Appendix D Great Eastern Highway Bypass Interchanges Project: Offset Strategy

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Great Eastern Highway Bypass Interchanges
EPBC Offset Strategy

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1. Introduction

1.1 Proposed Action Background

Main Roads Western Australia (Main Roads) is proposing to construct a grade separated interchange at the Great Eastern Highway Bypass and Roe Highway intersection (GEHBI). The Proposed Action occurs approximately 15km east of Perth CBD, within the City of Swan and Shires of Kalamunda and Mundaring.

The GEHB connects Guildford Road to Roe Highway, providing a bypass for traffic around Guilford and Midland. Roe Highway is a strategic road that stretches from Kwinana Freeway to Great Northern Highway, forming the outer ring road network for the Perth metropolitan area.

The Roe Highway and GEHB intersection is one of the last remaining signalised intersections on Roe Highway. In recent years, the intersection has become heavily congested with road users experiencing significant wait times during peak periods (Bennett et al., 2016). Main Roads proposes to improve safety and enhance freight efficiency through the construction of a grade separation at the intersection.

1.2 Proposed Action Description

The Proposed Action includes:

- Grade separation at the intersection of Roe Highway and Great Eastern Highway Bypass (GEHB).
- Upgrade of Roe Highway between Adelaide Street, Hazelmere and Clayton Street, Bellevue including a duplication of the bridge over Helena River.
- Principle shared pathway (PSP) connection south to Kalamunda Road and 300 m north of Clayton St.
- Stirling Crescent to be changed to terminate in a cul-de-sac.

The Proposed Action comprises approximately 68.07 ha of land (Figure 1).

1.3 Purpose of this Strategy

The purpose of this strategy is to demonstrate the environmental value of each proposed offset site that will contribute towards offsetting the residual impacts of the Project. This Offset Strategy has been prepared to provide additional information on offsets requested by the Department of Agriculture, Water and Environment (DAWE) (now the Department of Climate Change, Energy, the Environment and Water [DCCEEW]). This included provision of an offset package that consists of an offset proposal, key commitments, and management actions for delivering the proposed offset. The draft Offset Strategy has been prepared in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Environmental Offsets Policy (October 2012).

Prior to approving the Offset Strategy, DCCEEW require that the strategy must first meet the eight offset principles that are described in Section 5.

Acquisition of suitable offset land aims to satisfy both Commonwealth and State environmental compliance requirements. Should changes to the approved Offset Strategy be required subject to commercial negotiations with property owners, and consultation with the WA Department of Biodiversity, Conservation and Attractions (DBCA), DCCEEW will be notified of any changes and appropriate action will be taken to ensure offset requirements remain to be met under the EPBC Act.

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Datum: GDA 1994 Perth Coastal Grid 1994

1:20,000 (when printed at A4)

0 140 280 420 560 metres

Data sources: Main Roads WA

LEGEND

- WP4 Development Envelope – Assessed (8 Feb 22)
- Banksia Woodlands TEC

Proposed Action, Impacted Banksia Woodlands of the Swan Coastal Plain TEC

MAIN ROADS WA

GREAT EASTERN HIGHWAY BYPASS INTERCHANGE PROJECT

WP4 ROE HIGHWAY EPBC REFERRAL

Figure 1

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2. Proposed Action

2.1 Controlling Provisions

The Proposed Action may have a significant impact on Matters of National Environmental Significance (MNES) and was therefore determined to be a controlled action requiring assessment under the EPBC Act (EPBC 2020/8784).

On 11 September 2020, DAWE (now DCCEEW) requested Main Roads to prepare Preliminary Documentation to provide additional information required under s95A of the EPBC Act.

The MNES relevant to the Proposal include:

- Threatened Ecological Communities:
  - *Banksia Woodlands of the Swan Coastal Plain* Threatened Ecological Community (Endangered) (Banksia Woodlands TEC).
- Threatened Species:
  - Baudin's Cockatoo (*Zanda baudinii*) (Endangered).
  - Carnaby's Cockatoo (*Zanda latirostris*) (Endangered).
  - Forest Red-tailed Black Cockatoo (FRTBC) (*Calyptorhynchus banksii naso*) (Vulnerable).

The Preliminary Documentation (GCA, 2023a) provides details of the predicted impacts of the Proposed Action to the above MNES.

2.2 Residual Impacts

The offsets package will compensate 100% of the residual impacts listed below through land already managed by Main Roads, direct land acquisition, and research offsets.

The estimates presented in this Strategy are conservative, representing the full extent of MNES values within the 68.07 ha disturbance footprint. The actual clearing footprint is expected to be less and will be refined through the detailed design and construction planning process.

2.2.1 Threatened Ecological Communities

The Proposed Action will remove up to 14.94 ha of Banksia Woodland TEC across five patches, containing Floristic Community Types (FCTs) 20a, 21c, 23a, and 28. The vegetation composition of these FCTs are further described in Section 3.3.1. The proposed offset sites will offset the entire 14.94 ha of TEC impacted from clearing (Figure 1). The vegetation condition of the impacted TEC ranged from Excellent to Degraded, comprised of 4.74 ha of Excellent to Very Good, 4.71 ha of Very Good, and 4.02 ha of Good. The Banksia Woodland TEC within the Proposed Action has been assessed using the DCCEEW Habitat Quality Scoring (HQS) Tool and determined to have a habitat quality score of 6. As such the total quantum of impact to be offset is 8.96 ha. Further details and justification for the application of the HQS Tool for TEC quality is provided in Section 4.

2.2.2 Threatened Species

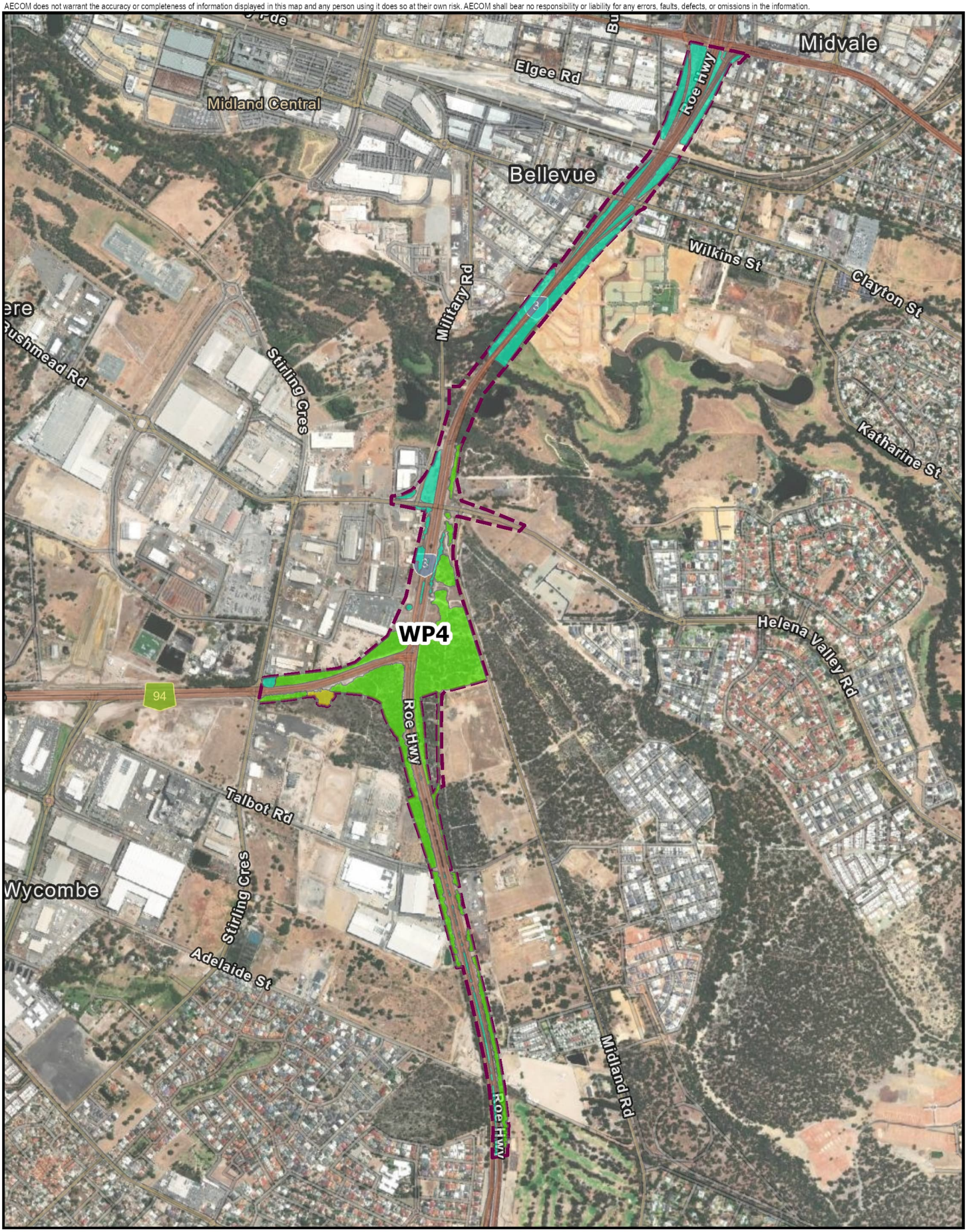
The Proposed Action will clear up to 33.48 ha of foraging habitat for the three Threatened Black Cockatoo species (Figure 2). The quality of foraging habitat for each Black Cockatoo species has been assessed using DCCEEW's Habitat Quality Scoring (HQS) Tool as follows:

- Baudin's Cockatoo – 33.48 ha of foraging habitat with a score of 3.
- Carnaby's Cockatoo – 33.48 ha of foraging habitat with a score of 6.
- FRTBC – 33.48 ha of foraging habitat with a score of 6.

Further details and justification for scoring of foraging quality within the Proposed Action is provided in Appendix 1.

Foraging habitat comprised roadside and scattered eucalyptus or marri trees, Banksia woodland and Fabaceous heathland. As this habitat has been determined to have a habitat quality score ranging from 3 to 6 depending on the Black Cockatoo species, the total quantum of impact of Black Cockatoo foraging habitat to be offset for each species is:

- Baudin's Cockatoo – 10.04 ha.
- Carnaby's Cockatoo – 20.09 ha.
- FRTBC – 20.09 ha.



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0 140 280 420 560 metres

Data sources: Main Roads WA

LEGEND

WP4 Development Envelope – Assessed (8 Feb 22)

Foraging Habitat

- Banksia woodland with scattered Eucalyptus/Marri
- Eucalyptus/Marri in road reserve
- Fabaceous healthland

Proposed Action, Impacted Black Cockatoo Foraging Habitat

MAIN ROADS WA

GREAT EASTERN HIGHWAY BYPASS INTERCHANGE PROJECT

WP4 ROE HIGHWAY EPBC REFERRAL

Figure 2

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v3.aprx (rob.mcgregor)

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3. Rationale for Offset Strategy

Main Roads has developed this package of offsets to counterbalance the significant residual impacts of the Proposed Action to Banksia Woodland TEC, Carnaby's Cockatoo, FRTBC and Baudin's Cockatoo. Sites are either Freehold land managed by Main Roads, or Main Roads has provided funding for the acquisition of land that will be transferred to the conservation estate under the management of DBCA. The offset package comprises a mix of land acquisition and funding of land management. Main Roads will meet up to 10% of its offset package for impacts to Black Cockatoos through investment in research programs.

The land acquisition of like-for-like bushland is increasingly challenging in Western Australia, and it is not always possible to find available remnant vegetation on privately owned property within the Perth metro area and surrounds. Whilst this strategy focusses on direct like-for-like land acquisition, alternative offset options have been included to complete the offset package.

These include:

- Protection of existing Main Roads' property via a notification on Title.
- Revegetation and management of degraded vegetation to enhance ecological function.
- Land acquisition of property containing large blocks of similar like for like habitat or vegetation, located in other WA regions outside of the Perth metro area.

Where acquisition of existing good condition or better vegetation was not possible, the strategy includes restoration and enhancement offsets.

Main Roads has adopted the following methodology to identify suitable offsets for the Proposed Action:

- Review of policies and guidance under the EPBC Act.
- EPBC Act Offset Calculator Tool to identify the scale of offsets required.
- Literature review, including EPBC Act approved conservation advice, peer-reviewed studies and research data.
- Consultation with DBCA to determine preferred options, indicative management actions and approximate costs.
- Biological surveys and desktop assessment of sites to quantify the offset values present.

As outlined in Section 4, offset sites have been selected that contain the TEC and/or Black Cockatoo habitat values required to be offset. By managing these areas for conservation purposes long term in accordance with the Offset Management Plan (GCA, 2023c), the offset sites will adequately offset all significant residual impacts to Banksia Woodland TEC and Black Cockatoo habitat.

3.1 Policy and Guidance

3.1.1 EPBC Guidance

This Strategy has used the following policy, guidelines, and conservation advice to identify suitable offset sites to counterbalance the significant residual impacts of the Proposed Action:

- EPBC Act Environmental Offsets Policy (DSEWPaC, 2012a).
- EPBC Act Offset Policy Principles (DCCEEW, 2022a).
- Habitat Quality Scoring Tool (Provided by DCCEEW, 2023).
- How to use the Offsets assessment guide (DSEWPaC, 2012c).
- Offsets Assessment Guide (DSEWPaC, 2012b).
- Offset scarcity: General introduction (draft) (DCCEEW, 2022b).

DCCEEW has defined eight offset policy principles that outline the criteria of an offset site, and two additional principles are listed that provide guidance on how the minister will assess offset proposals.

A detailed assessment of how the offset package complies with principles 1-8 is provided in Section 5.

3.1.2 Conservation advice

This Strategy considers the following EPBC Act approved conservation advice for each of the MNES relevant to the Proposed Action:

- Approved Conservation Advice for the Banksia Woodlands of the Swan Coastal Plain ecological community (DoEE, 2016).
- Referral guideline for 3 WA threatened black cockatoo species (DAWE, 2022).
- Carnaby's cockatoo (*Zanda latirostris*) Recovery Plan (DPaW, 2013).
- Conservation Advice (*Zanda baudinii*) Baudin's Cockatoo (TSSC, 2018).

3.2 Scale of Offsets to Counterbalance Significant Impacts

The EPBC Act Offset Calculator Tool was used to evaluate how suitable the identified offset sites are to counterbalance potential significant residual impacts.

The offsets package presented in Section 4 demonstrates that significant residual impacts can be sufficiently counterbalanced.

The offsets selected counterbalance at least 100% of the residual impacts to Banksia Woodland TEC, Carnaby's Cockatoo, FRTBC, and Baudin's Cockatoo.

3.3 Banksia Woodland TEC Offset Strategy

3.3.1 TEC Description

The Banksia Woodlands TEC occurs in patches throughout the Swan Coastal Plain, from Busselton in the southwest to Jurien Bay in the Wheatbelt region (DoEE, 2016). In Western Australia, the TEC is recognised as several distinct ecological communities, and may be listed as State endorsed TECs or Priority Ecological Communities (PECs). These State endorsed communities are defined by Floristic Community Types (FCTs) and are dependent on species composition and structure.

The Approved Conservation Advice (incorporating listing advice) for Banksia Woodland of the Swan Coastal Plain Ecological Community, defines minimum patch size and condition thresholds for patches to be considered Banksia Woodland TEC (DoEE, 2016). Minimum patch sizes are different for different levels of vegetation condition. In the preparation of the Offsets Strategy, Banksia Woodlands offsets have been assessed in line with these threshold levels to confirm their TEC status.

The composition of the four FCTs (FCT 20a, 21c, 23a, and 28) that the Proposed Action will impact are described below:

3.3.1.1 FCT 20a Banksia attenuata woodlands over species rich dense shrublands

FCT 20a occurs in the southern Perth metropolitan region, located in the Forrestfield, Koondoola and Chittering areas. The community is typically very species rich (average of 80 spp./100 m^2), with species comprising *Banksia attenuata* and/or *Eucalyptus marginata*, with mixed understorey (DoEE, 2016).

Biota (2021) determined that five 10x10 quadrats (100 m^2) across the survey area were representative of FCT 20a. These had a lower average species density compared with the DoEE (2016) average of 48.8 spp./100 m^2. The dominant trees recorded within the Proposed Action included *Banksia attenuata, B. menziesii, Eucalyptus todtiana, E. marginata* subsp. *marginata, Corymbia calophylla* and *Allocasuarina fraseriana*.

3.3.1.2 FCT 21c Low lying Banksia ilicifolia woodlands

FCT 21c is predominantly found in the Perth metropolitan region but has been recorded from Gingin to Bunbury. The community is typically found on the uplands of the Bassendean system, comprising low dues and wetlands (DoEE, 2016). FCT 21c can have a woodland or shrubland structure and is dominated by a mix of species including *Melaleuca preissiana, Banksia attenuata, B. menziesii, Regelia ciliata, Eucalyptus marginata* or *Corymbia calophylla*. The community has a relatively a low species density, with an average of 40 spp./100 m^2.

Biota (2021) determined that one quadrat was floristically similar to FCT 21c, which had a species density of 35 spp./m^2. The vegetation had a woodland structure and was dominated by *Eucalyptus marginata* subsp*. marginata, Banksia menziesii*, and *Allocasuarina fraseriana*.

3.3.1.3 FCT 23a Central Banksia attenuata - Banksia menziesii woodlands

FCT 23a is restricted to the Perth metropolitan region, located from Bullsbrook to Woodman Point. The community is found on the Bassendean system and is dominated with *Banksia attenuata* and *B. menziesii* species. The species richness is high with an average of 62 spp./100m^2.

Biota (2021) recorded 10 quadrats representing FCT 23a across the survey area with an average species richness of 47.3 spp./100m^2. Dominant trees recorded included *Corymbia calophylla, Nuytsia floribunda, Allocasuarina fraseriana, Eucalyptus marginata* subsp*. marginata, E. todtiana, Banksia attenuata, B. menziesii,* and *Jacksonia floribunda.*

3.3.1.4 FCT 28 Spearwood Banksia attenuata or Banksia attenuata – Eucalyptus woodlands

FCT 28 commonly consists of *Banksia attenuata* woodlands with *Eucalyptus marginata* and/or *Corymbia calophylla* with scattered *Eucalyptus gomphocephala*. This type has a medium-high species richness of 56 spp./100m2 (DoEE, 2016).

Biota (2021) revealed that two quadrats within the Proposed Action align with FCT 28. Characteristic species recorded for this FCT included *Banksia attenuata, Hibbertia hypericoides* subsp. *hypericoides, Mesomelaena pseudostygia* and *Trachymene pilosa*.

3.3.2 Proposed Action

The Proposed Action will clear up to 14.94 ha of Banksia Woodland TEC across five distinct patches. The proposed site to offset the clearing of TEC contains the same Banksia Woodlands of the Swan Coastal Plain. Details of the Banksia Woodland TEC located within the proposed action has been provided below. Suitability of the site acquired to offset the Banksia Woodlands impacted (i.e., like for like) have been described further in Section 4.

Based on the habitat quality scoring assessment (Appendix 1 a) and surveys of the site, the vegetation condition of the Banksia Woodland TEC is comprised of good (26.91%), very good (40.56%), excellent to very good (31.73%), or degraded (0.80%). The patches impacted have been assessed as having an average of 36 native species per 100m^2, suggesting species richness is within the top half of the recorded range for Banksia Woodland TECs. According to DCCEEW's (2022d) referral guidelines for 3 WA threatened Black Cockatoo species, the patches of Banksia Woodland within the Swan Coastal Plain provide critical habitat for Carnaby's Cockatoo and FRTBC.

To offset the impacts of the Proposed Action, a site containing Banksia Woodlands of the Swan Coastal Plain has been acquired (Offset 1 - Table 1). The offset site has an overall habitat quality score 'with offset' that is equal to or greater than the impacted area. Justification for scores is provided in Appendix 1 b and further details of the offset site is provided in Table 3.

Table 1–Banksia Woodland TEC Habitat Quality Scores for the Proposed Action and offset site 'with offset'

Offset	Location	Site Condition (out of 150)	Site Context (out of 100)	Habitat Quality Score (out of 10)
Impact (Proposed Action)	Hazelmere, Intersect of Great Eastern Highway Bypass Interchange and Roe Highway	105	45	6
Offset 1	Durigen Road, Cowalla	120	70	8

3.3.3 Potential offset scarcity

3.3.3.1 Availability of floristically similar offset sites

The Proposed Action is located on the edge of the Swan Coastal Plain sub-bioregion, close to the border of the Northern Jarrah Forest. A 30 km buffer (radius) from the Proposed Action was chosen to gather information on the extent of Banksia Woodland TEC in the surrounding area. The majority of remnant native vegetation within a 30 km radius of the Proposed Action is located east, within the Northern Jarrah Forest sub-region.

The extent of Banksia Woodland TEC remaining has been estimated by comparing pre-European vegetation extents against current native vegetation and TEC spatial datasets (Beard et al., 2013; DPIRD, 2020; DBCA, 2022). Within 30 km of the Proposed Action, there is approximately 7,000 ha of Banksia Woodland TEC (Figure 3). Of this, only 600 ha (9%) is mapped within freehold land, 6130 ha (87%) is protected within State Parks and Forests and Commonwealth National Parks and Reserves, and the remaining 4% is mapped as crown land. Given 87% (6130 ha) of the remaining Banksia Woodland TEC is already protected within State Parks, and only 9% (600 ha) is within freehold land, the acquisition of properties containing the TEC within 30 km of the Proposed Action is limited. Therefore, to make up the offset requirement, a site in Cowalla (located approximately 94 km north of the proposed action) has been selected to protect Banksia Woodlands TEC with similar features, in a region where Banksia Woodland is less protected.

3.3.3.2 Confidence in offset benefit (Comparison of protecting or restoring land)

The EPBC Act Environmental Offsets Policy states that environmental offsets should provide a measurable environmental conservation gain against the Proposed Action's residual impacts (DSEWPaC, 2012a). The degree to which a 'conservation gain' is realised, is influenced by the confidence of success for the offset approach adopted.

The Approved Conservation Advice for Banksia Woodland of the Swan Coastal Plain Ecological Community states that maintaining existing high-quality remnants of Banksia Woodland TEC is likely to provide more practical and successful outcomes for the long-term recovery of the TEC, rather than attempting rehabilitation of degraded vegetation (DoEE, 2016). Therefore, to achieve a conservation gain, the approach of acquiring, protecting, and maintaining high-quality remnant Banksia Woodland is generally preferred over rehabilitation approaches that have lower confidence in results.

The land acquisition offsets include offset management actions such as fencing, weed and predator control, and restricting access to the site. These actions directly address the DoEE (2016) key threats to the TEC, particularly, the spreading of dieback diseases, invasive species, feral animal grazing, and uncontrolled vehicle access. The benefits of these management actions on improving vegetation condition and Black Cockatoo habitat values have also been extensively documented within existing literature (Appendix 2). Given the management actions directly address identified key threats to Banksia Woodlands and there is supporting literature for the benefits of these actions, the confidence of success for this approach is high in comparison to the rehabilitation of degraded Banksia Woodland. Confidence in results is further supported by the methods presented in the Offset Management Plan (GCA, 2023c), that details the approach and schedule adopted to maximise the success of the proposed management actions.

In summary, protecting existing high-quality remnants of Banksia Woodland TEC will have a positive conservation gain with high confidence by reducing critical threats to its existence.

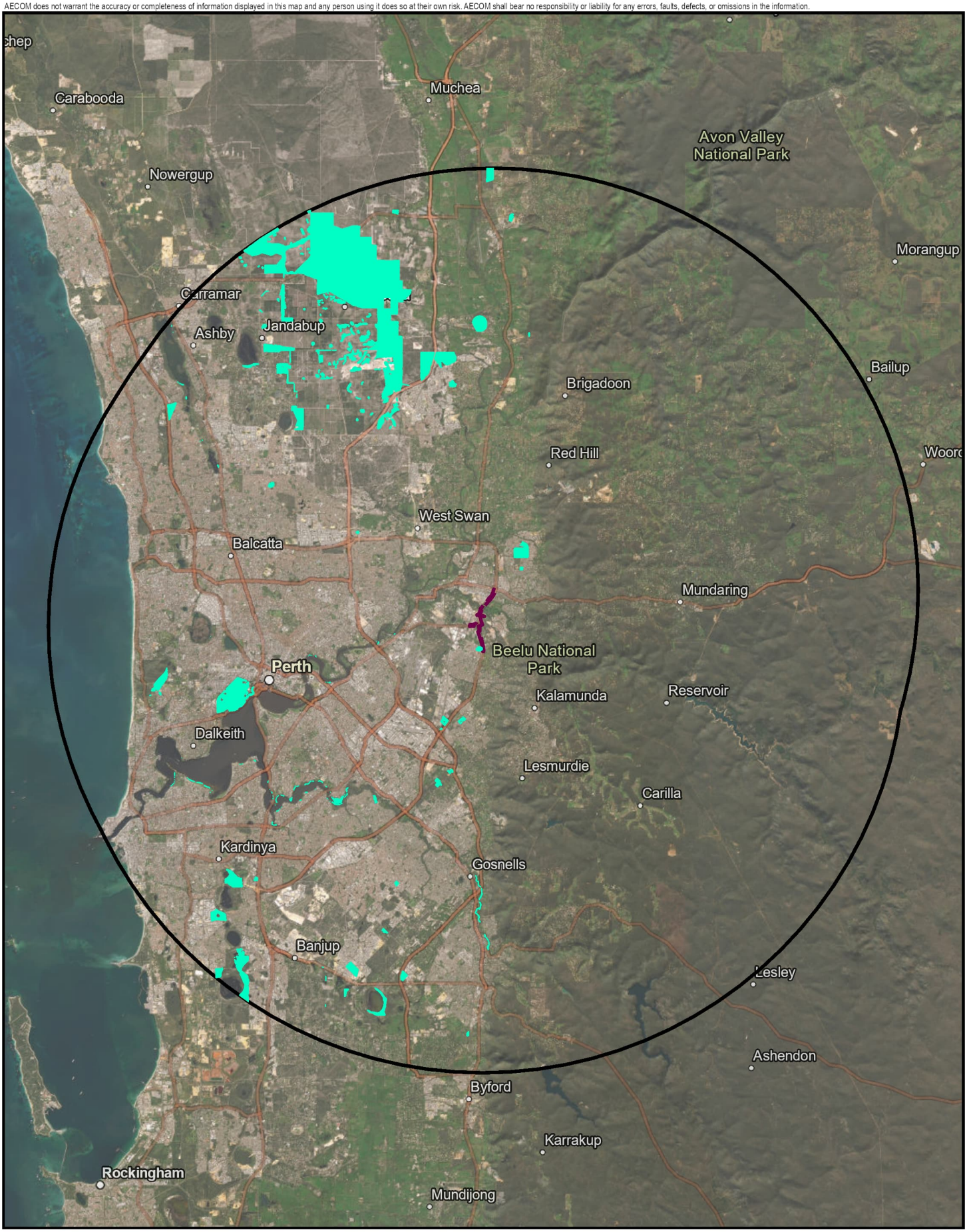
3.3.3.3 Low Success of Restoration

Banksia Woodland communities have been re-established on post-sand mines and post-pine harvested sites (Maher, 2009). For sand mining, the most successful restoration efforts include translocating topsoil from the sites to be mined to the sites to be restored (Rokich et al., 2002). The topsoil should be translocated to a site of the same soil type and topographical location (Maher, 2009). Broadcast seed typically has very low generation success (~7%).

Topsoil restoration is limited by available topsoil and generally favours species with canopy stored seeds that release post fire or disturbance (Maher, 2009). Other limitations include annual weed species and dieback, which will prevent the generation of native species.

Considering this context, the restoration of Banksia Woodlands TEC has been deemed not viable and has been excluded as an offset approach for the following reasons:

1. The Proposed Action will clear Banksia Woodlands in an area that has mostly been mapped as dieback infested (Gambara, 2021). Therefore, soil removed would mostly be dieback infested and unsuitable for use and restoration efforts at an offset site.
2. Of the total 14.94 ha of Banksia Woodland set to be cleared, 10.2 ha was rated between Very Good to Degraded due to the presence of annual weed species. The presence of weeds is further evidenced by Biota's Biological Survey and Gambara's weed assessment, that identified weeds such as**Watsonia bulbillifera, *Leptospermum laevigatum,* and **Zanthoxylum piperitum*.



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1:358,481 (when printed at A4)

0 2,500 5,000 7,500 10,000 metres

Data sources: Main Roads WA

LEGEND

- WP4 Development Envelope – Assessed (8 Feb 22)
- 30km Buffer
- Banksia Woodland of the Swan Coastal Plain

Remaining Banksia Woodland of the Swan Coastal Plain within 30km of Proposed Action

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WP4 ROE HIGHWAY EPBC REFERRAL

Figure 3

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3.4 Black Cockatoos Offset Strategy

The Proposed Action will clear up to 33.48 ha of foraging habitat with a HQS score ranging from 3 (Baudin's Cockatoo) to 6 (Carnaby's Cockatoo and FRTBC). Five sites have been identified to offset the foraging habitats for Black Cockatoos, with starting habitat quality ranging from 4 to 9 (Table 2). Further details of these offset sites have been provided in Table 3.

Table 2–Offset Sites acquired to offset Black Cockatoo Foraging Habitats

Offset no.	Offset Site	Black Cockatoo Species	Start Quality Score
1	Cowalla	Carnaby's	6
2	Neaves	Carnaby's	4
		FRTBC	6
3	Boallia	Carnaby's	9
		Baudin's	9
		FRTBC	9
4	Crossman	Carnaby's	8
		Baudin's	7
		FRTBC	7
5	Hoffman	Carnaby's	6
		Baudin's	8
		FRTBC	9

The total offset percentage is at least 100% for each of the three Black Cockatoo species. Where required, indirect research offsets (Black Cockatoo Conservation Management Project undertaken by Murdoch University) have been used to represent 10% of the overall offset percentage. Indirect offsets via research are further described in Section 4.6.

DCCEEW (2022d, Table 3) defines high quality Black Cockatoo foraging habitat as an area of at least 1 ha, that contains native vegetation used for foraging, and scores between 5-10 using the foraging quality scoring tool. Based on this assessment of foraging quality, offset sites returning a score greater than 5 through DCCEEW's HQS tool have similarly been considered 'high' quality with all other scores deemed as 'low' foraging quality.

During the breeding season, breeding pairs of Black Cockatoos will forage in areas up to 12 km from their nest and in the non-breeding season, up to 20 km from the night roosting site, but may travel further (DAWE, 2022). Black Cockatoos movements range from year-round residency to semi-migratory, depending on the breeding patterns of the individuals, vegetation density and local rainfall (Lee et al., 2013; DCCEEW, 2022c).

The Black Cockatoo Conservation Management Project (BCCMP) undertaken by Murdoch University used GPS tracking devices to record movement patterns for all three Black Cockatoo species (Murdoch University, 2022). The initial data shows cockatoos travel considerable distances (100 – 200 km) over short periods, as flocks, pairs or as individuals.

3.4.1 Potential offset scarcity

3.4.1.1 Availability of similar habitat

The Proposed Action is located on the edge of the Swan Coastal Plain sub-bioregion, close to the border of the Northern Jarrah Forest. A 30 km buffer (radius) from the Proposed Action was chosen to gather information on the extent of Black Cockatoo habitat in the surrounding area. The majority of remnant native vegetation within 30 km of the Proposed Action is located east, within the Northern Jarrah Forest sub-region.

To identify the estimated available foraging habitat for the three Black Cockatoo species, pre-European vegetation associations were used to classify habitat values. Using ArcGIS, these associations were then compared with the current mapped extent of remnant vegetation (DPIRD, 2020), so as to determine the available habitat excluding cleared and developed areas (Figure 4).

The estimated foraging habitat for each species within 30 km of the Proposed Action calculated using this method is as follows for each Black Cockatoo species:

- Baudin's Cockatoo:
  - 60,101 ha of estimated foraging habitat available
  - 1,530 ha (2.5%) is within available freehold land
  - 57,571 ha (96%) is protected as a DBCA managed land (includes State Parks and Forests and Commonwealth National Parks and Reserves)
  - 1000 ha (1.5%) is within crown land.
- Carnaby's Cockatoo:
  - 67,200 ha of estimated foraging habitat available
  - 1,800 ha (2.5%) is within available freehold land
  - 64,300 ha (96%) is protected as a DBCA managed land
  - 1,000 ha (1.5%) is within crown land.
- FRTBC:
  - 67,000 ha of estimated foraging habitat available
  - 1,764 ha (2.5%) is within free hold land
  - 64,300 ha (96%) is protected as a DBCA managed land
  - remaining 1000 ha (1.5%) is within crown land.

This assessment of remnant vegetation determined that 96% of the estimated foraging habitat for all three Black Cockatoo species surrounding the proposed action is already within protected land tenure and managed by DBCA, and only 4% is within freehold or crown land. This demonstrates that there is limited availability of properties containing suitable Black Cockatoo habitat in the vicinity of the Proposed Action, which can be acquired as an offset. Therefore, of the five offset sites presented within this Offset Strategy, three are located within 220 km from the Proposed Action.

3.4.1.2 Confidence in offset benefit

The offset strategy includes a combination of land acquisition, rehabilitation and research offsets, with land acquisition and rehabilitation comprising a minimum of 90% of the total offset strategy. Land acquisition offsets and land rehabilitation have been shown to be most effective in producing a measurable environmental benefit (May et al., 2017). Research offsets have fewer measurable outcomes (May et al., 2017) but will directly benefit the study of Black Cockatoo conservation.

The acquisition offsets for Black Cockatoo species will provide a measurable environmental conservation gain against the residual impacts of the Proposed Action (DSEWPaC, 2012a). The conservation gain of land acquisition and management is represented by a reduction in or mitigation of the threats to all three Black Cockatoo species.

The land acquisition offsets will include management actions such as fencing, weed control, grazing species control, and restricting human access to the site. Details of management actions for each offset site including the installation of fences, schedule and methods for weed control, and any other controls (e.g., dieback management) are outlined in the Offset Management Plan. The Offset Management Plan also includes monitoring and contingency measures to improve confidence in the success of protecting and restoring each offset site (GCA, 2023c). As suggested by research highlighted in Appendix 2, these actions directly address the DPaW (2013) key threats to Black Cockatoo species, through protection of foraging habitat from damage and a decline in quality, preventing spread of diseases, and reducing competition from non-native species.

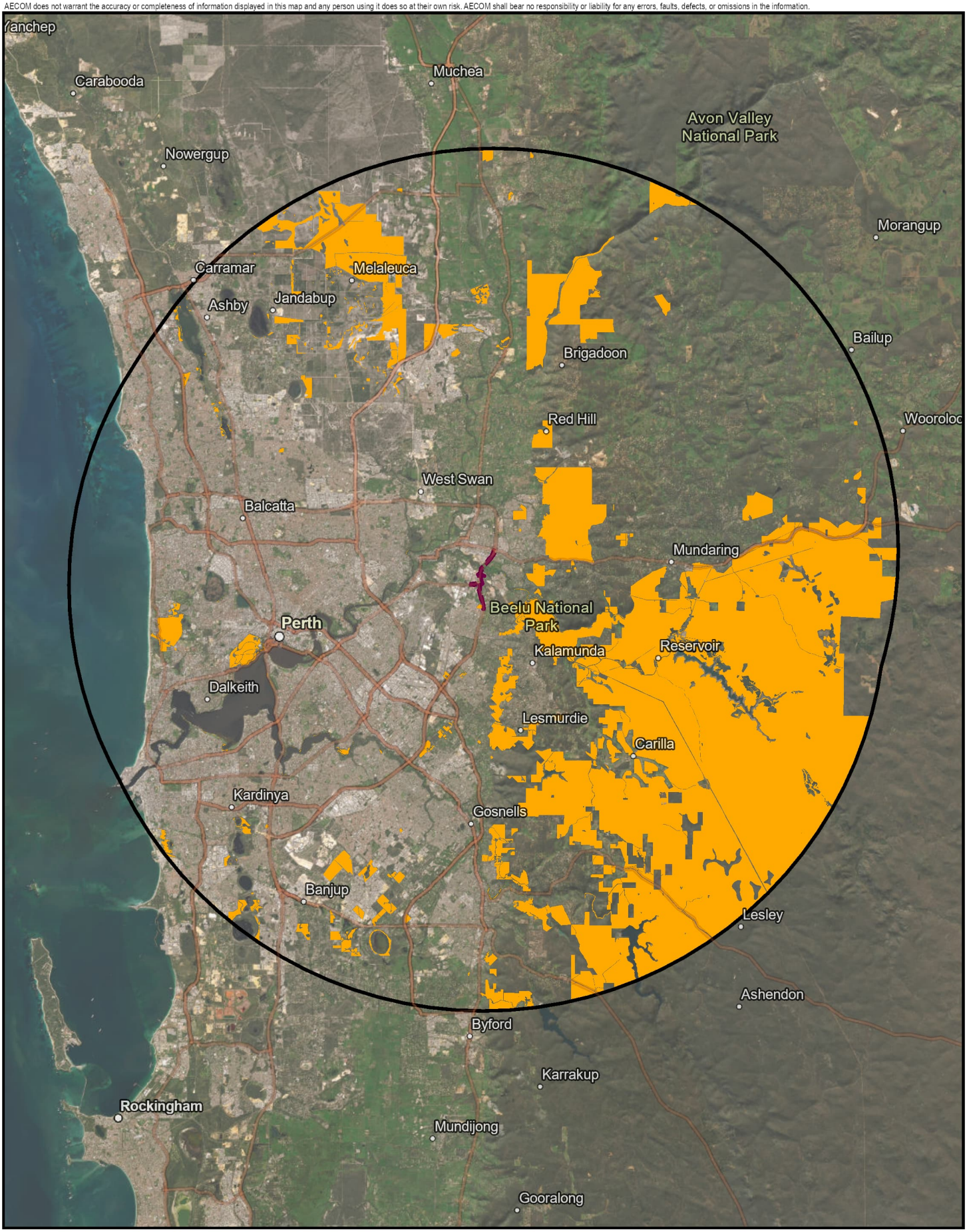
This will result in an environmental conservation gain and benefit to the three Black Cockatoo species, in comparison to the absence of offset protection and management.

3.4.1.3 Restoration success

The Proposed Action will clear up to 33.48 ha of foraging habitat with a HQS score ranging from 3 (Baudin's Cockatoo) to 6 (Carnaby's Cockatoo and FRTBC), comprising scattered eucalyptus or Marri trees, Banksia woodland, and Fabaceous heathland.

The Carnaby's Cockatoo Recovery Plan (2012) recognises protection and regeneration of existing habitat to be an efficient and effective solution to maintaining and improving habitat quality. The Plan encourages the planting of foraging tree species to support Carnaby's Cockatoo as this has been found to be effective over the long-term in improving suitable habitat (DPaW 2013). Murdoch University conducted a three-year study of cockatoo activity at a post-mining rehabilitation site. The study determined that foraging activity returned to most sites within eight years of revegetation for all three Black Cockatoo species (Lee et al. 2010, 2013). The study found that fast growing proteaceous shrubs and Marri regrowth were the most successful plants for foraging success (Lee et al., 2013). The offset site at Neaves Road will involve the revegetation of existing degraded foraging habitat. Given the similarity of vegetation in the mining area studied by Lee et al. (2013) with that of the Neaves Road offset area, it is estimated that a similar time period is applicable. The short timeframe until benefit is also supported by the results of a Black Cockatoo Action Plan (2016-2018) implemented by Curtin University. This involved revegetation in the campus (15 km from the GEHBI Proposed Action) with mature trees which was followed by a recorded increase of 499 Black Cockatoos between 2016-2019 (Curtin University, 2021).

The restoration offset located at Neaves Road currently containing foraging habitat for Carnaby's Cockatoo (HQS 4) and FRTBC (HQS 6), will be rehabilitated in line with the Neaves Road Revegetation Plan (GCA, 2023b). The existence of some already established low quality Black Cockatoo foraging habitat, and the Lee et al. study, support a lesser time until ecological benefit (10 years) for improved foraging habitat when compared to the other offset sites or a site that would require rehabilitation in its entirety.



PROJECT ID	60657311
CREATED BY	ROB.MCGREGOR
APPROVED BY	B.EATON
LAST MODIFIED	24 AUG 2023

Greater Connect ALLIANCE

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Datum: GDA 1994 Perth Coastal Grid 1994

0 2,500 5,000 7,500 10,000

metres

1:375,941 (when printed at A4)

Data sources: Main Roads WA

LEGEND

- WP4 Development Envelope – Assessed (8 Feb 22)
- 30km Buffer
- Foraging Habitat

Remaining Black Cockatoo Foraging Habitat within 30km of Proposed Action

MAIN ROADS WA

GREAT EASTERN HIGHWAY BYPASS INTERCHANGE PROJECT

WP4 ROE HIGHWAY EPBC REFERRAL

Figure 4

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v2.aprx (rob.mcgregor)

A4 size

3.5 Land Management Responsibilities

Main Roads has a role to plan, build, maintain and operate Western Australia's State Road Network. Under the *Main Roads Act 1930*, Main Roads is responsible for investing its resources and budget into the State's Road infrastructure and is not structured to ensure appropriate land management practices on areas of land that are not associated with road infrastructure.

As the State's agency responsible for ensuring effective management of our conservation estate, DBCA is by far the best placed to have governance of an offset site. In order to facilitate the appropriate management of offset properties beyond acquisition, Main Roads has a long-standing partnership with DBCA with regard to the identification and selection of offset properties.

Land acquisition offsets involve acquisition of land by the Crown and land transfer to the conservation estate. This enables land management by DBCA through the implementation of the *Conservation and Land Management Act 1984* (CALM Act). Land vested with DBCA, either through a reserve vesting or a management order on freehold estate, is the Department's responsibility to manage for the purposes of conservation. Land vested with DBCA in the conservation estate therefore provides a high level of security for the maintenance of the offset's ecological values and ensures it will be managed by DBCA in perpetuity.

Identification and acquisition of land to counterbalance significant residual environmental impacts associated with Main Roads' infrastructure projects is being managed through a Memorandum of Understanding (MoU) between Main Roads and DBCA. The MoU commits Main Roads funding to assist DBCA in identifying and acquiring suitable land offsets to be added to the conservation estate.

Once suitable offset land is acquired, Main Roads reimburses DBCA the land acquisition costs. Acquisition of suitable offset land aims to satisfy Commonwealth and State environmental compliance requirements.

For each of the land offsets acquired, Main Roads will fund 20 years of DBCA land management activities. Success targets for fencing and weed control management actions have been provided in the Offset Management Plan and Revegetation Plan for the Neaves Road offset site. These land management costs are negotiated on a site-by-site basis, and costs are formalised through separate Memorandum of Understandings (MoUs).

DBCA developed a Corporate Guideline 14 – Environmental Offsets – Proponent Land Management Contributions that outlines how proponents are to contribute management funding to DBCA for a land offset. This guideline specifies that DBCA seek payment from proponents for reasonable management expenses to establish and maintain offset properties for the first five to seven years (procedure 6.1(e)). Management actions typically covered by this funding include the maintenance of fences and firebreaks, as well as conducting weed control measures within the property.

Offset 2 occurs within freehold land owned by Main Roads. This site will be protected via a Notification on Title.

4. Description of Offsets Package

Five offset sites are proposed for the offset package as described below in Table 3 and Sections 4.1 to 4.5. This Strategy confirms the values of these offsets through referencing detailed surveys to quantify residual impacts and offset gains, and by demonstrating consultation with DBCA and ongoing measurable management.

Table 3–Overview of Offset Package

Offset Site	MNES Values Confirmed	Offsetting of Residual Impacts to MNES				Total Area
		Banksia Woodland TEC ***14.94 ha x quality 6 (impact)***	**Baudin's Cockatoo** **33.48 ha x quality 3 (impact)**	**Carnaby's Cockatoo** ***33.48 ha x quality 6 (impact)***	**FRTBC** ***33.48 ha x quality 6 (impact)***	
Offset 1 Durigen road, Cowalla	Surveyed (FVC, 2022)	163 ha, HQS without offset: 7; with offset: 8 100.27% of impact offset	Nil. Outside modelled distribution	163 ha, HQS without offset: 6; with offset: 7. 44.74% of impact offset	Nil. Outside modelled distribution	163 ha
Offset 2 Neaves Road	Inferred (AECOM 2020; Coffey, 2014)	Nil. No TEC present	Nil. Outside modelled distribution	29.29 ha, HQS without offset: 4; with offset: 7. 19.41% of impact offset	29.29 ha, HQS without offset: 6; with offset: 8. 14.29% of impact offset	29.29 ha
Offset 3 Jacka Road, Boallia	BC habitat surveyed (SW Environmental, 2022)	Nil. No confirmed TEC present	62.16 ha, HQS without offset: 8; with offset: 9. 34.13% of impact offset	62.16 ha, HQS without offset: 8; with offset: 9. 17.06% of impact offset	62.16 ha, HQS without offset: 8; with offset: 9. 20.81% of impact offset	62.16 ha
Offset 4 Albany Highway, Crossman	BC habitat surveyed (Kirkby, 2023; Aecom, 2023)	Nil. No TEC present	91 ha, HQS without offset: 7; with offset: 8. 49.96% of impact offset	91 ha, HQS without offset: 8; with offset: 9. 24.98% of impact offset	91 ha, HQS without offset: 7; with offset: 8. 30.47% of impact offset	91 ha
Offset 5 Hoffman, Shire of Harvey	BC habitat surveyed (Kirkby, 2023a; Aecom, 2023)	Nil. No TEC present	63 ha, HQS without offset: 8; with offset: 9. 34.59% of impact offset	80 ha, HQS without offset: 6; with offset: 7. 21.96% of impact offset	74 ha, HQS without offset: 9; with offset: 10. 24.78% of impact offset	80 ha
Offset 6 Research		Nil. No research offsets	0%, research offset not required	0%, research offset not required	0 ha, 10% of impact offset	
Total impact of offsets to MNES		163 ha, 100.27% of impact offset	216.16 ha, 118.67% of impact offset	425.45 ha, 128.16% of impact offset	256.45 ha, 100.35% of impact offset	425.45 ha

The Offset Policy requires environmental offsets to be based on 'sound environmental information and knowledge'. The offset package is supported by various comprehensive biological surveys carried out for each site, as summarised below in Table 4.

Table 4–Assessment for Offset Sites

Offset	Survey	Protected Matter to Offset (Start HQS)
Offset 1 – Durigen Road, Cowalla	FVC (2022) completed a biological survey of the entire Offset 1 area. The survey included: • Two phase detailed flora and vegetation assessment in accordance with the Environmental Protection Authority (EPA) (2016) and the Conservation Advice (DoEE, 2016) relevant to the Banksia Woodland TEC • Basic fauna assessment completed in accordance with the EPA (2020) Technical Guidance –Terrestrial Fauna Surveys for Environmental Impact Assessment • Black Cockatoo assessment completed in accordance with the DSWEPaC (2012d) and DoEE (2017) guidelines relevant to the three Threatened Black Cockatoo species. No significant limitations were identified for the survey (FVC, 2022).	• Banksia Woodland TEC (HQS 8) • Carnaby's Cockatoo (HQS 6)
Offset 2 – Neaves Road	Offset 2 was surveyed by Coffey in 2014 and partially surveyed by AECOM in 2020. The MNES values (Carnaby's and FRTBC foraging habitat) were confirmed by AECOM (2020).	• Carnaby's Cockatoo (HQS 4) and FRTBC (HQS 6) - to be revegetated
Offset 3 – Jacka Road, Boallia	SW Environmental (2022) completed a detailed fauna habitat survey and Targeted Black Cockatoo assessment (in accordance with DSEWPaC [2012d] guidelines). A site inspection of Lot 2829 to assess flora and vegetation was completed by Webb in 2015.	• Carnaby's Cockatoo (HQS 9), Baudin's Cockatoo (HQS 9) and FRTBC (HQS 9)
Offset 4- Albany Highway, Crossman	AECOM (2023) completed a reconnaissance vegetation and targeted Black Cockatoo Survey with reference to DSWEPaC (2012d) and DoEE (2017) guidelines relevant to the three Threatened Black Cockatoo species and the draft DCCEEW HQS tool.	• Carnaby's (HQS 8), Baudin's (HQS 7) and FRTBC (HQS 7)
Offset 5 – Hoffman, Shire of Harvey	AECOM (2023) completed a reconnaissance vegetation and targeted Black Cockatoo Survey with reference to DSWEPaC (2012d) and DoEE (2017) guidelines relevant to the three Threatened Black Cockatoo species and the draft DCCEEW HQS tool.	• Carnaby's Cockatoo (HQS 6), Baudin's Cockatoo (HQS 8) and FRTBC (HQS 9)

4.1 Offset 1 Lots 87 and 88 Durigen Road, Cowalla

4.1.1 Site description

Offset 1 is 163 ha located within a 1383.30 ha site approximately 95 km north of the Perth CBD and the Proposed Action. The land tenure is TYP-01 (freehold or crown grant), and the entire site is zoned as rural (general). The offset site is located on two adjacent lots (lots 87and 88) on Duringen Road, Cowalla, Shire of Gingin.

Main Roads commissioned Focused Vision Consulting (FVC) to undertake a biological survey of Offset 1. According to the report, Beard et al. (2013) mapped two pre-European vegetation associations (Bassendean 949 associated with low woodland banksia and 37 associated with shrublands; teatree thicket) and Heddle et al. (1980) mapped two vegetation complexes (Bassendean – North and Karrakatta – North) within Offset 1. All are considered to be associated with the Banksia Woodland TEC.

Focused Vision Consulting (FVC) (2022) determined that 890.43 ha, which constitutes 64.37% of the survey area, is representative of Banksia Woodland TEC, of which 80% is in excellent condition. An average habitat quality score (HQS) of 8 was determined. Three vegetation units were mapped that comprised of Low lying *Banksia attenuata* woodlands, *Banksia ilicifolia* woodlands, and *Banksia attenuata-Banksia menziesii* woodlands (FVC, 2022).

The site is within the known distribution range for Carnaby's Cockatoo and FRTBC but is outside the Baudin's Cockatoo modelled distribution. The majority of the site provides foraging habitat for Carnaby's Cockatoo and limited foraging habitat for FRTBC. The quality of foraging habitat ranges from 'low to moderate' to 'very high' for Carnaby's Black-Cockatoos. All vegetation within Offset 1 is considered 'low' (2) quality foraging habitat for the FRTBC (FVC, 2022). Given the low quality foraging habitat for FRTBC, the benefits of the site for FRTBC were considered negligible and have not been claimed as part of the offset site.

The total suitable foraging habitat for Carnaby's Cockatoo, containing *Banksia* spp. and *Corymbia calophylla* trees, collectively comprise 846.53 ha.

FVC (2022) recorded 21 suitable DBH trees, one with a potentially suitable hollow for Black Cockatoo breeding. However, there was no evidence of use for the hollow. All suitable DBH trees were Marris.

4.1.2 Suitability of site as an offset

The vegetation in this offset site is representative of Banksia Woodland TEC and has been assessed as being predominantly (70%) in excellent condition. The offset site has an average of 39 native species per 100m^2. As such, a high habitat quality score has been applied to this offset site (HQS 8) (Appendix 1 a).

Offset 1 contains critical habitat for Carnaby's Cockatoo as the area is large (163 ha, within a 1393.30 ha vegetated site) and is located within the Swan Coastal Plain subregion (DCCEEW, 2022d). The habitat is within Carnaby's Cockatoo distribution range and provides high quality foraging, assessed as HQS 6 (Appendix 1 b).

The future value of the offset site once acquired for both Banksia Woodland TEC (HQS 8) and Carnaby's Cockatoo (HQS 7) is higher than the quality score of the impact site (HQS 6). Offset 1 will greatly contribute to the offset requirements for these matters by offsetting 100.27% of the Banksia Woodlands TEC residual impact and approximately 43% of Carnaby's Cockatoo Foraging Habitat residual impact. Figure 5 illustrates the extent of Banksia Woodland TEC and Black Cockatoo Foraging Habitat at the site. The offset site meets the relevant requirements for TECs as set out in the Environmental Offsets Policy (EPBC Act, 2012) and explained in Section 5.

Due to the clear environmental benefits of this offset to the protected matters, and the scarcity of suitable land within closer proximity to the Proposed Action (as discussed in Section 3.3.3 and 3.4.1), the site has been considered suitable as an offset despite being 95 km away from the Proposed Action.

The habitat is anticipated to decline without the offset being acquired due to existing threats such as grazing by Kangaroos, weed invasion, and dieback infestation as explained in Appendix 1 a and Appendix 1 b. There is also a proposed sand mining project (Bidaminna Project) that has been referred to the EPA, the boundary of which intersects the offset site to the north. This Project is anticipated to contribute further to edge effect threats which may result in the deterioration of the TEC and foraging habitat for Carnaby's Cockatoo at the site. Hence, a future habitat quality score of 7 for TEC (without acquisition of the land) has been suggested. The habitat can be protected and maintained through management actions such as fencing, weed management and dieback hygiene, with the area acquired as an offset site. With these management actions in

place, the habitat quality will maintain a score of 8 for Banksia Woodland TEC (preventing future decline) and will improve by a score of one to attain a future quality score of 7 for Carnaby's Cockatoo.

The HQS assessment for this site is presented in Appendix 1 a and Appendix 1 b along with detailed reasoning as to how the area provides suitable habitat for Banksia Woodlands TEC and Carnaby's Cockatoo. A summary of the offset values and calculator inputs is included in Sections 4.1.2.1 to 4.1.2.3.

4.1.2.1 Offset values to counterbalance residual impacts

The offset site is considered suitable to counterbalance 100.27% of a total quantum of impact of 8.96 ha of residual impacts to Banksia Woodland TEC and 44.74% of a total quantum of impact of 20.09 ha of foraging habitat for Carnaby's Cockatoo for the following reasons:

- Banksia Woodland TEC
  - Offset 1 contains a total of 890.43 ha of Banksia Woodland TEC (of which 163 ha has been allocated as an offset for the Proposed Action) with species composition similar to that of the impact site.
  - The 163 ha offset site is comprised of TEC with vegetation in 'excellent' condition and high quality habitat (HQS 8)
  - Vast area of Banksia Woodland in condition similar to that of the offset site is present in the surrounding area including those connected to the offset site. The 163 ha will be acquired by DBCA with funding for the acquisition provided by Main Roads and will be managed by DBCA in perpetuity to ensure that the land will continue to hold the value for the protected matters in future.
- Carnaby's Cockatoo
  - The 163 ha offset site is comprised of 'high' (HQS 6) quality foraging habitat for Carnaby's Cockatoo
  - The offsite site contains 21 mature trees that are of a similar age to those impacted with a suitable DBH (ranging from 500-800mm) for Black Cockatoo Use

The area that will be acquired for Banksia Woodland TEC and Carnaby's Cockatoo has been illustrated in Figure 5.

4.1.2.2 Conservation gain for the protected matters

Offset 1 represents 163 ha of sizeable intact bushland with 70% of the vegetation in excellent condition and high habitat quality (HQS 8). Land management actions are specified in the Offset Management Plan and include fencing, weed management, bushfire control, grazing control and restricting human access to the offset site. This will reduce the potential spread of weeds, dieback diseases, invasive species, feral animal grazing and uncontrolled vehicle access as per the HQS assessment in Appendix 1 a and Appendix 1 b. DBCA will manage the site through their Parks and Wildlife Services for 20 years through an MoU between Main Roads and DBCA.

As Offset 1 and the surrounding vegetation is adjacent to the Moore River National Park (managed by DBCA), protection of this vegetated land will help reduce the impacts of edge effects on the national park and maintain the ecological link between the park and remnant native vegetation west of Offset 1. Additionally, the introduction of the land management actions described will have a positive impact on the site as supported by research (detailed in Appendix 2) and will increase the vegetation quality and structure by a score of one at a minimum.

4.1.2.3 Offset calculator values Offset 1 Durigen Road Cowalla

Given DBCA will be managing the land for 20 years, a conservative time frame of 20 years has been allowed for Time Until Ecological Benefit, at which point improvements to the ecology of the area from conservation efforts should be abundantly clear (Table 5). Without the offset, the Bidaminna Project would likely clear part of the offset site that intercepts the Project extent, leading to possible degradation of the offset site. Part IV and Part V of the *EP Act 1986,* states that sites containing significant values (such as Bidaminna) would require referral and offset should they be cleared. As a result, a score of 0 has been given for risk of loss without offset as any clearing that may proceed without the land being acquiring and protected as an offset would be offset.

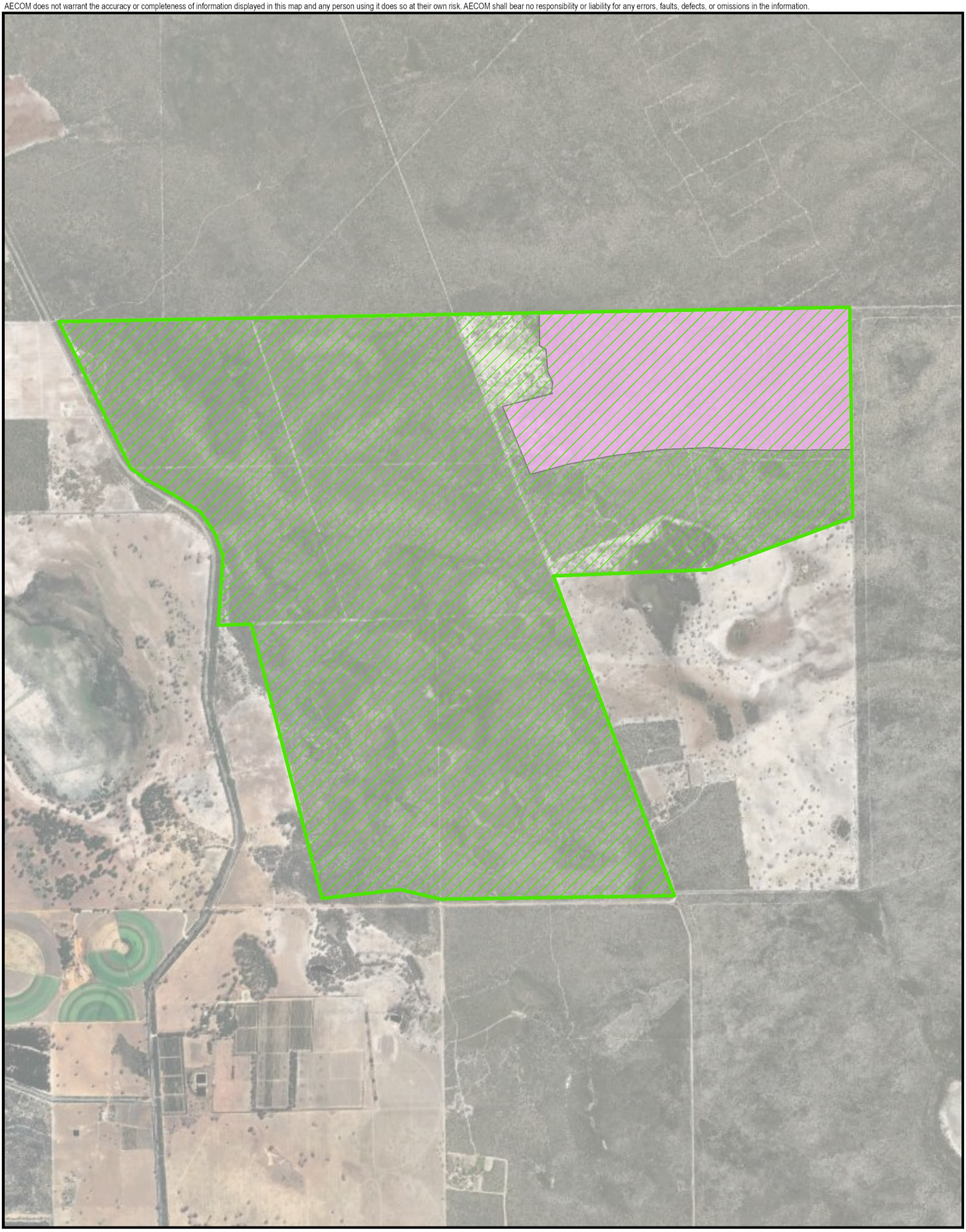
For TEC, a start quality of 8 was calculated. This is anticipated to fall to a score of 7 without intervention due to the excellent quality of the vegetation and threats described earlier such as future development and spread of dieback and weeds. Implementing fencing and weed control management actions will prevent the condition from further deteriorating and maintain a score of 8 (Table 5).

For Carnaby's Cockatoo, the start quality was scored as 6 and anticipated to remain as 6 for future quality without offset. Fencing and weed control management in this instance is expected to improve the habitat quality for Carnaby's Cockatoo to a score of 7, by enabling the regrowth of preferred foraging trees.

The total quantum of impact for Banksia Woodland TEC is 8.96 ha and Carnaby's Cockatoo foraging habitat is 20.09 ha. The offsite site (163 ha) will offset 8.99 ha value for both Banksia Woodland TEC and foraging habitat for Carnaby's Cockatoo with the value of impact offset being 100.27% and 44.74%, respectively, as shown in Table 5.

Table 5–Offset 1 Calculator Values

MNES	Description	Time Until Ecological Benefit	Start Quality	Future Quality Without Offset	Future Quality With Offset	Offset Value (ha)	Offset Value (%)
Banksia Woodland TEC	Banksia Woodland TEC (Excellent condition)	20	8	7	8	8.99	100.27
BC habitat	Carnaby's Cockatoo foraging habitat – high quality	20	6	6	7	8.99	44.74



PROJECT ID	60657311
CREATED BY	ROB.MCGREGOR
APPROVED BY	B.EATON
LAST MODIFIED	23 JAN 2024

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Datum: GDA2020 MGA Zone 50

1:30,000 (when printed at A4)

0 220 440 660 880 metres

Data sources: Main Roads WA

LEGEND

Environmental Offset Areas (27 Apr 2023)

Offset Allocations

Black Cockatoo Foraging Habitat and Banksia Woodlands TEC

Offset Property Allocations, Cowalla

MAIN ROADS WA

GREAT EASTERN HIGHWAY BYPASS INTERCHANGE PROJECT

WP4 ROE HIGHWAY EPBC REFERRAL

Figure 5

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v4.aprx (rob.mcgregor)

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4.2 Offset 2 Neaves Road, Lot 156 on Plan P056488

4.2.1 Site description

Offset 2 is 29.29 ha, located on the corner of Neaves Road and Tonkin Highway, in Bullsbrook, City of Swan, on Lot 156 on Plan P056488. Offset 2 is approximately 35 km north of the Perth CBD and 25 km north of the Proposed Action.

Two Beard et al. (2013) pre-European vegetation associations (Bassendean 1018 and Pinjarra 4), and one Heddle et al. (1980) vegetation complex (Yanga Complex) intersects the offset site.

The site was surveyed by Coffey Environments Australia Pty Ltd (Coffey) in 2014 as part of a biological survey for the Perth to Darwin National Highway (Coffey, 2015). The survey mapped the vegetation associations and condition for the entire site. Additionally, AECOM (2020) surveyed a strip approximately 100 m wide that extends from the south to north-east corner of the site. This survey included a detailed vegetation and fauna habitat assessment that was used to support and validate the information provided in Coffey's survey. The survey by AECOM (2020), in conjunction with a review of aerial imagery, confirmed there has been minimal change in the vegetation extent since 2014.

Native vegetation was mapped as predominantly Degraded-Completely Degraded, followed by Completely Degraded, and Good-Degraded condition (Coffey, 2015). The vegetation associations providing the most suitable foraging habitat include Revegetated *Corymbia* sparse mid woodland (R), *Corymbia* sparse mid woodland (CcEr[3]), and *Eucalyptus* sparse mid Woodland Creek line/floodplain (Er[5]). The *Melaleuca* open low woodland (MpMr) vegetation association also provides moderate quality foraging habitat (AECOM, 2020; Coffey, 2015). These vegetation associations (excluding MpMr) are dominated by remnant *Corymbia calophylla* (Marri), *Eucalyptus camaldulensis* (River Red Gum), *Eucalyptus todtiana* (Coastal Blackbutt/Pricklybark), and open paddocks with remnant *Corymbia calophylla* (marri) and *Eucalyptus rudis* subsp. *rudis* (flooded gum) (Coffey 2015).

4.2.2 Suitability of site as an offset

Given the degraded nature of the site and limited foliage cover of suitable trees (10-30%), the vegetation condition and structure were assessed as low value for Carnaby's Cockatoo and low to moderate for FRTBC (Appendix 1 b). AECOM (2020) recorded both male and female FRTBC foraging within Tuart trees located approximately 2.5 km east of the offset site. No confirmed direct or indirect evidence of Carnaby's Cockatoo within the site was observed in either survey, however Carnaby's Cockatoo were sighted flying over by AECOM (2020) and there is a known breeding site within 12 km for Carnaby's Cockatoo. Overall, a HQS of 4 and 6 was assigned for Carnaby's Cockatoo and FRTBC respectively (Appendix 1 b).

4.2.2.1 Offset values to counterbalance residual impacts

The 29.29 ha offset site is considered suitable to offset 19.41% of the total quantum of impact of 20.09 ha of foraging habitat for Carnaby's Cockatoo and 14.29% of the total quantum of impact of 20.09 ha of foraging habitat for FRTBC from the Proposed Action for the following reasons (Table 6):

- Suitable foraging habitat for Carnaby's Cockatoo and the FRTBC, characterised by the presence of suitable foraging trees (i.e., *Corymbia calophylla*, *Eucalyptus camaldulensis*, *Eucalyptus todtiana* and *Eucalyptus rudis* subsp. *rudis*).
- Rehabilitation of this site will improve the foraging habitat and vegetation structure from low quality to moderate to high as supported by the revegetation plan (GCA, 2023b).
- Confidence in achieving a HQS of 7 for Carnaby's Cockatoo and 8 for FRTBC after rehabilitating the site objectives has been set at 50% due to the preparation of the revegetation plan that includes clear objectives (i.e., protection and enhancement of Black Cockatoo Foraging Habitat) and completion targets (GCA, 2023b).
- Confirmed recent direct evidence of FRTBC foraging and sightings of Carnaby's Cockatoo flying over the site (AECOM, 2020).
- Ecological benefit will be reached in 10 years allowing Tube stock planting additional time to establish beyond the scope of the revegetation plan and provide suitable foraging for Black Cockatoos (GCA, 2023b).

The areas that will be rehabilitated for Black Cockatoo Foraging Habitat has been illustrated in Figure 6.

4.2.2.2 Conservation gain for the protected matters

Offset 2 is within the distribution range for Carnaby's Cockatoo and FRTBC. The site provides an ecological link to the Kirby Road bushland (northwest) and Pearce Aerodrome Bushland (southeast) (Coffey, 2014).

A revegetation plan has been developed for the site which includes a detailed description of the existing native vegetation and weeds of the site, the objectives, strategy, and completion targets for revegetation efforts, and implementation methodology and monitoring requirements (GCA, 2023b). In summary, revegetation efforts will be split into three zones, and depending on the condition and extent of native vegetation in the area, will be subject to partial revegetation (Zone 1), full revegetation (Zone 2), or weed control only (Zone 3). Further details of the revegetation plan and approach can be viewed within the GCA (2023b) Neaves Road Revegetation Plan.

Once the objectives and completion criteria of the Revegetation Plan have been met, the site will contain a greater number of food resources for Carnaby's and FRTBC and strengthen the site's ecological link between large intact areas of bushland. Revegetation efforts resulting in an increase in available foraging resources is expected to significantly increase the HQS for the site, leading to a conservation gain.

4.2.2.3 Offset calculator values

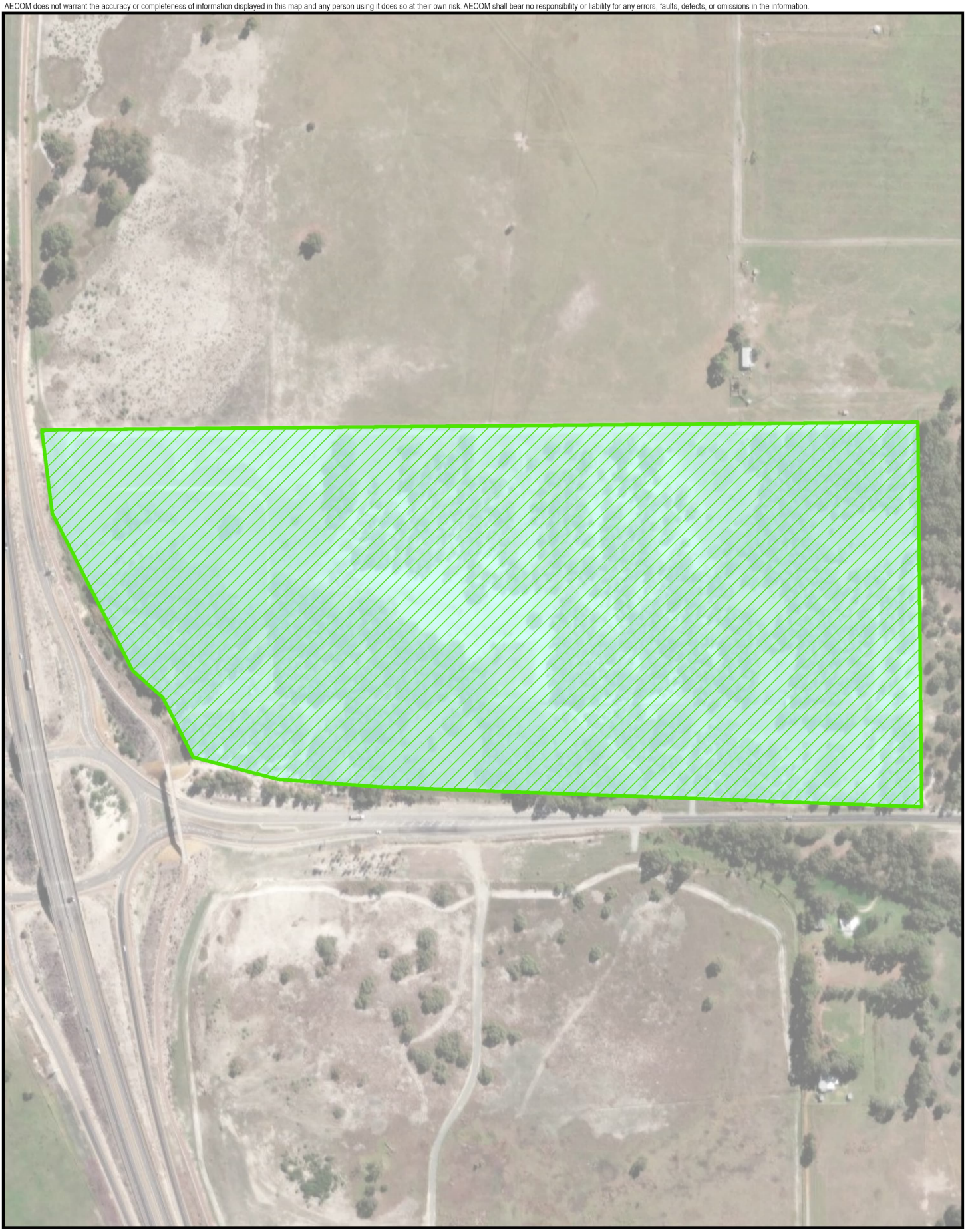
The Neaves Road offset site will be revegetated using Tube stock seedlings, giving the site a head-start over other offsets that are only being protected to encourage natural restoration over time. As a result, Time Until Ecological Benefit has been estimated as 10 years. This is supported by past studies that have highlighted the use of revegetated sites by Black Cockatoos 10 years after revegetation efforts (Lee et al., 2010, 2013). A score of 0 has been given for risk of loss without offset, as no known development is proposed for the area and therefore there is no risk of the habitat being completely lost in the foreseeable future.

For Black Cockatoos, the start quality was scored as 4 for Carnaby's Cockatoo and 6 for FRTBC. The vegetation condition of the site has been predominantly scored as degraded to completely degraded. Without the threat of further clearing, the foraging habitat is unlikely to become further degraded over time and therefore the HQS for both Black Cockatoo species are unlikely to change for future quality without offset. As a result of revegetation efforts, the site is expected to significantly improve foraging habitat for both Black Cockatoo species, with Carnaby's Cockatoo scored as 7 and FRTBC scored as 8 for future quality with offset respectively (Table 6).

With the increased future quality values (with offset) for Black Cockatoo Habitat, the total quantum of impact offset for foraging habitat is 3.90 ha (19.41%) for Carnaby's Cockatoo and 2.87 ha (14.29%) for FRTBC.

Table 6–Offset 2 Calculator Values

MNES	Description	Time Until Ecological Benefit	Start Quality	Future Quality Without Offset	Future Quality With Offset	Offset Value (ha)	Offset Value (%)
BC habitat	Carnaby's Cockatoo foraging habitat – low quality	10	4	4	7	3.90	19.41
BC habitat	FRTBC foraging habitat – high quality	10	6	6	8	2.87	14.29



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APPROVED BY B.EATON
LAST MODIFIED 23 JAN 2024

Greater Connect ALLIANCE

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Datum: GDA2020 MGA Zone 50

1:5,000
(when printed at A4)

0 30 60 90 120
metres

Data sources: Main Roads WA

LEGEND

Environmental Offset Areas (27 Apr 2023)

Offset Allocations

Carnaby's and Forest Red-tailed Black Cockatoo Foraging Habitat

Offset Property Allocations, Corner of Neaves Rd and Tonkin Hwy

MAIN ROADS WA

GREAT EASTERN HIGHWAY BYPASS INTERCHANGE PROJECT

WP4 ROE HIGHWAY EPBC REFERRAL

Figure 6

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v4.aprx (rob.mcgregor)

A4 size

4.3 Offset 3 Jacka Road, Boallia

4.3.1 Site description

Offset 3 is 65.51 ha in size, of which 62.16 ha provides suitable Black Cockatoo foraging habitat, and the remaining 3.35 ha is cleared (not included in this assessment). The site is located on Lot 2628 on Plan 203052, Jacka Road Boallia, City of Busselton and is approximately 210 km south of the Perth CBD and the Proposed Action.

All vegetation within Offset 3 (62.16 ha) is mapped as remnant native vegetation (DPIRD, 2020). Beard et al. (2013) mapped two pre-European vegetation units within Offset 3, including Chapman 1000 and Chapman 1181, both described as medium woodland or forest dominated with Jarrah. Chapman 1000 also comprises Banksia and Teatree species. Neither Chapman 1000 nor 1181 is associated with the Banksia Woodland TEC. The survey carried out by Webb in 2015 for DBCA reported that the site may contain up to 4 ha of vegetation representative of the Banksia Woodland TEC. However, this offset site has not been assessed as an offset for Banksia Woodland TEC as at least 100% of the offset has already been met by Offset 1, 2 and 3.

The offset area falls between the Swan Coastal Plain Sub-region (SWA02) of the Swan Coastal Plain IBRA region to the north (dominated by Banksia Woodland) and Jarrah Forest (JAF02) to the south (dominated by Jarrah-Marri Forest).

Main Roads commissioned SW Environmental to undertake a fauna survey of Offset 3 in 2022 and Focused Vision to undertake a biological survey in March 2023. Focused Vision (2023) mapped approximately 62 ha of the site as Jarrah, Marri, and Sheoak Woodland. Using the HQS Tool, this habitat was found to provide high quality foraging habitat (HQS 9) for all three Black Cockatoo species (Appendix 1 b). SW Environmental (2022) recorded direct and indirect evidence of foraging for all three Black Cockatoo species.

DBCA conducted a preliminary fauna assessment of Lot 2628 in March 2022. No direct observations of significant fauna species were recorded. Old indirect evidence of Brushtail Possum (dry scats), Quenda (diggings) and Black Cockatoos (chewed nuts) were recorded (Williams, 2022f).

Webb (2015) mapped five vegetation communities within the offset area, with the entire site considered to be in Excellent-Pristine condition. One Threatened flora species was recorded, *Daviesia elongata* (Vulnerable). Webb (2015) also recorded Baudin's Cockatoo and the FRTBC foraging within the site.

4.3.2 Suitability of site as an offset

The site is located within the buffer of South Western Regional Ecological Linkage and therefore has high value in terms of habitat connectivity and linkage for fauna both at patch and landscape scales. 76% of the habitat contains Jarrah-Marri which are the key feeding and breeding species for Black Cockatoos. The site provides high quality foraging habitat (HQS 9) for all the three Black Cockatoo species. For this reason, the offset area is determined to be suitable as an offset, despite being located 210 km away from the Proposed Action. The start value (HQS 9) of the offset site for all the three species of Black Cockatoos' foraging habitat is greater than the Proposed Impact quality (HQS 6 for Carnaby's Cockatoo and FRTBC, and HQS 3 for Baudin's Cockatoo).

4.3.2.1 Offset values to counterbalance residual impacts

The 62.16 ha offset site is considered suitable to offset 34.13% of the total quantum of impact of 10.04 ha of foraging habitat for Baudin's Cockatoo, 20.81% of the total quantum of impact of 20.09 ha of foraging habitat for FRTBC, and 17.06% of a total quantum of impact of 20.09 ha of foraging habitat for Carnaby's Cockatoo. The site is considered suitable to offset the impacts from the Proposed Action for the following reasons:

- It contains 62.16 ha of high quality foraging habitat (HQS 9) for all three Black Cockatoo, and recent foraging evidence for all species.
- It contains numerous mature Jarrah and Marri trees of a similar age to those impacted with a suitable DBH (>500 mm) for Black Cockatoo Use.

The areas that will be acquired for Black Cockatoo foraging habitat has been illustrated in Figure 7.

4.3.2.2 Conservation gain for the protected matters

Offset 3 represents an area of large intact bushland with the majority of vegetation in Excellent to Pristine Condition. SW environmental reported that the area is heavily grazed by Kangaroos, therefore a lack of land management is likely to lead to degradation of foraging habitat for all three Black Cockatoo species. Anthropogenic disturbances were also noted for the site including a cleared gravel pit and two drainage lines. Land management will include fencing, weed control, bushfire control, and restricting access to the site as explained in Appendix 1 a. This will reduce the potential spread of weeds, dieback diseases, invasive species, feral and native animal grazing and uncontrolled vehicle access. These management actions will have a positive impact on the site as supported by research (detailed in Appendix 2) and will maintain the vegetation quality and structure scored as 'high'.

Offset 3 is adjacent to the Blackwood State Forest (managed by DBCA) and will help reduce the impacts of edge effects to the national park and maintain the ecological link between the state forest and remnant vegetation north of Offset 3. DBCA will manage the site through their Parks and Wildlife Service under an MoU signed with Main Roads which provides certainty in land management actions being implemented and undertaken regularly.

4.3.2.3 Offset calculator values

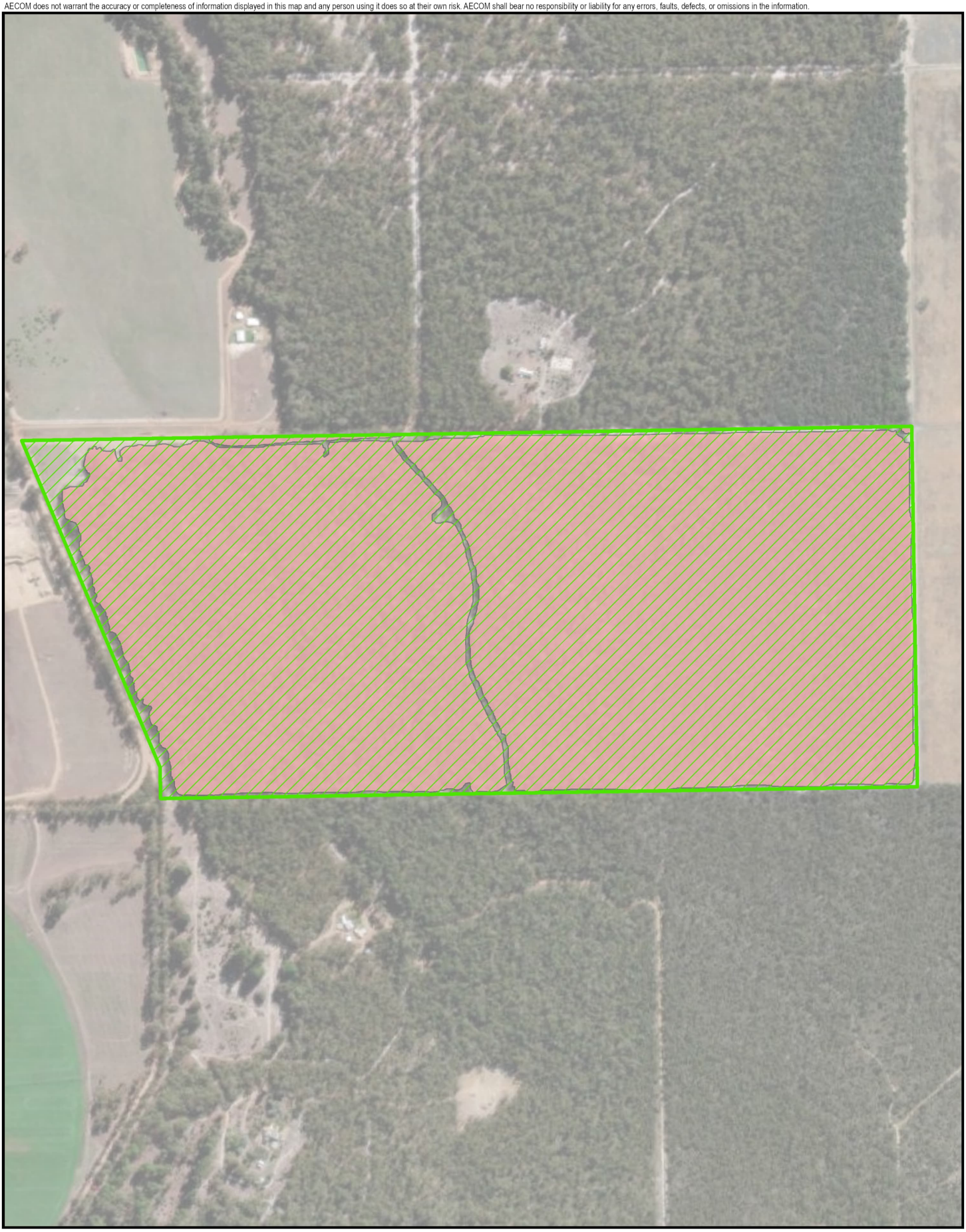
Given DBCA will be managing the land for 20 years, a conservative time frame of 20 years has been allowed for Time Until Ecological Benefit, at which point improvements to the ecology of the area from conservation efforts should be abundantly clear (Table 7). A score of 0 has been given for risk of loss without offset, as no known development is proposed for the area and therefore there is no risk of the habitat being completely lost in the foreseeable future.

For all three species of Black Cockatoo, a start quality of 9 was calculated. This is anticipated to fall to a score of 8 without intervention due to the excellent quality of the vegetation and threats described earlier such as kangaroo grazing and anthropogenic disturbances. Implementing fencing and weed control management actions will prevent the condition from further deteriorating and maintain a score of 9 (Table 7).

With the increased future quality values (with offset) for Black Cockatoo Habitat, the total quantum of impact offset for foraging habitat is 3.43 (34.13%) for Baudin's Cockatoo, 3.43 ha (17.06%) for Carnaby's Cockatoo, and 4.18 ha (20.81%) for FRTBC.

Table 7–Offset 3 Calculator Values

MNES	Description	Time Until Ecological Benefit	Start Quality	Future Quality Without Offset	Future Quality With Offset	Offset Value (ha)	Offset Value (%)
BC habitat	Baudin's Cockatoo foraging habitat – high quality	20	9	8	9	3.43	34.13
BC habitat	Carnaby's Cockatoo foraging habitat – high quality	20	9	8	9	3.43	17.06
BC habitat	FRTBC foraging habitat – high quality	20	9	8	9	4.18	20.81



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APPROVED BY	B.EATON
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Datum: GDA2020 MGA Zone 50

1:7,500 (when printed at A4)

0 50 100 150 200 metres

Data sources: Main Roads WA

LEGEND

Environmental Offset Areas (27 Apr 2023)

Offset Allocations

Black Cockatoo Foraging Habitat

Offset Property Allocations, Lot 2628 Jacka Road, Boallia

MAIN ROADS WA

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Figure **7**

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v4.aprx (rob.mcgregor)

A4 size

4.4 Offset 4 Albany Hwy, Crossman

4.4.1 Site description

Lot 3 Albany Highway, Crossman, is located in the Wheatbelt region within the Shire of Boddington. The offset site is located approximately 100 km south-east of the Proposed Action, extending west of Albany Highway. The entire site is over 300 ha in size, however, for the purposes of this offset package, only 91 ha of the acquired 300ha has been allocated as part of the offset for the Proposed Action.

Two Beard et al. (2013) pre-European vegetation associations (Bannister 3 and Bannister 4) occur in Offset 4. Both are associated with mainly Jarrah and Marri, with Bannister 4 also known to include Wandoo. No Banksia TEC is associated with the site.

The upper storey vegetation is dominated by Jarrah (*Eucalyptus marginata*) and Wandoo (*Eucalyptus wandoo*), with limited Marri (*Corymbia calophyla*). Dominant understorey and midstorey species used by Black Cockatoos as food included Rock Sheoak (*Allocasuarina hugeliana*), *Hakea lissocarpha*, *Banksia sessilis*, *B. dallanneyi*, *B. fraseri* and *B. squarrosa* (AECOM, 2023). All species, within the offset site are used by Black Cockatoo as food resources.

4.4.2 Suitability of site as an offset

All species within the offset site are known to be utilised by Black Cockatoos. The vegetation condition and structure were assessed as 'Moderate to High' for Carnaby's Cockatoos and 'Moderate' for Baudin's Cockatoos and FRTBC. The proximity of site in relation to other habitat was assigned a score of 3 for all three species. This results in an overall HQS of 8 for Carnaby's Cockatoo and 7 for Baudin's Cockatoo and FRTBC (Appendix 1 b). Foraging evidence was recorded for Carnaby's Cockatoo at six locations by AECOM (2023). Evidence for foraging was also recorded at 21 locations and 10 locations for Baudin's Cockatoo and FRTBC, respectively, within the offset site. Carnaby's Cockatoo has a nearby known breeding site within 13 km (Bannister and Boddington areas), while the nearest known breeding site for Baudin's Cockatoo is approximately 40 km west.

4.4.2.1 Offset values to counterbalance residual impacts

The 91 ha offset site is considered suitable to offset 49.96% of the total quantum of impact of 10.04 ha of foraging habitat for Baudin's Cockatoo, 24.98% of the total quantum of impact of 20.09 ha of foraging habitat for Carnaby's Cockatoo, and 30.47% of total quantum of impact of 20.09 ha of foraging habitat for FRTBC (Table 8). The site is considered suitable to offset the impacts from the Proposed Action for the following reasons:

- Contains 91 ha of high quality foraging habitat for Carnaby's Cockatoo (HQS 8), Baudin's Cockatoo (HQS 7), and FRTBC (HQS 7).
- Contains an abundance of Jarrah and Wandoo eaten by all three Black Cockatoo species, and mature Proteaceae species that are primary foraging trees for Carnaby's Cockatoo and Baudin's Cockatoo.

The area that will be allocated for Black Cockatoo foraging habitat has been illustrated in Figure 8.

4.4.2.2 Conservation gain for the protected matters

Offset 4 contains 91 ha of suitable foraging habitat for Carnaby's Cockatoo, Baudin's Cockatoo and FRTBC. Land management will include fencing, weed control, bushfire control, grazing control and restricting access to the site as explained in Appendix 1 b. This will reduce the potential spread of weeds, dieback diseases, invasive species, feral and native animal grazing, and uncontrolled vehicle access, leading to a conservation gain for the protected matter. These management actions will have a positive impact on the site as supported by research (detailed in Appendix 2) and will transition the vegetation quality and structure from 'moderate' to 'high' for Baudin's Cockatoo and FRTBC, and from 'moderate-high' to 'high' for Carnaby's Cockatoo.

4.4.2.3 Offset calculator values

The land will be managed for 20 years, therefore, a conservative time frame of 20 years has been allowed for Time Until Ecological Benefit, at which point improvements to the ecology of the area from conservation efforts should be abundantly clear. A score of 0 has been given for risk of loss without offset, as no known development is proposed for the area and therefore there is no risk of the habitat being completely lost in the foreseeable future.

The start quality for both Baudin's and FRTBC was scored as 7 and Carnaby's Cockatoo as 8. Without the threat of further clearing, the foraging habitat is unlikely to become further degraded over time and therefore the HQS for the Black Cockatoo species are unlikely to change for future quality without offset. Some of the threats identified by AECOM (2023) are weeds, feral pigs and foxes, and littering. Management actions including weed control and fencing to mitigate herbivore grazing, weed infestation, and the spread of dieback will encourage the regeneration of preferred foraging trees. As a result, the habitat quality for all three Black Cockatoos is expected to increase by a score of one (Table 8).

With the increased future quality values (with offset) for the three Black Cockatoo Habitat, the total quantum of impact offset for foraging habitat is 5.02 ha (49.96%) for Baudin's Cockatoo, 5.02 ha (24.98%) for Carnaby's Cockatoo, and 6.12 ha (30.47%) for FRTBC.

Table 8–Offset 4 Calculator Values

MNES	Description	Time Until Ecological Benefit	Start Quality	Future Quality Without Offset	Future Quality With Offset	Offset Value (ha)	Offset Value (%)
BC habitat	Baudin's Cockatoo foraging habitat – high quality	20	7	7	8	5.02	49.96
BC habitat	Carnaby's Cockatoo foraging habitat – high quality	20	8	8	9	5.02	24.98
BC habitat	FRTBC foraging habitat – high quality	20	7	7	8	6.12	30.47

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Datum: GDA2020 MGA Zone 50

1:21,000 (when printed at A4)

0 150 300 450 600

metres

Data sources: Main Roads WA

LEGEND

Environmental Offset Areas (27 Apr 2023)

Offset Allocations

Baudin's and Carnaby's Black Cockatoo Foraging Habitat

Offset Property Allocations, Lot 3 Albany Hwy, Crossman

MAIN ROADS WA

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WP4 ROE HIGHWAY EPBC REFERRAL

Figure 8

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v4.aprx (rob.mcgregor)

A4 size

4.5 Offset 5 Lancaster Road, Hoffman

4.5.1 Site description

Offset 5 is an 85 ha property located on Lot 579 Lancaster Road in Hoffman, Shire of Harvey, approximately 130 km south of the Proposed Action. The land parcel includes approximately 5 ha of land which has been cleared or falls within a gazetted Western Power easement. This area has been excluded from offset calculations, with the remaining 80 ha providing Black Cockatoo foraging habitat.

According to the vegetation unit mapped by Beard et al. (2013), the offset area falls within the West Darling 1185 vegetation association, described as woodland with Jarrah, Marri and Wandoo. The entire offset site has a vegetation condition varying from moderate to high and provides high quality foraging habitat for all three Black Cockatoo species.

4.5.2 Suitability of site as an offset

AECOM (2023) recorded the area of suitable Black Cockatoo habitat for each species, excluding the Western Power easement, as follows:

- Carnaby's Cockatoo – 80 ha
- Forest Red-Tailed Black Cockatoo – 74 ha
- Baudin's Cockatoo – 63 ha

The offset site is dominated by Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia calophylla*) with some large Marri and Blackbutt (*Eucalyptus patens*). It provides high quality foraging habitat (HQS 9) for FRTBC, Baudin's Cockatoo (HQS 8), and Carnaby's Cockatoo (HQS 6). The future value of offset for all three Black Cockatoos' foraging habitat is greater than the impact area quality (HQS 6 for Carnaby's Cockatoo and FRTBC, and HQS 3 for Baudin's Cockatoo).

4.5.2.1 Offset values to counterbalance residual impacts

The offset site is considered suitable to offset 34.59% of the total quantum of impact of 10.04 ha of foraging habitat for Baudin's Cockatoo, 24.78% of the total quantum of impact of 20.09 ha of foraging habitat for FRTBC, and 21.96% of a total quantum of impact of 20.09 ha of foraging habitat for Carnaby's Cockatoo from the Proposed Action, for the following reasons:

- It contains 80 ha, 74 ha, and 63 ha of high-quality foraging habitat for Carnaby's Cockatoo (HQS 6), FRTBC (HQS 9), and Baudin's Cockatoo (HQS 8) respectively.
- The vegetation is dominated by Jarrah and Marri, including some large trees, and is therefore likely to contain suitable DBH trees to offset those impacted in the Proposed Action.

The areas that will be acquired for Black Cockatoo Foraging Habitat has been illustrated in Figure 9.

4.5.2.2 Conservation gain for the protected matters

Offset 5 represents an area of large intact native vegetation with dominant Jarrah and Marri species. The site has a contiguous connection to lands being managed by DBCA and would provide a valuable addition to the State's conservation estate.

Threats to the site include feral animals such as cats, kangaroos, goats, pigs and foxes and weed infestation which increases competition for native species and may lead to an increased risk from bushfires (Appendix 1 b). A Western Power easement crosses the site at the western edge. Maintenance activities conducted by Western Power have restricted the regrowth of trees in proximity to the overhead powerlines. This portion of the site has not been captured as part of the Black Cockatoo Habitat acquired, however the easement represents a potential threat due to edge effects from uncontrolled access in this area. Land management will include fencing, weeding, bushfire control, predator control and restricting access to the site. This will reduce the potential spread of weeds, dieback disease, invasive species, herbivore grazing, and uncontrolled vehicle access. The introduction of these management actions will have a positive impact on the site as supported by research (Appendix 2) and will increase the vegetation quality and structure by a score of one at a minimum.

4.5.2.3 Offset calculator values

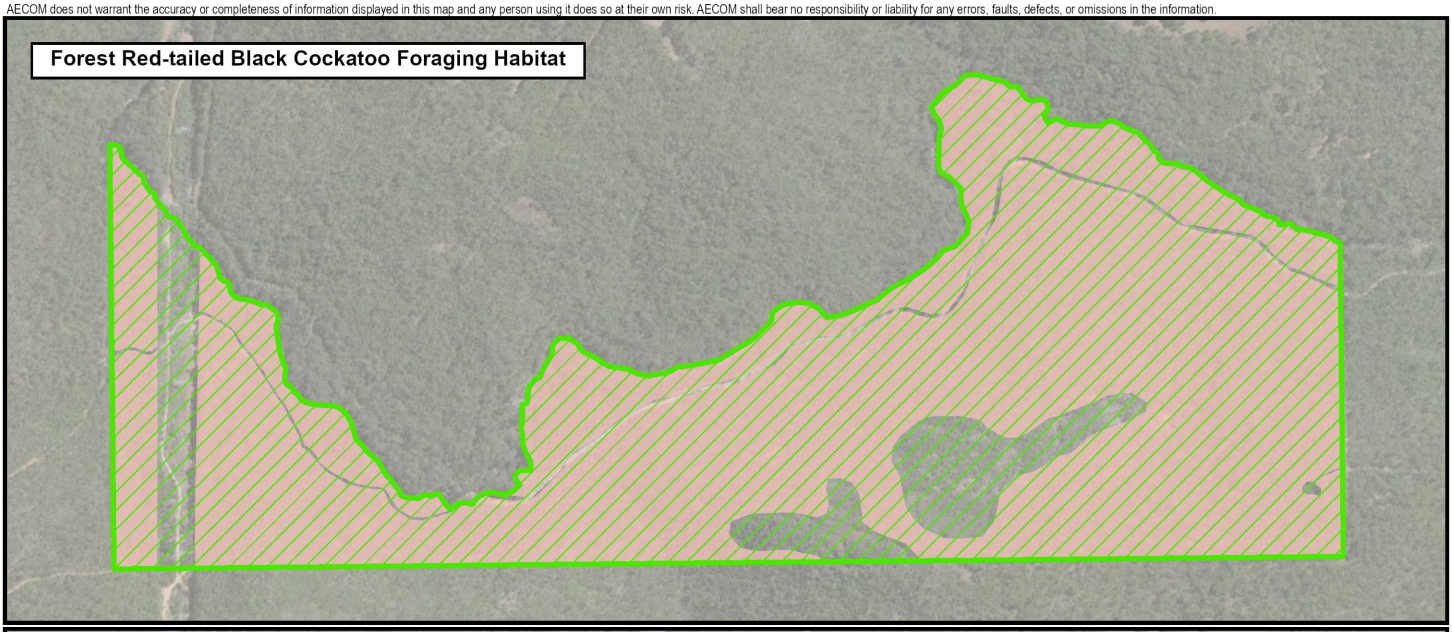
The land will be managed for 20 years, therefore, a conservative time frame of 20 years has been allowed for Time Until Ecological Benefit, at which point improvements to the ecology of the area from conservation efforts should be abundantly clear. A score of 0 has been given for risk of loss without offset, as no known development is proposed for the area and therefore there is no risk of the habitat being completely lost in the foreseeable future**Error! Reference source not found.**.

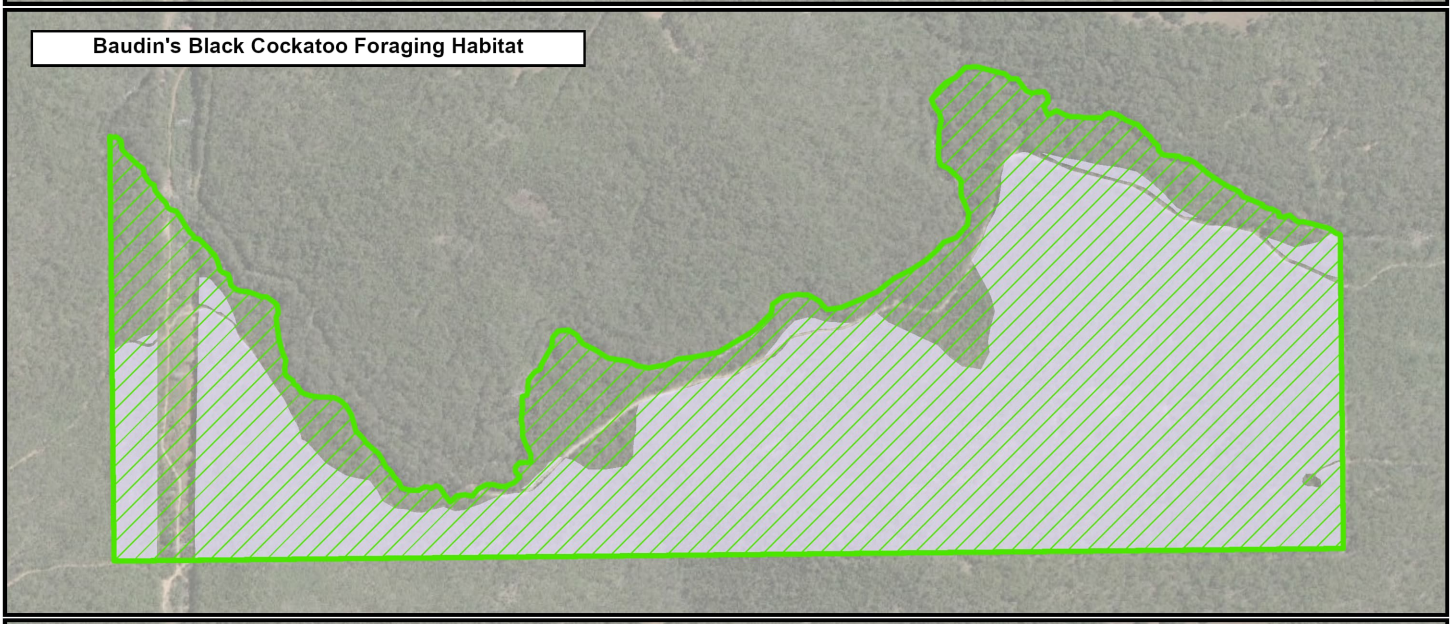
Carnaby's Cockatoo scored 6 for start quality due to a lack of foraging evidence and or nearby breeding sites. Baudin's Cockatoo and FRTBC scored 8 and 9 respectively for start quality, with evidence of foraging noted as well as the presence of suitable foraging trees. Without the threat of further clearing, foraging habitat is unlikely to become further degraded over time and therefore the HQS for Black Cockatoos' foraging habitat is unlikely to change for future quality without offset. Management actions including weed control and fencing to mitigate herbivore grazing, weed infestation, and the spread of dieback will encourage the regeneration of preferred foraging trees. As a result, the habitat quality for all three Black Cockatoo Species' is expected to increase by a score of one (Table 9).

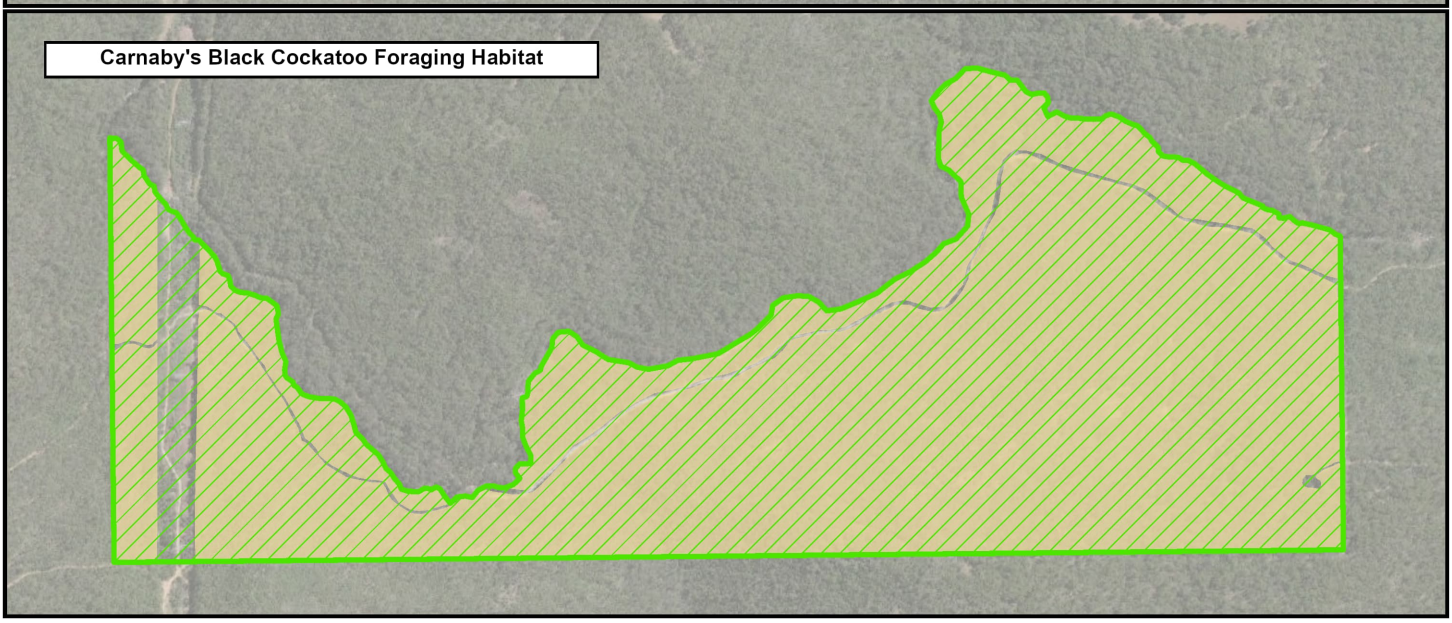
With the increased future quality values (with offset) for all three Black Cockatoo Species' Habitat, the total quantum of impact offset for foraging habitat is 3.47 ha (34.59%) for Baudin's Cockatoo, 4.41 ha (21.96%) for Carnaby's Cockatoo, and 4.98 ha (24.78%) for FRTBC.

Table 9–Offset 5 Calculator Values

MNES	Description	Time Until Ecological Benefit	Start Quality	Future Quality Without Offset	Future Quality With Offset	Offset Value (ha)	Offset Value (%)
BC habitat	Baudin's Cockatoo foraging habitat – high quality	20	8	8	9	3.47	34.59
BC habitat	Carnaby's Cockatoo foraging habitat – high quality	20	6	6	7	4.41	21.96
BC habitat	FRTBC foraging habitat – high quality	20	9	9	10	4.98	24.78







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Datum: GDA2020 MGA Zone 50

0 80 160 240 320
metres

Data sources: Main Roads WA

LEGEND

Environmental Offset Areas (27 Apr 2023)

Offset Allocations

Forest Red-tailed Black Cockatoo Foraging Habitat
Baudin's Black Cockatoo Foraging Habitat
Carnaby's Black Cockatoo Foraging Habitat

Offset Property Allocations, Lot 579 Lancaster Rd, Hoffman

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Figure **9**

Map Document: \\auper1pfiln001.na.aecomnet.com\local\Perth\Legacy\Projects\606X\60657311\900_CAD_GIS\930_ENV_GIS\WORKSPACE\2023_04_24_RNM_MPT296_OffsetShapefilePackageFigures_Alix_C\60657311_MPT296_v4.aprx (rob.mcgregor)

A4 size

4.6 Offset 6 Black Cockatoo Research - Murdoch University

The Black Cockatoo offset strategy is built around direct offsets, with only 10% of the total proposed offset package being indirect, in the form of research.

The research offset proposed is the Black Cockatoo Conservation Management Project (BCCMP) undertaken by Murdoch University.

4.6.1 Overview

4.6.1.1 Research objectives

The Murdoch University study aims to determine habitat use and threatening processes to the three Black Cockatoo species in modified landscapes. Warren et al. (2021) have defined five study objectives, which include:

- Characterise Black Cockatoo movement and habitat use across the Perth-Peel Coastal Plain and in the Southwest forest region for all three Black Cockatoo species
- Study known Carnaby's Cockatoo breeding sites, focusing on characterising habitat suitability, food resource availability and selection, nestling health, specific threatening processes and fledgling dispersal routes
- Identify new breeding sites in inland or southern areas for all three species based on migratory movement of birds to breeding grounds
- Apply new ecotoxicology methods to investigate Carnaby's Cockatoo Hindlimb paralysis Syndrome (CHiPs) toxicity cases, particularly in the agricultural zone
- Predictively model survivorship scenarios for all three species of Black Cockatoo using movement.

The study uses innovative tracking methodologies to track Black Cockatoo movement on the Perth-Peel Coastal Plain and in the Southwest forest region.

4.6.1.2 Outcomes to date

Several releases of Black Cockatoos with GPS tracking devices occurred between 2016 to 2018 and 2021 to 2022. The movement patterns have been ground-truthed to confirm flock numbers, foraging and breeding evidence. Release sites are scattered between Cataby and Newdegate, located approximately 150 km north of and 300 km southeast of the Perth CBD, respectively.

A total of 48 Black Cockatoos from the Kaarakin Conservation Centre were GPS tagged and released into wild flocks between 2016 – 2022, comprising 27 Carnaby's Cockatoo, five Baudin's Cockatoo and 16 FRTBC. Distribution modelling is in progress, with development ongoing.

Between 2017 – 2021 the research team anaesthetised 16 wild breeding female and male Black Cockatoos for tag attachment and health checks. The team also conducted health checks on 37 nestlings over this period. Murdoch University (2022) have confirmed the research paper with the interpretation of nestling health data collected from 2010 to 2015, 2020 and 2021, involving 426 individual birds is nearing submission.

4.6.2 Suitability of offset

4.6.2.1 Offset values to counterbalance residual impacts

The research offset is considered suitable for the Proposed Action for the following benefits to Black Cockatoos:

- Provides new and unique information on the cockatoo movement, health and foraging requirements of Black Cockatoos, as well as movement patterns for breeding Carnaby's Cockatoo
- The study encompasses the entire distribution range for all three species, including areas in proximity to the Proposed Action
- Research methods were developed in accordance with the following approved plans and conservation advice:

- EPBC Act Referral Guidelines for Black Cockatoos (DSEWPaC, 2012)
- DEC (2007) Carnaby's Cockatoo Recovery Plan (DEC, 2007)
- FRTBC Recovery Plan (DEC, 2012)
- MNES Significant Impact Guidelines (DEWHA, 2009)
- Consideration of MNES by the WA land use planning system Discussion Paper (WA Department of Planning, 2010).

The proposed research offset will comprise 10% of the impact offset for Black Cockatoo species that do not meet the 100% offset requirement. Using the EPBC Act Offset Calculator Tool, this is roughly equivalent to rehabilitating 15 ha of low-quality Black Cockatoo foraging habitat or protecting 35 ha of moderate quality foraging habitat.

Main Roads is currently assessing the monetary value required to sufficiently meet 10% of the Proposed Action's impact on Black Cockatoos.

4.6.2.2 Conservation gain for the protected matters

The landscape of the Peel-Perth and Southwest forest region has become highly modified, particularly near urban areas. The findings from this project will provide new and invaluable information on the movement patterns, foraging resources and behaviour, as well as determine key threats and challenges for all three Black Cockatoo species.

The continued research depends on funding to employ senior and junior researchers, purchase tracking equipment, pathogen testing, casual technician/field team and mobilisation costs (fieldwork).

5. Application of EPBC Act Environmental Offsets Policy

The proposed offset strategy is consistent with the principles of the EPBC Act Environmental Offsets Policy (DSEWPaC, 2012) as explained below. The Policy overarching principles which have been considered in preparing the preliminary offsets package are:

- Suitable offsets must deliver an overall conservation outcome that improves or maintains the viability of the protected matter.
- Suitable offsets must be built around direct offsets but may include other compensatory measures.
- Suitable offsets must be in proportion to the level of statutory protection that applies to the protected matter.
- Suitable offsets must be of a size and scale proportionate to the residual impacts on the protected matter.
- Suitable offsets must effectively account for and manage the risks of the offset not succeeding.
- Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs.
- Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable.
- Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.

5.1 Banksia Woodland TEC

The Proposed Action will clear up to 14.94 ha of Banksia Woodland TEC in an Excellent to Degraded condition. Of the 14.94 ha, the three dominant vegetation conditions included 4.74 ha mapped as Excellent to Very Good, 4.71 ha mapped as Very Good, and 4.02 ha mapped as Good. As such, the overall vegetation condition of the site is characterised as Very Good.

The proposed offsets will counterbalance 100% of the impacts of clearing 14.94 ha of Banksia Woodland TEC in Very Good condition.

5.1.1 Suitable offsets must deliver an overall conservation outcome that improves or maintains the viability of the protected matter

The offsets will provide a conservation outcome that maintains or improves the viability of the Banksia Woodland TEC. The proposed offset includes land acquisition and land management actions such as fencing, weed control, and feral animal control to improve or maintain the condition of the protected matter as explained in Appendix 1 a.

The proposed offset sites will counterbalance the residual impacts to Banksia Woodland TEC by at least 100%. The offsets package protects about 162 ha of Banksia Woodland TEC for conservation.

The selection of sites protects remnant Banksia Woodland TEC within proximity to the Proposed Action as well as larger areas of intact bushland. Conservation of large intact patches of TEC results in a greater overall conservation benefit (DBCA 2022, pers comm.). Larger patches of Banksia Woodland TEC sustain higher native species diversity and are less susceptible to disturbances such as edge effects.

5.1.2 Suitable offsets must be built around direct offsets but may include other compensatory measures

The Banksia Woodland offset strategy is 100% built around direct land acquisition offsets.

5.1.3 Suitable offsets must be in proportion to the level of statutory protection that applies to the protected matter

Offsets were calculated using the Offset Assessment Guide (DCCEEW, 2022e). This included an input for the current listing of the MNES, so as to ensure that the offset size is in proportion to the level of statutory protection of the protected matter.

5.1.4 Suitable offsets must be of a size and scale proportionate to the residual impacts on the protected matter

The provision of direct offsets is based on completed EPBC Act Offset Assessment Guide calculations, incorporating evidence-based justification for all inputs.

5.1.5 Suitable offsets must effectively account for and manage the risks of the offset not succeeding

The estimation of direct offsets is based on completed offset assessment guide calculations, incorporating a conservative assessment of confidence in results of the offset succeeding (70%) and Main Roads' track record for achieving DBCA's acceptance of land into the conservation estate.

Management actions proposed to be undertaken on the offset sites will include:

- Access control – fencing and gates
- Fire breaks
- Weed control
- Dieback assessment and management
- Rubbish removal.

These actions will prevent the decline or deterioration of the protected matters within the offset sites.

Several sites are adjacent to a DBCA managed land, which provides additional assurance in implementing land management actions. The adjacent vegetation protects the offset sites from edge effects and unrestricted access.

To further manage the risk of the offset not succeeding, the Offset Management Plan (GCA, 2023c) includes a section which describes contingency actions to be implemented in the event offset targets are at risk of not being met.

5.1.6 Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs

The offsets have been selected specifically to counterbalance significant residual impacts, so as to meet the requirements of Commonwealth and State policy. These offsets are additional to any other requirements.

5.1.7 Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable

5.1.7.1 Efficient and Effective

The offsets selected are deemed efficient as they aim to both meet Commonwealth regulatory requirements and aid in the achievement of WA State offset requirements where applicable. Where possible, large offset sites have been acquired to reduce management requirements. For example, Cowalla offsets 100% of the Banksia Woodland TEC impacts, meaning all land acquired for the management of TEC can be targeted for just this site. This ensures the efficient use of resources (i.e., labour) and further validates the effectiveness of the offset based on the protection and enhancement of a large-scale lot of suitable Banksia Woodland TEC.

5.1.7.2 Timely

Management actions including the installation of fences and weed control will be conducted in accordance with the works schedule provided in the Offsets Management Plan. In relation to the acquirement of land, all of the sites are already owned by the State of WA and are managed by DBCA or Main Roads.

5.1.7.3 Transparent and Scientifically Robust

Details for each offset site has been detailed in Section 4. Information has been acquired from either pertinent literature including research papers or past environmental reports and surveys, or directly from biological reports or surveys conducted specifically for the purpose of informing GCA of the offset site's characteristics and conservation values. All information has been presented in a clear and concise manner stating facts and summarising details as they are written in the referenced documents.

5.1.8 Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced

This Offset Strategy has been developed to present an offset package to demonstrate that Main Roads is able to adequately counterbalance significant residual impacts of the Proposed Action. The governance of each offset site, including monitoring, auditing and reporting, is documented within the Offset Management Plan, which will be refined over time based on the findings of any additional surveys and consultation with DBCA.

5.2 Black Cockatoo Species

The Proposed Action will clear up to 33.48 ha of foraging habitat for the three Threatened Black Cockatoo species. The quality of foraging habitat for each Black Cockatoo species has been assessed using DCCEEW's Habitat Quality Scoring (HQS) Tool as follows:

- Baudin's Cockatoo – 33.48 ha of foraging habitat with a score of 3 (low quality).
- Carnaby's Cockatoo – 33.48 ha of foraging habitat with a score of 6 (high quality).
- FRTBC – 33.48 ha of foraging habitat with a score of 6 (high quality).

Foraging habitat comprised roadside and scattered eucalyptus or Marri trees, Banksia woodland, and Fabaceous heathland.

5.2.1 Suitable offsets must deliver an overall conservation outcome that improves or maintains the viability of the protected matter

As outlined in Section 3.2, the proposed offset strategy will include a combination of land acquisition, rehabilitation, and research offsets, with land acquisition and rehabilitation comprising a minimum of 90% of the total offset strategy. Land acquisition offsets and land rehabilitation have shown to be most effective in producing a measurable environmental benefit (May et al., 2017). Table 3 demonstrates at a minimum, the conservation outcome will maintain (offset by 100%) and improve (any offset additional to 100%) the Black Cockatoo Foraging Habitat.

5.2.2 Suitable offsets must be built around direct offsets but may include other compensatory measures

The offset strategy is built around direct offsets, with only 10% of the total proposed offset package being indirect, in the form of research from Murdoch University. The direct offsets included within the strategy comprise a package of offset properties to provide offsets for the three species of Black Cockatoo. Details of the research offset are provided in Section 4.6.

5.2.3 Suitable offsets must be in proportion to the level of statutory protection that applies to the protected matter

Offsets were calculated using the Offset Assessment Guide. This included an input for the current listing of the MNES to ensure that the offset size is in proportion to the level of statutory protection of the protected matter.

5.2.4 Suitable offsets must be of a size and scale proportionate to the residual impacts on the protected matter

The provision of direct offsets is based on completed offset assessment guide calculations, incorporating evidence-based justification for all inputs.

5.2.5 Suitable offsets must effectively account for and manage the risks of the offset not succeeding

The estimation of direct offsets is based on completed offset assessment guide calculations, incorporating a conservative assessment of confidence in results of the offset succeeding (70%) and Main Roads' track record for achieving DBCA's acceptance of land into the conservation estate.

Management actions proposed to be undertaken on the offset sites will include:

- Access control – fencing and gates
- Fire breaks
- Weed control
- Dieback assessment and management
- Rubbish removal.

These actions will prevent the decline or deterioration of the protected matters within the offset sites.

Several sites are adjacent to a DBCA managed land, which provides additional assurance in the implementation of land management actions. The offset sites are also protected by the existing adjacent vegetation from edge effects and unrestricted access.

To further manage the risk of the offset not succeeding, the Offset Management Plan includes a section which describes contingency actions to be implemented in the event offset targets are at risk of not being met.

For the Neaves Road Offset Site, a Revegetation Management Plan has been developed which also includes contingency actions specific to revegetation success (GCA, 2023b). Contingency Actions include:

- Evaluate the cause of revegetation failure/issues
- Determine the appropriate corrective actions, which may include:
  - Changes to species lists
  - Altered weed control scheduling
  - Altered herbicides or weed management techniques
  - Pest management.

5.2.6 Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs

The proposed offsets have been selected specifically to counterbalance significant residual impacts, so as to meet the requirements of Commonwealth and State policy. These offsets are additional to any other requirements.

5.2.7 Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable

5.2.7.1 Efficient and Effective

The offsets selected are deemed efficient as they aim to both meet commonwealth regulatory requirements and aid in the achievement of state offset requirements where applicable. Where possible, large offset sites have been acquired to reduce management requirements. For example, the Crossman site offsets approximately 50% of the total impacts to Baudin's Cockatoo, meaning a significant portion of the land acquired for Baudin's Cockatoo foraging habitat will be managed at just this one site. This ensures the efficient use of resources (i.e., labour) and further validates the effectiveness of the offset based on the protection and enhancement of large-scale suitable foraging habitat sites.

5.2.7.2 Timely

Management actions including the installation of fences and weed control will be conducted in accordance with the works schedule provided in the Offsets Management Plan. In relation to the acquirement of land, a majority of the proposed sites are already owned and/or managed by Main Roads. Any outstanding offsets will be acquired upon the acceptance of this offset strategy by DCCEEW.

5.2.7.3 Transparent and Scientifically Robust

Details for each offset site has been detailed in Section 4. Information has been acquired from either pertinent literature including research papers or past environmental reports and surveys, or directly from biological reports or surveys conducted specifically for the purpose of informing GCA of the offset site's characteristics and conservation values. All information has been presented in a clear and concise manner stating facts and summarising details as they are written in the referenced documents.

5.2.8 Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced

This draft Offset Strategy has been developed to present a preliminary offset package, to demonstrate that Main Roads is able to adequately counterbalance significant residual impacts of the Proposed Action. The governance of each offset site, including monitoring, auditing and reporting, is documented within the Offset Management Plan (GCA, 2023c), which will be refined over time based on the findings of any additional surveys and consultation with DBCA.

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Appendix 1–Habitat Quality Scoring Tool Outputs and Justification

Appendix 1 a Banksia Woodlands of the Swan Coastal Plain TEC

Appendix 1 b Black Cockatoo Foraging Habitat

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Impact site

Habitat Scoring Framework			**Score - Impact Site**
Site Condition (70%)	Vegetation condition (Keighery 1994)	- Pristine (100) - Excellent (80) - Very good (60) - Good (40) - Degraded (20) - Completely Degraded (0)	A total of four remnant vegetation patches considered to be the representative of Banksia Woodland of the Swan Coastal Plain (BWSCP) TEC occur either entirely or in part within the Development Envelope. The total area of the BWSCP comprises 14.94 ha within the DE, of which 31.53% are in very good condition and 31.73% are excellent-very good condition. This gives an overall vegetation condition of "very good".
		Score	**60**
	Species Richness	- Average native species richness within the top half of recorded range for the TEC (10) - Average native species richness within the bottom half of recorded range for the TEC (0)	Species data was acquired from 31 quadrats and 15 releves. The average species richness from the survey data is 36 species per 100m^2 (Biota, 2021). The average species richness of 50 per 100m^2 has been recorded for Banksia Woodland in Perth (Keighery, 2016; TSSC, 2016). The average species richness of the TEC is within the top half of the recorded range.

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Score - Impact Site
	Presence of Threatened taxa	- Patch is critical habitat for, and hosts Threatened taxa (10) - Patch is critical habitat for Threatened taxa (5) - Patch is not critical habitat for Threatened taxa (0)	One individual *Conospermum undulatum* (Vulnerable under both EPBC Act, and BC Act) was recorded in the impacted TEC. A total of 391 individuals were recorded in the local population. Results of the Biota (2021) survey indicates the presence of 2.62 ha suitable habitat within the DE and 12.11 ha in the broader survey area, making up to 21.6% of suitable habitat for the species for the entire survey area. Additionally, 61.9 ha of suitable habitat is in the surrounding contextual area. An area recently surveyed by Woodman (2021) approximately 12km south of the Proposed Action recorded 1,114 individuals. According to the recovery plan for *C. undulatum*, all known habitat where the species occurs in the wild are critical for survival of the species. Populations occurring in the geographic bioregion of Swan Coastal Plain and Jarrah Forest are therefore considered critical. Carnaby's Cockatoo and Forest Red Tailed Black Cockatoo were recorded foraging in the area near the intersection between Roe Highway and Great Eastern Highway Bypass (GEHB). Approximately 16,051 ha and 3,773 ha of foraging habitat remains within 12km and 6km of the impact area, respectively. For Carnaby's Black Cockatoos, Swan Coastal Plain is a critical foraging area (DCCEEW, 2022). Patch is a critical habitat for threatened taxa.
		Score	**10**
	Contains State listed TEC/PEC	- Patch contains WA FCT listed as State TEC (20) - Patch contains WA FCT listed as State PEC (10) - Patch does not contain WA FCT listed as either TEC or PEC (0)	BWSCP is listed as Commonwealth TEC and State PEC. FCT 20a is listed Endangered and FCT 21c is state PEC (P3).
		Score	**20**

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Score - Impact Site
	Presence of Dieback	- Patch is dieback free (10) - Patch is partly dieback free (5) - Patch is dieback infested (0)	FCT23(a) within the DE is dieback infested. A total of 4.11 ha of the BWSCP TEC were found to be infested (Glevan, 2020)
		Score	**5**
	Condition total (out of 150)		**105**
	Condition Score (Condition total / 150 * 70)		**49**
Site Context (30%)	Connectivity	- Patch is continuous with remnant vegetation and forms a corridor that links different landscape units (30) - Patch is continuous with remnant vegetation that forms a medium to large local remnant (20) - Patch is within 1km of other medium to large remnants (10) - Patch is within 12km of other significant remnants and contributes to support of significant avifauna (i.e. known Black Cockatoo Breeding sites are located within 12km) (5) - Patch does not meet any of the above criteria (0)	Patch is fragmented by cleared roads and buildings and not continuous with other remnant vegetation. However, the DE supports Carnaby's and Forest Red Tailed Black Cockatoos (FRTBC) evidenced by records of foraging within the DE. A large area of native vegetation in Kalamunda National Park and Beelu National Park lies within 12km of the TEC.
		Score	**5**
	Patch size	- 20 hectares or more (50) - 10-20 hectares (40) - 5-10 hectares (30) - 2-5 hectares (20) - Less than 2 hectares (10)	The total impact area on TEC is 14.94 ha.
		Score	**40**

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Score - Impact Site
	Site location and risk	- Patch is located in an area where the TEC has been extensively cleared (10)	The DE comprises vegetation complex Bassendean 1001 but has been extensively cleared for urban development such as roads (Roe Highway, Great Eastern Highway Bypass), commercial areas (airport), and industrial and agricultural purposes. On a broader scale, the City of Swan has 43% (44,000 ha) of the pre-European vegetation remaining according to DBCA (2019).
		Score	**0**
	Site location and risk	- Patch is located at the geographical edge of the recorded range (10)	The patch is located approximately 8km from the nearest geographical edge to the east (DCCEEW, 2022). The extent of Banksia Woodland TEC to the north, south, and west is otherwise extensive. The patch is not considered near the geographical edge.
		Score	**0**
	Context total (out of 100)		**45**
	Context Score (Context total / 100 * 30)		**14**
Habitat quality score	**Quality total (out of 100)**	Condition Score + Context Score	**63**
	Final Patch Habitat Quality Score (out of 10)	Quality total / 10	**6**

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Offset 1 (Cowalla)

Habitat Scoring Framework			Start quality	With Offset	Without Offset
Site Condition (70%)	Vegetation condition (Keighery 1994)	- Pristine (100) - Excellent (80) - Very good (60) - Good (40) - Degraded (20) - Completely Degraded (0)	Floristic data was analysed in comparison to the Keighery et al. (2012) data set. Six vegetation units were recorded during the field assessment of which three represent Banksia Woodland TEC. Banksia TEC comprise 890.43 ha (64.37%) of the total 1,383.30 ha survey area. Of the 890.43 ha, the offset area measures 163 ha (Focused Vision, 2022). The survey includes 7 quadrats (C18.01, C18.02, C19.01, C19.02, C20.01, C20.02, C22) in the offset area, of which five were assessed as "excellent" and two quadrats "very-good" vegetation condition. 70% of the total quadrats have vegetation in excellent condition.	A total of 28 introduced species were recorded within the survey area at Cowalla. Management actions to address potential threats include weed management and installation of a fence around the site to prevent destructive grazing. The fence will also prevent unwarranted access to the area which in turn reduces potential spread of dieback, weeds, and littering. These actions have been deemed likely to improve the vegetation condition, with further justification and evidence provided in Appendix 2. While it will not be pragmatic to expect Pristine vegetation condition, the implementation of management measures can help improve vegetation in "very good" condition that comprise 54% of the offset site to "Excellent condition".	Image Resources NL is planning to develop a project for mineral sands mine that requires clearing of up to 950 ha. Besides this footprint, the project will also have to develop infrastructure for power supply, pipelines, water bores, access roads, accommodation facilities, storage areas, and other supporting infrastructure. Moreover, development of the ancillary facilities of the project will likely encroach into the offset site requiring it to be cleared. Taking account of these impacts, patches of ‘excellent’ condition vegetation are likely to deteriorate to 'very good' condition without intervention.
		Score	**80**	**80**	**60**

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Start quality	With Offset	Without Offset
	Species Richness	- Average native species richness within the top half of recorded range for the TEC (10) - Average native species richness within the bottom half of recorded range for the TEC (0)	Vegetation units BaBmEt, BABmMp and MpBaBm are found within the survey area and are representative of Banksia Woodland TEC. BABmMp and MpBaBm are representative of FCT22 and BaBmEt for FCT 23b (Focused Vision, 2022). The average species richness for vegetation units BaBmEt, BABmMp, and MpBaBm has been assessed as 47.4, 34.2, and 21.8 species per 100m^2 respectively. An average species richness of 50 per 100m^2 has been recorded for Banksia Woodland in Perth. The average species richness for FCT 22 and 23b is 30 and 47 per 100m^2 respectively. (Keighery, 2016). Therefore, the average species richness for BABmEt and BABmMp is 55% and MpBaBm is 72%.	Protection of vegetation using fencing allows native species richness to increase within the fenced area. This is supported by a study carried out by Nilar et al. (2019) that concluded a 25% increase of native species richness when compared to an unfenced area. These findings are summarised in Appendix 2 of the offset strategy.	The average species richness of the offset site is within the top half of the recorded range as explained in start quality. Focused Vision identified threats from human disturbances and weeds. Western Grey Kangaroos were also recorded in the area grazing on herbs (Bidaminna Project, 2022). Further, the development near the offset will aggravate the threats. Increased human disturbance, overgrazing, and weed invasion will likely lead to a decline in species richness in the area.
		Score	**10**	**10**	**10**
	Presence of Threatened taxa	- Patch is critical habitat for, and hosts Threatened taxa (10) - Patch is critical habitat for Threatened taxa (5) - Patch is not critical habitat for Threatened taxa (0)	The Focused Vision Biological Assessment lists three threatened fauna species: CBC (EN) - regular visitor, BC (VU) - vagrant, FRTBC (VU) - irregular visitor. The offset site is located within a breeding area for Carnaby's Cockatoo (DBCA 054). For	Patch will remain as critical habitat for the threatened taxa.	The offset site is within the known breeding area for Carnaby's Cockatoos. The offset site will likely remain critical habitat for the species.

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Start quality	With Offset	Without Offset
			Carnaby's Cockatoo, the Swan Coastal Plain is a critical foraging area according to the referral guideline for three threatened Black Cockatoo species (DCCEEW, 2022). Using the foraging habitat quality scoring tool in Appendix A of DCCEEW's referral guideline, the score is more than 5, indicating the habitat is of high quality. Therefore, the habitat is critical for survival of the Black Cockatoos.		
		Score	**10**	**10**	**10**
	Contains State listed TEC/PEC	- Patch contains WA FCT listed as State TEC (20) - Patch contains WA FCT listed as State PEC (10) - Patch does not contain WA FCT listed as either TEC or PEC (0)	Patch does not contain State listed TEC. Patch contains State listed Priority 3 PEC, including FCT22 and FCT 23b.	The environmental significance of the TEC will not change with the offset.	FCT 22 and FCT 23b are State listed PEC.
		Score	**10**	**10**	**10**
	Presence of Dieback	- Patch is dieback free (10) - Patch is partly dieback free (5) - Patch is dieback infested (0)	Across the entire survey area, a total of 42 quadrats were sampled, of which 14 quadrats were found to have dieback present or possible. None of the quadrats in the offset site were indicated to have, or potentially have, dieback presence (Focused Vision, 2022)	Management actions include weed management and the installation of a fence around the site to prevent destructive grazing as well as unwarranted access to the area, which in turn reduces the potential spread of dieback.	Fencing can prevent the spread of dieback into the TEC through restricting entry by people, animals, and vehicles. Without such management measures in place, dieback is more likely to spread into the offset site, therefore, reducing the score.
		Score	**10**	**10**	**5**

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Start quality	With Offset	Without Offset
	Condition total (out of 150)		**120**	**120**	**95**
	Condition Score (Condition total / 150 * 70)		**56**	**56**	**44**
Site Context (30%)	Connectivity	- Patch is continuous with remnant vegetation and forms a corridor that links different landscape units (30) - Patch is continuous with remnant vegetation that forms a medium to large local remnant (20) - Patch is within 1km of other medium to large remnants (10) - Patch is within 12km of other significant remnants and contributes to support of significant avifauna (i.e. known Black Cockatoo Breeding sites are located within 12km) (5) - Patch does not meet any of the above criteria (0)	The Banksia Woodland TEC is connected to a larger patch that comprises 19,064 ha. The patch is intact, provides a large extent of remnant vegetation, and is located in conservation areas (Moore River National Park which is connected to Moore Nature Reserve): adjacent to the eastern boundary of the offset site (Focused Vision, 2022).	Patch will be continuous with large local remnants in Moore River National Park and Moore Nature reserve.	Same as start quality
		Score	**20**	**20**	**20**
	Patch size	- 20 hectares or more (50) - 10-20 hectares (40) - 5-10 hectares (30) - 2-5 hectares (20) - Less than 2 hectares (10)	Total offset site is 163 ha.	The offset area will be 163 ha.	Same as start quality.
		Score	**50**	**50**	**50**

Appendix 1a: Habitat Quality Score for Banksia Woodland of Swan Coastal Plain TEC

Habitat Scoring Framework			Start quality	With Offset	Without Offset
	Site location and risk	- Patch is located in an area where the TEC has been extensively cleared (10)	Towards the west of the patch a large area of degraded vegetation complex (Bassendean-37) exists. Further west and south of the patch is another large area of Bassendean-949 that has been cleared for agriculture. Despite clearing, large portions of native vegetation are still intact surrounding the TEC. Therefore, the TEC is not located in an extensively cleared area. On a broader scale, 55.28% (176,727.13 ha) of the pre-European vegetation remains within the Shire of Gingin according to DBCA (2019).	The patch is not located within an extensively cleared area.	Same as start quality.
		Score	**0**	**0**	**0**
	Site location and risk	- Patch is located at the geographical edge of the recorded range (10)	The nearest geographical edge is approximately 18 km west (nearest coastline). The rest of the patch is surrounded by Banksia Woodland TEC.	The location of the Patch from the geographical edge of the recorded range will not change.	Same as start quality.
		Score	**0**	**0**	**0**
	Context total (out of 100)		**70**	**70**	**70**
	Context Score (Context total / 100 * 30)		**21**	**21**	**21**
Habitat quality score	**Quality total (out of 100)**	Condition Score + Context Score	**77**	**77**	**65**
	Final Patch Habitat Quality Score (out of 10)	Quality total / 10	**8**	**8**	**7**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Impact Site

Carnaby's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	3	Low to Moderate	According to Biota (2021) the survey area contains multiple habitats suitable for Black Cockatoo foraging such as Banksia woodland, Eucalyptus/Marri, and scattered Eucalyptus/Marri and Fabaceous heathland measuring a total area of 88.4 ha. The area also contains approximately 55 ha of flooded gum over grassland, planted Eucalyptus/Marri, and wetland/river habitat. The area is dominated by Banksia woodland with scattered Eucalyptus/Marri. The habitat contains a wide range of vegetation types, including *Eucalyptus marginata* subsp. *marginata* woodland, *Eucalyptus rudis* subsp. *rudis* open forest, *Eucalyptus rudis* subsp. *rudis* closed forest, *Melaleuca rhaphiophylla* low closed forest, *Corymbia calophylla* open woodland, and open woodland of *Banksia menziesii* and *B. attenuata*. The dominant vegetation type is Banksia open woodland over *Xanthorrhoea preissii* open shrubland. The NVIS (2017) Structural Formation Terminology suggests the projected foliage cover for 'open woodland' is less than 10%. Since there is foraging evidence of Carnaby's Cockatoos and due to the presence of suitable foraging habitat and Banksia trees, projected foliage cover of 10% has been considered. The site is, therefore, assessed to provide 'low to moderate' foraging habitat for Carnaby's Cockatoo.
Proximity of the site in relation to other habitat	3		The site is located approximately 15 km from the nearest known breeding site south-east of the Development Envelope at Canning National Park (DBCA-054). Foraging habitat was identified within 6 km of the site providing 3,733 ha of suitable foraging habitat, of which 44% is managed by DBCA. The foraging habitat within 6 km represents more intact and high-quality habitat than the Proposed Action site.
Confirm presence/ absence of species	Yes		Six individuals of Carnaby's Cockatoo were observed directly in the Banksia Woodland surrounding the intersection between Roe Highway and Great Eastern Highway Bypass. Evidence for foraging such as bite mark and chewed Marri nuts were also recorded during the survey (Biota, 2021).
Total score	**Start quality**		**6**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Baudin's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	3	Low to Moderate	According to Biota (2021) the survey area contains multiple habitats suitable for Black Cockatoo foraging such as Banksia woodland, Eucalyptus/Marri, and scattered Eucalyptus/Marri and Fabaceous heathland measuring a total of area of 88.4 ha. The area also contains approximately 55 ha of flooded gum over grassland, planted Eucalyptus/Marri, and wetland/river habitat. The area is dominated by Banksia woodland with scattered Eucalyptus/Marri. The habitat contains wide range of vegetation types, including *Eucalyptus marginata* subsp. *marginata* woodland, *Eucalyptus rudis* subsp. *rudis* open forest, *Eucalyptus rudis* subsp. *rudis* closed forest, *Melaleuca rhaphiophylla* low closed forest, *Corymbia calophylla* open woodland, and open woodland of *Banksia menziesii* and *B. attenuata*. The dominant vegetation type is Banksia open woodland over *Xanthorrhoea preissii* open shrubland. The NVIS (2017) Structural Formation Terminology suggests the projected foliage cover for 'open woodland' to be less than 10%. Since, there is no foraging evidence and the site is located at the geographical edge of the foraging habitat of the species, a foliage cover of less than 10% has been assigned. The presence of Marri/Jarrah trees represent limited foraging habitat. The site has therefore been assessed to provide 'low to moderate' (5-10%) foraging habitat for Baudin's Cockatoo.
Proximity of the site in relation to other habitat	0		A large breeding ground has been recorded approximately 200 km south of the site (Biota 2021). The nearest breeding area is approximately 35 km south-east at the Wungong catchment (T. Kirkby, pers. comm.). According to the telemetry study carried out by Murdoch University in 2015 and Action Management Plan for Tonkin Highway Extension (Main Roads, 2021), the species has been recorded foraging in a nature road reserve in Mundijong, located approximately 40km from the proposed action.
Confirm presence/ absence of species	No		No evidence of foraging was found and the Development Envelope is located at the edge of the foraging range for the species (Biota 2021).
Total score	**Start quality**		**3**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

FRTBC	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	3	Low to Moderate	According to Biota (2021) the survey area contains multiple habitats suitable for Black Cockatoo foraging such as Banksia woodland, Eucalyptus/Marri, and scattered Eucalyptus/Marri and Fabaceous heathland measuring a total of area of 88.4 ha. The area also contains approximately 55 ha of flooded gum over grassland, planted Eucalyptus/Marri, and wetland/river habitat. The area is dominated by Banksia woodland with scattered Eucalyptus/Marri. The habitat contains wide range of vegetation types, including *Eucalyptus marginata* subsp. *marginata* woodland, *Eucalyptus rudis* subsp. *rudis* open forest, *Eucalyptus rudis* subsp. *rudis* closed forest, *Melaleuca rhaphiophylla* low closed forest, *Corymbia calophylla* open woodland, and open woodland of *Banksia menziesii* and *B. attenuata*. The dominant vegetation type is Banksia open woodland over *Xanthorrhoea preissii* open shrubland. The NVIS (2017) Structural Formation Terminology suggests the projected foliage cover for 'open woodland' to be less than 10%. Given there is foraging evidence of Forest Red Tailed Black Cockatoos (FRTBC) and the presence of suitable foraging trees such as *Corymbia calophylla* and *Banksia sp*., the highest range (i.e., 10%) projected foliage cover has been assigned. The site has therefore been assessed to provide 'low to moderate' foraging habitat for Forest Red Tailed Black Cockatoo.
Proximity of the site in relation to other habitat	3		Nearest breeding site located is located 5-7 km south-east of the Development Envelope in Kalamunda National Park.
Confirm presence/ absence of species	No		The species was not observed however bite marks were recorded. This has been treated as "infrequent" and therefore assigned a score of "No".
Total score	**Start quality**		**6**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Offset 1 (Cowalla)

Carnaby's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	4	Moderate	Focused Vision Consulting Biological Assessment has scored the site a 4 based on their criteria contained in Table 11, Page 31. For Carnaby's Cockatoo, the offset site has been assessed to have Moderate foraging value with the following vegetation: - Woodland/low forest with tree banksias (of key species *B. attenuata* and *B. menziesii*) 20-40% projected foliage cover. - Kwongan/Shrubland containing species of foraging value, such as shrubby banksias, have 20-40% projected foliage cover. - Eucalypt Woodland/Forest with Marri 20-40% projected foliage cover. The dominant vegetation type in the offset area is woodland of *Banksia menziesii*, *Banksia attenuata* and *Melaleuca preissiana o*ver shrubland of *Xanthorrhoea preissii*. Focused Visions score is further validated using the NVIS Structural Formation Terminology, under which woodlands have a projected foliage cover of 10-30%. As the habitat is in "good to excellent" condition, the maximum foliage cover (30%) has been assigned. According to Focused Vision (2022) the presence of *Banksia spp*., *Corymbia calophylla* and even *Eucalyptus todtiana* provide 'very high' (7) quality foraging habitat for Carnaby's Cockatoo which collectively comprises 61.20% of the total survey area.
Proximity of the site in relation to other habitat	2		Site is located within the 12km buffer of breeding areas according to DBCA's Carnaby's Cockatoo Confirmed Breeding Areas within the Swan Coastal Plain and Jarrah Forest IBRA Regions (DBCA-054).
Confirm presence/ absence of species	No		The field assessment did not record any Carnaby's Cockatoo at the offset site, however, a flock was observed within 200 m of the survey area. No evidence of foraging activity was observed within the survey area during the field assessment, however, activity was noted just outside the boundary on Banksia cones and wild radish (*Raphanus raphanistrum*). A large portion of the survey area, which makes up the Banksia woodlands contains numerous flora species (*Banksia attenuata, B. ilicifolia, B. menziesii, Eucalyptus todtiana* and *Xanthorrhoea preissii*) that are known to be foraging food source for Carnaby's Cockatoos. As the species was observed outside the survey area, presence within the survey area cannot be confirmed.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Total score	**Start quality**	**6**
	Without offset	**6**
	With offset	**7 -** The dominant threat identified by Focused Vision on the vegetation at the offset site is disturbances caused by grazing, weed invasion and Phytophthora dieback which can affect the regeneration of potential foraging habitat for the Black Cockatoos (DCCEEW). Habitat management and protection through fencing and weed control can improve habitat values for Black Cockatoos. It has also been evidenced that fencing can enable recovery of vegetation cover and species richness (Nilar, H.M. (2019) by preventing weed invasion and spread of Phytophthora dieback from off-road vehicles. The score for the vegetation condition, therefore, has been increased by 1 as the habitat is envisaged to shift from 'moderate' value to 'moderate-high'.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Offset 2 (Neaves Road)

Carnaby's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	2	Low	A survey conducted in 2014 by Coffey (2015) recorded three vegetation units containing trees suitable for Carnaby's Cockatoo foraging (mostly *Corymbia calophylla* and *Eucalyptus todtiana*), described as: 1. Revegetated Corymbia sparse mid woodland 2. Corymbia sparse mid woodland 3. Eucalyptus sparse mid Woodland Creek line/floodplain The offset site is dominated by revegetated *Corymbia calophylla* (marri), *Eucalyptus camaldulensis* (river red gum) and *Eucalyptus todtiana* (coastal blackbutt/pricklybark), and open paddocks with remnant *Corymbia calophylla* (marri) and *Eucalyptus rudis* subsp. *rudis* (flooded gum) (Coffey 2015, p8-22). Vegetation condition was scored mostly as degraded to completely degraded and recorded as 'woodland', which under the NVIS Structural Formation Terminology, indicates a 10-30% foliage cover (NVIS Technical Working Group, 2017). Given the degraded nature of the vegetation, lack of preferred proteaceous species, and cleared paddock areas, foliage cover suitable for foraging is more accurately estimated to be less than 10 percent, suggesting a condition score of 2.
Proximity of the site in relation to other habitat	2		A confirmed Carnaby's Cockatoo Breeding Area (DBCA-054) intercepts the offset site. DBCA's Carnaby's breeding dataset applies a 12km buffer from a confirmed breeding site. Therefore, the offset site is known to be within 12km of the nearest confirmed breeding site (score of 2).
Confirm presence/ absence of species	No		Six Carnaby's Cockatoo were sighted flying over the offset area during a survey conducted in 2020 by AECOM (2020). No foraging evidence was collected for Carnaby's Cockatoo for the same survey.
Total score	**Start quality**		**4** - Sum of vegetation condition and proximity of site to Black Cockatoo Habitat, as justified above.
	Without offset		**4** - Sum of vegetation condition and proximity of site to Black Cockatoo Habitat, as justified above.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

With offset	**7** - Revegetation efforts are anticipated to result in a significant increase in vegetation suitable for Carnaby's Cockatoo foraging. Based on the environmental report by Coffey (2015) and 2022 aerial imagery, the three vegetation units containing suitable habitat currently make up approximately 50% of the offset site, with the remaining 50% presenting unsuitable habitat being either low open woodland (without suitable black cockatoo trees) or cleared habitat. The intent of revegetation efforts is to protect and enhance the existing habitat and revegetate the cleared areas. The revegetation plan includes completion targets that require a minimum overall foliage cover of 26% post revegetation efforts, through seedling planting and native regeneration (GCA, 2023). This alone will increase the vegetation condition and score to "Moderate" (4) as a minimum. Additionally, fencing and weed management in the area is further anticipated to improve vegetation condition, with previous studies on similar habitats having linked fencing and weed management to enhanced plant growth, native species richness, plant cover, and increased vegetation condition (Main Roads, 2022; Prober et al., 2011). Overall, revegetation and protection efforts are expected to result in a "Moderate to High" score (5) for vegetation condition and structure of marri/eucalyptus woodlands.

FRTBC	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	3	Low to moderate	A survey conducted in 2014 by Coffey (2015) recorded three vegetation units containing trees suitable for FRTBC foraging (mostly *Corymbia calophylla* and *Eucalyptus todtiana*), described as: 1. Revegetated Corymbia sparse mid woodland 2. Corymbia sparse mid woodland 3. Eucalyptus sparse mid Woodland Creek line/floodplain The offset site is dominated by revegetated *Corymbia calophylla* (marri), *Eucalyptus camaldulensis* (river red gum) and *Eucalyptus todtiana* (coastal blackbutt/pricklybark), and open paddocks with remnant *Corymbia calophylla* (marri) and *Eucalyptus rudis* subsp. *rudis* (flooded gum) (Coffey 2015, p8-22). Vegetation condition was scored mostly as degraded to completely degraded and recorded as 'woodland', which under the NVIS Structural Formation Terminology, indicates a 10-30% foliage cover (NVIS Technical Working Group, 2017). Given the degraded nature of the vegetation, and cleared paddock areas, foliage cover suitable for foraging is more accurately estimated to be between 5-20%, suggesting a condition score of 3 for FRTBC.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Proximity of the site in relation to other habitat	3		An ecological survey conducted by AECOM (2020) for Rutland Road recorded both male and female FRTBC foraging within Tuart trees located approximately 2.5km east of the offset site. Suitable foraging resources within a 12km radius of the site indicates a score of 3.
Confirm presence/ absence of species	Yes		Past surveys have not confirmed the presence of FRTBC within the site, however the Rutland Road Survey recorded chewed marri nuts suspected to be FRTBC foraging.
Total score	**Start quality**		**6**
	Without offset		**6**
	With offset		**8** - Revegetation efforts are anticipated to result in a significant increase in vegetation suitable for FRTBC foraging. Based on the environmental report by Coffey (2015) and 2022 aerial imagery, the three vegetation units containing suitable habitat currently make up approximately 50% of the offset site, with the remaining 50% presenting unsuitable habitat being either low open woodland (without suitable black cockatoo trees) or cleared habitat. The intent of revegetation efforts is to protect and enhance the existing habitat and revegetate the cleared areas. The revegetation plan includes completion targets that require a minimum overall foliage cover of 26% post revegetation efforts, through seedling planting and native regeneration (GCA, 2023). This alone will increase the vegetation condition and score to "Moderate" (4) as a minimum. Additionally, fencing and weed management in the area is further anticipated to improve vegetation condition, with previous studies on similar habitats having linked fencing and weed management to enhanced plant growth, native species richness, plant cover, and increased vegetation condition (Main Roads, 2022; Prober et al., 2011). Overall, revegetation and protection efforts are expected to result in a "Moderate to High" score (5) for vegetation condition and structure of marri/eucalyptus woodlands.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Offset 3 (Boallia)

Carnaby's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	6	High	Jarrah (*Eucalyptus marginata*) is structurally dominant across all habitat types, and marri occurs throughout habitat types 1 and 2 which account for approximately 73% of the study area in total (SW Environmental, 2022). The dominant flora family identified for the site was Proteaceae, recording 20 taxa. Five vegetation communities (used to inform fauna habitats) were identified for the site. Each community was recorded as having an 'open forest' tree structure and all but one community was graded as 'excellent' for vegetation condition. Under the NVIS Structural Formation Terminology, 'open forest' indicates a 30-70% foliage cover (NVIS Technical Working Group, 2017). Carnaby's Cockatoo prefer to forage on Proteaceae species but are also known to feed on the seeds of jarrah and marri (DoE, 2023). Based on the excellent quality condition, with some anthropogenic disturbances (cleared gravel pit and two drainage lines), a predicted foliage cover of 40-50% has been determined (SW Environmental, 2022). A total of 71 dead trees were recorded during a potential black cockatoo breeding tree assessment, as well as a few dead Banksias. Tree deaths account for <10% of overall forest cover (Focused Vision, 2023). Overall, the assessment suggests a quality score of 6.
Proximity of the site in relation to other habitat	3		Marri nuts chewed by Carnaby's Cockatoo were recorded within the site (SW Environmental, 2022). Given the foraging evidence and a vegetation condition and structure score of 6, the habitat is deemed suitable for foraging. Aerial imagery reveals east and west of the site is cleared paddocks, however north and south of the site contains open forest that would likely provide similar suitable foraging habitats for all three Black Cockatoo Species (GEHBI Online Data Portal). This suggests the 'site is within 12km of other foraging resources with site condition of at least 3 (score of 3).
Confirm presence/ absence of species	Yes		Extensive evidence of chewed Marri nut residue was observed broadly over the site for Carnaby's Cockatoo (SW Environmental, 2022).
Total score	**Start quality**		**9**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Without offset	**8 -** Focused Vision (2023) identified the main disturbances or impacts to the site as kangaroo grazing, logging, and weeds (Appendix D & Section 6.1). Kangaroo grazing or disturbance was recorded at eight of the nine quadrats (Focused Vision, 2023). This suggests a significant presence of kangaroos in the area that is likely associated with a large local population. Previous studies have found that with high enough population densities, kangaroos can affect the environment in much the same way as domestic livestock, contributing to environmental degradation (Alviano, 2000). Degradation is mostly observed as reduced vegetation cover and diversity (from understory grazing), degraded soil structure, and increased erodibility (Main Roads, 2022). Six introduced (weed) species were recorded at the site, contributing to 3.8% of total species diversity (Focused Vision, 2023). Weeds are known to increase competition for native species and grass weeds have also been linked to changing fire frequency and intensity which have long-term impacts on the structure and composition of native communities (Brown & Brooks, 2002). Based on the known impacts and evidence from existing literature, it has been determined that the site would likely degrade over time by a score of at least one without intervention.
With offset	**9** - To address the impacts described above and prevent a reduction in the quality of the habitat, management actions include the installation of a fence around the site to prevent destructive grazing, unwarranted access to the area (reduces potential spread of dieback and weeds), and littering. Weed management is also proposed for the site. Several studies have demonstrated the ecological benefits of fencing to prevent kangaroo grazing, with natural regeneration and increased plant growth commonly observed as a positive outcome (Nilar, 2019; Brown et al, 2016). Weed management is frequently undertaken and endorsed for conservation significant areas to reduce competition for native seeds and seedlings and increase native cover (Main Roads, 2023). With fencing and weed management, it is anticipated that the percentage of species diversity from weeds will decrease, and native foliage cover will increase for the *Eucalyptus marginata* dominated woodlands and Proteaceae species, maintaining a vegetation condition and structure score of 6 (high) at a minimum.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Baudin's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	6	High	Jarrah (*Eucalyptus marginata*) is structurally dominant across all habitat types, and marri occurs throughout habitat types 1 and 2 which account for approximately 73% of the study area in total (SW Environmental, 2022). The dominant flora family identified for the site was Proteaceae, recording 20 taxa. Five vegetation communities (used to inform fauna habitats) were identified for the site. Six introduced (weed) species were recorded as contributing to 3.8% of the species diversity (Focused Vision, 2023). Each community was recorded as having an 'open forest' tree structure and all but one community was graded as 'excellent' for vegetation condition. Under the NVIS Structural Formation Terminology, 'open forest' indicates a 30-70% foliage cover (NVIS Technical Working Group, 2017). The Marri-Jarrah forest with abundant Proteaceae species provide suitable habitat for Baudin's Cockatoo foraging (DoE, 2023a). Based on the excellent quality condition, with some anthropogenic disturbances (cleared gravel pit and two drainage lines), a predicted foliage cover of 40-50% has been determined (SW Environmental, 2022). A total of 71 dead trees were recorded during a potential black cockatoo breeding tree assessment, as well as a few dead Banksias. Tree deaths account for <10% of overall forest cover (Focused Vision, 2023).
Proximity of the site in relation to other habitat	3		Evidence of Baudin's cockatoo roosting within the offset site was recorded (Focused Vision, 2023, Table 29, p81). *Eucalyptus marginata*, *Corymbia calophylla*, and *Hakea spp*. Was recorded within the offset site as suitable foraging species for Baudin's Cockatoo (Focused Vision, 2023, Table 32, p87). Approximately six Baudin's Cockatoo have been previously observed foraging on Marri trees across the site (SW Environmental, 2022, p26). The surrounding remnant vegetation provides similar habitat for Baudin's Cockatoo.
Confirm presence/ absence of species	Yes		Approximately six Baudin's Cockatoo were observed foraging on marri trees across the site (SW Environmental, 2022, p26).
Total score	**Start quality**		**9**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Without offset	**8 -** Focused Vision (2023) identified the main disturbances or impacts to the site as kangaroo grazing, logging, and weeds (Appendix D & Section 6.1). Kangaroo grazing or disturbance was recorded at eight of the nine quadrats (Focused Vision, 2023). This suggests a significant presence of kangaroos in the area that is likely associated with a large local population. Previous studies have found that with high enough population densities, kangaroos can affect the environment in much the same way as domestic livestock, contributing to environmental degradation (Alviano, 2000). Degradation is mostly observed as reduced vegetation cover and diversity (from understory grazing), degraded soil structure, and increased erodibility (Main Roads, 2022). Six introduced (weed) species were recorded at the site, contributing to 3.8% of total species diversity (Focused Vision, 2023). Weeds are known to increase competition for native species and grass weeds have also been linked to changing fire frequency and intensity which have long-term impacts on the structure and composition of native communities (Brown & Brooks, 2002). Based on the known impacts and evidence from existing literature, it has been determined that the site would likely degrade over time by a score of at least one without intervention.
With offset	**9** - To address the impacts described above and prevent a reduction in the quality of the habitat, management actions include the installation of a fence around the site to prevent destructive grazing, unwarranted access to the area (reduces potential spread of dieback and weeds), and littering. Weed management is also proposed for the site. Several studies have demonstrated the ecological benefits of fencing to prevent kangaroo grazing, with natural regeneration and increased plant growth commonly observed as a positive outcome (Nilar, 2019; Brown et al, 2016). Weed management is frequently undertaken and endorsed for conservation significant areas to reduce competition for native seeds and seedlings and increase native cover (Main Roads, 2023). With fencing and weed management, it is anticipated that the percentage of species diversity from weeds will decrease and native foliage cover will increase for the *Eucalyptus marginata* dominated woodlands and Proteaceae species, maintaining a vegetation condition and structure score of 6 (high) at a minimum.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

FRTBC	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	6	High	Jarrah (*Eucalyptus marginata*) is structurally dominant across all habitat types, and marri occurs throughout habitat types 1 and 2 which account for approximately 73% of the study area in total (SW Environmental, 2022). Five vegetation communities (used to inform fauna habitats) were identified for the site. Six introduced (weed) species were recorded as contributing to 3.8% of the species diversity (Focused Vision, 2023). Each community was recorded as having an 'open forest' tree structure and all but one community was graded as 'excellent' for vegetation condition. Under the NVIS Structural Formation Terminology, 'open forest' indicates a 30-70% foliage cover (NVIS Technical Working Group, 2017). Based on the excellent quality condition, with some anthropogenic disturbances (cleared gravel pit and two drainage lines), a predicted foliage cover of 40-50% for jarrah-marri forest has been determined (SW Environmental, 2022). A total of 71 dead trees were recorded during a potential black cockatoo breeding tree assessment, as well as a few dead Banksias. Tree deaths account for <10% of overall forest cover (Focused Vision, 2023).
Proximity of the site in relation to other habitat	3		Marri nuts chewed by FRTBC were recorded within the site (SW Environmental, 2022). Given the foraging evidence and a vegetation condition and structure score of 6, the habitat is deemed suitable for foraging. Aerial imagery reveals the east and west of the site is cleared paddocks, however north and south of the site contains open forest that would likely provide similar suitable foraging habitat for all three Black Cockatoo Species (GEHBI Online Data Portal). This suggests the 'site is within 12km of other foraging resources with site condition of at least 3' (score of 3).
Confirm presence/ absence of species	Yes		Extensive evidence of chewed Marri nut residue was observed broadly over the site for FRTBC (SW Environmental, 2022).
Total score	**Start quality**		**9**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Without offset	**8 -** Focused Vision (2023) identified the main disturbances or impacts to the site as kangaroo grazing, logging, and weeds (Appendix D & Section 6.1). Kangaroo grazing or disturbance was recorded at eight of the nine quadrats (Focused Vision, 2023). This suggests a significant presence of kangaroos in the area that is likely associated with a large local population. Previous studies have found that with high enough population densities, kangaroos can affect the environment in much the same way as domestic livestock, contributing to environmental degradation (Alviano, 2000). Degradation is mostly observed as reduced vegetation cover and diversity (from understory grazing), degraded soil structure, and increased erodibility (Main Roads, 2022). Six introduced (weed) species were recorded at the site, contributing to 3.8% of total species diversity (Focused Vision, 2023). Weeds are known to increase competition for native species and grass weeds have also been linked to changing fire frequency and intensity which have long-term impacts on the structure and composition of native communities (Brown & Brooks, 2002). Based on the known impacts and evidence from existing literature, it has been determined that the site would likely degrade over time by a score of at least one without intervention.
With offset	**9** - To address the impacts described above and prevent a reduction in the quality of the habitat, management actions include the installation of a fence around the site to prevent destructive grazing, unwarranted access to the area (reduces potential spread of dieback and weeds), and littering. Weed management is also proposed for the site. Several studies have demonstrated the ecological benefits of fencing to prevent kangaroo grazing, with natural regeneration and increased plant growth commonly observed as a positive outcome (Nilar, 2019; Brown et al, 2016). Weed management is frequently undertaken and endorsed for conservation significant areas to reduce competition for native seeds and seedlings and increase native cover (Main Roads, 2023). With fencing and weed management, it is anticipated that the percentage of species diversity from weeds will decrease and native foliage cover will increase for the marri-jarrah woodlands, maintaining a vegetation condition and structure score of 6 (high) at a minimum.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Offset 4 (Crossman)

Carnaby's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	5	Moderate to high	The upper storey vegetation within and surrounding the offset site is dominated by Jarrah (*Eucalyptus marginata*) and Wandoo (*Eucalyptus wandoo*), with limited Marri (*Corymbia calophyla*). Each of these upper storey species are used by Black Cockatoos as food. Powderbark Wandoo (*Eucalyptus accedens*), which is not used by Black Cockatoos as food, was noted as a dominant upper storey species in some releve's outside the offset site. Dominant understorey and midstorey species used by Black Cockatoos as food included Rock Sheoak (*Allocasuarina hugeliana*), *Xanthorrhoea preissii, Hakea lissocarpha*, *Banksia sessilis*, *B. dallanneyi*, and *B. fraseri* (AECOM, 2023). Overall foliage cover was estimated by averaging the total cover of suitable foraging trees across the 12 releves for the site (AECOM, 2023). The average was 42.23% foliage cover, which following the HQS Tool is slightly above a moderate-high score but is on the low end of scoring high. Given the area contains a significant portion of Powderbark Wandoo not utilised by Black Cockatoos and the presence of threats such as foxes, feral pigs, littering, and past logging, the score has been adjusted to moderate-high which places suitable foliage cover between 30-40%.
Proximity of the site in relation to other habitat	3		Carnaby's Cockatoo are known to breed in the nearby (within 13 km) Bannister and Boddington areas. DBCA's Carnaby's Cockatoo Breeding Areas dataset (BDCA-054) confirmed there is a breeding site within 6km of the site. Foraging evidence was noted for Carnaby's Cockatoo at six of locations during the Crossman survey (AECOM, 2023). There is suitable foraging resources within the offset site and therefore suitable foraging habitat in the remnant bush immediately adjacent to the offset boundary.
Confirm presence/ absence of species	Yes		Multiple records of feeding residue confirm presence of Carnaby's Cockatoo.
Total score	**Start quality**		**8**
	Without offset		**8**
With offset			**9 -** The field survey identified threats to Black Cockatoos and impacts to their habitat, in the form of: - Feral animals including pigs and foxes - Signs of rubbish, littering, and past logging activities - Weeds, although they pose a minimal threat generally comprising less than 1% of the foliage cover for recorded releves. To address these threats/impacts, recommended management actions include pest control (trapping or baiting) for foxes, fencing to mitigate pig grazing and unwarranted access to the site, and weed control.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

	Management of the site will include weed management and the installation of a fence around the site to prevent destructive herbivore grazing, unwarranted access to the area (reduces potential spread of dieback and weeds), and littering. Several studies have been conducted that demonstrate the ecological benefits of fencing to prevent destructive grazing, with natural regeneration, increased plant growth, and enhanced native species richness and cover commonly observed as positive outcomes (Main Roads, 2022; Nilar, 2019; Prober et al., 2011). Weed management is frequently undertaken and endorsed for conservation significant areas to reduce competition for native seeds and seedlings and increase native cover (Main Roads, 2023). Fencing and weed management are anticipated to improve native regeneration, leading to a greater overall cover of native species utilised as food by Carnaby's Cockatoo. Based on existing research and proposed management actions, the vegetation condition and structure is envisaged to shift from "Moderate to high" to "High" (6).

Baudin's Cockatoo	**Score**	**Value**	**Reasoning**
Vegetation condition and structure. Habitat features.	4	Moderate	The upper storey vegetation within and surrounding the offset site is dominated by Jarrah (*Eucalyptus marginata*) and Wandoo (*Eucalyptus wandoo*), with limited Marri (*Corymbia calophyla*). Each of these upper storey species are used by Black Cockatoos as food. Powderbark Wandoo (*Eucalyptus accedens*), which is not used by Black Cockatoos as food, was noted as a dominant upper storey species in some releves outside the offset site. Dominant understorey and midstorey species used by Black Cockatoos as food included Rock Sheoak (*Allocasuarina hugeliana), Xanthorrhoea preissii, Hakea lissocarpha, Banksia sessilis*, *B. dallanneyi*, and *B. fraseri* (AECOM, 2023). Overall foliage cover was estimated by averaging the total cover of suitable foraging trees across the 12 releves for the site (AECOM, 2023). The average was 28.17% foliage cover, which scores within moderate. Accounting for the significant portion of Powderbark Wandoo not utilised by Baudin's Black Cockatoo and the presence of threats such as foxes, feral pigs, littering, and past logging, the score remains within a 20-30% foliage cover range (moderate).
Proximity of the site in relation to other habitat	3		Foraging evidence was noted for Baudin's Cockatoo at 21 locations during the Crossman survey (AECOM, 2023). An additional five records of Baudin's Cockatoo sighted or heard within the area further confirmed their presence. There is suitable foraging resources within the offset site and therefore suitable foraging habitat in the remnant bush immediately adjacent to the offset boundary. The offset site is well outside the breeding range of Baudin's Cockatoo and the nearest known breeding site is 40 km to the west. No evidence of Baudin's Cockatoo breeding areas within a 15km radius was found.
Confirm presence/ absence of species	Yes		Multiple records of feeding residue confirm presence of Baudin's Cockatoo.
Total score	**Start quality**		**7**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

	Without offset	**7**
	With offset	**8 -** The field survey identified threats to Black Cockatoos and impacts to their habitat, in the form of: - Feral animals including pigs and foxes - Signs of rubbish, littering, and past logging activities - Weeds, although they pose a minimal threat generally comprising less than 1% of the foliage cover for recorded releves. To address these threats/impacts, recommended management actions include pest control (trapping or baiting) for foxes, fencing to mitigate pig grazing and unwarranted access to the site, and weed control. Management of the site will include weed management and the installation of a fence around the site to prevent destructive herbivore grazing, unwarranted access to the area (reduces potential spread of dieback and weeds), and littering. Several studies have been conducted that demonstrate the ecological benefits of fencing to prevent destructive grazing, with natural regeneration, increased plant growth, and enhanced native species richness and cover commonly observed as positive outcomes (Main Roads, 2022; Nilar, 2019; Prober et al., 2011). Weed management is frequently undertaken and endorsed for conservation significant areas to reduce competition for native seeds and seedlings and increase native cover (Main Roads, 2023). Fencing and weed management are anticipated to improve native regeneration, leading to a greater overall cover of native species utilised as food by Baudin's Cockatoo. Based on existing research and proposed management actions, the vegetation condition and structure is envisaged to shift from " Moderate" to "High" (5).

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

FRTBC	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	4	Moderate	Jarrah, Wandoo, and Marri are all considered primary food sources for FRTBC and combined dominate the upper storey of the site. FRTBC are also known to occasionally feed on the *Allocasuarina* species, bringing the total suitable foraging tree foliage cover to 29.68%. Considering the presence of threats such as foxes, feral pigs, littering, and past logging, the score has been determined to be moderate, falling within the 20-30% foliage cover range.
Proximity of the site in relation to other habitat	3		Foraging evidence was noted for FRTBC at 10 locations during the Crossman survey (AECOM, 2023). There are suitable foraging resources within the offset site and therefore suitable foraging habitat in the remnant bush immediately adjacent to the offset boundary. No evidence of FRTBC breeding areas within a 15km radius was found.
Confirm presence/ absence of species	Yes		Multiple records of feeding residue confirm presence of FRTBC Cockatoo.
Total score	**Start quality**		**7**
	Without offset		**7**
	With offset		8 - The field survey identified threats to Black Cockatoos and impacts to their habitat, in the form of: - Feral animals including pigs and foxes - Signs of rubbish, littering, and past logging activities - Weeds, although they pose a minimal threat generally comprising less than 1% of the foliage cover for recorded releves. To address these threats/impacts, recommended management actions include pest control (trapping or baiting) for foxes, fencing to mitigate pig grazing and unwarranted access to the site, and weed control. Management of the site will include weed management and the installation of a fence around the site to prevent destructive herbivore grazing, unwarranted access to the area (reduces potential spread of dieback and weeds), and littering. Several studies have been conducted that demonstrate the ecological benefits of fencing to prevent destructive grazing, with natural regeneration, increased plant growth, and enhanced native species richness and cover commonly observed as positive outcomes (Main Roads, 2022; Nilar, 2019; Prober et al., 2011). Weed management is frequently undertaken and endorsed for conservation significant areas to reduce competition for native seeds and seedlings and increase native cover (Main Roads, 2023). Fencing and weed management are anticipated to improve native regeneration, leading to a greater overall cover of native species utilised as food by FRTBC. Based on existing research and proposed management actions, the vegetation condition and structure is envisaged to shift from " Moderate" to "High" (5).

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Offset 5 (Hoffman)

Carnaby's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	6	High	The offset site is dominated by small Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia calophylla*) with some large Marri and Blackbutt (*E. patens*). Only a handful of mature trees that had survived fire were noted. The area has dense undergrowth, possibly from the recent fire as recorded during the survey (AECOM, 2023). Carnaby's Cockatoo feed on Jarrah and Marri seeds but favour proteaceous species which were not present at the time of the survey (possibly due to past fires). Overall foliage cover was estimated by averaging the total cover of suitable foraging trees across 11 releves for the site (AECOM, 2023). The average was 52.11% foliage cover, which following the HQS Tool, represents high value habitat. However, given a lack of proteaceous species for Carnaby's Cockatoo, presence of threats such as dieback and feral animals, evidence of unwarranted recreational use of the area (recently used dirt tracks), and fire damage, the condition and habitat features have been scored as high (>40% foliage cover) to more accurately reflect some of the limitations of the site as an offset.
Proximity of the site in relation to other habitat	0		No foraging evidence of Carnaby's Cockatoo was confirmed within the offset site (AECOM 2023). However, feeding residue from *Pinus radiata* was located at a nearby pine plantation. Pine plantations would not score a minimum of 3 for site condition and therefore does not count as a suitable foraging resource. Given the dominance of small Jarrah and Marri with few larger trees present, the area is not considered suitable breeding habitat. No confirmed Carnaby's Cockatoo Breeding sites have been noted within a 20km radius, based on publicly available information (DBCA-054).
Confirm presence/ absence of species	No		No evidence of Carnaby's Cockatoo was confirmed within the offset site.
Total score	**Start quality**		**6**
	Without offset		**6**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

With offset	7 - The field survey identified threats to Black Cockatoos and impacts to their habitat, in the form of: - Feral animals including cats, kangaroos, goats, pigs, and foxes and dogs. Notably, the remains of a Baudin's Cockatoo was identified on site which may have been attacked by a feral cat or other predator - Direct evidence of the site being used recreationally for the purpose of riding motorbikes - Overhead powerlines which reduce opportunities for natural regrowth by maintaining access tracks and trimming trees that grow too close to powerlines - Recent evidence of fire damage. As the understorey improves over time, more proteaceous species suitable for both Carnaby's and Baudin's Cockatoos are expected to occur. - Weeds, although they pose a minimal threat generally comprising less than 1% of the foliage cover for recorded releves. To address these threats/impacts, recommended management actions include pest control (trapping or baiting) for cats and foxes, fencing to mitigate kangaroo and pig grazing and unwarranted access to the site, and weed control. Pest control including trapping and/or baiting will assist in removing the direct threat of feral foxes and cats making the habitat more suitable for Black Cockatoos by reducing mortality rates. Removing weeds and installing a fence to prevent kangaroos and pigs from grazing will allow the new native regrowth post-fire (particularly preferred proteaceous species) the best chance of survival (Brown et al., 2016). Research conducted on similar habitats has linked fencing and weed management to enhanced plant growth, native species richness, plant cover, and increased vegetation condition (Main Roads, 2022; Prober et al., 2011). The installation of a fence will also deter recreational motorbike riding in the area which would reduce the likelihood of introducing and/or spreading dieback and allow opportunity for regrowth along motorbike tracks. These enhancements will further improve the vegetation condition and structure, and therefore the suitability of the site for Carnaby's Cockatoo foraging. Based on existing research and proposed management actions, the vegetation condition and structure is envisaged to shift from "High " to " Very High" (7).

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

Baudin's Cockatoo	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	5	Moderate to High	The offset site is dominated by small Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia calophylla*) with some large Marri and Blackbutt (*E. patens*). Only a handful of mature trees that had survived fire were noted. The area has dense undergrowth, possibly from the recent fire as recorded during the survey (AECOM, 2023). Baudin's Cockatoo feeds on Jarrah and Marri seeds and also primarily feeds on proteaceous species which were limited at the time of the survey (possibly due to past fires). Overall foliage cover was estimated by averaging the total cover of suitable foraging trees across 11 releves for the site (AECOM, 2023). The average was 40.02% foliage cover, which following the HQS Tool, is on the low end of being scored as high value habitat. However, given a lack of preferred proteaceous species for Baudin's Cockatoo, presence of threats such as dieback and feral animals, evidence of unwarranted recreational use of the area (recently used dirt tracks), and fire damage, the condition and habitat features have been scored as moderate to high (30-40% foliage cover) to more accurately reflect some of the limitations of the site as an offset.
Proximity of the site in relation to other habitat	3		Evidence of foraging for Baudin's Cockatoo was noted at 27 locations, of which four are unconfirmed. A significant portion of the feeding residue was recent (green), suggesting the presence of Baudin's Cockatoo. The offset site is surrounded by similar remnant bush with a condition score likely greater than 3. The area provides suitable foraging resources for Baudin's Cockatoo. No evidence of Baudin's Cockatoo breeding areas within a 15km radius was found.
Confirm presence/ absence of species	Yes		Evidence of Baudin's Cockatoo feeding on seeds confirms presence.
Total score	**Start quality**		**8**
	Without offset		**8**

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

With offset	**9 -** The field survey identified threats to Black Cockatoos and impacts to their habitat, in the form of: - Feral animals including cats, kangaroos, goats, pigs, foxes, and dogs. Notably, the remains of a Baudin's Cockatoo was identified on site which may have been attacked by a feral cat or other predator - Direct evidence of the site being used recreationally for the purpose of riding motorbikes - Overhead powerlines which reduce opportunities for natural regrowth by maintaining access tracks and trimming trees that grow too close to powerlines - Recent evidence of fire damage. As the understorey improves over time, more proteaceous species suitable for both Carnaby's and Baudin's Cockatoos are expected to occur. - Weeds, although they pose a minimal threat generally comprising less than 1% of the foliage cover for recorded releves. To address these threats/impacts, recommended management actions include pest control (trapping or baiting) for cats and foxes, fencing to mitigate kangaroo and pig grazing and unwarranted access to the site, and weed control. Pest control including trapping and/or baiting will assist in removing the direct threat of feral foxes and cats making the habitat more suitable for Black Cockatoos by reducing mortality rates. Removing weeds and installing a fence to prevent kangaroos and pigs from grazing will allow the new native regrowth post-fire (particularly preferred proteaceous species) the best chance of survival (Brown et al., 2016). Research conducted on similar habitats has linked fencing and weed management to enhanced plant growth, native species richness, plant cover, and increased vegetation condition (Main Roads, 2022; Prober et al., 2011). The installation of a fence will also deter recreational motorbike riding in the area which would reduce the likelihood of introducing and/or spreading dieback and allow opportunity for regrowth along motorbike tracks. These enhancements will further improve the vegetation condition and structure, and therefore the suitability of the site for Carnaby's Cockatoo foraging. Based on existing research and proposed management ations, the vegetation condition and structure is envisaged to shift from "Moderate to High" to "High" (6).

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

FRTBC	Score	Value	Reasoning
Vegetation condition and structure. Habitat features.	6	High	The offset site is dominated by small Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia calophylla*) with some large Marri and Blackbutt (*E. patens*). Only a handful of mature trees that had survived fire were noted. The area has dense undergrowth, possibly from the recent fire as recorded during the survey (AECOM, 2023). FRTBC feeds mainly on the seeds of Jarrah and Marri, and unlike White Tailed Black Cockatoos, does not feed on nectar and grubs or forage on proteaceous species. Overall foliage cover was estimated by averaging the total cover of suitable foraging trees across 11 releves for the site (AECOM, 2023). The average was 47.28% foliage cover, which following the HQS Tool, represents high value habitat. Similarly, to Baudin's and Carnaby's Cockatoo, FRTBC habitat in the area is threatened by dieback and feral animals, evidence of unwarranted recreational use of the area (recently used dirt tracks), and fire damage. However, unlike White Tailed Black Cockatoos, the lack of proteaceous species and dominance of Jarrah, Marri, and Blackbutt provides excellent foraging for the FRTBC. As such, a 'high' score (>40% foliage cover) has been retained despite the limitations of the threats imposed on the site.
Proximity of the site in relation to other habitat	3		Evidence of FRTBC foraging was noted at 45 locations, with feeding residues mostly found to be fresh and recent. FRTBC was sighted feeding on seeds from Marri during the survey. The offset site is surrounded by similar remnant bush with a condition score likely greater than 3. The area provides suitable foraging resources for FRTBC. No evidence of FRTBC breeding areas within a 15km radius was found.
Confirm presence/ absence of species	Yes		Sightings and evidence of FRTBC feeding on seeds confirms presence.
Total score	**Start quality**		**9**
	Without offset		**9**
	With offset		**10 -** The field survey identified threats to Black Cockatoos and impacts to their habitat, in the form of: - Feral animals including cats, kangaroos, goats, pigs, and foxes and dogs. Notably, the remains of a Baudin's Cockatoo were identified on site which may have been attacked by a feral cat or other predator - Direct evidence of the site being used recreationally for the purpose of riding motorbikes - Overhead powerlines which reduce opportunities for natural regrowth by maintaining access tracks and trimming trees that grow too close to powerlines - Recent evidence of fire damage. As the understorey improves over time, more proteaceous species suitable for both Carnaby's and Baudin's Cockatoos are expected to occur. - Weeds, although they pose a minimal threat generally comprising less than 1% of the foliage cover for recorded releves.

Appendix 1b: Habitat Quality Score for Black Cockatoo Foraging Habitat

	To address these threats/impacts, recommended management actions include pest control (trapping or baiting) for cats and foxes, fencing to mitigate kangaroo and pig grazing and unwarranted access to the site, and weed control. Pest control including trapping and/or baiting will assist in removing the direct threat of feral foxes and cats making the habitat more suitable for Black Cockatoos by reducing mortality rates. Removing weeds and installing a fence to prevent kangaroos and pigs from grazing will allow the new native regrowth post-fire (particularly preferred proteaceous species) the best chance of survival (Brown et al., 2016). Research conducted on similar habitats has linked fencing and weed management to enhanced plant growth, native species richness, plant cover, and increased vegetation condition (Main Roads, 2022; Prober et al., 2011). The installation of a fence will also deter recreational motorbike riding in the area which would reduce the likelihood of introducing and/or spreading dieback and allow opportunity for regrowth along motorbike tracks. These enhancements will further improve the vegetation condition and structure, and therefore the suitability of the site for Carnaby's Cockatoo foraging. Based on existing research and proposed management actions, the vegetation condition and structure is envisaged to shift from "High" to "Very High" (7).

Appendix 2–Supporting Evidence for HQS: A Literature Review

Appendix 2: Supporting Evidence for HQS: A Literature Review

Purpose

This document has been produced for the Great Eastern Highway Bypass Interchanges Project (GEHBI), as an appendix for the Offset Strategy. The purpose of this document is to provide supporting evidence for an increase in Habitat Quality Score (HQS) of at least one for Banksia Woodlands of the Swan Coastal Plain TEC and Black Cockatoo Foraging Habitat, under the EPBC Guidelines. An increase in habitat quality of one is attributed mainly to the benefits contributed by fencing, which improves native vegetation foliage cover and species richness, as supported by various literature outlined below. Weed management has also been proposed as a secondary measure to improve native vegetation condition and contribute towards an increase of one for habitat quality. An assessment of the literature provided below aims to provide sufficient evidence to demonstrate that the proposed fencing and weed control management actions for offset sites will improve habitat quality by a score of one.

Introduction

Weeds are known to outcompete native plants for water, nutrients, and space, and change the composition of vegetation communities, all of which affects the value of native vegetation and its value as habitat for native fauna such as threatened Black Cockatoos. Weed invasion is also known to prevent recruitment of native vegetation and cause displacement of native species, therefore reducing native species richness, diversity, and abundance (Linda, 2021; Wotton and McAlpine, 2012). Multiple studies conducted on the impacts of weeds in Australia have demonstrated that species richness, percentage canopy cover, and frequency of native species recruitment decline substantially with increased weed coverage (R.J. Adair & R.H. Groves 1998). Dieback causes irreversible damage to the environment by infecting the native vegetation. According to DBCA, dieback impacts the environment by reducing biomass, biodiversity, and food for native animals. Over 40% of the native plant species such as *Proteaceae* (banksia's and hakeas), *Ericaceae* (snotty gobble), *Myrtaceae* (eucalypts) and *Xanthorrhoeaceae* (grass-trees) families are susceptible to the disease (Shearer et al, 2004).

According to DPAW (2023), threatened Black Cockatoo habitat is under major threat due to hollow shortages and a lack of regeneration of potential nest trees caused by grazing, weed invasion, and Phytophthora dieback, among others. For this Project, the Biological Survey

Appendix 2: Supporting Evidence for HQS: A Literature Review

Report highlighted the key threats to native vegetation at the offset sites to be grazing by herbivores, weed invasion, and dieback (Biota, 2021).

Literature Review & Assessment of Findings

Prowse (2019) found that grazing pressure from herbivores (native and non-native) can significantly affect native species and ecological communities by herbivores competing for resources, leading to a degraded understory that can potentially alter species richness and diversity (Read et al. 2021b). Fencing of remnant vegetation to control grazing has been suggested as one of the approaches to manage weeds by the Environmental Weed Strategy of Western Australia (1999).

One study on fencing found fencing resulted in negative impacts including limiting seed dispersal, change in vegetation structure and composition, reduced plant density and degradation of soil nutrient in long-term (Lorite et al. 2021; Liu et al. 2019). Conversely, Nilar et al. (2019) who evaluated the effects of herbivore exclusion plots on the richness and composition of naturally regenerating native vegetation showed that groundcover vegetation was more than two-times higher (by percentage cover) in exclusion than unfenced plots, and shrub-layer vegetation cover was about 20 percent higher in exclusion plots compared with unfenced plots. Further, total native plant species richness was significantly higher in exclusion plots, with these plots containing 25 percent more native plant species on average than unfenced plots. Native vegetation community composition also differed significantly between exclusion and unfenced plots, with species tending to be more abundant within exclusion plots than in unfenced plots. In addition to the above, percentage cover of bare soil was five times lower in fenced plots compared to that of unfenced plots, and exclusion plots also had significantly higher percentage cover of leaf litter (but not litter depth) than unfenced plots.

Research carried out by Murdoch University in 2011 to study vegetation and topsoil condition in grazed and fenced woodland and its role in recovery of the grazed land, found that native cover including that of trees, understory, shrubs, and ground layer were greater in the exclusion area than the unfenced area. Similarly, native species richness was also recorded to be lesser in the unfenced area compared to the fenced area (Prober et al. 2011). Further, a monitoring program carried out by Department of Environment, Land, Water and Planning of Victorian State Government, to evaluate effectiveness of fencing in maintaining or improving

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native vegetation condition, found out that fencing “maintained or improved native vegetation condition” in most of the instances (DELWP 2020).

It is widely believed that weed management helps eliminate the detrimental effects of weed on native vegetation. The effect of weed management on native biodiversity was assessed by Wonton and McAlpine (2012) through a literature review of 48 studies in Australia (5 in Western Australia), New Zealand and other countries. Some of these studies used multi-site comparison approach and some used the weed removal experiment. All studies using multi-site comparison found that all aspects of native vegetation such as species richness, percentage cover, and diversity were greater at sites with weeds managed than areas where weeds were not managed and were more abundant. Assessments of weed removal approaches widely carried out in New Zealand have demonstrated signs of recovering native vegetation in one year of weed management. Unlike the multi-site comparison approach, studies using weed removal experiment demonstrated both positive and negative conservation outcomes, with some sites suggesting a decrease in species richness from weed treatment.

Dieback is a major threat to biodiversity in Western Australia, as it causes vegetative health to decline particularly in susceptible vegetation such as banksia and jarrah. The declining health of vegetation contributes to a loss of breeding and foraging habitat for Black Cockatoos (EPA Advice 2019). Studies have demonstrated that *Phytophthora* dieback causes alteration to vegetative structure which will likely affect the suitability of fauna habitat by altering foliage cover, nesting sites, and food resources (Garkalis et al. 2004). Apart from native and feral animals, dieback can be introduced to sites through human access, which often spreads the disease faster than any other means of introduction. Allowing a site to be accessible by vehicles and equipment also poses a high risk of introducing dieback disease. DBCA’s (2020) Phytophthora Dieback Management Manual suggests fencing as one option to reduce the risk of dieback, by restricting access to dieback spreading agents.

Neaves Road Case Study

Unlike other offsets which involve land acquisition and protection through tenure, the offset site at Neaves road (offset 4) involves rehabilitation of the existing degraded foraging habitat. It is anticipated that rehabilitation will improve the foraging habitat for Carnaby’s and Forest Red-tailed Black Cockatoos, as is supported by literature explained subsequently.

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According to Lee et al. (2010, 2013), Carnaby's Black Cockatoos were observed feeding on seeds and flowers of young proteaceous shrubs in revegetated areas of the Newmont Boddington Gold Mine located 120 km southeast of Perth within eight years of commencing revegetation efforts. Evidence of foraging post-revegetation efforts suggests that revegetation when implemented correctly can provide a suitable food source for Black Cockatoos (Marieke 2008). Plant species that occur in the forest surrounding the mine area include Sheoak (*Allocasuarina fraseriana*), proteaceous shrubs such as *Banksia* and *Hakea* spp., and canopy-forming species including Jarrah, Marri, and Wandoo (*E. wandoo*). Given the similarity of vegetation and presence of preferred feeding species at the Neaves Road offset site, the above study supports that revegetation at the offset site will improve foraging habitat for Black Cockatoos likely within a short time frame (8 years) from commencing revegetation.

Apart from the above literature the following information also supports the success of revegetation:

- The Carnaby's Black Cockatoo Recovery Plan (DPaW 2013) encourages revegetation with species supporting the Black Cockatoo as it is considered effective.
- The Black Cockatoo Action Plan implemented by Curtin University in 2016 for improvement of Black Cockatoo habitat, aimed to increase the existing habitats that are available on campus through plantation and retention of habitat. The Recovery Plan involved plantation across 116 ha of various mature trees, including Tuart (*Eucalyptus gomphocephala*), Marri (*Corymbia calophylla*), Banksia (*Banksia grandis* and *Banksia menziesii*), Willow myrtle (*Agonis Flexuosa*) and Red-flowering gum (*Corymbia ficifolia*) which are preferred food sources of the Black Cockatoos. As a result, it achieved an increase of 499 Black Cockatoo numbers as recorded by Birdlife Western Australia's 2019 Great.

Summary of Findings & Conclusion

The literature reviewed indicates that fencing and weed management can provide ecological benefits that improve vegetation condition over time, particularly from reduced herbivore grazing, reduced weed coverage, and reduced risk of dieback. Studies specific to weed management demonstrated benefits mostly from reduced competition, leading to increased foliage cover and thus improved habitat for Black Cockatoos. While a select few studies identified negative impacts associated with limiting seed dispersal from fencing and reduced species diversity from weed treatment, a vast majority of the studies highlighted the positive

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effects of fencing and weed management on vegetation condition and biodiversity. Overall, these findings suggest that the fencing and weed control management actions proposed for the offset sites will likely improve habitat quality by a score of at least one.

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Appendix 2: Supporting Evidence for HQS: A Literature Review

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Literature Review

Effects of herbivore (kangaroo) grazing on terrestrial biodiversity

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Contents

1 INTRODUCTION

This literature review, prepared by Main Roads, considers the key ecological effects of grazing by kangaroos (and at times also includes grazing by introduced herbivores such as rabbits) on terrestrial biodiversity, in particular ecological communities and fauna habitat, and the conservation benefits of kangaroo exclusion fencing to these communities.

The purpose of this review is to provide documented, qualitative evidence of the benefits of exclusion fencing to demonstrate the value and critical importance of this management measure for conservation outcomes at Main Roads land acquisition (and revegetation/created habitat) offset sites.

2 BACKGROUND AND CONTEXT

As part of offsetting significant residual impacts of projects on key environmental factors as identified by the Environmental Protection Authority (EPA) and Matters of National Environmental Significance (MNES) identified under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), it has been standard practice to date for Main Roads to purchase and manage extant areas of threatened ecological communities (TECs) and threatened fauna habitat. Management actions, usually implemented under guidance of a management plan, are undertaken to manage threatening processes and aim to maintain and/or enhance the vegetation condition/habitat quality.

Overgrazing by herbivores is often identified as a primary threatening process at these sites. Grazing pressure from rabbits is a well known threat in relation to conservation within Australia, with the benefit of species control on vegetation and habitat conservation being equally well understood (Lowe, Wheeler & Twigg, 2003; Lange & Graham, 1983; Leigh, 1989; Travers, 2019; Lambert, 2015).

Another threatening process common to conservation areas within Australia but that has not been well documented is the impact of grazing by kangaroos. Recent studies have demonstrated that kangaroos can have a significant impact on conversation areas, especially through overgrazing. Prevention of grazing damage from overabundant kangaroos was recently listed by the Australian government as a priority management action in relation to biodiversity and ecological community conservation (Commonwealth of Australia, 2016).

Total grazing pressure from both native and non-native herbivores can have a significant effect on native species and ecological communities (Prowse, 2019). In the absence of an efficient top-down control mechanism, periods of high rainfall and resource availability can result in rapid increases in herbivore populations. Since 2010, when the Millennium drought broke, densities of native macropod species have increased south of the dingo fence across Australia (Prowse, 2019). Effectively unlimited year-round access to water and abundant grazing opportunities have led to unrestricted population growth in native macropod species (Alviano, 2000), including the Western Grey Kangaroo.

Overgrazing by native herbivores impacts the ecological functions in native plant communities, including on the provision of habitat for fauna, ecological flows of water and nutrients, and disturbance regimes. Changes in primary production, fire regimes, nutrient cycling, vegetation structure and fauna distributions have all been reported where native herbivores are overabundant (Morgan, 2021).

Despite being native, overabundant kangaroos directly threaten the survival of biodiversity on both private and public lands. They degrade understory, impact threatened plants and compete with other native species for resources and habitat (Read *et al.* 2021b). Kangaroos are known to preferentially graze grasses and grass-like plants (Wann & Bell, 1997) but will also graze on other species and plant forms when resources are scarce. The selection of particular species for consumption by kangaroos leads to changes in species diversity and composition. Under overgrazing conditions, this can result in less palatable and introduced species becoming dominant and in favoured species, which are heavily grazed, not maturing to seed production stage (Alviano, 2000). Further, kangaroos tend to overgraze in much the same way as rabbits and sheep, in that they will feed until almost no forage remains (Alviano, 2000).

This literature review draws on over a dozen references to show the impacts of overgrazing by kangaroos on native vegetation and habitat, and the benefit of restricting kangaroo grazing pressure, typically demonstrated through exclusion fencing, on extant and planted (revegetated) vegetation. Seven studies involved the use of kangaroo grazing exclusion plots or exclusion fencing, two of which specifically investigated impacts of grazing on post-fire vegetation recovery. One study is from WA (Brown, 2016), two from South Australia (Finlayson, 2021; Freeman, 2021), two from New South Wales (Chard, 2022; Nilar, 2019), and two from Victoria (Alviano, 2000; Meers & Adams, 2003). The vegetation type studied also varied, from coastal eucalypt forest to eucalypt woodland to rainforest.

3 EXCLUSION PLOT AND FENCING STUDIES

3.1 Exclusion plot and fencing study methodologies overview

The seven studies that implemented exclusion plots or exclusion fencing aimed to determine and quantify impacts of kangaroo grazing on various factors including vegetation cover and diversity, soil structure and erodibility, and nutrient mobilisation. Fences installed around these plots or study areas were designed to exclude kangaroos. Study duration, i.e. the length of time fences were in place, varied between studies. Once data was collected and collated, comparative analysis of that from fenced and unfenced or control plots was undertaken.

3.2 Exclusion plot and fencing study outcomes

All studies showed that kangaroo overgrazing resulted in deleterious effects on the conservation areas being assessed, as outlined below.

3.2.1 Vegetation impacts

In their South Australian study, Finlayson *et al.* (2021) demonstrated that an increase in plant cover and a reduction in bare ground was associated with the exclusion of kangaroos, with impacts notable on ground cover and perennial grasses in particular. Perennial grasses were essentially absent outside of exclusion areas. Finlayson *et al.* (2021) note that their findings mirror those of studies of long-term exclosures in adjacent western NSW where vegetation density, grass and forb cover are all greater in plots where herbivores are excluded.

Alviano (2000) conducted a detailed study on the impact of kangaroo herbivory on vegetation in the Yan Yean Reservoir catchment and nearby Plenty Gorge Parklands in Victoria. Like Finlayson *et al.* (2021), Alviano (2000) observed the direct impact of kangaroo grazing was a statistically significant decrease in above ground plant biomass levels. In his study, biomass levels on the ungrazed runoff plots were over six times greater than on the grazed plots. Species richness on the

grazed and ungrazed plots was identical, however composition varied. Grazing encouraged the growth of two native grasses, *Danthonia* spp. and *Euchiton gymnochephalus*, and one exotic, *Hypochaeris radicata*, whereas one native grass *Themeda triandra*, and one exotic, *Plantago lanceolata*, were statistically significantly more abundant in the ungrazed plots. The primary difference was that the ungrazed plots contained a greater level of above-ground biomass, with *Schoenus apogon* filling in the spaces between tussocks of native grasses. This was not the case on the grazed plots, which had a higher proportion of bare ground (Alviano, 2000).

Native herbivore impacts on vegetation can intensify after fire (Morgan, 2021). Brown *et al.* (2016) investigated changes in species richness and cover in native and introduced flora following an autumn prescribed fire in a 700 ha reserve south of Perth, Western Australia, containing Banksia-Tuart woodland that had not been burnt for more than 30 years. Their results showed that exclusion fencing resulted in a significant increase in native species cover, including shrubs, geophytes and some native grasses. The shrubs most severely impacted by grazing were postfire re-seeders, *Gompholobium tomentosum* and *Hardenbergia comptoniana*, both almost totally absent outside the exclosures. Postfire grazing also reduced cover of geophytes, particularly *Dichopogon capillipes*.

Chard *et al.* (2022) investigated the effects of post-fire herbivory on understory plant communities in a coastal eucalypt forest in southeastern Australia. They quantified herbivore activity, understory plant diversity, and dominant plant morphology following a wildfire in 2017. Like Finalyson *et al.* (2021) and Alviano, (2000) Chard *et al.* (2022) showed that post-fire herbivory by macropods reduced plant species richness, diversity, and evenness, and promoted the dominance of the most abundant plants within the understory. The outcome was a depauperate vegetation community.

Nilar *et al.* (2019) evaluated the effects of herbivore (deer and macropod) exclusion plots on the richness and composition of naturally regenerating native vegetation as well as the growth of revegetated seedlings on the slopes of the Illawarra Escarpment near Balgownie, NSW. Their results showed that groundcover vegetation was more than two-times higher (by percentage cover) in exclusion than unfenced plots, and shrub-layer vegetation cover was about 20 per cent higher in exclusion plots compared with unfenced plots. Further, total native plant species richness was significantly higher in exclusion plots, with these plots containing 25 per cent more native plant species on average than unfenced plots. Native vegetation community composition also differed significantly between exclusion and unfenced plots, with species tending to be more abundant within exclusion plots than in unfenced plots. In addition to the above, percentage cover of bare soil was five times lower in fenced plots compared to that of unfenced plots, and exclusion plots also had significantly higher percentage cover of leaf litter (but not litter depth) than unfenced plots.

Prowse *et al*. (2019) evaluated the evidence for grazing-pressure trends over twelve years between 2004 and 2016 in native vegetation in both protected and unprotected areas across an agricultural landscape covering circa 180 000 km^2 of South Australia. This unique dataset enabled assessment of grazing impacts over time at a large, regional scale. Their results demonstrate that grazing pressure is having a severe, sustained and increasing impact on native vegetation in temperate South Australian landscapes. Model estimates of the proportion of grazed plants within native vegetation that were heavily or severely grazed ranged from 45 per cent to 54 per cent across all five sampled regions[1] in 2016. Prowse *et al*. (2019) suggest that native macropods have contributed

[1] Eyre Penisula, Northern, York & Vincent and South-Australian Murray Darling Basin and Adelaide & Mt Lofty Ranges regions of South Australia.

to this increase in grazing pressure, noting that results of annual aerial surveys indicate that estimated macropod densities increased substantially over the same timeframe. The authors propose that such high-intensity grazing has the potential to undermine the structure and composition of native vegetation in areas otherwise protected for conservation purposes, and warn that the trajectory of decline may be worsened by increasing vulnerability of plant assemblages under climate change.

Freeman (2021) studied the relative impacts of kangaroos (Macropus and Osphranter spp.) and introduced mammalian herbivores on the success of two South Australian landscape-scale vegetation restoration projects ('WildEyre' and Sheoak Grassy Woodlands) using herbivore exclusion plots. They found that in the Sheoak Grassy Woodlands plots established in Venus Bay Conservation Park, total plant cover was higher inside the herbivore exclosures compared to the grazed controls. At the time of trial plot establishment (2003), the differences in plant cover were small, mostly <3%. From 2007 onwards, plant cover was substantially higher where kangaroo grazing was excluded, and by 2019 the difference in plant cover between grazed and ungrazed plots was around 20%. Freeman *et al* (2021) demonstrated that kangaroos were most abundant herbivore and the cause of recruitment failure at the Sheoak Grassy Woodland sites, results which supported those of previous studies. Freeman *et al.* (2021) found that an overabundance kangaroos can significantly impede the rehabilitation of degraded habitats in both the WildEyre and Sheoak Grassy Woodland restoration projects.

Meers and Adams (2003) used exclusion plots to assess kangaroo grazing on post-fire vegetation in Reef Hills Regional Park, 170 km northeast of Melbourne. The Park is a significant isolated remnant within the Box-Ironbark region of Victoria where there is a high population density of herbivores. They found that initial grazing on monocots and composites appeared to result in reduced flowering and seedset in these species. Nine months following the fire, the seed heads of monocots were observed within the fenced plots but were rarely observed on plants outside the plots. Flowering of grasses such a Grey Tussock-grass and Spear-grass were only observed within fenced plots. In addition to the impact on monocots, the growth of resprouting shrubs was observed to be slowed by grazing, with plants of these species outside the exclusion plots no larger one year after fire than at six months post-fire. At one year post-fire, shrubs that had resprouted after the fire had been grazed to the base outside the fenced plots. The authors noted that repeated grazing of resprouting shrubs to the base has been observed to lead to their eventual death.

Meers and Adams (2003) also demonstrated that there was a significant decline in the survival of naturally regenerated seedlings over time both within and outside of the herbivore exclusion areas. Seedling densities were significantly higher in the fenced (ungrazed) areas at each sampling time. With regard to species diversity, the mean number of species per quadrat remained unchanged in fenced areas but declined in unfenced areas, with a significant decrease in the number of shrub species per quadrat in grazed areas.

In regards to impacts on vegetation, results of the above mentioned studies are consistent, and show that overgrazing by kangaroos results in reduced species diversity, changed vegetation composition and therefore structure and complexity, and a reduction in above-ground plant biomass and more bare ground. Reduced vegetation biomass in turn reduces cover for small vertebrates, increasing the likelihood of predation (Finlayson, 2021). It can also increase the likelihood of erosion and nutrient export, and contribute to changes in catchment hydrology (Alviano, 2000). As Nilar *et al.* (2019) demonstrated, the installation of exclusion fences not only

protected a high proportion of plant species, but also significantly increased ground, shrub and leaf litter cover, while reducing the cover of bare soil and alien plant diversity.

3.2.2 Hydrological, soil and nutrient impacts

This portion of the literature review draws primarily on the Doctoral thesis of Alviano (2000). While assessment of impacts to vegetation and groundcover (biomass) formed part of his study, Alviano's (2000) investigation focused on the impact of kangaroo grazing on sediment and nutrient mobilisation, and is one of few studies to do so.

The static foot pressure exerted by kangaroo does not differ greatly to that of sheep and camels (Alviano, 2000). Under the conditions of overabundant kangaroo populations, this impact can be significant and lead to compaction of the soil surface. Increased soil compaction leads in turn to decreased permeability, and combined with the reduction in biomass and vegetative cover, increases vulnerability of the soil surface to erosion.

Ground cover is considered the most important factor in producing changes to erosion rates. As stated by Alviano (2000), "Any reduction in ground cover increases the amount of exposed soil and this, coupled with a reduced infiltration rate due to soil compaction, increases the flow and speed of water across the surface, which is then able to transport more sediment" (p 29).

Alviano (2000) analysed both natural (rainfall) and artificial surface water run-off from grazed and ungrazed areas to quantify run-off volumes and suspended sediment. Sixteen of the seventeen rainfall events measured produced greater surface runoff from the grazed plots, and the artificially generated runoff[2] also resulted in a significantly greater level of runoff from the grazed plots. Suspended sediment levels were measured through analysis of artificially induced run-off collected from the first litre of available run-off and again from a second sample collected ten minutes after the first sample. Suspended sediment levels in initial (first-flush) run-off samples taken from grazed and ungrazed plots were not significantly different. However, second samples that were taken from grazed plots had significantly higher levels of suspended sediment than those of ungrazed plots, indicating that grazed plots continued to have available soil fines material available for detachment and transport.

These results indicate that the reduced above ground biomass that resulted from overgrazing by kangaroos increased both surface runoff volumes (i.e. decreased infiltration) and nutrient mobilisation from grazed areas, and may also have caused increased erosion levels from grazed areas.

4 POTENTIAL NEGATIVE IMPACTS OF FENCES

Hayward and Kerley (2009) highlight that while conservation fencing has the potential to address eight of the ten major threatening processes identified by the IUCN and yield significant conservation benefits, it can also become a threat in itself. Whilst the authors acknowledge that the benefits of fencing for conservation far outweigh the costs when these are listed alongside each other, they identify the following potential impacts:

- Fences pose a direct mortality risk
- Fences can act as barriers to dispersal and migration (and associated lack of gene transfer)

[2] Via a sprinkler system designed to resemble the characteristics of rainfall.

- Fences can lead to the overuse of resources within the fenced area[3], and potential collapse of species' populations and ecosystems
- Fences may limit the population size within the fenced area (small and/or capped populations)
- Hard edges allow little scope for biodiversity to move with their bioclimatic envelope.

These impacts primarily relate to the containment of biodiversity within rather than excluded from the fenced area. These and other relevant potential impacts should be considered in conservation projects for which fencing is proposed as a management tool.

Brown *et al.* (2016) observed an increase in exotic annual grasses in fenced areas, and concluded that kangaroos may be suppressing exotic annual grass cover across the study site, as well as native plant cover. Therefore monitoring and/or management of the prevalence of exotic annual grasses may be required in some fenced sites to ensure conservation aims are achieved.

5 IMPLICATIONS FOR MANAGEMENT AND CONCLUSION

This literature review demonstrates the significant deleterious impacts to native vegetation, fauna habitat, soil stability and structure, hydrodynamics and nutrient mobilisation that can result from overgrazing by kangaroos. Given a high enough population density, kangaroos can affect the environment in much the same way as domestic livestock, and contribute to environmental degradation (Alviano, 2000).

By contrast, exclusion of kangaroos from conservation areas through fencing has been shown to result in natural regeneration and increased plant growth, which in turn improve soil stability and structure, nutrient holding capacity and water retention capacity. Exclusion of kangaroos has also been shown to result in increased species diversity, vegetation complexity, plant cover and therefore vegetation condition. Areas of bare soil were also reduced. These factors are beneficial for the conservation of plant communities, and also greatly improve the value of vegetation as habitat for native fauna.

This review has shown that mitigation of kangaroo overgrazing impacts through land fencing is likely to improve the vegetation condition and habitat quality within the fenced area. Over time, fencing is also expected to lead to improved long-term viability and resilience of the offset area vegetation and/or habitat through improvement of soil structure, hydrodynamics and ecosystem functions.

[3] i.e., fenced conservation areas, not exclusion plots.

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