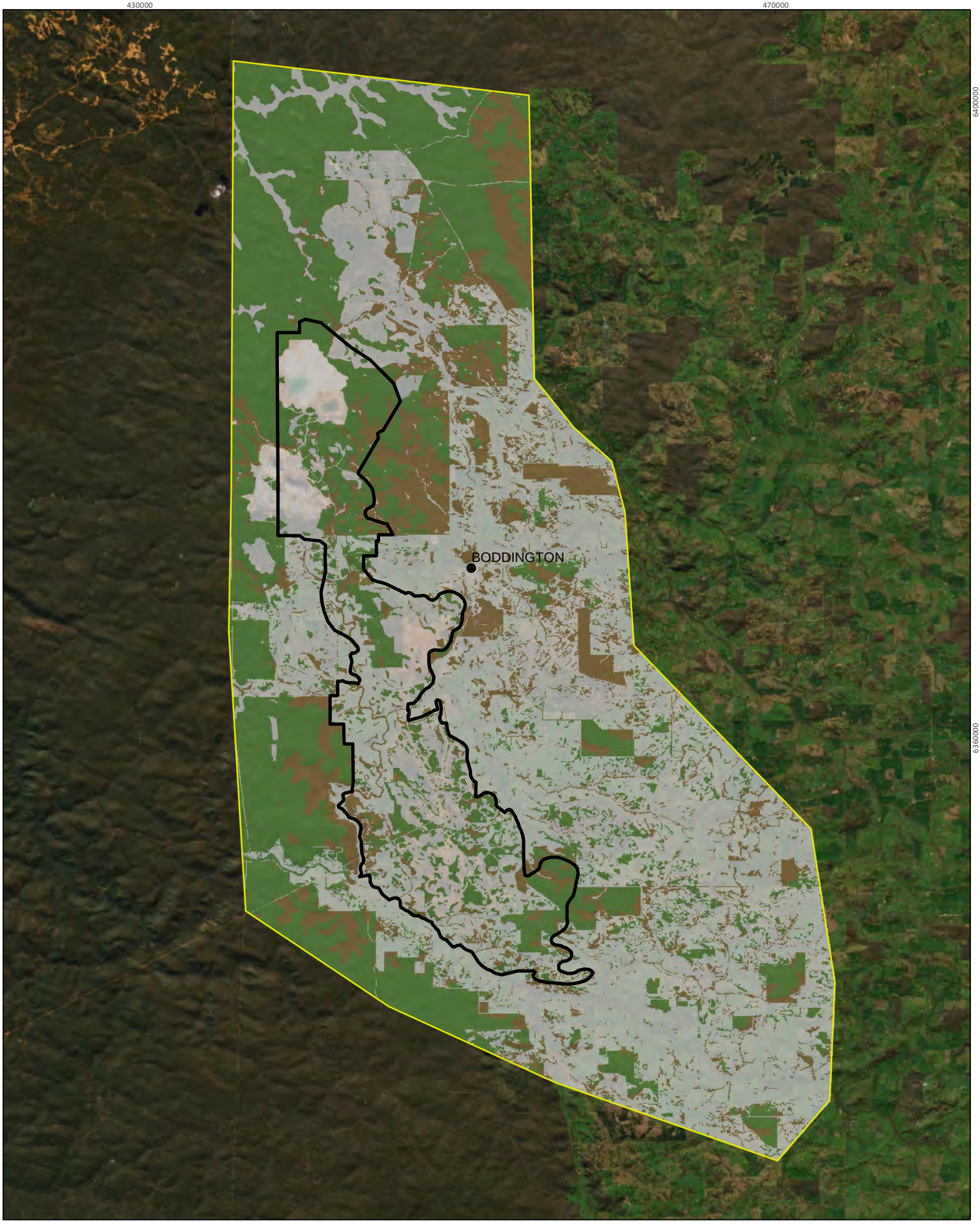

S32
Worsley Mine Expansion

Project No	1562
Date	23-May-23
Drawn by	AJ
Map author	AJ

0 6 12
Kilometers

1:307,204 (at A4) GDA 1994 MGA Zone 50

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Study area
PAA

Breeding habitat value

High
Low
n/a

Figure 5-4c

Forest Red-tailed Black Cockatoo breeding habitat within the study area

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5.3 FIELD SURVEY

5.3.1 Habitats

A total of 12 remnant habitats occur within the study area, and of these, 9 were able to be sampled (Table 5-5). The most abundant habitat types: JM, WO, and JC (40,941 ha, 23,229 ha, and 9,918 ha respectively) were the most frequently surveyed (66, 51 and 27 quadrats respectively).

Table 5-5 Habitat types sampled

Habitat type	Description	Site/s	Representative photograph
Blackbutt woodlands on lower slopes (BB)	Open Eucalyptus woodlands (wet) on sands, clay loam or sandy-gravel on lower slopes and valley floors	Q122, Q156, Q246, Q425	
Marri/Jarrah on lower slopes (DL)	Open Jarrah/Marri woodlands on sands, clay loam or sandy-gravel on lower slopes and valley floors	Q102, Q116, Q119, Q128, Q145, Q364	

Habitat type	Description	Site/s	Representative photograph
E. rudis woodlands which may include Jarrah, Marri, *Banksia* or Wandoo. Riparian community (FG)	Open Eucalyptus woodlands (wet) on sands, clay loam or sandy-gravel on lower slopes and valley floors	Q124, Q424	
Jarrah/Marri/Allocasuarina (JC)	Open forest of Jarrah/Marri on sandy-loam gravelly soils on mid slopes and ridges	Q051, Q059, Q064, Q066, Q068, Q071, Q073, Q077, Q084, Q108, Q109, Q112, Q113, Q114, Q118, Q150, Q161, Q217, Q233, Q240, Q242, Q244, Q376, Q377, Q378, Q379, Q380	
Jarrah/Marri on slopes (JM)	Open forest to woodland of Jarrah/Marri on slopes and less undulating hills	Q000, Q001, Q014, Q015, Q016, Q020, Q021, Q027, Q037, Q040, Q044, Q045, Q052, Q058, Q078, Q085, Q088, Q089, Q115, Q117, Q120, Q121, Q130, Q131, Q132, Q167, Q168, Q183, Q184, Q186, Q187, Q188, Q197, Q198, Q199, Q200, Q201, Q202, Q205, Q207, Q208, Q209, Q210 Q211, Q213, Q222, Q226, Q272, Q273, Q276, Q278, Q309, Q346, Q347, Q348, Q350, Q352, Q353, Q354, Q381, Q385, Q400, Q407, Q412, Q423, Q435	

Habitat type	Description	Site/s	Representative photograph
Melaleuca shrublands on seasonally wet valley floors (MS)	Melaleuca woodlands/shrublands on seasonally wet or water-logged clays and clay loams on valley floors	Q087, Q133, Q170, Q176, Q178, Q179, Q192, Q194, Q245, Q275, Q277	
Melaleuca, E. rudis woodlands on seasonally wet valley floors (MW)	Eucalyptus rudis and melaleuca drainage line	Q270, Q360	
Heath and/or perched heath (PH)	Heath/shrubland on shallow soils on granite or outcrops	Q220, Q248, Q253	

Habitat type	Description	Site/s	Representative photograph
Wandoo woodlands (WO)	Open woodland of Wandoo on clay and clay loam soils on lower slopes	Q008, Q017, Q023, Q024, Q026, Q035, Q038, Q041, Q042, Q048, Q086, Q111, Q134, Q135, Q154, Q173, Q174, Q191, Q193, Q203, Q204, Q212, Q214, Q224, Q225, Q227, Q228, Q229, Q230, Q231, Q256, Q262, Q291, Q299, Q300, Q301, Q303, Q304, Q331, Q332, Q333, Q334, Q336, Q337, Q345, Q351, Q365, Q382, Q399, Q403, Q438	

5.3.2 Black cockatoo records

All 3 black cockatoo species were recorded during the survey (Table 5-6; Figure 5-7). Red-tailed Black Cockatoos were the most common in terms of direct sightings and foraging evidence, however Carnaby's Cockatoo was also recorded from foraging evidence, direct sightings and calls. Baudin's Cockatoo was only recorded at one site in the study area from foraging evidence.

Red-tailed Black Cockatoos were recorded throughout the study area, however most of the records were located in 4 distinct areas:

- State forest along the western and south-western boundary of the study area
- Quindanning Block – immediately east of Saddleback Mine
- Mooradung Nature Reserve
- Northern part of the study area.
- Carnaby's Cockatoo was recorded from the northern and central part of the study area indicating this may be more important.

Table 5-6 Details of black cockatoo records during the field survey

Species	Status	Sites recorded	Habita types	Record type
Baudin's Cockatoo (*Zanda baudinii*)	EN (EPBC & BC Acts)	Q089	JM	Foraging evidence
Carnaby's Cockatoo (*Zanda latirostris*)	EN (EPBC & BC Acts)	Q217, Q229	JC, WO	Foraging evidence
		Q089, Q192, Q309	JM, MS	Direct sighting and heard calling
Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksia naso*)	VU (EPBC & BC Acts)	Q016, Q020, Q023, Q042, Q045, Q048, Q051, Q086, Q174, Q191, Q217, Q276, Q346, Q353	JM, JC, WO	Foraging evidence
		Q014, Q035, Q115, Q128, Q376, Q378, Q407	DL, JM, JC, WO	Calling
		Q348	JM	Calling and foraging evidence
		Q015, Q089, Q168, Q345, Q347, Q364, Q379, Q385, Q403	JM, WO	Direct sighting and heard calling
		Q021, Q352, Q380, Q381, Q412	JM, JC	Direct sighting, heard calling and foraging evidence

5.3.3 Potential habitat trees

A total of 3,918 PHT were surveyed over 138.5 ha across the 9 habitats. Habitat types differ in their floristic species composition and presence. For this reason, there is overlap in the PHT species across habitats, however, the abundance and densities of these species are expected to fluctuate. As expected, the highest number of PHTs were recorded in the most frequently sampled habitat types (JM – 1,456 trees) and WO (1,415 trees). Across the 9 habitat types that were sampled, 5 species of PHT were identified in the field surveys. Jarrah trees were the most abundant species recorded (2,312), followed by Wandoo (1,020), Marri (457), Powerbark Wandoo (59) and Flooded Gum (13)

(Table 5-7). A total of 52 unidentified tree species were also recorded as a result of tree not showing obvious identifying characters, was dead, or an introduced or uncommon species. Jarrah, Wandoo, and Marri were recorded in a variety of DBH measurements, with ranges above 1,100 mm. The largest PHT recorded was a Marri tree at 2,000 mm (Table 5-7).

Table 5-7 Summary of DBH (mm) per species

Scientific name	Vernacular	Tree count	Min. DBH (mm)	Max. DBH (mm)	Range DBH (mm)	Mean DBH (mm)	Std. Dev. DBH (mm)
Eucalyptus accedens	Powderbark Wandoo	58	300	1,250	950	450	171
Eucalyptus marginata	Jarrah	2,312	500	1,940	1,440	673	182
Eucalyptus rudis	Flooded Gum	13	500	1,100	600	728	215
Eucalyptus wandoo	Wandoo	1,026	300	1,400	1,100	442	151
Corymbia calophylla	Marri	457	500	2,000	1,500	673	196
Eucalyptus sp.	unidentified Eucalypt	52	500	1,330	830	730	230
Total		**3,918**	**300**	**2,000**	**1,800**	**621**	**1,283**

To compare the densities of PHT between habitats, the mean PHT per hectare have been summarised (Table 5-8). PHTs are normally distributed across the study area (Figure 5-5). WO had the highest mean number of PHT per hectare, followed by habitats dominated by other eucalypt species (FG, BB, JM, and JC), consisting mostly of *E.marginata* (Jarrah) and *C. calophylla* (Marri). Perched Heath had the lowest mean density of PHTs. Due to the small proportion of each habitat sampled, the standard deviations for each habitat type are considerable, ranging from 18 (DL) to 5 (BB and MW).

Extrapolating the results of the survey across the entire study area, it is estimated that 2,369,865 PHTs occur within the study area. Additional habitat trees occur sporadically in cleared areas and plantations, however the number of PHTs in these areas is likely to represent a very small proportion of the total compared to forest remnants, with an estimated 0.3 – 1 % additional PHTs within these areas.

Table 5-8 Total and extrapolated numbers of PHT and Hollows recorded by habitat type

Habitat type	Survey area		Number of PHT			Proportion of habitat type surveyed
	Surveyed (ha)	Total ha within study area	Total surveyed (n)	PHT/ha	study area extrapolated	
BB	4	321	117	29.25	9,399	1.24%
CL[1]	0	71,607	0	0	0	0%
DL	5	1,254	119	23.8	29,838	0.40%
DM[1]	0	5	0	0	0	0%
FG	1.5	1,495	48	32	47,855	0.10%
FG/DL	0	5	0	0	0	0%
JB	0	18	0	0	0	0%
JC	22.5	9,918	476	21.16	209,820	0.23%
JM	50	40,941	1,456	29.12	1,180,554	0.12%

ML[2]	0	16	0	15[2]	240[2]	0%
MS	8	2,563	215	26.88	68,880	0.31%
MW	3	1,690	48	16	27,044	0.18%
PH	3	525	24	8	4,199	0.57%
PL[1]	0	7,505	0	0	0	0%
RE[1]	0	3,491	0	0	0	0%
WO	41.5	23,229	1,415	34.1	79,2033	0.18%
Total	**138.5**	**164,184**	**3,918**	**ave 13.7**	**2,369,865**	**0.08%**

[1] not a remnant habitat type, [2] not sampled during survey, this value was obtained from a previous survey (Phoenix 2023)

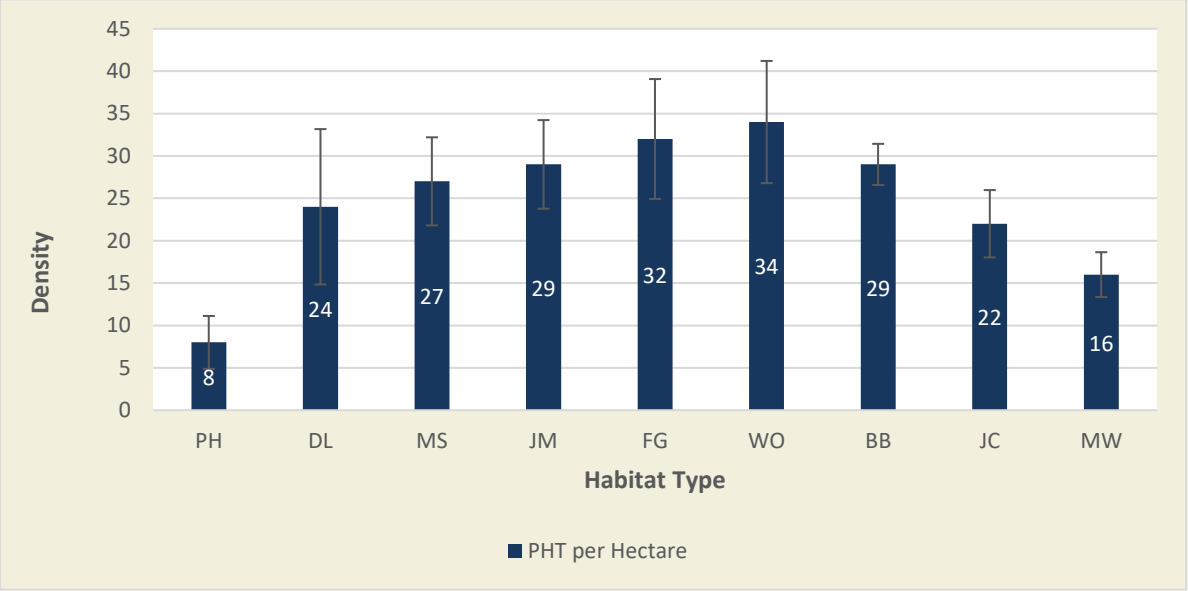


Figure 5-5 Mean density of PHT per hectare across different habitat types

5.3.4 Breeding hollows

A total of 903 hollows from 696 trees were recorded amongst the 3,918 PHTs recorded during the survey (Table 5-9).

As with the number of PHTs recorded in the most common habitat types present within the study area, JM and WO also recorded the highest number of trees containing suitable hollows. While the JM habitat type covered a larger area (50 ha of JM compared to 41.5 ha of WO), the WO habitat is dominated by Wandoo species which have a lower minimum DBH (≥300mm) required for potential hollow forming, whereas Jarrah, Marri, and most other eucalypts have a minimum DBH of ≥500mm, thus increasing the potential sample sizes in WO.

Table 5-9 Total and extrapolated numbers of PHT and Hollows recorded by habitat type

Habitat type	Survey area		Number of hollows			Proportion of habitat type surveyed
	Surveyed (ha)	Total within study area	Total surveyed (n)	Hollow/ha	Study area extrapolated	
BB	4	321	16	4	1,285	1.24%
CL[1]	0	71,607	0	0	0	0%
DL	5	1,254	15	3	3,761	0.40%
DM[1]	0	5	0	0	0	0%

FG	1.5	1,495	6	4	5,982	0.10%
FG/DL	0	5	0	0	0	0%
JB	0	18	0	0	0	0%
JC	22.5	9,918	119	5.3	52,455	0.23%
JM	50	40,941	352	7	285,409	0.12%
ML	0	16	0	0	0	0%
MS	8	2,563	47	5.8	15,057	0.31%
MW	3	1,690	15	5	8,451	0.18%
PH	3	525	6	2	1050	0.57%
PL[1]	0	7,505	0	0	0	0%
RE[1]	0	3,491	0	0	0	0%
WO	41.5	23,229	327	7.9	183,035	0.18%
Total	**138.5**	**164,184**	**903**	**Ave 4.9**	**556,486**	**0.08%**

[1] not a remnant habitat type. [2]Values have been rounded to the nearest whole number. When reviewing the extrapolated data it should be noted that only relatively small proportion of each habitat type was sampled, and subsequently the entire study area has not been surveyed. Therefore, the values included should be used indicatively.

To compare the number of hollows between habitats, mean values for hollows per hectare in each habitat type have been summarised (Figure 5-6). Mean hollows per hectare are also normally distributed, ranging from 2 to 8.

The highest number of hollows were recorded in the habitats with the highest mean densities of PHT per hectare (WO and JM). The standard deviations are also considerably large in proportion to the mean densities of hollows per hectare, such as the MW habitat having a mean density of 5 hollows per hectare and a standard deviation of 9.

Extrapolating the results of the survey across the entire study area, it is estimated that 556,486 hollows occur within the study area, however not all of these are likely to be suitable.

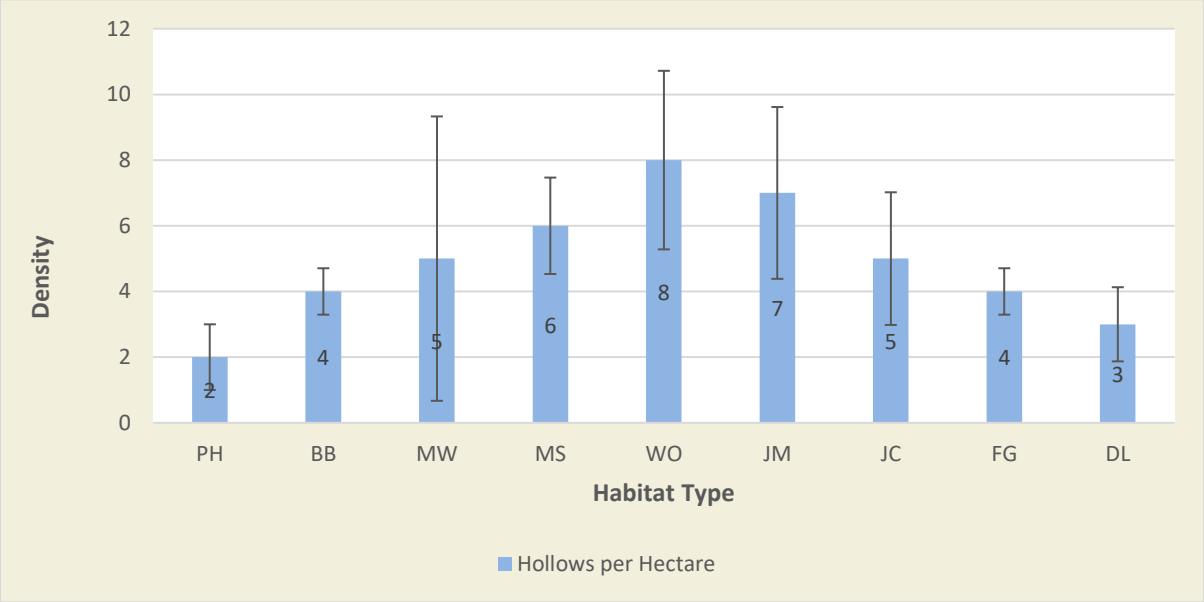


Figure 5-6 Mean density of hollows found on PHT per hectare across different habitat types

5.3.5 Hollow evidence of use

Of the 696 trees with hollows, a total of 62 trees were recorded where one or more hollows had evidence of hollow use by birds, however none appeared to be occupied. Three different species of tree were recorded with hollows having evidence of use including *Eucalyptus wandoo* (Wandoo), *Eucalyptus marginata* (Jarrah), and *Corymbia calophylla* (Marri). Evidence of use was only recorded in 5 habitat types including DL, JC, JM, MS, and WO. Of the 62 trees with evidence of use, 51 displayed scarring around the hollow indicating possible galah use, 6 had old chewing around the hollow entrance and 5 had recent chewing around the hollow entrance.

The DBH of PHTs with evidence of hollow use varied from 500 mm to 1,710 mm. The 5 trees that showed signs of relatively recent chewings include one Marri in DL habitat, and 4 Jarrah trees in WO habitat (Table 5-10; Table 5-11). The majority of the PHTs that have hollows showing evidence of use occur in areas of high breeding value for FRTBC, Carnaby's Cockatoo, and low breeding value for Baudin's Cockatoo i.e. Jarrah/Marri and Wandoo dominated (DL, JB, JC, JM, WO) habitats, however, melaleuca woodland (MW) also contained some trees with suitable hollows with scarring evidence.

Based on the results of PHTs with suitable hollows and evidence of recent or historic chewing, 5 areas stood out as having a higher potential to support a breeding area (Figure -7):

- the north-west corner, which is between a confirmed and unconfirmed Carnaby's Cockatoo breeding area (DBCA)
- a patch within north-east section of the study area
- central area – close to known confirmed breeding area
- Quindanning Block
- southern boundary of the study area.

Table 5-10 Summary of hollow evidence of us recorded during survey

Habitat type	Site	Number of hollows	Evidence of use	Tree species	DBH (mm)
Marri and/or Jarrah on lower slopes (DL)	Q364	1	Chewing around hollow (recent)	Marri	530
Jarrah, Marri and/or Allocasuarina (JC)	Q051	1	Scarring	Marri	780
	Q380	1	Scarring	Jarrah	500
Jarrah and/or Marri on slopes (JM)	Q014	1	Scarring	Jarrah	510
	Q014	1	Scarring	Marri	520
	Q014	2	Scarring	Jarrah	890
	Q014	3	Scarring	Wandoo	660
	Q015	6	Scarring	Jarrah	600
	Q021	1	Scarring	Wandoo	510
	Q021	1	Scarring	Wandoo	780
	Q021	1	Scarring	Jarrah	680
	Q037	3	Scarring	Jarrah	920
	Q037	2	Scarring	Jarrah	690
	Q037	3	Scarring	Jarrah	680
	Q040	1	Scarring	Jarrah	610
	Q040	1	Scarring	Jarrah	730
	Q044	1	Scarring	Jarrah	1120

Habitat type	Site	Number of hollows	Evidence of use	Tree species	DBH (mm)
	Q044	4	Scarring	Jarrah	1710
	Q052	2	Scarring	Marri	690
	Q088	2	Scarring	Jarrah	710
	Q168	1	Chewing around hollow (old)	Jarrah	960
	Q183	1	Chewing around hollow (old)	Jarrah	1140
	Q207	1	Scarring	Wandoo	550
	Q222	1	Chewing around hollow (old)	Marri	900
	Q222	1	Chewing around hollow (old)	Jarrah	650
	Q346	1	Scarring	Jarrah	530
	Q348	1	Scarring	Marri	780
	Q352	1	Scarring	Marri	700
	Q400	1	Scarring	Jarrah	620
	Q400	1	Scarring	Jarrah	1140
	Q400	1	Scarring	Jarrah	610
	Q400	1	Scarring	Jarrah	810
	Q400	2	Scarring	Jarrah	660
	Q407	1	Scarring	Jarrah	610
	Q407	1	Scarring	Jarrah	710
	Q407	1	Scarring	Jarrah	940
Melaleuca shrublands on seasonally wet valley floors (MS)	Q087	1	Scarring	Marri	1020
	Q087	1	Scarring	Marri	640
	Q192	2	Scarring	Jarrah	1000
Wandoo woodlands (WO)	Q331	2	Chewing around hollow (recent)	Jarrah	900
	Q331	1	Chewing around hollow (old)	Jarrah	690
	Q332	3	Chewing around hollow (recent)	Jarrah	950
	Q403	1	Chewing around hollow (recent)	Jarrah	540
	Q403	3	Scarring	Jarrah	540
	Q403	3	Chewing around hollow (recent)	Jarrah	630
	Q017	1	Scarring	Jarrah	610
	Q017	1	Scarring	Jarrah	750
	Q017	1	Scarring	Jarrah	630
	Q038	3	Scarring	Jarrah	730
	Q038	1	Scarring	Jarrah	710
	Q038	1	Scarring	Jarrah	540
	Q038	1	Scarring	Jarrah	1220
	Q038	3	Scarring	Jarrah	1020
	Q038	1	Scarring	Jarrah	960
	Q042	2	Scarring	Marri	730
	Q042	1	Scarring	Marri	690
	Q382	1	Scarring	Wandoo	570
	Q023	1	Scarring	Jarrah	840
	Q023	1	Scarring	Jarrah	550

Habitat type	Site	Number of hollows	Evidence of use	Tree species	DBH (mm)
	Q026	2	Scarring	Jarrah	540
	Q026	2	Scarring	Jarrah	1240
	Q229	1	Chewing around hollow (old)	Marri	800

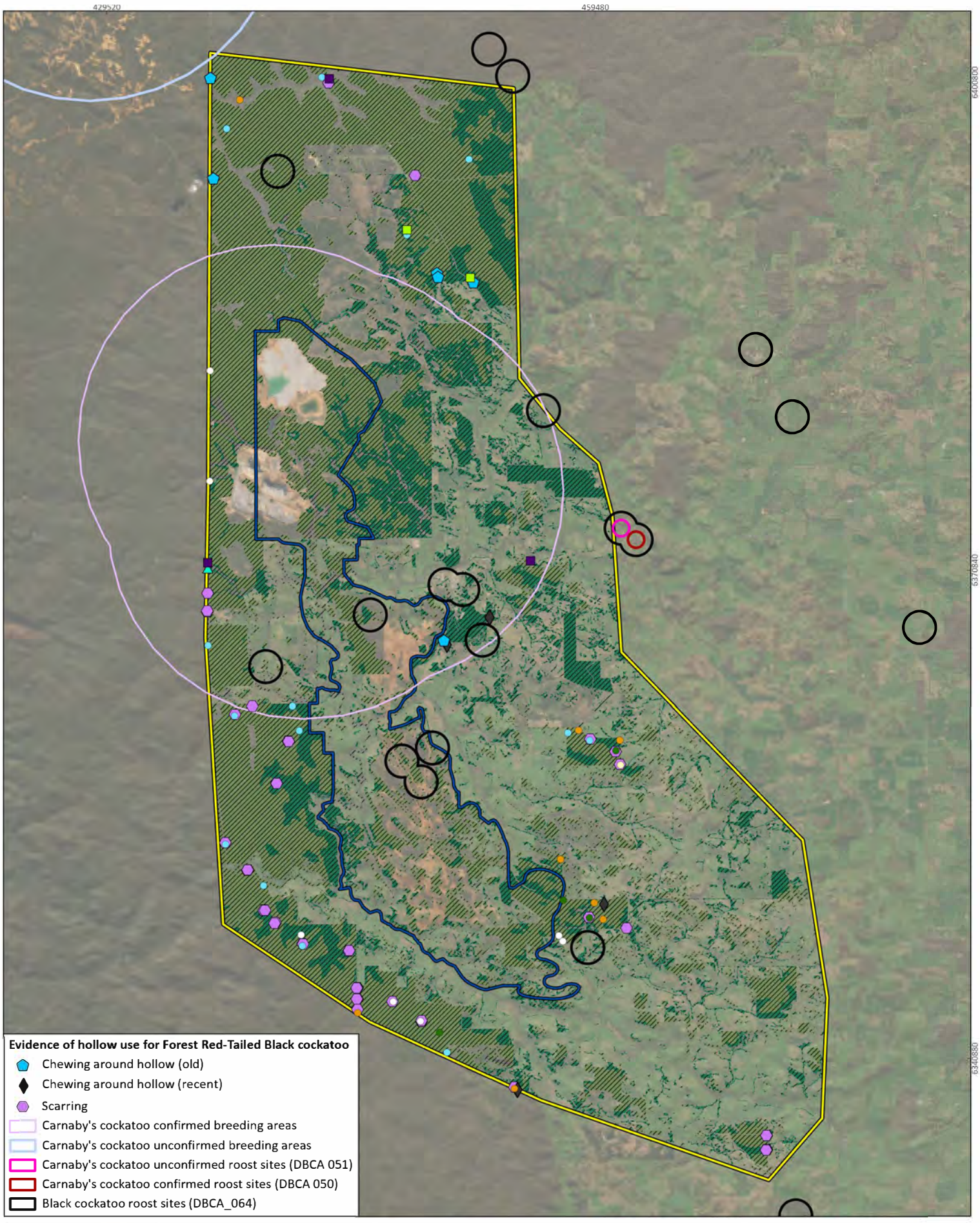
Table 5-11 Total and extrapolated numbers of hollows with recorded evidence (chewing around hollows only) recorded by habitat type

Habitat type	Surveyed (ha)	Total within study area	Chewing around hollow entrance	Hollows with evidence of breeding / ha	Extrapolated number of hollows with evidence of breeding	Proportion of habitat type surveyed
DL	5	1,254	1	0.2	251	0.40%
JM	50	40,941	4	0.08	3,275	0.12%
WO	41.5	23,229	6	0.14	3,358	0.18%
Total	**138.5**	**164,184**	**11**	**ave 0.14**	**6,884**	**0.08%**

[1] not a remnant habitat type. [2]Values have been rounded to the nearest whole number. When reviewing the extrapolated data it should be noted that only relatively small proportion of each habitat type was sampled, and subsequently the entire study area has not been surveyed. Therefore, the values included should be used indicatively.

Based on the evidence of hollow use and the desktop records, the results support the breeding value of the study area identified in the desktop review (Phoenix 2023c). All breeding evidence was identified on Jarrah, Marri and Wandoo trees in habitat types dominated by Jarrah, Marri or Wandoo. By extrapolating these findings to the entire study area (as was assumed in the desktop), the same breeding value and extent of breeding habitat were found. Areas containing PHT are abundant with tree species suitable for hollows as well as foraging species located within or nearby providing suitable breeding habitat.

Approximately 78,472.40 ha (47.8%) of the study area is considered to have breeding potential for Carnaby's Cockatoo, of which 74,960 ha is considered high value. Baudin's cockatoo breeding habitat within the study area comprises of 76,782 ha of low value habitat. Forest Red-tailed Black Cockatoo breeding habitat occupies 76,782.10 ha within the study area, of which 51,730.70 ha is considered high value breeding habitat.



S32
Worsley Mine Expansion

Project No	1562
Date	26/06/2023
Drawn by	BK
Map author	KF

0 5 10
Kilometers

1:299,600 (at A4) GDA 1994 MGA Zone 50

Study area
PAA
Breeding value:
Carnaby's Cockatoo
High
Forest Red-tail Black Cockatoo
High
Baudin's Cockatoo
Low
Evidence type:
Carnaby's Cockatoo
Direct sighting and calling
Foraging Evidence

Forest Red-tail Black Cockatoo
Calling
Foraging evidence
Direct sighting and calling
Calling and foraging evidence
Direct sighting, calling and foraging evidence
Baudin's Cockatoo
Foraging evidence

Figure 5-7
Records of black cockatoos and potential breeding hollows from the survey

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5.3.6 Habitat quality assessment

Most survey sites contained a mixed understory of shrubs and groundcover and nearly all sites surveyed recorded known foraging species for black cockatoos, such as Marri, Jarrah, Banksia spp., and Allocasuarina sp. (Appendix 3) (DAWE 2022), however some level of disturbance was recorded at nearly all sites (Figure 5-8). Vehicle tracks were the most common cause of disturbance throughout the study area, along with historic clearing or current clearing and prescribed burning practices. Weed presence, firebreaks, and disease risk areas were also relatively common causes of disturbance. Other signs of disturbance were recorded at a relatively low number of sites. Most sites been subject to prescribed burning and it was noted that at some of these sites, large habitat trees had fallen as a result. *Phytophthora* dieback was evident at multiple sites and could potentially spread to uninfected areas.

Overall, the habitat quality of the study area is high in some form for all 3 species of black cockatoo (Table 5-12). Based on the areas surveyed, and the known breeding and roosting sites, the extrapolations from the desktop review appear accurate. Approximately 81,576 ha of high quality native foraging habitat is present for all 3 species of black cockatoo. Low quality foraging habitat comprising of rehabilitation occupies 3,491 ha of the study area, which when mature, produces forage resources that may be a valuable source of nutrition. Exotic foraging habitat in the form of plantations, i.e. Pine, Blue Gum, occupy 7,505 ha of the study area and the remaining 71,612 ha is CL which is of negligible foraging value (Table 5-9).

The field survey supported the findings of the desktop review regarding foraging habitat scores (Phoenix 2023a). The foraging potential was high and there was evidence of foraging opportunistically recorded at several sites throughout the study area for all 3 species of black cockatoo (Figure 5-5). The landscape of the study area contained useable patches of habitat, Carnaby's Cockatoo and FRTBC were also opportunistically seen moving through the study area.

Table 5-12 Foraging habitat quality scoring for the remnant native vegetation in the study area based on field results

Attribute	Baudin's Cockatoo	Carnaby's Cockatoo	Forest Red-tailed Black Cockatoo
Starting score	**10**	**10**	**10**
Foraging potential	- 0	- 0	- 0
Connectivity	- 0	- 0	- 0
Proximity to breeding	- 2	- 0	- 0
Proximity to roosting	- 0	- 0	- 0
Impact from significant plant disease	- 1	-1	- 1
Total score	**7**	**9**	**9**

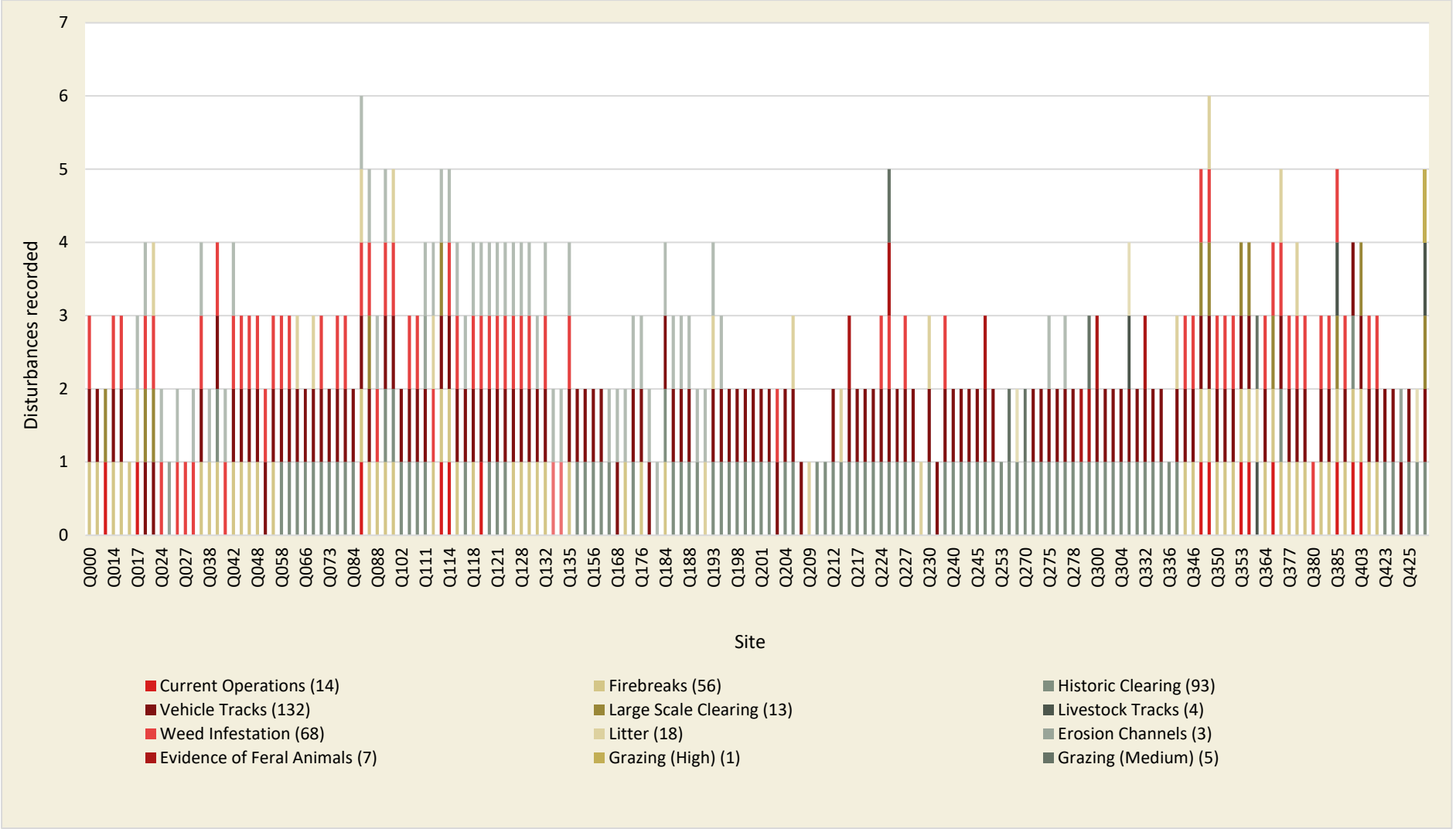


Figure 5-8 Disturbance recorded throughout the survey (total number of site records across study area)

5.4 SURVEY LIMITATIONS

The limitations of the survey have been considered in accordance with EPA (2016c, d) (Table 5-13).

Table 5-13 Consideration of potential survey limitations

Limitations criteria	Limitation	Comments
Availability of contextual information at a regional and local scale	No	Contextual information is available at a regional and local scale, however some areas of local scale were less well defined than others.
Competency/experience of the team carrying out the survey	No	Teams were led by zoologists experienced with PHT assessments and black cockatoo ecology.
Scope and completeness	No	The scope was completed; however, the study area was very large therefore only a small proportion of the study area was inspected, however repetitive (where possible) samples were taken in each habitat type. Some habitat types were inaccessible and/or present in very low proportions and could not be sampled.
Proportion of flora and fauna recorded and/or collected, any identification issues	No	Trees were measured in quadrats of 1 ha in size. To increase coverage, some quadrats were sampled at 0.5 ha, allowing better coverage of the study area and habitat types.
Access within the study area	Yes	Some privately managed lands were not accessible. Some forest blocks could not be completely surveyed due to prescribed burning activities.
Timing, rainfall, season	No	PHT and habitat assessments were undertaken at a suitable time, however the timing did not allow for observations of potential breeding behaviours during the peak period of breeding
Disturbance that may have affected the results of the survey	No	No disturbances were experienced that would have affected the results of the survey.

6 DISCUSSION

6.1 HABITATS

Twelve broad scale remnant habitat types were identified during the desktop review (Phoenix 2023a). While survey limitations restricted all 12 remnant habitat types from being sampled, the 9 different habitat types surveyed in situ (JM, JC, PH, WO, FG, BB, DL, MW and MS) matched the previously completed habitat mapping. It should be noted that only a very small proportion of each habitat type was sampled due to the large size of the study area, however repetitive samples of each habitat type were undertaken to counteract this limitation. In addition to this, field teams required vehicle access to efficiently move between sites and habitats to complete the survey.

To better validate the previous habitat mapping, a considerable proportion of all habitat types should be surveyed. Additional surveys would benefit from including areas that are not as easily accessible and therefore are less likely to be disturbed. Including habitats not previously surveyed. Yet the scale of the study area and manhours required to access and accurately survey this area are extensive.

6.2 BLACK COCKATOO RECORDS

Forest Red-tailed Black Cockatoo was the most frequently observed species recorded during the survey, detected across 36 of the sampled sites. Carnaby's Cockatoo evidence was observed much less frequently, being recorded at 5 sites, followed by one site with evidence of Baudin's Cockatoo. Forest Red-tailed Black Cockatoo foraging was far more widespread and were recorded throughout the study area, consistent with the desktop records (Figure -7).

Feeding residues of Carnaby's Cockatoo occurred centrally and in the northern part of the study area, as well as in the northeastern areas of the study area (Figure -7). These results are consistent with desktop results which also showed a higher abundance of Carnaby's in the northern half of the study area, as well as the confirmed and unconfirmed breeding areas.

Based on the sightings, 3 distinct clusters of FRTBC appear, between sites Q345 to Q354, Q364 to Q385, and Q403 to Q020 (Figure -7) These clusters all have a variety of evidence including calling FRTBC, foraging evidence, and direct sightings. Since black cockatoos can range up to 20 km from their night roosting habitat and 12 km from nests (DAWE 2022), it is unlikely that these records are the same mobile group of cockatoos moving through the landscape, as the Q403 to Q020 cluster is more than 25 km from the Q345 to Q354 cluster and moving further than 20 km requires high energy expenditure and is likely to reduce the fledgling survival rate (Phoenix 2023a). There is also a weaker cluster of FRTBC evident in the northern part of the study area. This cluster is likely to be a separate group from the clusters detected in the southern parts of the study area, as they occur more than 40 km apart.

A single foraging record of Baudin's Cockatoo was recorded during the survey at site Q089 (Table 5-6). Site Q089 also had records of Carnaby's Cockatoo and FRTBC. These species were differentiated by calls, direct sightings and the distinctive foraging marks left behind on Marri nuts.

It is important to note that these records were opportunistic only and only observed in areas accessible during the survey and are therefore not well represented across the entire study area. The broad range of evidence available without a targeted approach suggests that FRTBC and Carnaby's Cockatoos are still using the available habitat for foraging and possibly roosting and breeding. Given limited available evidence for Baudin's Cockatoo it is unclear as to how and where this species may be using habitats within the study area.

6.3 POTENTIAL HABITAT TREES

A total of 3,918 PHT were surveyed across 138.5 ha, allowing extrapolation of PHT density across the entire study area and each sampled habitat type. The desktop review estimated a total of 2,166,950 PHT over the entire 164,184 ha of the study area. In contrast, the data from the field survey estimated the total number of PHT across the study area as 2,369,625. Given the relatively small proportion of the total study area that has been surveyed (0.08%, or 0.17% of remnant vegetation types), the field survey estimate supports the desktop review estimate, although the true number of PHT across the study area could vary.

The highest density of PHT per hectare, with a mean value of 34 ±7, n = 1,415 was the WO habitat. WO was the second highest surveyed habitat type, with a total of 41.5 ha surveyed (first being JM, 50 ha surveyed). It is unsurprising that Wandoo habitats would have a high PHT density, given that *E. wandoo* dominate this habitat type and are considered PHT at a DBH of 300 mm or more, compared to most other Eucalypt species requiring a DBH of 500 mm or more. Based on the mean number of PHT per hectare, there are potentially 792,034 PHT across the entire study area in WO habitat. The desktop review estimated 610,931 PHT across the entire study area. While the data from the field survey estimated a mean value of 34 ±7, n = 1,415 PHT, the margin of error for this mean is relatively high. The true mean could fall between 27 and 41 PHT per hectare.

Most other habitat types were dominated by or included Jarrah and Marri (DL, FG, BB, JC, JM, and MW). These habitat types return relatively high mean PHT densities DL 24 ±9, n = 119 PHT per hectare, FG 32 ±7, n = 48, BB 29 ±2, n = 117, JC 22 ±4, n = 476, JM 29 ±2, n = 1,456 and MW 16 ±3, n = 48 PHT per hectare. Most of these habitats were sampled over large areas including JM over 50 ha (albeit only 0.12% of the total habitat type across the study area) and JC over 22.5 ha (0.23% of the total habitat type). The large sample area has resulted in a relatively low margin of area for these habitat types.

The habitat types dominated and including Jarrah and Marri account for a large proportion of the total number of PHT over the entire study area. The JM habitat is approximately 25% of the total study area and is estimated to account for more than half of the total number of PHT, 1,180,554 PHT out of 2,2369,625 total. The remaining habitats that consist predominantly of Jarrah and Marri (DL, FG, BB, JC and MW) account for 323,956 of the total 2,369,625 PHT.

The field survey has represented the desktop review findings for the density of PHT per hectare. Given the impracticality of surveying the entire study area and the relatively high margin of error of the mean PHT density in some habitats, the estimated PHT density of the desktop is considered relatively close to the extrapolated value calculated using field data. The density of PHT per hectare quantifies the potential impacts of land clearing and can assist in selecting areas of less significant impact or providing an estimated number of offset hollows that may be required. The abundance of Jarrah and Marri trees throughout the study area further supports the foraging, breeding, and roosting capability of the study area.

6.4 BREEDING HOLLOWS

A total of 903 hollows were recorded during the field survey, of those 96 hollows occurred on trees that had evidence of use. None of the hollows recorded appeared occupied by any species however the survey period was conducted outside the expected breeding period for Carnaby's Cockatoo (July to December) and Baudin's Cockatoo (August to January) (DAWE 2022). FRTBC breeding can occur throughout the year, but peak periods are expected during April to June (during the survey period) and August to October (DAWE 2022). Therefore the lack of detection of breeding no way suggests that the black cockatoos are not breeding within the study area.

While there is a lack of breeding evidence from the results of this survey, it should be noted that breeding surveys and thorough hollow checking is outside the scope of this field survey which was to

determine habitat quality and the density of habitat. Hollows were checked, as records would be significant and may aid the project in future breeding surveys. Additional information has been included opportunistically to provide as much contextual information as possible. To better understand the potential breeding value of the study area, targeting breeding surveys that can adequately inspect hollows (such as pole cameras) is recommended, although time-consuming and labour-intensive over such a large area.

Hollow Density was highest in WO habitat, with a mean hollow density per hectare of 8 ±3, n = 327. The JM habitat had the second highest density of hollows of 7 ±3, n = 352. Given the composition of the habitats, it is unsurprising that PH had the lowest mean density of hollows of 2 ±1, n = 6. Habitats that consist mostly of Jarrah and Marri had relatively consistent hollow densities ranging from 4 ±1, n = 6 and 16 (FG and BB) to 6 ±1, n = 47 (MS). It is important to consider that only a small proportion of the total habitat has been sampled, and therefore these values have a wide margin of error. Nonetheless, having a guide on the potential number of hollows in each hectare of habitat will assist in minimising the potential impacts of clearing, as well as assisting in the selection of artificial hollow placement and quantities.

6.5 BREEDING HOLLOW EVIDENCE OF USE

The data collected from the field survey regarding evidence of hollow use falls entirely within high breeding value habitat for Carnaby's Cockatoo, predominantly high breeding habitat value for FRTBC and in low value breeding habitat for Baudin's Cockatoo (Figure -7).

The evidence of hollow use aligns with the desktop records for 3 black cockatoo roosting areas, confirmed Carnaby's Cockatoo breeding areas and unspecified black cockatoo breeding records (Figure -1).

Where clear evidence of black cockatoo evidence use was present at hollows (ie. chewing around hollows), 5 distinct areas appear to have a higher potential to support a breeding area, however these require further investigation to confirm whether or not black cockatoos are using these for breeding:

- the north-west corner, which is between a confirmed and unconfirmed Carnaby's Cockatoo breeding area (DBCA)
- a patch within north-east section of the study area
- central area – close to known confirmed breeding area
- Quindanning Block
- southern boundary of the study area.

Four Jarrah trees and 2 Marri trees had evidence of old chewing around hollows, while 4 Jarrah trees and one Marri had evidence of recent hollows. The hollows that show evidence of use all occur in the Carnaby's Cockatoo high breeding value areas, but only 2 hollows were within the Forest Red-tail black cockatoo high value breeding area (Figure -7).

Only 4 records of recently chewed hollows were found in the study area. Of these, 2 were located in the centre of the study area (within the confirmed Carnaby's Cockatoo breeding area), and 2 were located in the southern part of the study area (Figure -7).

Old chewing around hollows was recorded only in the northern part of the study area, including one near 2 recently chewed hollows in the centre of the study area. The older chewed hollows in the northern part of the study area occur between the confirmed and unconfirmed Carnaby's Cockatoo breeding areas.

Comparing the recent evidence of use areas with the desktop records, the 3 central chewed hollows (recently and old) overlap with confirmed Carnaby's Cockatoo breeding areas and known roosting

sites (Figure -7) and are within 3 km of a FRTBC breeding tree. These records may indicate important breeding trees for either Carnaby's Cockatoo or FRTBC.

Scarring was the most abundant type of evidence of hollow use, and is known habit of galahs, however this indicates that a hollow is suitable for use. Most of the scarred trees were Jarrah (37), followed by Marri (9) and Wandoo (5). Most of the scarring occurs in continuous habitat in the south-western corner of the study area, while others occur in small groups or isolated areas in the northern and southern areas of the study area. Scarring indicates many trees in the study area contain suitable hollows, however do not indicate black cockatoo use.

The extrapolated value of 556,486 PHTs containing hollows and 6,884 with evidence of use may be present within the study area is likely an overestimation of actual use. Confirmed breeding cannot be determined until either a female cockatoo is flushed from a nest while incubating eggs, or an egg or chicks are seen (via use of a camera or audible sounds from within the nest. In a monitoring programme of 59 natural hollows near Chittering (Phoenix 2022), 18 (30.5%) have had evidence of breeding in the 6 years of monitoring, of which 8 (13.5% of total/44% of those with evidence) have had a confirmed breeding event. In any one year, the rate of a confirmed breeding event occurring in a hollow that has evidence (i.e., chewing) varied between 16% to 50%, with an average of 33%. This indicated that a large number of hollows with evidence of breeding have not had an actual breeding event occur. Carnaby's breeding is thought to be more prevalent in the Wheatbelt, with a higher concentration north of Perth (Chittering to Kalbarri), and scattered records on the Swan Coastal Plain, Jarrah Forest, and eastern and southern Wheatbelt areas, while Forest Red-tail Black Cockatoos are known to have a more cosmopolitan breeding range and Baudin's generally in higher rainfall denser forested areas (DAWE 2022), however records indicate that at least Carnaby's Cockatoo and Forest Red-tails may have breeding populations at sites within the study area. While breeding habitat value for Baudin's cockatoo is of low value due to the paucity of records and uncertainty around the significance of the breeding records of that species within the study area, it is likely those records represent outliers in the known breeding areas of Baudin's cockatoo.

Given the high breeding value of these areas and the similar patterns of the desktop records, the evidence of hollow use is more likely to be attributed to Carnaby's Cockatoo or FRTBC rather than Baudin's Cockatoo. Further confirmation of potential nesting hollows through repetitive use can be used to further support survey and desktop records and solidify the importance of the habitats available within the study area, rather than a definitive guide to breeding locations within the study area.

6.6 HABITAT QUALITY ASSESSMENT

The quality of the habitat was determined based on signs of disturbance present at each sampled site. Nearly every site had at least one type of disturbance present, while most had 2 or more (Figure -). While the most prolific kind of disturbance was vehicle tracks, evident at 132 different sites, this type of disturbance is unlikely to negatively impact habitat use by black cockatoos. the presence of vehicle tracks is unlikely to reduce the availability of foraging species or reduce the availability of PHT or hollows for breeding. Furthermore, black cockatoos are known to use hollows in or near tracks (Phoenix 2023b) or other developments.

The next most common sign of disturbance recorded throughout the survey was historic clearing, identified at 93 different sites. Historic land clearing may have permanently reduced the availability of foraging, nesting, and roosting habitat for black cockatoos. The Map of Old-Growth Forest (DBCA 2020) displays the remaining areas of unchanged forest throughout the Southwest region. Only a very small proportion in the southern area of the study area remains unchanged forest. The majority of available habitat within the study area appears to be state forest, timber reserves and miscellaneous reserves, other DBCA lands or privately owned lands with remnant vegetation (DBCA 2020). In addition to historic clearing.

Prescribed burning was evident at most sites. The impacts of prescribed burning appeared detrimental to the PHT health and density at many sites where it was noted many trees had burned through the core creating unusable (cracked, open) trunk hollows, or had weakened the core and the tree had fallen.

Disturbance most likely to impact black cockatoos include those most likely to impact the availability of nesting habitat and food availability, such as land clearing and dieback (DEC 2007). While wildfires have the ability to destroy habitat and habitat trees, prescribed burning is also a significant threat if not undertaken or managed appropriately, and if due diligence is not undertaken prior to ensure current or potential future breeding trees are not affected. Planned burns undertaken prior to the breeding season may also affect the availability and density of foraging resources during the breeding season if not undertaken properly.

Recording the presence of disturbances is important for the overall health of the ecosystem. While some of the disturbances recorded are considered less significant threats to black cockatoos than clearing, such as weed invasion and vehicle tracks; these disturbances may continue to degrade the availability of foraging habitat and the recruitment of future breeding habitat (Cale 2003; DEC 2007) and may become significant threats to black cockatoos within the study area if unmanaged.

The relationships between the different types of disturbance also play a role in their ability to establish and degrade the study area. As mentioned previously, vehicle tracks were the most common records of disturbance, occurring at 132 different sites. Vehicle tracks can facilitate the introduction and spread of other types of disturbances, further intensifying their impacts. For example, vehicle tracks provide access to otherwise difficult or inaccessible parts of the ecosystem to feral animals and livestock. Vehicle tracks can also provide access for recreational off-road drivers, illegal tree felling, and facilitate the spread of weeds which may lead to the out-competition of native forage species, and compacting track substrate, which in turn, can intensify the impacts of erosion and spread diseases like dieback (Doherty *et al.* 2015). For this reason, identifying disturbances is important to determine the overall quality of the habitat and guide the management of these threats. However, in the context of black cockatoo habitat requirements, these impacts will not directly influence the current quality of available habitat, rather, they have the potential to impact black cockatoo habitat quality in the future.

Overall, disturbance was abundant throughout the study area and has likely already reduced the availability of foraging and breeding habitat, particularly the historic clearing of the Northern Jarrah Forest as a whole (DBCA 2020). Despite the disturbances evident, most of the impacts do not immediately reduce the availability of foraging habitat, PHT or hollows. The study area is likely to have more than 2 million PHT and half a million hollows and thus is of good quality. Given the records of black cockatoos throughout the study area and the evidence of use persisting near known roosting sites for black cockatoos, the value of the study area for black cockatoos is generally high, though localised variations in foraging habitat quality likely exists throughout the high quality habitat, and can be validated through individual assessment of forage species, density and evidence. Habitat critical to survival includes areas occupied by cockatoos, consists of nests, feeding and roosting locations and has natural vegetation (specifically Marri, Jarrah and Wandoo) connecting different patches of habitat (DEC 2007). For this reason, the study area has recorded high quality foraging scores for all 3 species of black cockatoo (Table 5-12). The study area contains large areas of habitat critical to the survival of black cockatoos (DEC 2007), providing essential resources to support these populations, further increasing the value and solidifying the importance of the available habitat within the study area.

7 DETERMINATION OF LOCATIONS FOR ARTIFICIAL HOLLOWS

The selection of artificial hollows placement should consider several factors including previous breeding areas, habitat use, accessibility and artificial hollow density (DEC 2010), availability of foraging resources and water. Artificial hollow placement is recommended in:

1. secure conservation reserves such as S32s Biodiversity Offset sites
2. known black cockatoo breeding areas, as adults typically return to their natal areas to breed. Additionally, competition for hollows is high within populations and between different species.
3. areas where there are available food resources: Potential foraging habitat is abundant in the western part of the study area however much of the eastern and southern part of the study area is cleared. Even in the heavily cleared area, all potential breeding habitats are located within 12 km of suitable foraging habitat, mostly in the form of blocks of remnant vegetation such as Lavender Nature Reserve or Quindanning Timber reserve, however roadside vegetation, isolated pockets of vegetation within cleared areas, pine and blue gum plantations, agricultural species such as canola, and weeds such as storksbill also provide a food source for black cockatoos. Marri nuts and Banksia cones provide the highest quality food resources for black cockatoos. These must be abundant to support breeding pairs and fledgelings. While black cockatoos can fly up to 20 km to forage, the energy usage is greater if a bird has to fly further and this may result in failed breeding therefore the distance to abundant and quality food resources.
4. areas where there is nearby access to water. Access to water is also a factor in determining black cockatoo habitat value, however these are generally not a limiting factor in the study area given watering points throughout the Jarrah forest occur in the form of permanent pools within rivers and streams, swamps, and low lying areas. Within the cleared areas towards the south and east of the study area, farm dams, reservoirs and other watering points are a common feature.
5. in all suitable habitat types, particularly those that support known breeding tree species such as Marri, Jarrah and Wandoo, but also lesser-known species such as Flooded Gum, Blackbutt, and Bullich
6. areas where is there is ease of access for installation, monitoring, and maintenance
7. tree selection should also favour inconspicuous locations to mitigate the threat of poaching or public interaction with nests (DEC 2010).

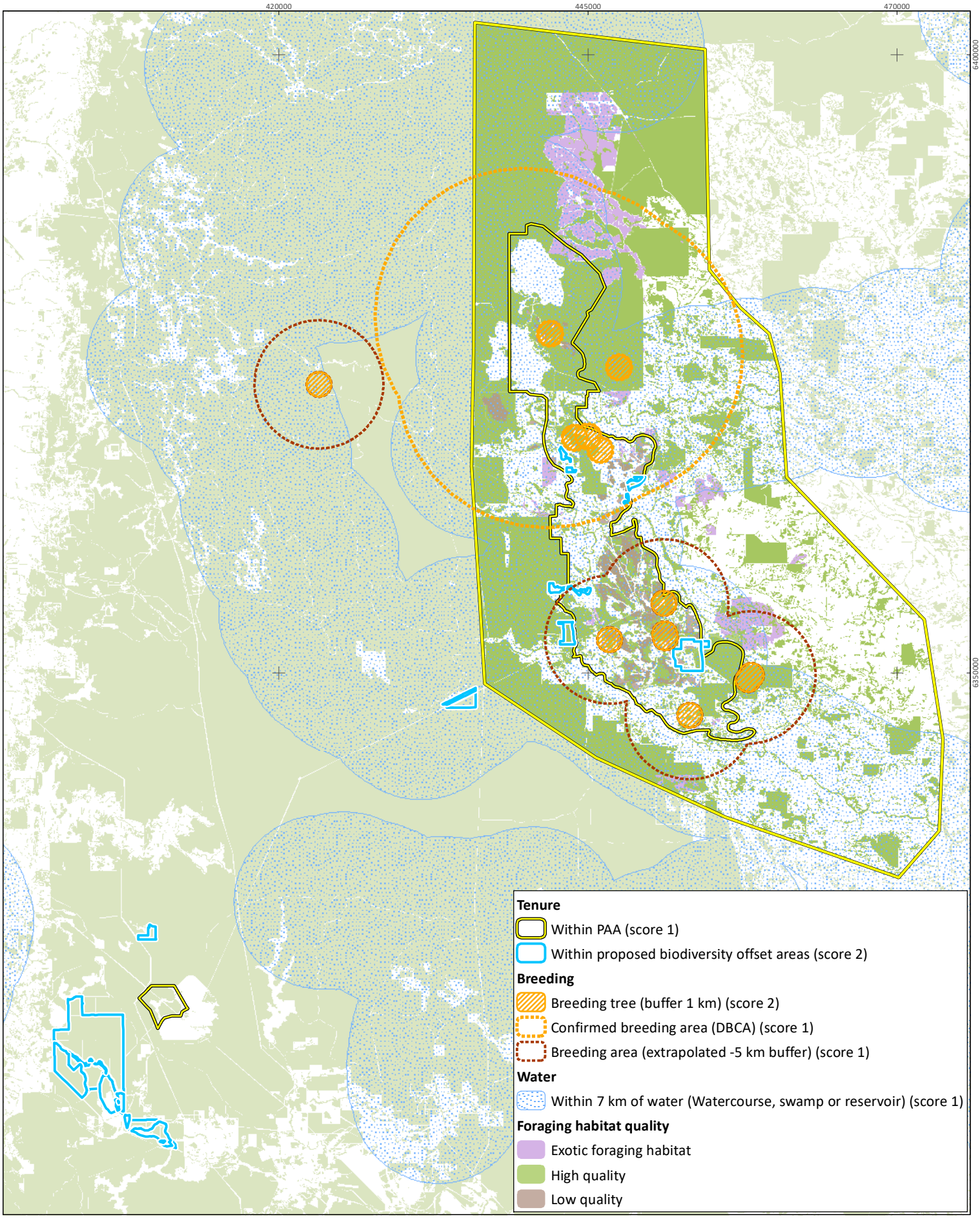
In order to determine the most suitable areas to place nest boxes, a spatial analysis of factors 1-4 was undertaken. Areas of known breeding, water sources buffered by a 7 km radius, and tenure were combined and then each polygon was then scored against each of the criteria according to Table 7-1 and shown in Figure 7-1. Foraging habitat was estimated using existing habitat mapping and native vegetation extent mapping. A combined score was then attributed to each polygon with a maximum achievable score of 7. Generally higher scores indicate more of the requirements are met for what would be considered suitable black cockatoo breeding habitat, or that higher quality breeding habitat is present.

Some areas are deficient in information, particularly the offset block Lot 102 and 100 (IOP#1) which did not form part of the study area, inaccessible areas, and areas of the study area where breeding is suspected (chewed hollows) but not confirmed. These areas may have a higher score than what is presented here if breeding is confirmed or suspected nearby.

Figure 7-2 displays the areas which are considered to be the most suitable areas to further investigate locations to install artificial nest boxes. It is advisable to install nest boxes in a variety of areas to maximise the chances of usage and avoid too high density or risk of damage through known threats.

Table 7-1 Criteria for scoring suitable locations to install artificial nest boxes

Factor	Criteria	Score
Tenure	S32 Biodiversity offset site	2
	PAA	1
	Other	0
Breeding habitat	Known from within 1 km of a known breeding tree	2
	Known from within the buffer of confirmed breeding area (DBCA, or within 3 km from a known breeding tree)	1
Foraging habitat	>50% remnant vegetation (Jarrah, Marri or Banksia) present within 7 km	2
	25 - 50% remnant vegetation (Jarrah, Marri or Banksia) present within 7 km	1
	Highly fragmented and isolated foraging habitat within 7 km	0
Water	Known water (swamps, major watercourses and reservoirs) within 7 km	1



S32
Worsley Mine Expansion

Project No	1562
Date	21-Aug-23
Drawn by	AJ
Map author	AJ

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Kilometers

1:394,912 (at A4) GDA 1994 MGA Zone 50

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Study area
Native vegetation extent (DPIRD)

Foraging habitat quality
Exotic foraging habitat
High quality
Low quality

Figure 7-1

Selection criteria for artificial nest box locations

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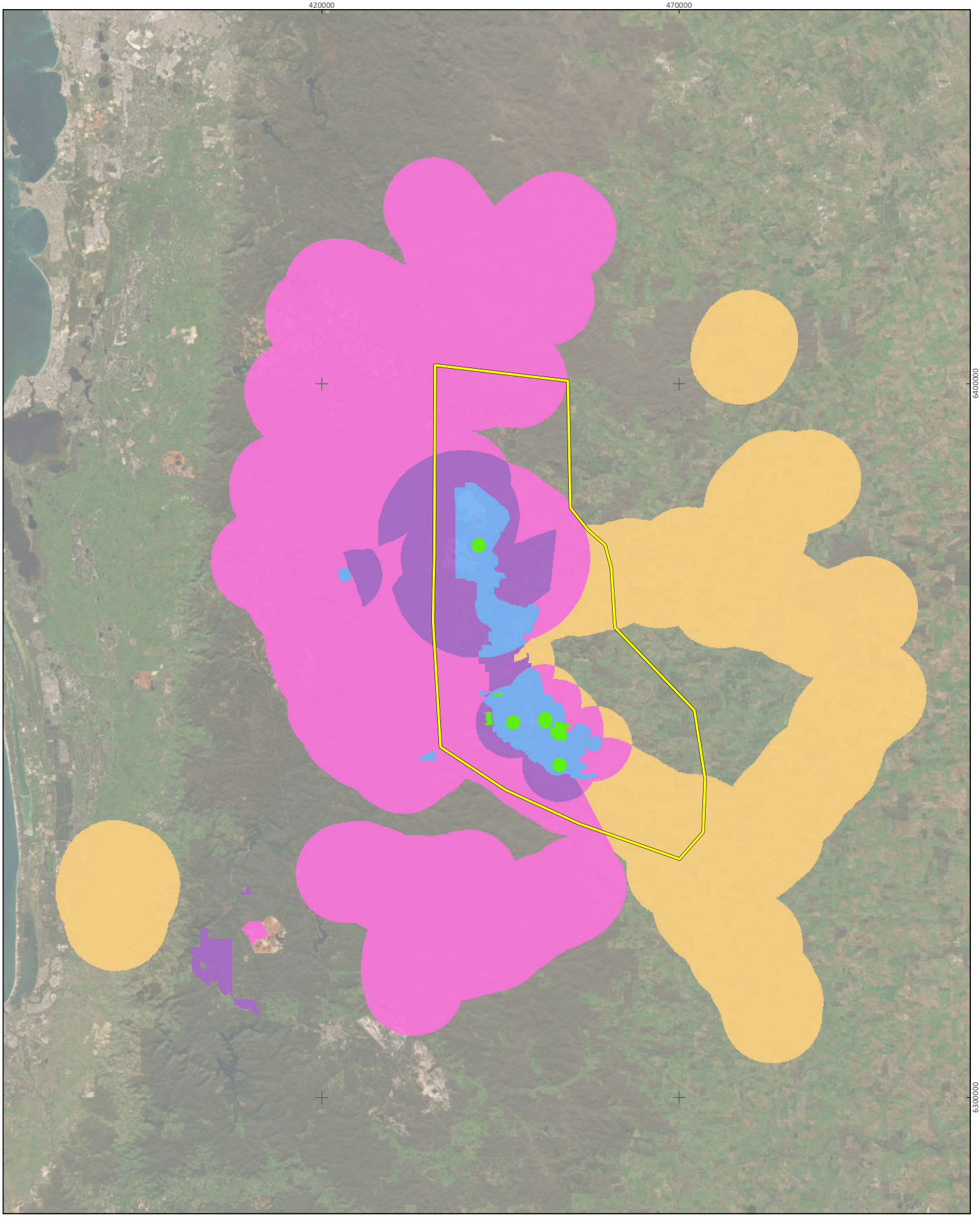

S32
Worsley Mine Expansion

Project No	1562
Date	21-Aug-23
Drawn by	AJ
Map author	AJ

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Study area

Nest box habitat suitability score

- 2
- 3
- 4
- 5 - most suitable
- 6 - most suitable

Figure 7-2

Suitable areas for artificial nest box placement

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8 CONCLUSION

In summary, the study area represents both breeding and foraging habitat for all 3 species of black cockatoo with an abundance of sighting and foraging records throughout. However, local variations of foraging habitat quality are likely to be present throughout and each parcel may be individually validated based on density of forage species and evidence of use. The estimated number of PHT across the study area from the desktop review was 2,166,950 compared to 2,369,625 in the field survey (91% of the PHT of the field survey was estimated). While the evidence of hollow use follows the patterns of the desktop results for black cockatoo breeding, breeding use throughout the study area is still not well understood. Given that black cockatoo sightings were relatively widespread between sites, and that high quality foraging habitat is present throughout all remnant areas of the study area, the study area generally represents critical habitat for all 3 black cockatoo species, particularly Carnaby's and FRTBC.

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Appendix 1 Survey site locations