

**Square Kilometre Array Road Upgrade Project
October 2016
Fauna Assessment**



Bourke's Parrots in Mulga (photo: Joanna Riley)

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Executive summary

Bamford Consulting Ecologists (BCE) was commissioned by Aurecon (on behalf of Main Roads) to conduct a Level 1 fauna impact assessment (desktop review and site inspection) along the proposed access route (the survey area) to the Square Kilometre Array (SKA) project in the Murchison region of Western Australia. The fauna investigations were based on a desktop assessment and field surveys undertaken in October 2016. The desktop assessment identified 286 vertebrate fauna species as potentially occurring in the site: four fish, nine frogs, 80 reptiles, 166 birds, 25 native and 10 introduced mammals. A total of 88 vertebrate species were recorded during the field survey: two fish, one frog, nine reptiles, 65 birds, six native mammals and five introduced mammals. The vertebrate assemblage includes up to 28 species of conservation significance.

Key fauna values are:

Fauna assemblage. Considered to be relatively intact, within a relatively intact, largely uncleared landscape. A large number of birds are restricted to the major riverine environments with additional species likely to breed there, and a number of saxicoline species are restricted to rocky areas.

Species of conservation significance. Six conservation significant species were recorded within the survey area and an additional four have been recorded in nearby areas. The Western Spiny-tailed Skink, Malleefowl, Major Mitchell's Cockatoo, Peregrine Falcon and Bush Stone-curlew are likely to have resident populations in the survey area. Only ancient, inactive mounds of the Western Pebble-mound Mouse were recorded from the site, suggesting the species no longer occurs in the area. The Rainbow Bee-eater, Eastern Great Egret and Common Greenshank are regular migrants to the area. The Shield-backed Trapdoor Spider is known to occur nearby and is therefore expected to occur as a resident within the survey area. Several additional species are known from the local area and are anticipated to reside or regularly visit the area.

Vegetation and Substrate Associations (VSAs). The majority of the survey area is composed of VSAs considered widespread in the region, such as open Acacia dominated shrublands on hardpan and wash plains. Ten VSAs were identified across the survey area and surrounding landscape. VSAs of particular significance include:

1. Major drainage lines: the Murchison and Roderick Rivers are fringed with large mature trees providing roosting and breeding sites for several species (e.g. Major Mitchell's Cockatoo), contains seasonal and permanent pools supporting freshwater fish, waders and waterbirds, and provides linkage across the landscape;
2. Granite Outcrops: support a highly-restricted fauna assemblage including the Western Spiny-tailed Skink.
3. Rocky, lateritic hills and breakaways supporting dense Acacia shrublands support the conservation significant Malleefowl and Shield-backed Trapdoor Spider.
4. Floodplain depressions supporting chenopod shrublands (potential habitat for the Slender-billed Thornbill).

Patterns of biodiversity. Biodiversity is likely to be spread across most VSAs, however some areas support a concentration of fauna, an elevated richness or abundance of fauna or highly

specialised species restricted to particular habitats. The most significant areas for fauna are considered to be major drainage lines (the Murchison and Roderick Rivers), granite outcrops and rocky breakaways.

Key ecological processes. One of the dominant ecological processes currently affecting the fauna assemblage in the project area is hydrology, with other significant processes including fire, feral species and interactions with native species, habitat degradation due to weed invasion and connectivity. Riverine and riparian habitats are sensitive to hydrological change and weed invasion.

Potential impacts upon fauna include:

- Altered local hydrology which could impact distinct mesic refugia;
- Ongoing mortality; and
- Loss and fragmentation of habitat.

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1 Introduction

1.1 Introduction

The Square Kilometre Array (SKA) is a global radio telescope project, located on Boolardy Station in the Murchison region of Western Australia. As part of the project's development, Main Roads Western Australia (Main Roads) is co-ordinating a road upgrade for access to the SKA site (the project). This involves the widening of the existing road formation, minor realignments and a single lane seal over approximately 150 kilometres (km) of road (see Table 1). Road works will also require road building material, identified from eight potential material sources ('borrow pits') located adjacent to the road formation. It is currently undetermined how much native vegetation will be cleared as part of these proposed works, but the total footprint of borrow pits is 1,356 hectares (ha), and much of the footprint is in pastoral country where existing clearing is minimal.

As part of the environmental impact assessment (EIA) for the project, Bamford Consulting Ecologists (BCE) was commissioned by Aurecon (on behalf of Main Roads Western Australia (Main Roads) to conduct a Level 1 fauna assessment of the SKA access road upgrade area (referred to hereafter as the "survey area"). The SKA survey area included the proposed road upgrade route with a 100 m buffer and the proposed borrow pit areas (see Figure 1). BCE had previously conducted a similar assessment for the upgrading of other sections of the same road (Bamford and Turpin 2015). The function of the fauna assessment, consistent with the Environmental Protection Authority (EPA) Guidance (desktop review and reconnaissance survey), is to identify the fauna values of a site so that impacts upon these from any proposed development can be assessed and, where possible, minimised. The purpose of this report is to provide information on the fauna values, particularly for significant species, an overview of the ecological function of the site within the local and regional context, and to provide discussion on the interaction of the proposal on these fauna values and functions.

1.2 General Approach to Fauna Impact Assessment

The purpose of impact assessment is to provide government agencies with the information they need to decide upon the significance of impacts of a proposed development. BCE uses an impact assessment process with the following components:

- The identification of **fauna values**:
 - Assemblage characteristics: uniqueness, completeness and richness;
 - Species of conservation significance;
 - Recognition of ecotypes or vegetation/substrate associations (VSAs) that provide habitat for fauna, particularly those that are rare, unusual and/or support significant fauna;
 - Patterns of biodiversity across the landscape; and
 - Ecological processes upon which the fauna depend.
- The review of **impacting processes** such as:
 - Habitat loss leading to population decline;
 - Habitat loss leading to population fragmentation;
 - Degradation of habitat due to weed invasion leading to population decline;
 - Ongoing mortality from operations;
 - Species interactions including feral and overabundant native species;
 - Hydrological change;
 - Altered fire regimes; and
 - Disturbance (dust, light, noise).
- The **recommendation** of actions to mitigate impacts (provided in a separate document).

Descriptions and background information on these values and processes can be found in Appendices 1 to 4. Based on this impact assessment process, the objectives of investigations are to: identify fauna values; review impacting processes with respect to these values and the proposed development; and provide recommendations to mitigate these impacts.

1.3 Project Scope

A scope of works was provided to BCE by Aurecon and Main Roads with the following actions to be undertaken with reference to EPA Guidance Statement No.56 (EPA, 2004):

- complete a desktop assessment of the study area prior to a field assessment to identify all fauna constraints which may be in or near the survey area;
- identify and review any existing and relevant fauna reports;
- identify significant fauna values and potential sensitivity to impact;
- identify broad vegetation type(s) / vegetation and soil associations present within the survey area;
- conduct a field survey to verify / ground truth the desktop assessment findings;
- undertake relevant fauna constraints mapping using GIS mapping software;
- assess all fauna aspects likely to require referral of the project to the EPA;
- assess Matters of National Environmental Significance (MNES) and indicate whether potential impacts on MNES as protected under the EPBC Act are likely to require referral of the project to the Commonwealth Department of the Environment and Energy. Provide

justification of decision as to whether referral is likely to be required. Ensure to reference relevant Commonwealth significant impact guidelines;

- determine the legislative context of fauna aspects required for the assessment;
- provide a concise report on the findings of the fauna survey.

1.4 Description of Survey Area

Main Roads required a fauna assessment for 100 m either side of the ‘upgrade’ sections of road and at the eight borrow pit sites (Figure 1). The proposed access road upgrade extends over approximately 150 km of unsealed roads from the Murchison River (116 km north of Mullewa, 50J, 379146E, 6955484N) to near the Murchison settlement (397423E, 7016804N), Wooleen (414301E, 7001628N) and the Boolardy – Kalli Rd (50, 480452E, 7027590N). Table 1 summarises the locations of the road upgrade with borrow pit locations listed in Table 2. The survey area is shown in Figure 1.

Table 1. Locations of Road Upgrade.

Name	Comments	Length
Boolardy–Kalli Rd	From Beringarra-Pindar Road Intersection to approximately 20 SLK	23 km
Twin Peaks-Wooleen Rd	From Carnarvon-Mullewa Road intersection to the Meeberrie-Wooleen Road Intersection	51 km
Carnarvon-Mullewa Rd	From approximately Ballinyoo Bridge (where previous assessment finished) to the Meeberrie-Wooleen Road Intersection	78 km
Total Length		152 km

Table 2. Locations of Borrow Pit survey areas (UTM Zone 50J).

Borrow Pit	Location	Easting	Northing	Area
Borrow Pit	Beringarra Pindar Rd	442319	7001599	126 ha
Borrow Pit	Wooleen Mt Wittencoom Rd	421208	6992754	175 ha
Borrow Pit	Wooleen RHS	420462	6990685	100 ha
Borrow Pit	Twin Peaks Wooleen Rd 1	400934	6977968	150 ha
Borrow Pit	Beringarra Pindar Rd 2	442176	6995022	185 ha
Borrow Pit	Wooleen Mt Wittencoom Rd 3	416190	6999704	200 ha
Borrow Pit	Twin Peaks Wooleen Rd 2	401366	6976156	250 ha
Borrow Pit	Carnarvon-Mullewa Rd	370606	6913596	170 ha
Total Area				1,356 ha

2 Background

2.1 Regional Description

The Interim Biogeographic Regionalisation of Australia (IBRA) (Environment Australia, 2000) has identified 26 bioregions in Western Australia. Bioregions are classified on the basis of climate, geology, landforms, vegetation and fauna (Thackway and Cresswell, 1995). IBRA Bioregions are affected by a range of different threatening processes and have varying levels of sensitivity to impact (EPA, 2004). As the survey area extends over 180 km it passes over two IBRA Bioregions – the Murchison and Yalgoo Bioregions. Both bioregions are divided into subregions, of which the survey area extends over the Talling Subregion (Yalgoo) and the Western Murchison Subregion (Murchison). The subregions are summarised below.

Talling Subregion

The Talling Subregion an interzone between the South-western Bioregions and the Murchison. It is characterised by low woodlands to open woodlands of Eucalyptus, Acacia and Callitris on red sandy plains. Mulga, Callitris, *E. salubris* and Bowgada open woodlands and scrubs occur on sandy-loam plains. The climate is arid to semi-arid warm Mediterranean, and the subregional area is 4,858,849 ha (Desmond and Chant, 2001).

Western Murchison Subregion

The Western Murchison is characterised by Mulga low woodlands, often rich in ephemerals (usually with bunch grasses), on extensive hardpan washplains. Areas of hummock grasslands on sandplains, saltbush shrublands on calcareous soils and Halosarcia low shrublands occur on saline alluvia. The region contains the headwaters of the Murchison and Wooramel Rivers, which drain the subregion westwards to the coast. The climate is arid with bimodal rainfall, although with the majority of rain in winter. The subregional area is 7,847,996 ha. The dominant land use is grazing with lesser areas of UCL and Crown reserves (Desmond, Cowan and Chant, 2001).

2.2 Land Systems

Pringle *et al.* (1994) classified and mapped the landforms of the northern Goldfields region. This includes the survey area. Landforms are grouped into “Land Types”, which are classified according to similarities in landform, soil, vegetation, geology and geomorphology. Six Land Types have been mapped across the survey area (see Table 3). Land Types are further divided into Land Systems based on similarities of vegetation, landform and soil. The Land Systems present in the survey area are listed below (Table 4). Land Systems provide an indication of the fauna habitats present within the survey area. The Land Systems present within each borrow pit area are shown in Table 5.

Table 3. Land Types within the survey area.

Land Type	Description
5	Mesas, breakaways and stony plains with acacia or eucalypt woodlands and halophytic shrublands
15	Gritty-surfaced plains and granite tors and domes with acacia shrublands
17	Stony plains with acacia shrublands and halophytic shrublands
25	Sandplains and occasional dunes with grassy acacia shrublands
31	Wash plains on hardpan with mulga shrublands
32	Wash plains and sandy banks on hardpan, with mulga shrublands and wanderrie grasses or spinifex

Table 4. Land Systems within the survey area.

Land System	Description
Kalli	Elevated, gently undulating red sandplains edged by stripped surfaces on laterite and granite; tall acacia shrublands and understorey of wanderrie grasses (and spinifex locally); replaced by more extensive areas of Bullimore land system.
Nerramyne	Undulating plains of sandy-surfaced laterite and weathered granite with low remnant plateaux, breakaways and rises supporting acacia shrublands.
Tindalarra	Near level hardpan wash plains, narrow drainage lines and moderately saline drainage floors; supporting tall mixed acacia shrublands with wanderrie grasses, also minor saltbush/bluebush low shrublands.
Narryer	Low hills and lateritised breakaways above very gently undulating stony slopes and plains on gneiss and granite with sparse acacia shrublands.
Yanganoo	Almost flat hardpan wash plains, with or without small banks supporting mulga shrublands and wanderrie grasses.
Violet	Gently undulating gravelly plains on greenstone, laterite and hardpan, with low stony rises and minor saline plains; supporting mulga groves and bowgada shrublands, and patchy halophytic shrublands.
Challenge	Gently undulating gritty-surfaced plains, occasional granite hills, tors and low breakaways, with acacia shrublands.
Jundee	Hardpan plains with ironstone gravel mantles and occasional sandy banks supporting mulga shrublands.
Sherwood	Breakaways, kaolinised footslopes and extensive gently sloping plains on granite supporting mulga shrublands and minor halophytic shrublands.

Table 5. Land Systems present within the borrow pit areas.

Borrow Pit	Land Systems								
	Tindalarra	Kalli	Challenge	Violet	Narryer	Yanganoo	Nerramyne	Jundee	Sherwood
1		X	X						
2		X	X						
3			X						
4				X					
5		X				X			X
6					X	X			
7				X	X			X	
8	X						X		

3 Methods

3.1 Overview

The methods used for this assessment are based upon the general approach to fauna investigations for impact assessment as outlined in Section 1.2 and with reference to Appendices 1 to 4. Thus, the impact assessment process involves the identification of fauna values, review of impacting processes and preparation of mitigation recommendations.

This approach to fauna impact assessment has been developed with reference to guidelines and recommendations set out by the Western Australian EPA on fauna surveys and environmental protection, and Commonwealth biodiversity legislation (EPA 2002; EPA 2004). The EPA proposes two levels of investigation that differ in the approach to field investigations, Level 1 being a review of data and a site reconnaissance to place data into the perspective of the site, and Level 2 being a literature review and intensive field investigations (e.g. trapping and other intensive sampling). The level of assessment recommended by the EPA is determined by the size and location of the proposed disturbance, the sensitivity of the surrounding environment in which the disturbance is planned, and the availability of pre-existing data.

The following approach and methods is divided into three groupings that relate to the stages and the objectives of impact assessment:

- Desktop assessment. The purpose of the desktop review is to produce a species list that can be considered to represent the vertebrate fauna assemblage of the project area based on unpublished and published data using a precautionary approach.
- Field investigations. The purpose of the field investigations is to gather information on this assemblage: confirm the presence of as many species as possible (with an emphasis on species of conservation significance), place the list generated by the desktop review into the context of the environment of the project area, collect information on the distribution and abundance of this assemblage, and develop an understanding of the project area's ecological processes that maintain the fauna. Note that field investigations cannot confirm the presence of an entire assemblage, or confirm the absence of a species. This requires far more work than is possible in the EIA process. For example, in an intensive trapping study, How and Dell (1990) recorded in any one year only about 70% of the vertebrate species found over three years. In a study spanning over two decades, Bamford *et al.* (2010) has found that the vertebrate assemblage varies over time and space, meaning that even complete sampling at a set of sites only defines the assemblage of those sites at the time of sampling.
- Impact assessment. Determine how the fauna assemblage may be affected by the proposed development based on the interaction of the project with a suite of ecological and threatening processes.

3.2 Desktop Assessment

3.2.1 Sources of information

Information on the fauna assemblage of the project area was drawn from a wide range of sources (Table 1). These included state and federal government databases and results of regional studies including BCE surveys conducted in 2007, 2008, 2015 (Bamford and Turpin, 2007, 2008, 2015). The BCE (2015) study was particularly relevant as it was a level 1 survey of much the same road alignment and region, but a different suite of borrow pits and road sections, and was carried out by some of the same personnel as the current project. Databases accessed were the DPaW Naturemap, BirdLife Australia's Atlas Database, the EPBC Protected Matters Search Tool and the BCE database (Table 6). Information from the above sources was supplemented with species expected in the area based on general patterns of distribution.

Table 6. Sources of information used for the desktop assessment.

Database / Survey	Comment	Area searched
NatureMap (DPaW 2016)	Records in the WAM and DPaW databases. Includes historical data and records on Threatened and Priority species in WA.	Project area – plus 40 km buffer
BirdLife Australia Atlas Database	Records of bird observations in Australia, 1998-2014.	Species list for one degree cells containing project area
EPBC Protected Matters	Records on matters of national environmental significance protected under the EPBC Act.	Project area – plus 40 km buffer
SKA Fauna Assessment (BCE 2007)	BCE Level 1 Fauna Assessment conducted in 2007	Boolardy Station adjacent to survey area
SKA Main Roads Fauna Assessment 2015 (BCE 2015)	BCE Level 1 Fauna Assessment conducted in 2015	Boolardy, Wooleen, Meeberrie, Woolgorong, Murchison and Greenough Rivers
Weld Range Fauna Assessments (BCE 2008)	Fauna Assessment, conducted at Weld Range by Bamford Consulting Ecologists.	2007, 2008, Weld Range (80km east of project)
Boolardy / Murgoo Fauna records	BCE records from Boolardy and Murgoo Stations.	Boolardy and Murgoo Stations

3.2.2 Previous fauna surveys

BCE conducted the fauna assessment for the initial approval of the SKA project during 2007 and also for Main Roads during 2015 (BCE 2007, 2015). Field surveys recorded 120 fauna species (one freshwater fish, 16 reptile, 92 bird, six native mammal species and five introduced mammal species). Several species of conservation significance were recorded including the Western Spiny-tailed Skink (*Egernia stokesii*, recorded from Wooleen), Malleefowl (*Leipoa ocellata*, recorded at Twin Peaks, Boolardy, Murgoo), Major Mitchell's Cockatoo (*Lophochroa leadbeateri*, Boolardy, Murchison River), Slender-billed Thornbill (*Acanthiza iredalei*, Mungada), Peregrine Falcon (*Falco*

peregrinus, Boolardy) and Shield-backed Trapdoor Spider (*Idiosoma nigrum*, Tallering area). Records from previous surveys are summarised in Appendix 4.

3.2.3 Nomenclature and taxonomy

As per the recommendations of the EPA (2004), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's (WAM) *Checklist of the Fauna of Western Australia 2016*. The authorities used for each vertebrate group were: amphibians (Doughty *et al.* 2016), reptiles (Doughty *et al.* 2016), birds (Johnstone and Darnell 2016), and mammals (Travouillon 2016). In some cases, more widely-recognised names and naming conventions have been followed, particularly for birds where there are national and international naming conventions in place (e.g. the BirdLife Australia working list of names for Australian Birds). English names of species, where available, are used throughout the text; Latin species names are presented with corresponding English names in tables in the appendices.

3.2.4 Interpretation of species lists

Species lists generated from the review of sources of information are generous as they include records drawn from a large region and possibly from environments not represented in the survey area. Therefore, some species that were returned by one or more of the data searches have been excluded because their ecology, or the environment within the survey area, meant that it is highly unlikely that these species will be present. Such species can include, for example, seabirds that might occur as extremely rare vagrants at a terrestrial, inland site, but for which the site is of no importance.

Species returned from the databases and not excluded on the basis of ecology or environment are therefore considered potentially present or expected to be present in the survey area at least occasionally, whether or not they were recorded during field surveys, and whether or not the survey area is likely to be important for them. This list of expected species is therefore subject to interpretation by assigning each a predicted status in the survey area.

The status categories used are:

- Resident: species with a population permanently present in the survey area;
- Regular migrant or visitor: species that occur within the survey area regularly in at least moderate numbers, such as part of annual cycle;
- Irregular Visitor: species that occur within the survey area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades but when the species is present, it uses the survey area in at least moderate numbers and for some time;
- Vagrant: species that occur within the survey area unpredictably, in small numbers and/or for very brief periods. Therefore, the survey area is unlikely to be of importance for the species; and
- Locally extinct: species that would have been present but has not been recently recorded in the local area and therefore is almost certainly no longer present in the survey area.

These status categories make it possible to distinguish between vagrant species, which may be recorded at any time but for which the site is not important in a conservation sense, and species

which use the site in other ways but for which the site is important at least occasionally. This is particularly useful for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive, and further recognises that even the most detailed field survey can fail to record species which will be present at times. The status categories are assigned conservatively based on the precautionary principle. For example, a lizard known from the general area is assumed to be a resident unless there is very good evidence the site will not support it, and even then it may be classed as a vagrant rather than assumed to be absent if the site might support dispersing individuals.

3.3 Field survey

3.3.1 Overview

The field assessment incorporated a range of survey techniques, so as to maximise sampling results. Techniques utilised included:

- Identification of Vegetation and Soil Associations (that provide fauna habitats);
- Targeted searches for significant fauna and an assessment of their likelihood of occurrence;
- Bird survey in each location visited;
- Use of motion-sensitive cameras;
- Use of acoustic recordings for bats (ANABAT); and
- Opportunistic fauna observations.

3.3.2 Dates and Personnel

The SKA project was assessed during 30th October till the 4th November 2016. Personnel involved in the survey included:

- Dr Michael Bamford (B.Sc. Hons. Ph.D.) – field survey and report production;
- Ms Mandy Bamford (B.Sc. Hons., Zool.) – field survey;
- Ms Joanna Riley (B.Sc. Hons) – field survey; and
- Mr Jeff Turpin (B.Sc. Zool.) – field survey and report production.

3.3.3 Vegetation and Substrate Associations

Vegetation and substrate associations (VSAs) combine broad vegetation types, the soils or other substrate with which they are associated, and the landform. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. All major VSAs present within the survey area were identified and sampled for fauna. Those deemed suitable to support conservation significant fauna were subject to further intensive targeted searching.

3.3.4 Targeted searching for conservation significant species

Significant species recorded during the desktop assessment include several that can be found by searching for evidence of their activities (e.g. scats, tracks, diggings, burrows, nests) or listening for their call. Searching for evidence of significant fauna was therefore undertaken by walking through habitat considered suitable for such species. Species of particular interest (and the search method) included:

- Western Spiny-tailed Skink: searching for scat latrines amongst granite boulders;
- Malleefowl: Searching for tracks and mounds within dense Acacia shrublands;

- Mygalomorph Spiders (e.g. Shield-backed Trapdoor Spider): Searching for burrows in Acacia shrublands;
- Slender-billed Thornbill: systematic search in areas of chenopod shrubland;
- Searches amongst rocky areas for dasyurid scats and for the presence of bats.

Searches for the above species were undertaken at the borrow pit areas where suitable habitat occurred, and at the locations listed in Table 7 below.

Table 7. Areas selected to search for conservation significant fauna.

Location/VSA	Easting	Northing	Target Species
Borrow Pit 1: Beringarra Pindar Rd	442319	7001599	All
Borrow Pit 2: Wooleen Mt Wittenoom Rd	421208	6992754	All
Borrow Pit 3: Wooleen RHS	420462	6990685	All
Borrow Pit 4: Twin Peaks Wooleen Rd 1	400934	6977968	All
Borrow Pit 5: Beringarra Pindar Rd 2	442176	6995022	All
Borrow Pit 6: Wooleen Mt Wittenoom Rd 3	416190	6999704	All
Borrow Pit 7: Twin Peaks Wooleen Rd 2	401366	6976156	All
Borrow Pit 8: Carnarvon-Mullewa Rd	370606	6913596	All
Woodlands and shrublands fringing Murchison River	379017	6954745	Major Mitchell's Cockatoo and waterbirds
Woodlands and shrublands fringing Murchison River	390927	6973199	Major Mitchell's Cockatoo and waterbirds
Sapphire low shrubland near Murchison River	392194	6972884	Slender-billed Thornbill
Drainage line	418488	6998342	Major Mitchell's Cockatoo and waterbirds
Granite Outcrop	401768	6982841	Western Spiny-tailed Skink
Acacia shrubland	427381	6993670	Shield-backed Trapdoor Spider
Acacia shrubland	472351	7027191	Shield-backed Trapdoor Spider

3.3.5 Motion Sensitive Cameras

Baited motion-sensitive cameras (Bushnell Trophycam) were set at two sites (over three nights) targeting species of conservation significance (e.g. Long-tailed Dunnart). Details for camera locations are provided in Table 8 below.

Table 8. Details of motion cameras in operation during the 2016 fauna assessment (Zone 50J).

Camera	Easting	Northing	Description
Bushnell	420643	6993007	Acacia shrubland on stony plain
Bushnell	421517	6993134	Breakaway on eastern margin of project

3.3.6 Bird Surveys

Bird surveys were conducted at each borrow pit site and along the proposed road upgrade areas. This included at several locations deemed suitable to support conservation significant fauna, listed in Table 7.

3.3.7 Opportunistic observations

At all times, observations of fauna were noted when they contributed to the accumulation of information on the fauna of the site. These included such casual observations as birds or reptiles seen while travelling through the site.

3.4 Survey limitations

The EPA Guidance Statement 56 (EPA 2004) outlines a number of limitations that may arise during surveying. These survey limitations are discussed in the context of the BCE fauna survey in Table 9.

Table 9. Survey limitations as outlined by EPA (2004).

EPA Survey Limitations	BCE Comment
Level of survey.	Level 1 (desktop study and reconnaissance field survey). Survey intensity was deemed adequate due to the level of survey and the number of fauna surveys previously conducted in the region.
Competency/experience of the consultant(s) carrying out the survey.	The authors have had extensive experience in conducting desktop reviews and reconnaissance surveys for environmental impact assessment.
Scope. (What faunal groups were sampled and were some sampling methods not able to be employed because of constraints?)	The survey focussed on terrestrial vertebrate fauna, although some targeted searching for conservation significant invertebrates and opportunistic observations on freshwater fish took place. Due to the nature of the survey, birds were intensively sampled and reptiles and mammals sampled opportunistically and with motion sensitive cameras.
Proportion of fauna identified, recorded and/or collected.	All fauna observed were identified.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Sources include previous fauna survey for nearby sites e.g. SKA project on Boolardy (BCE, 2007), BCE Main Raods upgrade 2015 (BCE 2015), BCE surveys at Weld Range (BCE, 2010); databases (BA, DPaW, EPBC, BCE), BCE records from Boolardy and Murgoo Stations.
The proportion of the task achieved and further work which might be needed.	Level 1 Survey complete.
Timing/weather/season/cycle.	Survey was conducted in October 2016 during warm and dry conditions and after seasonal winter rainfall.
Disturbances (e.g. fire, flood, accidental human intervention etc.) which affected results of survey.	No disturbances affected the survey results.
Intensity. (In retrospect, was the intensity adequate?)	Survey intensity was moderate (desktop study, reconnaissance survey with some targeted surveying for conservation significant fauna) and was adequate to satisfy EPA guidelines.
Completeness (e.g. was relevant area fully surveyed).	The entire survey area was visually inspected and all major fauna habitats sampled. Environments likely to support conservation significant fauna were subject to further intensive sampling.
Resources (e.g. degree of expertise available in animal identification).	Personnel have a combined 60+ years' experience in environmental impact assessment including multiple surveys in the general area.
Remoteness and/or access problems.	All parts of the survey area were accessible.
Availability of contextual (e.g. biogeographic) information.	Regional information was available and was consulted.

3.5 Presentation of results for Impact Assessment

While some impacts are unavoidable during a development, of concern are long-term, deleterious impacts upon biodiversity. This is reflected in documents such as the Significant Impact Guidelines provided by DSEWPaC (see Appendix 4). Significant impacts may occur if:

- There is direct impact upon a VSA and the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna.
- There is direct impact upon conservation significant fauna.
- Ecological processes are altered and this affects large numbers of species or large proportions of populations, including significant species.

The impact assessment process therefore involves reviewing the fauna values identified through the desktop assessment and field investigations with respect to the project and impacting processes. The severity of impacts on the fauna assemblage and conservation significant fauna can then be quantified on the basis of predicted population change.

The presentation of this assessment follows the general approach to impact assessment as given in Section 1.2, but modified to suit the characteristics of the site. Key components to the general approach to impact assessment are addressed as follows:

Fauna values

This section presents the results of the desktop and field investigations in terms of key fauna values (described in detail in Appendix 1):

- Assemblage characteristics (uniqueness, completeness and richness) - based upon desktop assessment and information from the site inspection;
- Species of conservation significance – based upon desktop assessment and site inspection;
- Recognition of ecotypes or vegetation/substrate associations (VSAs) - based upon desktop assessment and site inspection;
- Patterns of biodiversity across the landscape - based upon desktop assessment and site inspection;
- Ecological processes upon which the fauna depend - based upon desktop assessment and site inspection.

Impact assessment

This section reviews impacting processes (as described in detail in Appendix 3) with respect to the proposed works and examines the potential effect of these impacts upon biodiversity of the survey area. It thus expands upon Section 1.2 and discusses the contribution of the project to impacting processes, and the consequences of this with respect to biodiversity. A major component of impact assessment is consideration of threats to species of conservation significance as these are a major and sensitive element of biodiversity. Therefore, the impact assessment includes the following:

- Review of impacting processes; will the proposal result in:
 - Habitat loss leading to population decline, especially for significant species;
 - Habitat loss leading to population fragmentation, especially for significant species;
 - Weed invasion that leads to habitat degradation;
 - Ongoing mortality;
 - Species interactions that adversely affect native fauna, particularly significant species;
 - Hydrological change;
 - Altered fire regimes; and
 - Disturbance (dust, light, noise).
- Summary of impacts upon significant species, and other fauna values.

The impact assessment concludes with recommendations based upon predicted impacts and designed to mitigate these.

3.5.1 Criteria for impact assessment

Impact assessment criteria are based on the severity of impacts on the fauna assemblage and conservation significant fauna, and quantified on the basis of predicted population change (Table 10). Population change can be the result of direct habitat loss and/or impacts upon ecological processes.

The significance of population change is contextual. The EPA (2004) suggests that the availability of fauna habitats within a radius of 15 km can be used as a basis to predict low, moderate or high impacts. In this case, a high impact is where the impacted environment and its component fauna are (<5% of the landscape within a 15 km radius or within the Bioregion), whereas a low impact is where the environment is widespread (e.g. 10% of the local landscape). Under the Ramsar Convention, a wetland that regularly supports 1% of a population of a waterbird species is considered to be significant. These provide some guidance for impact assessment criteria. In the following criteria (Table 10), the significance of impacts is based upon percentage population decline within a 15 km radius (effectively local impact) and upon the effect of the decline upon the conservation status of a recognised taxon (recognisably discrete genetic population, sub-species or species). Note that percentage declines can usually only be estimated on the basis of distribution of a species derived from the extent of available habitat.

Table 10. Assessment criteria of impacts upon fauna.

Impact Category	Observed Impact
Negligible	Effectively no population decline; at most few individuals impacted and any decline in population size within the normal range of annual variability.
Minor	Population decline temporary (recovery after end of project such as through rehabilitation) or permanent, but <1% within 15 km radius of centre-point of impact area (or within bioregion if this is smaller). No change in viability or conservation status of taxon.
Moderate	Permanent population decline 1-10% within 15 km radius. No change in viability or conservation status of taxon.
Major	Permanent population decline >10% within 15 km radius. No change in viability or conservation status of taxon.
Critical	Taxon extinction within 15 km and/or change in viability or conservation status of taxon.

4 Fauna Values

4.1 Vegetation and Substrate Associations (VSAs)

The road corridor covers a large area and so a large number of VSAs are contained within the survey area. In the north, the majority of the survey area follows the Murchison and Roderick Rivers, and the associated broad drainage floodplains, wash plains and hardpan plains. To the south, the road corridor traverses undulating stony plains. The road corridor crosses the Murchison River at two locations and the Roderick River floodplain is also crossed near the project's northern boundary. A

small number of ephemeral pools also flank the major drainages. The borrow pit locations are generally located on low stony rises to source gravel material. Throughout the survey area, vegetation is dominated by Acacia shrublands of varying density, influenced by substrate and drainage, while Eucalypt woodlands flank drainage lines and low chenopod shrublands occur in some low-lying areas adjacent to the major drainages. Ten major vegetation and substrate associations were recorded from the survey area (see Figure 2):

1. Drainage systems supporting *Eucalyptus camaldulensis*, Acacia shrublands and tussock grasslands. Major drainage systems also support areas of *Casuarina obesa* and contain pools of water with fringing sedgeland and grasslands;
2. Floodplain depressions supporting chenopod shrublands (Samphire, Bluebush, Saltbush);
3. Major riverine plains with active lower floodplains flanking channelled watercourses; supports mixed acacia shrublands, low woodlands with minor perennial grasses and areas halophytic shrublands. The Murchison and Roderick River floodplains;
4. Hardpan wash plains supporting mulga dominated shrublands and wanderie grasses on occasional sandy banks. Acacia shrublands occur at a variable density (*A. aneura*, *A. tetragonophylla*, *A. grasbyi*, *A. ramulosa*), with *Eremophila* shrubs and scattered tussock grasses;
5. Sandplains supporting Acacia shrublands (eg. *A. ramulosa*, *A. aneura*) with occasional minor areas of granite outcropping;
6. Stony footslopes and undulating stony plains supporting sparse / open Acacia and *Eremophila* shrublands. Occasional low rocky hills support Acacia shrubs;
7. Granite Outcrops, Granite domes and hills supporting scattered Acacia shrublands and areas of *Callitris* woodland and fringing dense shrublands;
8. Low lateritic stony rises supporting Acacia shrublands (dominated by *A. aneura* and *A. quadramarginea*) with minor areas of outcropping;
9. Lateritic, gravelly hills and stony rises supporting Mulga shrublands with an *Eremophila* shrub layer. Upper, stony slopes support areas of *Thryptomene decussata*.
10. Rocky breakaways, varying relief, some minor areas with cliff faces up to 3 m, supporting *A. aneura* and *A. quadramarginea* shrublands.

A summary of the VSAs within each borrow pit survey area and along the road corridor is presented in Table 11. The borrow pit sites are generally similar and have a range of VSAs, but are dominated by VSAs 6, 8 and 9. Borrow pit 8 contains a distinctive example of VSA 9 (lateritic rise), where persisting annual plants suggested greater retention of moisture than in other examples of this VSA. VSA 7 is found only in small areas within borrow pits 1, 2 and 6, while VSA 10 occurs minimally, only in portions of borrow pits 1, 5 and 7. None of the borrow pits contains VSAs associated with wetlands (VSAs 1, 2 and 3) but surface and sub-surface drainage is a feature of most VSAs. The western road section passes through a range of VSAs whereas the eastern road section passes only through VSAs 2, 3 and 4, and is thus close to drainage system. The western road section includes a very well-developed area of granitic outcropping (VSA 7). Within the survey area, the most distinctive features of particular locations are:

- Borrow pit 1; one of only three borrow pits with VSA 10 (breakaway) and one of only three with VSA 7 (granite outcrops).
- Borrow pit 2; one of only three with VSA 7 (granite outcrops).
- Borrow pit 5; one of only three borrow pits with VSA 10 (breakaway).

- Borrow pit 7; one of only three borrow pits with VSA 10 (breakaway).
- Borrow pit 8; has a distinctive moisture-retaining area of VSA 8 (lateritic rise).
- The road sections are the only parts of the survey area that pass through wetland VSAs and the western section has a well-developed example of VSA 7 (granite outcrop).

Table 11. Summary of VSAs present within each survey area.

VSA	Borrow Pits								Road	
	1	2	3	4	5	6	7	8	West	East
1.Drainage systems supporting Eucalypts and Acacia shrublands									X	
2.Floodplain depressions supporting chenopod shrublands									X	X
3.Major riverine plains supporting mixed acacia shrublands.									X	X
4.Hardpan wash plains supporting mulga dominated shrublands.									X	X
5.Sandplains supporting Acacia shrublands.		X			X		X	X	X	
6.Stony footslopes and undulating stony plains	X	X	X	X	X	X	X	X	X	
7.Granite Outcrops, Granite domes and hills	X	X				X			X	
8.Low lateritic stony rises supporting Acacia shrublands.	X	X	X	X	X	X	X	X	X	
9.Lateritic, gravelly hills and stony rises supporting Mulga				X	X	X	X	X	X	
10.Rocky breakaways	X				X		X			

The extent of VSAs within each borrow pit area, are mapped below (Figures 3 - 11). The areas of granite outcropping are highlighted as a significant VSA and are also mapped in areas adjacent to borrow pits 1, 2 and 6, and also along the western section of the proposed access road.

Figure 2. Vegetation and Soil Associations recorded from the survey area.

VSA 1. Drainage systems supporting *Eucalyptus camaldulensis*, *Casuarina obesa*, Acacia shrublands and tussock grasslands.



VSA 2. Floodplain depressions supporting chenopod shrublands (Samphire, Bluebush, Saltbush).



VSA 3. Major riverine plains supporting mixed acacia shrublands.



VSA 4. Hardpan wash plains supporting mulga dominated shrublands.



VSA 5. Sandplains supporting Acacia shrublands.



VSA 6. Stony footslopes and undulating stony plains supporting open Acacia and Eremophila shrublands.



VSA 7. Granite Outcrops, Granite domes and hills supporting scattered Acacia shrublands.



VSA 8. Low lateritic stony rises supporting Acacia shrublands.



VSA 9. Lateritic, gravelly hills and stony rises supporting Mulga shrublands with an Eremophila shrub layer.



VSA 10. Rocky breakaways, supporting *A. aneura* and *A. quadramarginea* shrublands.



4.2 VSA Mapping

The Vegetation and Soil Associations occurring within the survey area are described in detail above. Those occurring within each borrow pit area and shown in Figures 3 – 10. A significant fauna VSA, granite outcropping supporting the Western Spiny-tailed Skink, is also shown in Figures 4 and 11.

Figure 3. Vegetation and Soil Associations at Borrow Pit 1.

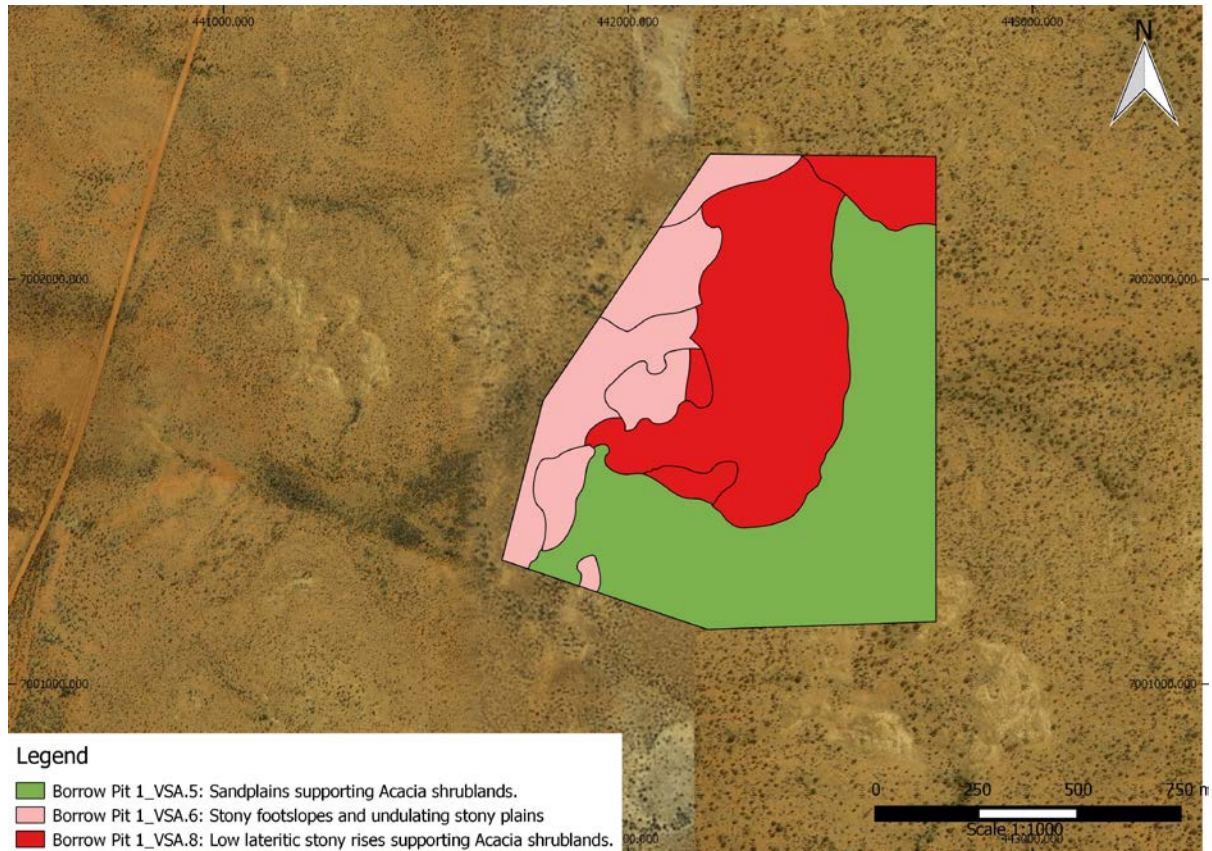


Figure 4. Vegetation and Soil Associations at Borrow Pit 2.

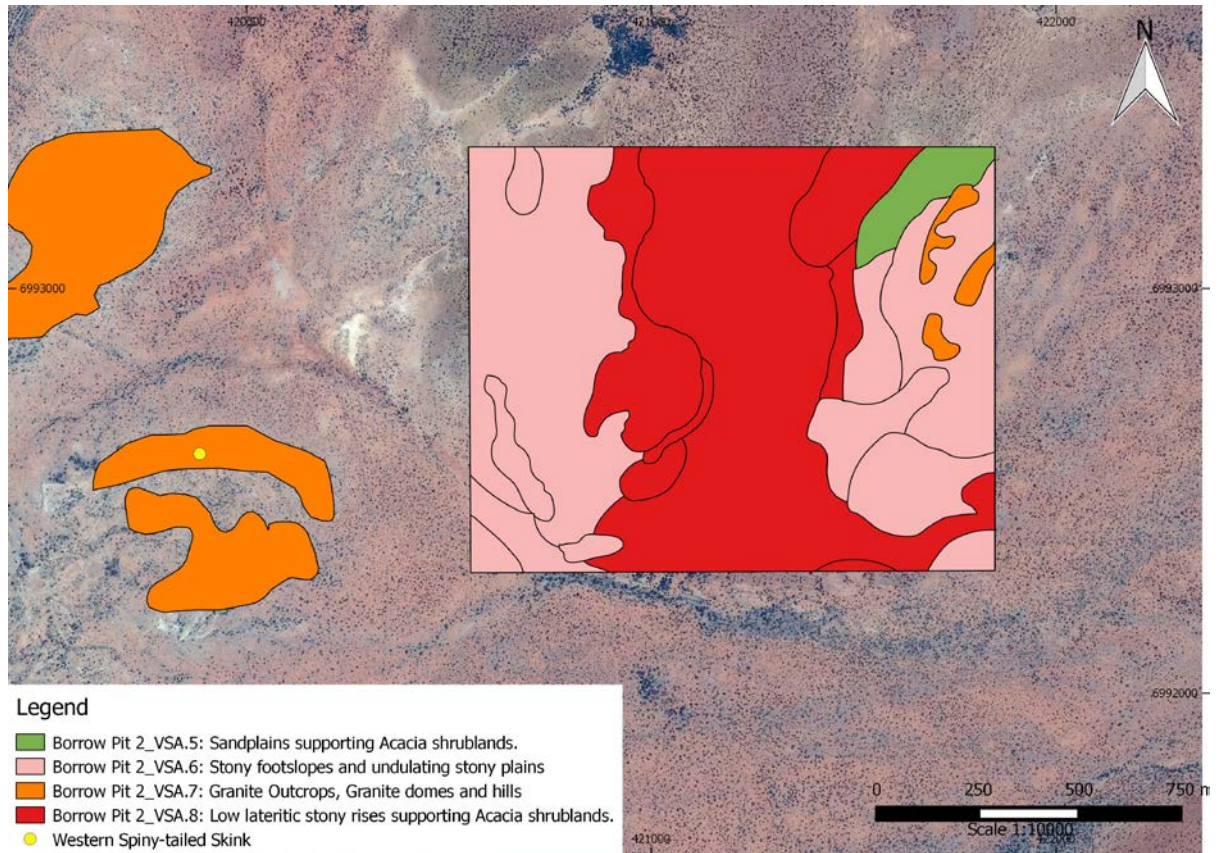


Figure 5. Vegetation and Soil Associations at Borrow Pit 3.

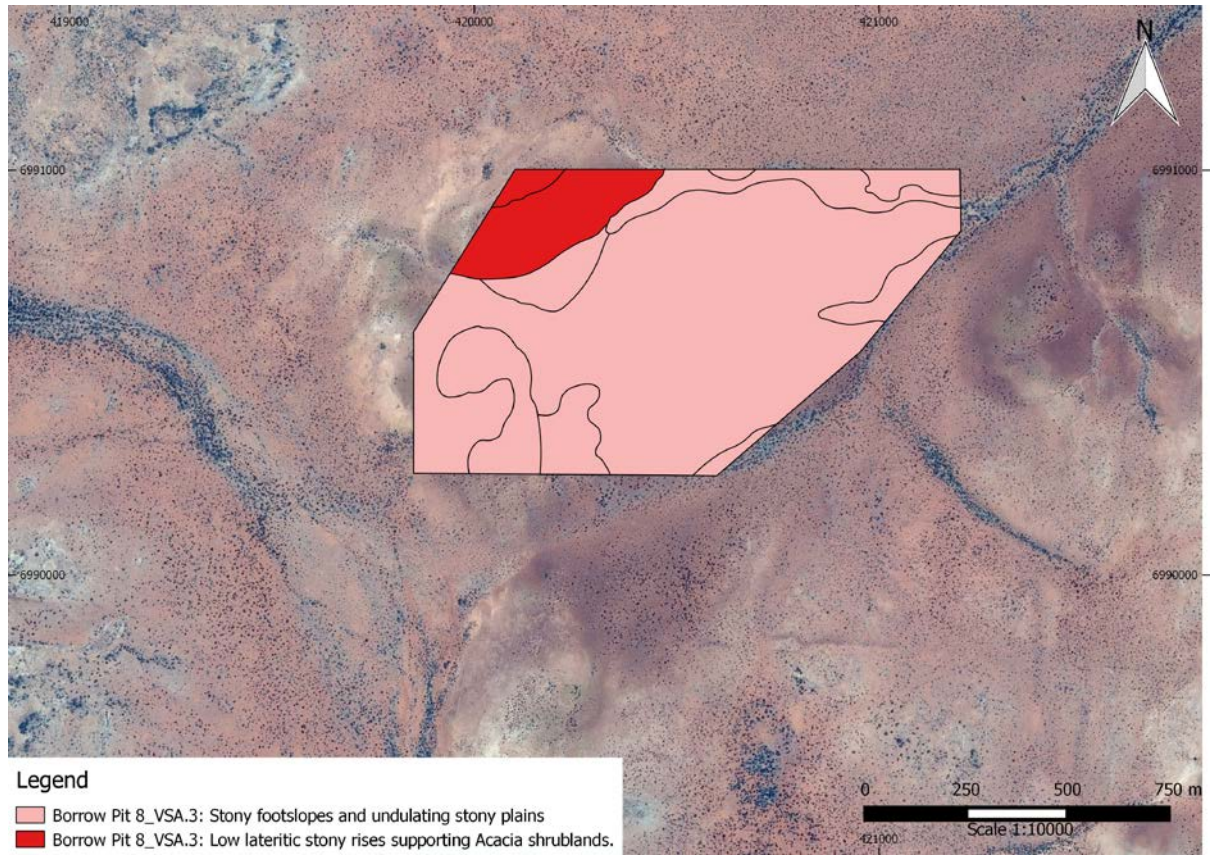


Figure 6. Vegetation and Soil Associations at Borrow Pit 4.

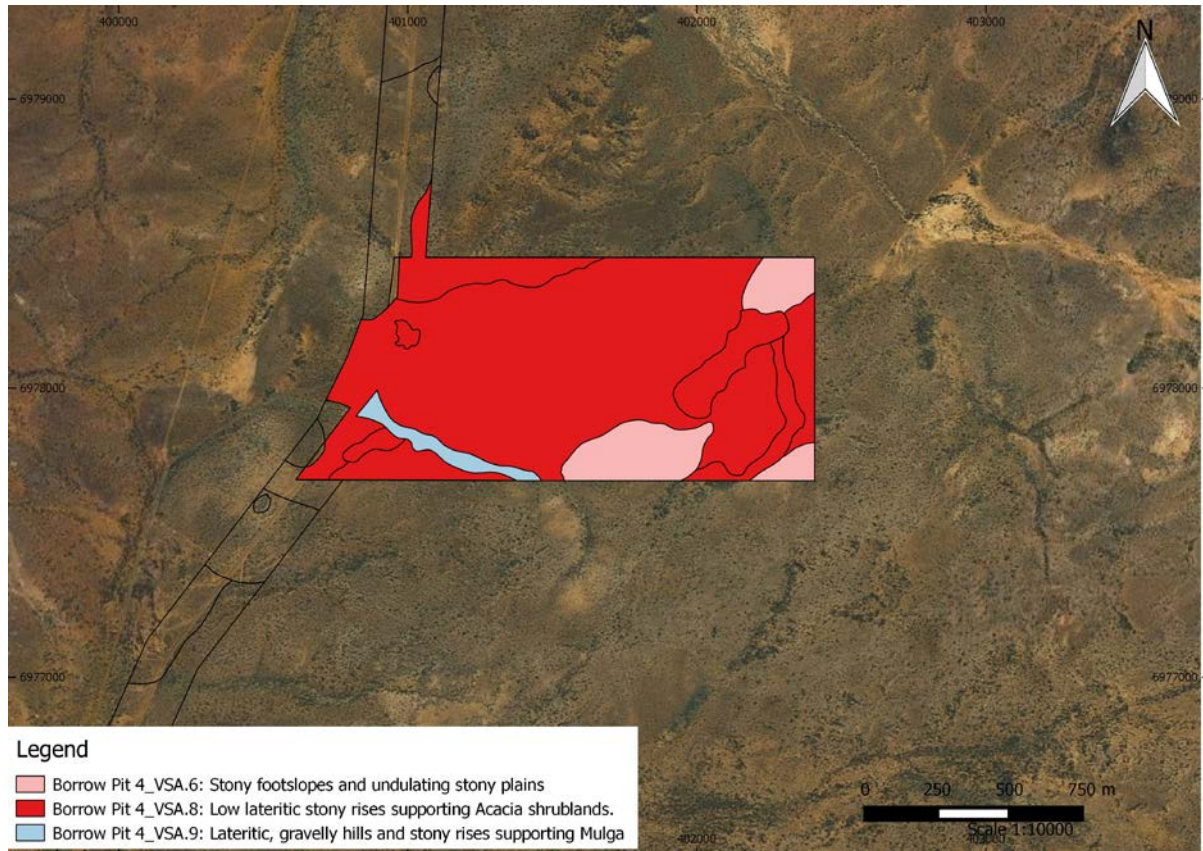


Figure 7. Vegetation and Soil Associations at Borrow Pit 5.

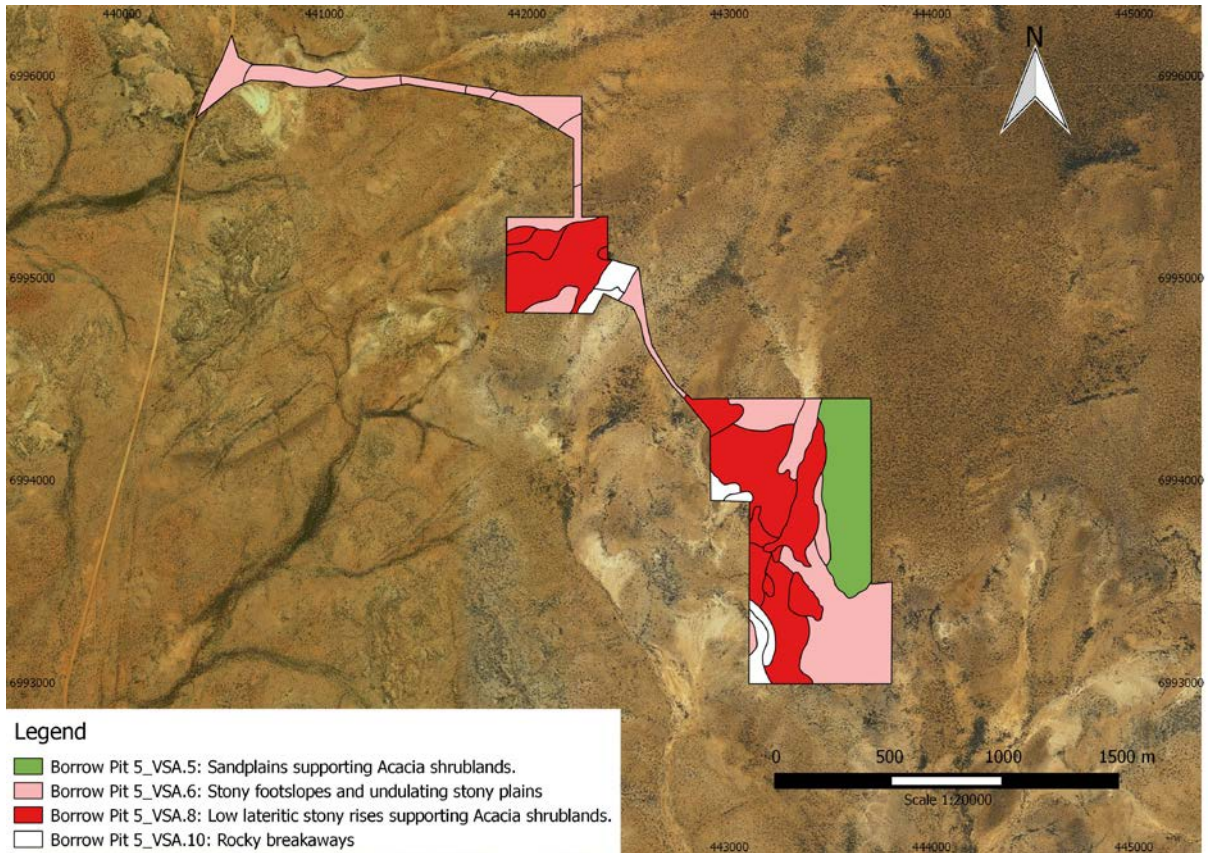


Figure 8. Vegetation and Soil Associations at Borrow Pit 6.

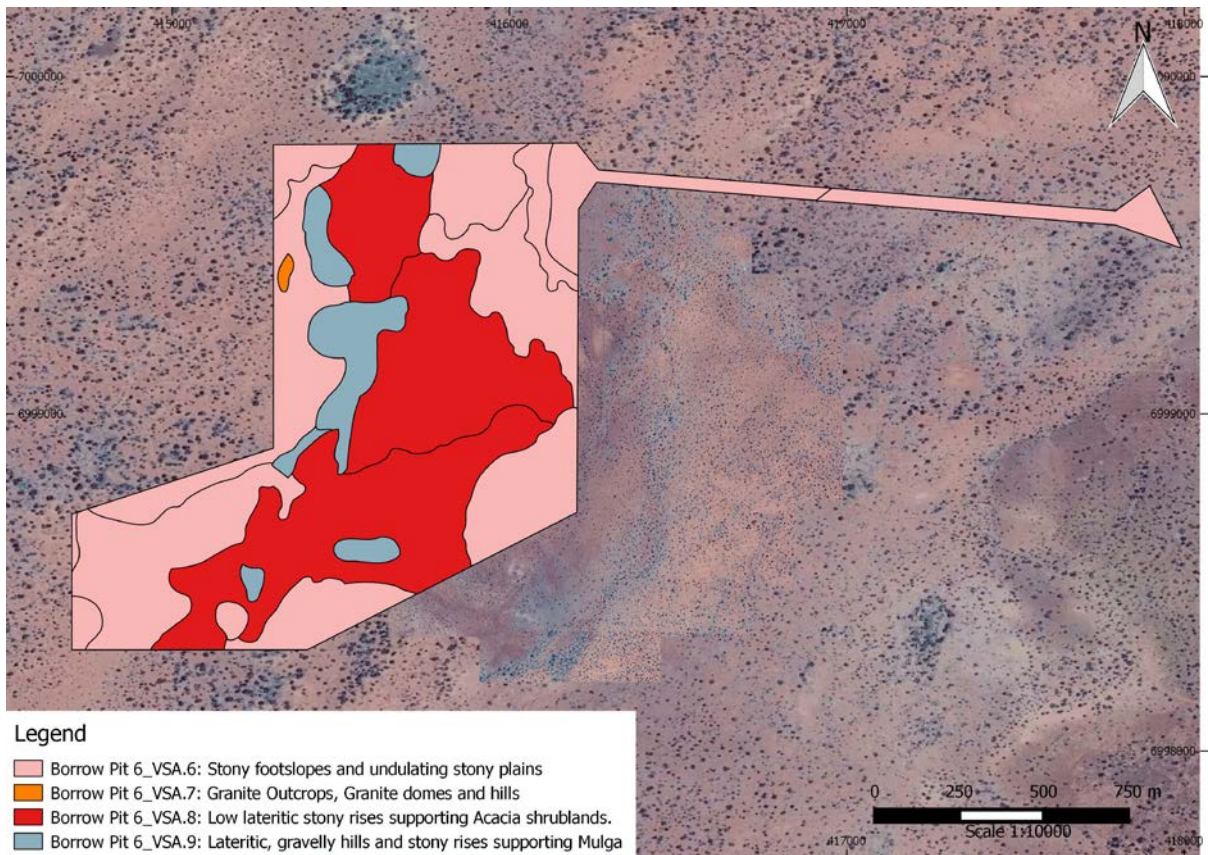


Figure 9. Vegetation and Soil Associations at Borrow Pit 7.

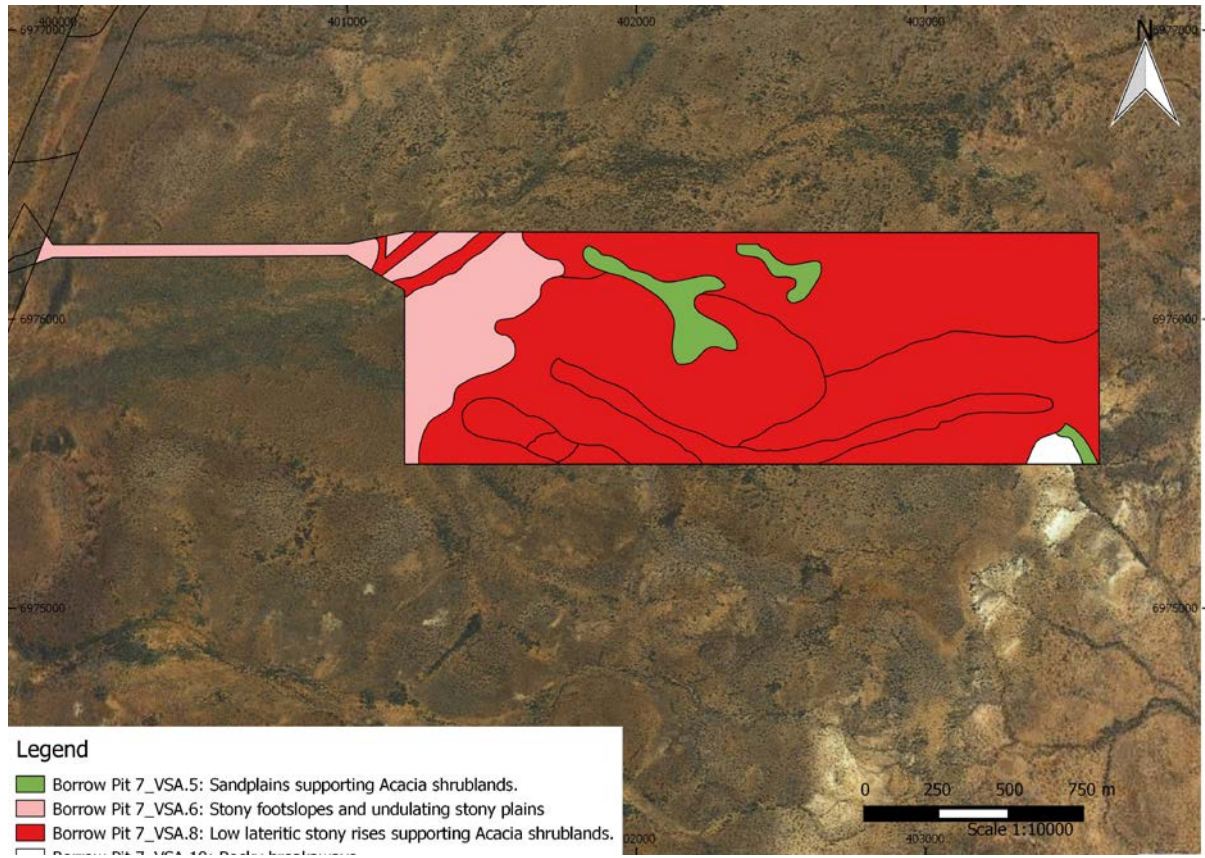


Figure 10. Vegetation and Soil Associations at Borrow Pit 8.

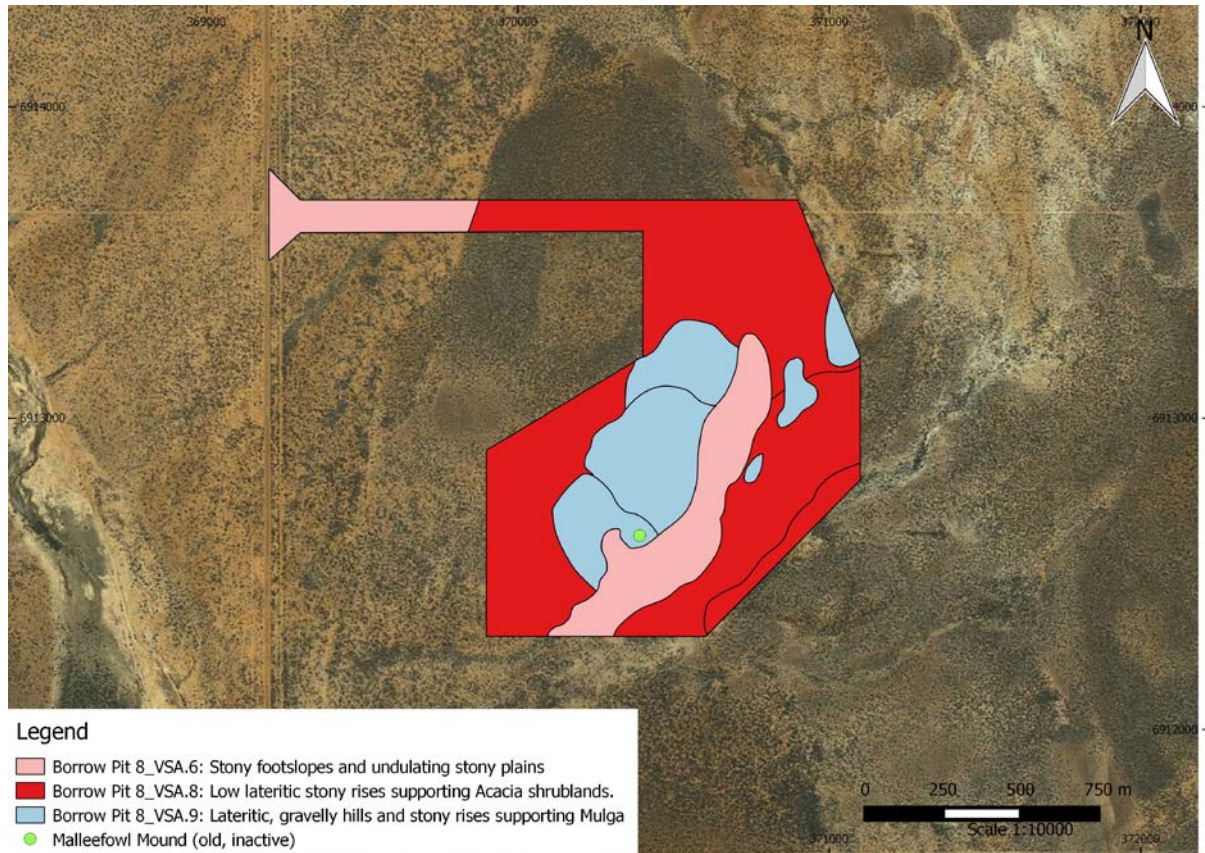
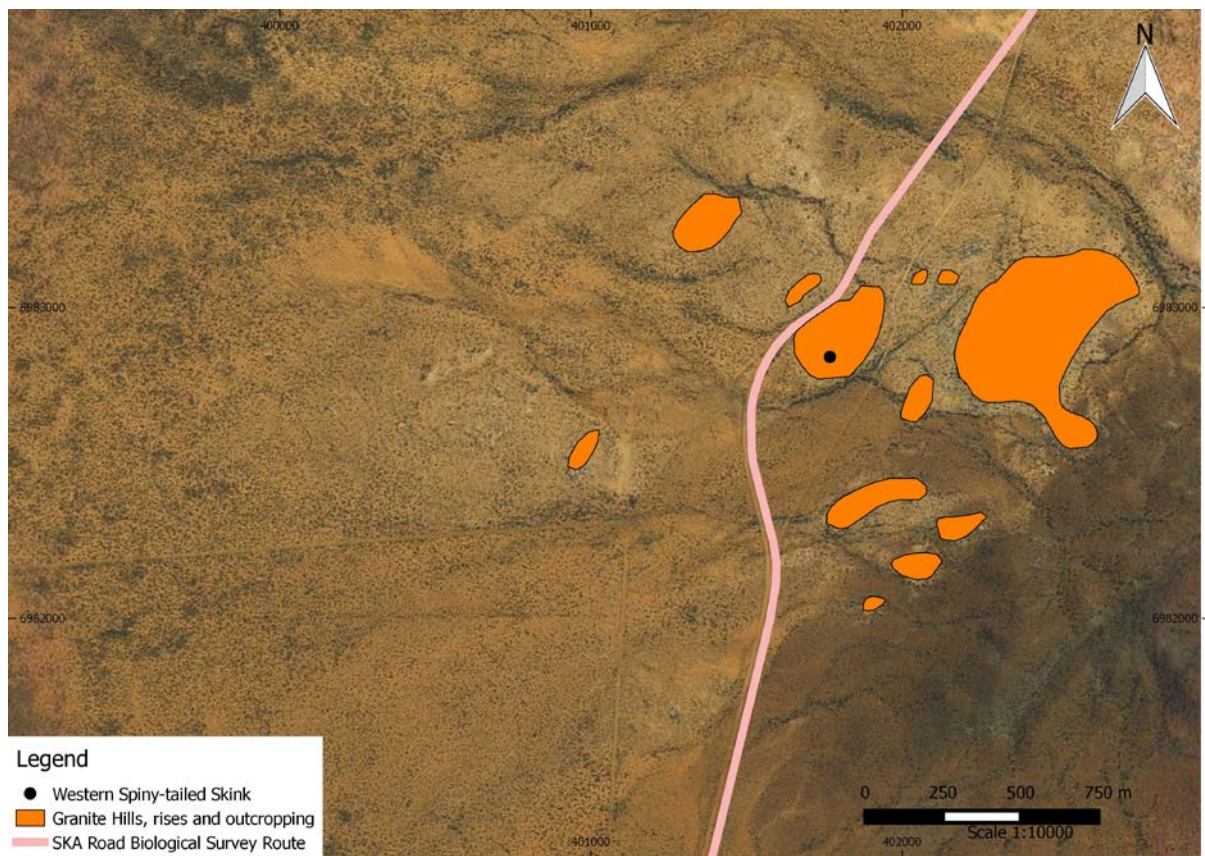


Figure 11. Western Spiny-tailed Skink habitat in the vicinity of the road corridor.



4.3 Vertebrate Fauna

4.3.1 Overview of fauna assemblage

The desktop study identified 286 vertebrate fauna species as potentially occurring in the survey area (see Table 12 and Appendix 5): four freshwater fish, nine frogs, 80 reptiles, 166 birds and 25 native and 10 introduced mammals. The presence of 88 species (two freshwater fish, one frog, nine reptiles, 65 birds, six native mammals and five introduced mammals) was confirmed during the 2016 field survey (see Appendix 6; annotated species list). Note that the expected species assemblage is based largely on databases and includes species that may occur occasionally, but for which it may not be important (such as birds that rarely fly overhead or waterbirds infrequently using temporary or seasonal waterbodies in small numbers). The vertebrate assemblage is likely to be typical of a very large region of arid and semi-arid shrublands across the Yilgarn and Murchison, and includes 28 species of conservation significance (Table 13).

The four fish species expected (two recorded) are all considered to be resident in the drainage systems in the region, and will disperse widely into minor watercourses during flood events.

The nine frog species (one confirmed) are all likely to be locally common and are considered to be residents. All the frog species can be expected to breed in ephemeral freshwater wetlands in the region that form after substantial rainfall events. Such wetlands include pools on and around granite outcrops as well as pools that form along the drainage systems. The one species recorded, the Inland Tree-Frog, occurs around artificial waterbodies but also along major drainage lines.

The 80 reptile species is a very rich assemblage and all species would not be present in one area. It is a rich assemblage because the project area is extensive and includes a wide variety of VSAs. Defining the actual assemblage of individual locations would require very intensive sampling probably over several years. Locations of greatest significance for reptiles are those that are restricted in extent and have specialised species, such as granite outcrops and breakaways (VSAs 7 and 10) and areas of sandy soil (VSA 5). Reptiles are generally considered to be residents and across the 2015 and 2016 surveys 18 of these were confirmed present.

The bird assemblage of 166 species is very rich because of the large region covered by the project and the variety of VSAs, which includes wetlands. Across the 2015 and 2016 surveys, 99 bird species were recorded and of the 102 species considered to be resident, 79 (77.4%) were observed. Of the 24 species considered to be migrants or regular visitors, 15 (62.5%) were observed. The distribution of birds across the landscape will be complex but waterbirds will obviously be associated with wetlands, while a few species have very specific requirements. For example, there are species likely to occur only in VSA 2 (chenopod shrublands). VSAs that provide dense and structurally complex shrublands are likely to be the richest in species.

The extant mammal fauna of 25 native and 10 introduced species is depauperate with at least five locally extinct species. The presence of eight native and five introduced species was confirmed. As with other fauna groups, determining patterns of distribution would require intensive field investigations, but some patterns can be predicted. For example, many of the nine bat species rely

on caves in rocky areas and large trees for roosting. Rocky areas are also favoured by Woolley's *Pseudantechinus*. The key features of the fauna assemblage expected in the survey area are:

- Uniqueness: The assemblage is likely to be typical of the region. The field survey confirmed the presence of numerous reptile, bird and mammal species expected from the region.
- Completeness: The assemblage is likely to be almost complete but with the loss of some mammal species (historical evidence from five species: Lesser Stick-nest Rat, Boodie, Common Brushtail Possum, Pebble-mound Mouse and Black-flanked Rock-Wallaby recorded during the survey). Many of the species expected may only utilise the area occasionally, when conditions are suitable.
- Richness: The assemblage is considered to be moderately rich, as expected for an arid area. Due to the range of substrates and associated vegetation types traversed by the project area, a wide range of reptiles, birds and mammals is expected. Bird richness will be seasonally variable and waterbirds will be restricted to seasonal wetlands and along the Murchison River. Due to the low regional richness, only a small number of freshwater fish are expected and these are restricted to the Murchison River and its tributaries.
- As a fauna value, the most important feature of the site's assemblage is that it is relatively intact and occurs in a largely intact landscape.

Table 12. Composition of vertebrate fauna assemblage of the survey area.

Taxon	Number of species expected	Number of species recorded 2015	Number of species recorded 2016	Number of species in each status category				
				Resident	Migrant or regular visitor	Irregular visitor	Vagrant	Locally extinct
Fish	4	1	2	4	-	-	-	-
Frogs	9	0	1	9	-	-	-	-
Reptiles	80	15	11	80	-	-	-	-
Birds	166	92	65	102	25	24	15	-
Native Mammals	25	5	8	25	-	-	-	5+
Introduced Mammals	10	6	5	9	-	1	-	-
Total	286	120	88	229	25	25	15	5+

4.3.2 Species of conservation significance

The current vertebrate assemblage potentially includes 28 species of conservation significance (Table 13), with a further five conservation significant species considered to be locally extinct. Including these locally extinct species, the overall list of significant species includes 22 CS1 species, five CS2 species and 6 CS3 species. Numbers and classes of significant species broken down by major taxonomic group and still expected to be present are:

Taxon	CS1	CS2	CS3
Fish	0	1	0
Frogs	0	0	0
Reptiles	2	1	0
Birds	16	0	4
Mammals	0	2	2

(excludes five locally extinct CS1 or CS2 species)

The current vertebrate assemblage potentially includes 28 species of conservation significance (Table 13), with a further four conservation significant species considered to be locally extinct. As outlined in Appendix 1, species classed as CS1 are those listed under legislation, while those classed as CS2 are listed as Priority by the Department of Parks and Wildlife. The CS3 class is more subjective, but includes species that have declined across the region and species that occur at the edge of their range. This makes their presence in the survey area significant as populations on the edge of a species' range are often less abundant and more vulnerable to extinction than populations at the centre of the range (Curnutt *et al.* 1996).

Six conservation significant fauna species were recorded during the October 2016 field survey. This included:

- Malleefowl, EPBC Vulnerable (old, abandoned mound recorded at borrow pit 8; bird recently seen by a local pastoralist near borrow pit 8);
- Western Spiny-tailed Skink, EPBC Vulnerable (latrines recorded amongst granite outcrops at Twin Peaks and also borrow pit 2);
- Eastern Great Egret, Schedule 5 of *WA Wildlife Conservation Act 1950*; currently being replaced by the *WA Biodiversity Conservation Act* (recorded from a pool in the Murchison River);
- Common Greenshank, EPBC Migratory (recorded from pools in the Murchison River);
- Rainbow Bee-eater, Schedule 5 of *WA Wildlife Conservation Act 1950* (recorded from borrow pit 8); and
- Australian Bustard (CS3, recorded along road upgrade).

An additional four species were recorded by BCE in the vicinity of the survey area during the 2015 fauna assessment of the region:

1. Shield-backed Trapdoor Spider, EPBC Vulnerable (recorded at several locations along the Carnarvon Mullewa Road);
2. Peregrine Falcon, Schedule 7 (recorded from wetland adjacent to Murchison River);
3. Major Mitchell's Cockatoo, CS3 (recorded at Murchison River); and
4. Bush Stone-curlew, CS3 (one observed along the Carnarvon Mullewa Road).

The locations of conservation significant fauna recorded from the survey area are listed in Table 14 and shown in Figure 12. Conservation significant fauna recorded or expected to occur within the survey area are discussed below.

Table 13. Details on the conservation significant fauna species of the survey area. This list is based on desktop review and their expected status within the site. * denotes species recorded during the survey.

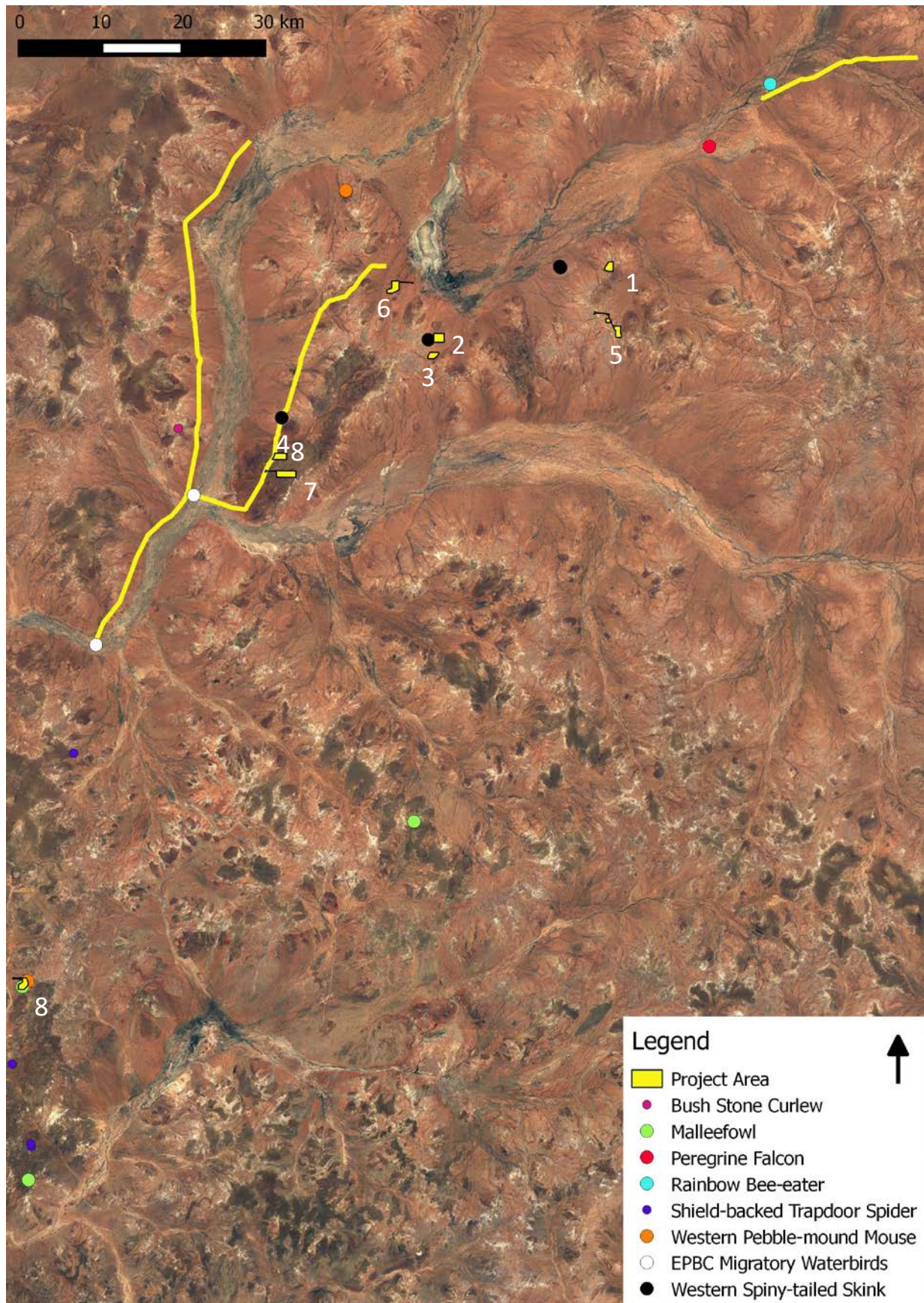
Common Name	Latin Name	Conservation Status			Expected status in project area
		1	2	3	
Fish					
Golden Carp Gudgeon	<i>Hypseleotris aurea</i>		P2		Resident: Murchison River and major tributaries
Reptiles					
Western Spiny-tailed Skink	<i>Egernia stokesii badia</i>	E			*Resident
Gilled Slender Blue-tongue	<i>Cyclodomorphus branchialis</i>	V			Resident
Good-legged Lerista	<i>Lerista eupoda</i>		P1		Resident
Birds					
Malleefowl	<i>Leipoa ocellata</i>	V			Resident
Grey Falcon	<i>Falco hypoleucos</i>	V			Visitor
Peregrine Falcon	<i>Falco peregrinus</i>	S7			Resident
Fork-tailed Swift	<i>Apus pacificus</i>	M			Irregular visitor
Eastern Great Egret	<i>Ardea modesta</i>	M			*Regular visitor
Common Sandpiper	<i>Acitis hypoleucos</i>	M			Irregular visitor
Common Greenshank	<i>Tringa nebularia</i>	M			*Visitor
Marsh Sandpiper	<i>Tringa stagnatalis</i>	M			Irregular visitor
Wood Sandpiper	<i>Tringa glareola</i>	M			Irregular visitor
Red-necked Stint	<i>Calidris ruficollis</i>	M			Irregular visitor
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	M			Irregular visitor
Curlew Sandpiper	<i>Calidris ferruginea</i>	M			Irregular visitor
Glossy Ibis	<i>Plegadis falcinellus</i>	M			Visitor
Night Parrot	<i>Pezoporus occidentalis</i>	E			Vagrant
Rainbow Bee-eater	<i>Merops ornatus</i>	M			*Regular migrant
Slender-billed Thornbill	<i>Acanthiza iredalei</i>			X	Resident
Major Mitchell's Cockatoo	<i>Cacatua leadbeateri</i>			X	Resident
Australian Bustard	<i>Ardeotis australis</i>			X	*Resident
Bush Stone-curlew	<i>Burhinus grallarius</i>			X	Resident
Cattle Egret	<i>Ardea ibis</i>	M			Vagrant
Elegant Parrot	<i>Neophema elegans</i>			X	Occasional visitor
Grey Honeyeater	<i>Conopophila whitei</i>			X	Resident
Mammals					
Long-tailed Dunnart	<i>Sminthopsis longicaudata</i>		P4		Resident
Kultarr	<i>Antechinomys laniger</i>			X	Resident
Inland Long-eared Bat			P4		Resident
Locally Extinct					
Black-flanked Rock-Wallaby	<i>Petrogale lateralis lateralis</i>	E			Locally Extinct
Lesser Stick-nest Rat	<i>Leporillus apicalis</i>	S4			Locally Extinct
Boodie	<i>Bettongia lesueur</i>	S4			Locally Extinct
Common Brushtail Possum	<i>Trichosurus vulpecula</i>			X	Locally Extinct
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>		P4		Locally Extinct

See Appendix 2 for descriptions of conservation significance levels. EPBC Act listed species: V = Vulnerable, E = Endangered, M = Migratory. WC Act listed species: S1 – S7 = Schedule 1 - 7; DPaw Priority Species: P1 - P5 = Priority 1 – 5.

Table 14. Conservation Significant Fauna recorded during the 2016 field assessment. Note 2015 records are included below.

Species	Conservation Status	Easting (Zone 50J)	Northing	Comments
2016				
Malleefowl	CS1	370391	6912623	Old, inactive mound
Malleefowl	CS1	418504	6933314	Malleefowl tracks
Western Spiny-tailed Skink	CS1	401768	6982841	Scat latrine
Western Spiny-tailed Skink	CS1	419884	6992591	Scat latrine
Rainbow Bee-eater	CS1	369579	6913630	2 observed
Eastern Great Egret	CS1	379041	6954681	One observed
Common Greenshank	CS1	379041	6954681	One observed
Common Greenshank	CS1	390965	6973213	One observed
2015				
Shield-backed Trapdoor Spider	CS1	371692	6893113	4 burrows
Shield-backed Trapdoor Spider	CS1	371607	6893418	3 burrows
Shield-backed Trapdoor Spider	CS1	369220	6903148	1 burrow
Shield-backed Trapdoor Spider	CS1	376435	6941350	7 burrows
Malleefowl	CS1	371395	6889008	Old, abandoned mound
Western Spiny-tailed Skink	CS1	436232	7001582	Scat latrine
Western Spiny-tailed Skink	CS1	436132	7001719	Scat latrine
Bush Stone-curlew	CS3	388971	6981401	1 observed
Major Mitchell's Cockatoo	CS3	405726	7014578	1 adult
Peregrine Falcon	CS1	454646	7016611	pair observed
Rainbow Bee-eater	CS1	462168	7024351	2 observed

Figure 12. Locations of Conservation Significant fauna records in the survey area.



Note Borrow Pits are labelled 1-8.

4.3.3 Species of Conservation Significance level 1

Malleefowl (*Leipoa ocellata*) EPBC Vulnerable

One old, abandoned Malleefowl mound was recorded from the survey area, at borrow pit 8 (see Table 14, Figure 12); there was also a recent sighting close to borrow pit 8 by a local pastoralist, and fresh tracks were recorded away from the project area on the Beringarra Pindar Road (Table 14, Figure 12), revealing an extant population persists in the region. In addition, there are several records of the species from the local area (including from Tallering and Twin Peaks Stations, DPaW, 2015; Malleefowl Recovery Team Database, J. Turpin pers. obs.). While no active or recently used mounds were recorded from the survey area, there is suitable habitat for mounds present (dense Acacia shrublands in parts of VSAs 5, 6, 8 and 9), and the species can move over several kilometres (Benshemesh, 1992) so individuals will move through the survey area.

Western Spiny-tailed Skink (*Egernia stokesii badia*) EPBC Endangered

The northern, rock dwelling form of the Western Spiny-tailed Skink is restricted to a select, small number of granite outcrops, scattered through the Murchison from Boolardy Station in the north to near Yalgoo in the south, and lives communally within deep rock crevices. The species was recorded from the survey area with scat latrines located amongst granite boulders on the Twin Peaks Wooleen Road and also adjacent to Borrow Pit 2 (Table 14, Figures 12, 13 and 14). The skink was also recorded during the 2015 fauna assessment near the SKA project area, and there are scattered records from across the local area (DPaW, 2015).

Figure 13. Western Spiny-tailed Skink scat latrines recorded during the survey.



Figure 14. Western Spiny-tailed Skink habitat recorded during the survey along the western section of the road.



Gilled Slender Blue-tongue (*Cyclodomorphus branchialis*) WCA Schedule 3 (Vulnerable)

The Gilled Slender Blue-tongue inhabits semi-arid shrublands on heavy red soils with a small number of records scattered through the region (e.g. 15 km north of Mullewa and Mount Magnet, DPaW, 2015). South of the survey area, it has been recorded on the slopes of ironstone hills (BCE database). Due to the presence of suitable habitat (such as the undulating, stony terrain near Tallering Peak), this species has the potential to occur within the survey area.

Fork-tailed Swift (*Apus pacificus*) EPBC Migratory, Rainbow Bee-eater (*Merops ornatus*) Schedule 5

The Fork-tailed Swift is largely aerial but may fly over the project area occasionally. The Rainbow Bee-eater is an abundant, ground-nesting species that catches insects on the wing over a range of environments. It is a summer, breeding visitor to the South-West of WA and is likely to be present annually in the survey area.

Grey Falcon (*Falco hypoleucos*) WCA Schedule 3 (Vulnerable)

The Grey Falcon inhabits grasslands on open plains, low acacia shrublands and occurs along Eucalypt-lined drainage systems. Although this species has declined across parts of its range, it is still widespread across arid and semi-arid inland of Australia, with populations concentrated around inland drainage systems. It is considered an occasional visitor in the region (Storr, 1985a; 1985b). The Grey Falcon has been recorded on Wooleen Station (BirdLife Australia, 2015) and is likely to be an occasional visitor to the survey area.

Peregrine Falcon (*Falco peregrinus*) WCA Schedule 7 (Other Specially Protected Fauna)

The Peregrine Falcon is found in a variety of environments, including rocky ledges, cliffs, watercourses, open woodland and acacia shrublands. It nests on cliff faces, in tree hollows and in large abandoned nests of other birds (Birds Australia, 2012). The distribution of the Peregrine Falcon is often tied to the abundance of prey as this species prey heavily on other birds. Blakers *et al.* (1984) consider that Australia is one of the strongholds of the species, since it has declined in many other parts of the world. The Peregrine Falcon was recorded foraging in the vicinity of a semi-permanent pool adjacent to the Murchison River in October 2015 (pair recorded, preying on an abundance of waterbirds, see Table 13). It is likely to be resident in the survey area and may breed along the Eucalypt-lined drainage systems.

EPBC listed Migratory Birds (also WCA Schedule 5)

The Eastern Great Egret (*Ardea modesta*), Common Sandpiper (*Acitis hypoleucos*), Common Greenshank (*Tringa nebularia*), Marsh Sandpiper (*Tringa stagnatalis*), Wood Sandpiper (*Tringa glareola*), Red-necked Stint (*Calidris ruficollis*), Sharp-tailed Sandpiper (*Calidris acuminata*) and Curlew Sandpiper (*Calidris ferruginea*) are listed as Migratory under the EPBC Act or under Schedule 5 of the *Wildlife Conservation Act 1950*. All are migratory, and generally associate with waterbodies and riparian areas. The Curlew Sandpiper is also listed as Critically Endangered under the EPBC Act. All have the potential to be occasional visitors in small numbers to seasonal wetland areas and along the margins of the Murchison River. The Great Egret and Common Greenshank were recorded from pools along the Murchison River during the 2016 survey.

4.3.4 *Species of Conservation Significance level 2*

Long-tailed Dunnart (*Sminthopsis longicaudata*) DPaW Priority 4

The Long-tailed Dunnart inhabits rocky areas, such as banded ironstone hills and ridges. The species has been recorded by BCE in the region at Weld Range (80 km east of the survey area). Suitable habitat occurs within the survey area, particularly associated with the undulating hills in the vicinity of Tallering Peak. Due to the presence of suitable habitat, a resident population of the Long-tailed Dunnart is likely in the project area.

Inland Long-eared Bat (*Nyctophilus major tor*) DPaW Priority 4.

Shelters in tree hollows and crevices and forages widely, so anticipated to be a resident across the survey area but potentially reliant on large trees along drainage lines for roosting.

Golden Carp Gudgeon (*Hypseleotris aurea*) DPaW Priority 2

The Golden Carp Gudgeon occurs in pools along the Murchison River, with records both upstream and downstream of the Murchison River crossings associated with the project (DPaW, 2015). It is able to tolerate high salinity levels and is likely to occur in the vicinity of the project area in permanent pools. It will also disperse during periods of high water levels.

Good-legged Lerista (*Lerista eupoda*) DPaW Priority 1

Lerista eupoda is listed as Priority 1 due to its restricted range, occurring only in the vicinity of Meekatharra, Cue and Weld Range. At Weld Range the species occurs in a range of environments, ranging from the crests of banded ironstone hills, gravelly footslopes supporting Acacia shrublands,

drainage lines and Eucalypt Woodland in sandy areas (J. Turpin pers. obs.). The species may be resident in the survey area due to the known presence of a nearby population and the availability of suitable habitat.

4.3.5 *Species of Conservation Significance level 3*

Australian Bustard (*Ardeotis australis*) CS3

The Australian Bustard is nomadic and may range over very large areas, largely dependent on rainfall and hence food availability. It is likely to be an irregular visitor to the project area and has been previously recorded on Wooleen Station (BirdLife Australia, 2015).

Bush Stone-curlew (*Burhinus grallarius*) CS3

The Bush Stone-curlew was formerly listed as a Priority species by DPaW. It is listed here as CS3 due to the decline of the species in southern and arid parts of its range where it is now uncommon. Scattered records occur along the Murchison River (BirdLife Australia, 2015) and the species was recorded from the local area during the 2015 assessment (see Table 13). Due to the presence of suitable habitat throughout the survey area, this species is highly likely to occur across the survey area.

Major Mitchell's Cockatoo (*Cacatua leadbeateri*) CS3

Major Mitchell's Cockatoo has a restricted range across the general region, concentrating along the Eucalypt-fringed Murchison River (J. Turpin pers. obs.). This species was recorded along the Murchison River during the 2015 survey when a single adult bird was observed roosting in a eucalypt tree, indicating the possibility of a breeding female nearby in a tree hollow. This species is likely to breed within the large, hollow-bearing eucalypt trees fringing the Murchison River and associated drainages.

Elegant Parrot (*Neophema elegans*) CS3

The Elegant Parrot occurs principally within the south-west of Western Australia, although small numbers occasionally move north through the region (J. Turpin, pers. obs.). The Elegant Parrot has been previously recorded on Wooleen Station and in the arid zone has been observed feeding on Acacias near the fringes of seasonal waterbodies (J. Turpin, pers. obs.). This species is likely to be an occasional visitor to the survey area.

Slender-billed Thornbill (*Acanthiza iredalei*) CS3

The Slender-billed Thornbill inhabits chenopod shrublands that are dominated by samphires or *Maireana* and *Atriplex* associations (DoTE, 2015). It has a scattered distribution across the Murchison, with records from Coolcalalaya (fringing the Murchison River, BirdLife Australia, 2015) and from Mungada (J. Turpin, pers. obs.). The survey corridor passes through a stretch of approximately 6km of suitable samphire habitat flanking the Murchison River and while surveys in this location failed to find the species, it is assumed to be present.

Grey Honeyeater (*Conopophila whitei*) CS3

The Grey Honeyeater is sparsely distributed throughout inland Australia. It is often recorded in association with flowering acacias. The Grey Honeyeater has been previously recorded on Wooleen Station and is likely to occur within the survey area.

Kultarr (*Antechinomys laniger*) CS3

The Kultarr has declined significantly over parts of its range, but appears secure in Western Australia. The Kultarr is uncommon across the region and has been recorded on Wooleen Station (DPaW, 2015). In the region, it inhabits sparsely vegetated, stony plains and Acacia shrublands on hardpan. Due to the presence of suitable habitat and nearby records, the Kultarr is likely to occur within the survey area.

4.3.6 Conservation significant invertebrates

The Shield-backed Trapdoor Spider has been recorded from the local area and is discussed below. Overall, the project area generally lacks the distinctive and isolated geological features known to promote short-range endemism in invertebrates (such as isolated rocky ridges, deep caves or relictual habitats), with the exception of granite outcrops and well-developed breakaways (VSAs 7 and 10).

Shield-backed Trapdoor Spider (*Idiosoma nigrum*) EPBC Vulnerable

The Shield-backed Trapdoor Spider occurs throughout the Murchison, from Jack Hills in the north and extends south to the Western Australian Wheatbelt (DPaW, 2015). In the Murchison, the species favours dense Acacia shrublands, often on gravelly rises or at the footslopes of hills. Burrows of the Shield-backed Trapdoor Spider were recorded during the 2015 assessment (locations given in Figure 12), but were not recorded from the 2016 survey area. The Shield-backed Trapdoor Spider is associated with the slopes and hills of gravelly and rocky ranges in the region and has been previously recorded at Tallering Peak, Weld Range and Jack Hills (BCE records). It therefore has the potential to occur in VSAs 6, 8 and 9, which are widespread in the survey area. However, given that no spiders were found during field investigations, the populations may occur at very low densities or may be very localised.

4.3 Patterns of biodiversity

Patterns of biodiversity can be interpreted from sample data, field observations (including trapping and censusing results) and the characteristics of the VSAs described above. Within the project area, significant areas for fauna biodiversity include water sources (providing for a large range and concentration of fauna), linear environments (allowing for the movement of fauna) and restricted environments (supporting specialised and/or range-restricted fauna). These include:

1. Major drainage lines (VSA 1): the Murchison River is fringed with large mature trees providing roosting and breeding sites for several species (e.g. Major Mitchell's Cockatoo), contains seasonal and permanent pools supporting freshwater fish, waders (e.g. Common Greenshank) and other waterbirds, and provides linkage across the landscape;
2. Chenopod shrublands close to drainage systems (VSA 2): likely to have a distinctive fauna including the Slender-billed Thornbill;
3. Granite Outcrops (VSA 7): support a highly restricted fauna assemblage including the Western Spiny-tailed Skink.
4. Rocky, lateritic hills supporting dense Acacia shrublands (VSA 8) support the conservation significant Malleefowl and Shield-backed Trapdoor Spider. VSA 8 in borrow pit 8 includes an area where moisture retention appeared to be greater than nearby, creating a possible mesic refugium.
5. Sandplain (VSA 5) appears to be very restricted in the area, is likely to support a different reptile assemblage from VSAs with gravelly, rocky or clayey substrates, and within the survey area was recorded only in borrow pit 8.

Concentrations of fauna were observed around water sources and along drainage lines. The presence of water, breeding and roosting sites (tree hollows in mature eucalypts) and an intact Eucalypt canopy supported a higher abundance and richness of many birds, compared with the surrounding, less vegetated plains. Water-associated birds were only recorded from the Murchison River. The riparian vegetation along the river and drainage lines also supported elevated numbers of parrots and Eucalypt canopy specialists (such as the Striated Pardalote, Weebill and White-plumed Honeyeater). Permanent and semi-permanent pools were also observed within and adjacent to the Murchison River, supporting several waterbirds and freshwater fish.

Any waterway is usually of significance as it provides a unique environment for aquatic and riparian species such as waterbirds. The river within the survey area also provides connectivity along the river system through the landscape. The presence of large eucalypt trees containing hollows is likely to influence patterns of distribution of fauna that rely on such hollows for breeding, such as parrots and cockatoos.

4.4 Ecological processes

The nature of the landscape and the fauna assemblage indicate some of the ecological processes that may be important for ecosystem function (see Appendix 4 for descriptions and other ecological processes). These include:

Local hydrology. Hydrology will be important for all VSAs as the Murchison and Roderick Rivers are major systems influencing biodiversity of much of the region. Additionally, most of the plain VSAs are dominated by Mulga, the distribution of which is highly influenced by surface hydrology (run-on and runoff). Mulga groves are dependent on sheet flow (e.g. for the capture and transfer of nutrients) and so developments that obstruct the flow of sheet flow (roads, rail, pipelines) can affect the ecological community downslope of the development. Given that mulga may be impacted by altered surface flows, identifying and mapping sheetflow sensitive mulga vegetation may be important for the project. There was evidence of Mulga death along one side of some sections of the existing road, likely due to altered surface hydrology. One area of VSA 8 (gravelly rise supporting Mulga) in borrow pit 8 had particularly dense groves of trees and persisting everlasting flowers, suggesting that at least some gravelly rises may have retained moisture which could be significant for fauna.

Fire. The survey area is dominated by open Mulga shrublands and does not contain VSAs prone to regular fire (such as Spinifex grasslands). However, Mulga can be sensitive to fire. While appropriate fire regimes can benefit biodiversity, inappropriate regimes can lead to a loss of biodiversity.

Feral species and interactions with over-abundant native species. Feral species occur throughout Western Australia and are a major component of the current mammal fauna of the survey area. They have contributed to local extinction and may be affecting populations of extant species. The landscape and vegetation has also been altered through grazing by feral species, such as the Rabbit and Goat, and by livestock. Some native species may be over-abundant due to the provision of watering points by pastoralists, and these may also have altered the environment and affected other species.

Habitat degradation due to weed invasion. There was little evidence of weed invasion in most VSAs throughout the survey corridor, but the development has the potential to increase habitat degradation through weed invasion. This in turn will impact on fauna when vegetation density changes. The riverine woodland is expected to be the most impacted/susceptible to impact due to factors including soil disturbance from cattle grazing and regular water movement.

Connectivity and landscape permeability. The survey area is part of a vast region of native vegetation, but linear environments such as drainage lines and associate vegetation provide connectivity. Importantly, restricted VSAs are scattered across the landscape which means that granite areas (VSA 7), for example, are often isolated from each other.

5 Summary of Fauna Values

The desktop study identified 286 vertebrate fauna species as potentially occurring in the survey area (four freshwater fish, nine frogs, 80 reptiles, 166 birds and 25 native and 10 introduced mammals). The presence of 88 species (two freshwater fish, one frog, nine reptiles, 65 birds, six native mammals and five introduced mammals) was confirmed during the 2016 field survey (see Appendices 5 and 6). The vertebrate assemblage includes 28 species of conservation significance (Table 12).

Fauna values within the study area can be summarised as follows (see Table 15):

Fauna assemblage. Considered to be relatively intact, within a relatively intact, largely uncleared landscape. Most species considered to be widespread as the survey area passes through a very extensive region of broadly similar environments. Some mammal species are considered locally extinct. A large number of birds are restricted to the major riverine environments with additional species likely to breed there (Major Mitchell's Cockatoo and Cockatiel). A number of saxicoline species (associated with rocky outcrops) are restricted to rocky areas (e.g. Western Spiny-tailed Skink and Woolley's Pseudantechinus).

Species of conservation significance. A total of 28 species of conservation significance have the potential to be present at least occasionally within the project area. Six conservation significant species were recorded within the project area and an additional four have been recorded in nearby areas. The Western Spiny-tailed Skink, Malleefowl, Major Mitchell's Cockatoo, Peregrine Falcon and Bush Stone-curlew are likely to have resident populations in the project area. The Rainbow Bee-eater, Eastern Great Egret and Common Greenshank are regular migrants to the area. The Shield-backed Trapdoor Spider is known to occur nearby and is thus considered to be resident in suitable environments, although was not found.

Several additional species are known from the local area and are anticipated to reside or regularly visit the project area. These include the Golden Carp Gudgeon, Gilled Slender Blue-tongue, Australian Bustard, Long-tailed Dunnart and two locally significant birds (Elegant Parrot, Grey Honeyeater). Several conservation significant waterbirds also have the potential to be occasional visitors to seasonal wetland areas and along the margins of the Murchison River.

Vegetation and Substrate Associations (VSAs). The majority of the survey area is composed of VSAs considered widespread in the region (such as open Acacia dominated shrublands on hardpan and wash plains). Ten VSAs were identified across the survey area and surrounding landscape. VSAs of particular significance include:

- Major drainage lines (VSA 1): the Murchison and Roderick Rivers are fringed with large mature trees providing roosting and breeding sites for several species (e.g. Major Mitchell's Cockatoo), contains seasonal and permanent pools supporting freshwater fish, waders and waterbirds and provides linkage across the landscape;
- Granite Outcrops (VSA 7): support a highly-restricted fauna assemblage including the Western Spiny-tailed Skink.

- Rocky, lateritic hills and breakaways supporting dense Acacia shrublands support the conservation significant Malleefowl and Shield-backed Trapdoor Spider.
- Floodplain depressions supporting chenopod shrublands (providing habitat for the Slender-billed Thornbill).

Patterns of biodiversity. Biodiversity is likely to be spread across most VSAs, however some areas support a concentration of fauna, an elevated richness or abundance of fauna or highly specialised species restricted to particular habitats. The most significant areas for fauna are considered to be major drainage lines (the Murchison and Roderick Rivers), granite outcrops, sandplains and rocky breakaways.

Key ecological processes. One of the dominant ecological processes currently affecting the fauna assemblage in the survey area is hydrology, with other significant processes including fire, feral species and interactions with native species, habitat degradation due to weed invasion and connectivity. Surface and sub-surface hydrology is sensitive to change across most VSAs, while Riverine and riparian environments are sensitive to weed invasion.

Table 15. Summary of Fauna Values at each Borrow Pit and road corridor. Note X= recorded, L = likely to occur (suitable habitat present), Blank spaces = unlikely due to lack of habitat

Fauna Values	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Pit 7	Pit 8	Road (West)	Road (East)
Shield-backed Trapdoor Spider	L	L	L	L	L	L	L	L	L	
Malleefowl				L	L		L	X		
Slender-billed Thornbill									L	
Bush Stone-curlew	L	L	L	L	L	L	L	L	X	L
Major Mitchell's Cockatoo	L	L	L	L	L	L	L	L	L	L
Peregrine Falcon	L	L	L	L	L	L	L	L	L	L
Western Spiny-tailed Skink		L	L						X	
Rainbow Bee-eater	L	L	L	L	L	L	L	X	L	L
Golden-carp Gudgeon									L	
Gilled Slender Blue-tongue					L			L	L	
Long-tailed Dunnart	L	L	L	L	L	L	L	L	L	
Grey Honeyeater		L		L	L	L	L	L	L	L
Migratory Waterbirds									X	
Sensitive / Significant VSAs					X		X	X	X	X
Granite Outcrops		Near			X				X	
Drainage lines									X	X
Floodplain depressions									X	X
Gravelly slopes with dense Mulga				X	X	X	X	X	X	X

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8 Appendices

Appendix 1. Explanation of fauna values.

Fauna values are the features of a site and its fauna that contribute to biodiversity, and it is these values that are potentially at threat from a development proposal. Fauna values can be examined under the five headings outlined below. It must be stressed that these values are interdependent and should not be considered equal, but contribute to an understanding of the biodiversity of a site. Understanding fauna values provides opportunities to predict and therefore mitigate impacts.

Assemblage characteristics

Uniqueness. This refers to the combination of species present at a site. For example, a site may support an unusual assemblage that has elements from adjacent biogeographic zones, it may have species present or absent that might be otherwise expected, or it may have an assemblage that is typical of a very large region. For the purposes of impact assessment, an unusual assemblage has greater value for biodiversity than a typical assemblage.

Completeness. An assemblage may be complete (i.e. has all the species that would have been present at the time of European settlement), or it may have lost species due to a variety of factors. Note that a complete assemblage, such as on an island, may have fewer species than an incomplete assemblage (such as in a species-rich but degraded site on the mainland).

Richness. This is a measure of the number of species at a site. At a simple level, a species rich site is more valuable than a species poor site, but value is also determined, for example, by the sorts of species present.

Vegetation/substrate associations (VSAs)

VSAs combine broad vegetation types, the soils or other substrate with which they are associated, and the landform. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. The term habitat is widely used in this context, but by definition an animal's habitat is the environment that it utilises (Calver *et al.* 2009), not the environment as a whole. Habitat is a function of the animal and its ecology, rather than being a function of the environment. For example, a species may occur in eucalypt canopy or in leaf-litter on sand, and that habitat may be found in only one or in several VSAs. VSAs are not the same as vegetation types since these may not incorporate soil and landform, and recognise floristics to a degree that VSAs do not. Vegetation types may also not recognise minor but often significant (for fauna) structural differences in the environment. VSAs also do not necessarily correspond with soil types, but may reflect some of these elements.

Because VSAs provide the habitat for fauna, they are important in determining assemblage characteristics. For the purposes of impact assessment, VSAs can also provide a surrogate for detailed information on the fauna assemblage. For example, rare, relictual or restricted VSAs should automatically be considered a significant fauna value. Impacts may be significant if the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna. The

disturbance of even small amounts of habitat in a localised area can have significant impacts to fauna if rare or unusual habitats are disturbed.

Patterns of biodiversity across the landscape

This fauna value relates to how the assemblage is organised across the landscape. Generally, the fauna assemblage is not distributed evenly across the landscape or even within one VSA. There may be zones of high biodiversity such as particular environments or ecotones (transitions between VSAs). There may also be zones of low biodiversity. Impacts may be significant if a wide range of species is affected even if most of those species are not significant per se.

Species of conservation significance

Species of conservation significance are of special importance in impact assessment. The conservation status of fauna species in Australia is assessed under Commonwealth and State Acts such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Western Australian Wildlife Conservation Act 1950* (Wildlife Conservation Act; currently being replaced by the *WA Biodiversity Conservation Act*). In addition, the Western Australian Department of Environment and Conservation (DEC), now DPaW, recognises priority levels, while local populations of some species may be significant even if the species as a whole has no formal recognition. Therefore, three broad levels of conservation significance can be recognised and are used for the purposes of this report, and are outlined below. A full description of the conservation significance categories, schedules and priority levels mentioned below is provided in Appendix 2.

Conservation Significance (CS) 1: Species listed under State or Commonwealth Acts.

Species listed under the EPBC Act are assigned to categories recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), or are listed as migratory. Migratory species are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA), the Republic of South Korea Australia Migratory Bird Agreement (ROKAMBA), and/or the Convention on the Conservation of Migratory Species of Wild Animals (CMS; also referred to as the Bonn Convention). The Wildlife Conservation Act uses a series of Schedules to classify status, but also recognizes the IUCN categories and ranks species within the Schedules using the categories of Mace and Stuart (1994).

Conservation Significance (CS) 2: Species listed as Priority by the DEC but not listed under State or Commonwealth Acts.

In Western Australia, the DEC has produced a supplementary list of Priority Fauna, being species that are not considered threatened under the Wildlife Conservation Act but for which the DEC feels there is cause for concern. Some Priority species are also assigned to the Conservation Dependent category of the IUCN.

Conservation Significance (CS) 3: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

This level of significance has no legislative or published recognition and is based on interpretation of distribution information, but is used here as it may have links to preserving biodiversity at the

genetic level (EPA 2002). If a population is isolated but a subset of a widespread (common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Conservation significance is applied to allow for the preservation of genetic richness at a population level, and not just at a species level. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3, as may colonies of waterbirds. The Western Australian Department of Environmental Protection, now DPaW, used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of the Perth Bushplan (DEP 2000).

Invertebrate species considered to be short range endemics (SREs) also fall within the CS3 category, as they have no legislative or published recognition and their significance is based on interpretation of distribution information. Harvey (2002) notes that the majority of species that have been classified as short-range endemics have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of short-range endemic species: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the short-range endemic species hinders their conservation (Harvey 2002).

Introduced species

In addition to these conservation levels, species that have been introduced (INT) are indicated throughout the report. Introduced species may be important to the native fauna assemblage through effects by predation and/or competition.

Ecological processes upon which the fauna depend

These are the processes that affect and maintain fauna populations in an area and as such are very complex; for example, populations are maintained through the dynamic of mortality, survival and recruitment being more or less in balance, and these are affected by a myriad of factors. The dynamics of fauna populations in a project may be affected by processes such as fire regime, landscape patterns (such as fragmentation and/or linkage), the presence of feral species and hydrology. Impacts may be significant if processes are altered such that fauna populations are adversely affected, resulting in declines and even localised loss of species. Threatening processes as outlined in Appendix 3 are effectively the ecological processes that can be altered to result in impacts upon fauna.

Appendix 2. Categories used in the assessment of conservation status.

IUCN categories (based on review by Mace and Stuart 1994) as used for the *Environment Protection and Biodiversity Conservation Act 1999* and the *Western Australian Wildlife Conservation Act 1950* (and under the *WA Biodiversity Conservation Act*)

Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild (Ex)	Taxa known to survive only in captivity.
Critically Endangered (CR)	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (E)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (V)	Taxa facing a high risk of extinction in the wild in the medium-term future.
Near Threatened	Taxa that risk becoming Vulnerable in the wild.
Conservation Dependent	Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.
Data Deficient (Insufficiently Known)	Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.
Least Concern.	Taxa that are not Threatened.

Schedules used in the *WA Wildlife Conservation Act 1950* and the *WA Biodiversity Conservation Act*.

Schedule 1 (S1)	Critically Endangered fauna.
Schedule 2 (S2)	Endangered fauna
Schedule 3 (S3)	Vulnerable Migratory species listed under international treaties.
Schedule 4 (S4)	Presumed extinct fauna
Schedule 5 (S5)	Migratory birds under international agreement
Schedule 6 (S6)	Conservation dependant fauna
Schedule 7 (S7)	Other specially protected fauna

WA Department of Environment and Conservation Priority species (species not listed under the *Wildlife Conservation Act 1950* / *WA Biodiversity Conservation Act* but for which there is some concern).

Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4. (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change.
Priority 5 (P5)	Taxa in need of monitoring. Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years (IUCN Conservation Dependent).

Appendix 3. Explanation of threatening processes.

Potential impacts of proposed developments upon fauna values can be related to threatening processes. This is recognised in the literature and under the EPBC Act, in which threatening processes are listed (see Appendix 4). Processes that may impact fauna values are discussed below. Rather than being independent of one another, processes are complex and often interrelated. They are the mechanisms by which fauna can be affected by development. Impacts may be significant if large numbers of species or large proportions of populations are affected.

Loss of habitat affecting population survival

Clearing for a development can lead to habitat loss for a species with a consequent decline in population size. This may be significant if the smaller population has reduced viability. Conservation significant species or species that already occur at low densities may be particularly sensitive to habitat loss affecting population survival.

Loss of habitat leading to population fragmentation

Loss of habitat can affect population movements by limiting movement of individuals throughout the landscape as a result of fragmentation. Obstructions associated with the development, such as roads, pipes and drainage channels, may also affect movement of small, terrestrial species. Fragmented populations may not be sustainable and may be sensitive to effects such as reduced gene flow.

Degradation of habitat due to weed invasion leading to population decline

Weed invasion can occur as a result of development and if this alters habitat quality, can lead to effects similar to habitat loss.

Increased mortality

Increased mortality can occur during project operations; for example from roadkill, animals striking infrastructure and entrapment in trenches. Roadkill as a cause of population decline has been documented for several medium-sized mammals in eastern Australia (Dufty 1989, Jones 2000). Increased mortality due to roadkill is often more prevalent in habitats that have been fragmented (Scheick & Jones 1999; Clewenger & Waltho 2000; Jackson & Griffin 2000).

Increased mortality of common species during development is unavoidable and may not be significant for a population. However, the cumulative impacts of increased mortality of conservation significant species or species that already occur at low densities may have a significant impact on the population.

Species interactions, including predation and competition

Changes in species interactions often occur with development. Introduced species, including the feral Cat, Red Fox and Rabbit may have adverse impacts upon native species and development can alter their abundance. In particular, some mammal species are very sensitive to introduced predators and the decline of many mammals in Australia has been linked to predation by the Red Fox, and to a lesser extent the feral Cat (Burbidge & McKenzie 1989). Introduced grazing species, such as the Rabbit, Goat, Camel and domestic livestock, can also degrade habitats and deplete vegetation that may be a food source for other species.

Changes in the abundance of some native species at the expense of others, due to the provision of fresh watering points, can also be a concern. (Harrington 2002) found the presence of artificial fresh waterpoints in the semi-arid mallee rangelands to influence the abundance and distribution of certain bird species. Common, water-dependent birds were found to out-compete some less common, water-independent species. Over-abundant native herbivores, such as kangaroos, can also adversely affect less abundant native species through competition and displacement.

Hydroecology

Interruptions of hydroecological processes can have major effects because they underpin primary production in ecosystems and there are specific, generally rare habitats that are hydrology-dependent. Fauna may be impacted by potential changes to groundwater level and chemistry and altered flow regime. These changes may alter vegetation across large areas and may lead to habitat degradation or loss. Impacts upon fauna can be widespread and major.

Changes to flow regime across the landscape may alter vegetation and may lead to habitat degradation or loss, affecting fauna. For example, Mulga has a shallow root system and relies on surface sheet flow during flood events. If surface sheet flow is impeded, Mulga can die (Kofoed 1998), which may impact on a range of fauna associated with this vegetation type.

Fire

The role of fire in the Australian environment and its importance to vertebrate fauna has been widely acknowledged e.g. (Gill *et al.* 1981; Fox 1982; Letnic *et al.* 2004). Fire is a natural feature of the environment but frequent, extensive fires may adversely impact some fauna, particularly mammals and short-range endemic species. Changes in fire regimes, whether to more frequent or less frequent fires, may be significant to some fauna. Impacts of severe fire may be devastating to species already occurring at low densities or to species requiring long unburnt habitats to survive. Fire management may be considered the responsibility of managers of large tracts of land.

Dust, light, noise and vibration

Impacts of dust, light, noise and vibration upon fauna are difficult to predict. Some studies have demonstrated the impact of artificial night lighting on fauna, with lighting affecting fauna behaviour more than noise (Rich & Longcore 2006). Effects can include impacts on predator-prey interactions, changes to mating and nesting behaviour, and increased competition and predation within and between invertebrates, frogs, birds and mammals.

The death of very large numbers of insects has been observed around some remote mine sites and attracts other fauna, notably native and introduced predators (M. Bamford pers. obs). The abundance of some insects can decline due to mortality around lights, although this has previously been recorded in fragmented landscapes where populations are already under stress (Rich & Longcore 2006). Artificial night lighting may also lead to disorientation of migratory birds. Aquatic habitats and open habitats such as grasslands and dunes may be vulnerable to light spill.

Appendix 4. Ecological and threatening processes identified under legislation and in the literature.

Ecological processes are processes that maintain ecosystems and biodiversity. They are important for the assessment of impacts of development proposals, because ecological processes make ecosystems sensitive to change. The issue of ecological processes, impacts and conservation of biodiversity has an extensive literature. Following are examples of the sorts of ecological processes that need to be considered.

Ecological processes relevant to the conservation of biodiversity in Australia (Soule *et al.* 2004):

- Critical species interactions (highly interactive species);
- Long distance biological movement;
- Disturbance at local and regional scales;
- Global climate change;
- Hydroecology;
- Coastal zone fluxes;
- Spatially-dependent evolutionary processes (range expansion and gene flow); and
- Geographic and temporal variation of plant productivity across Australia.

Threatening processes (EPBC Act)

Under the EPBC Act, a key threatening process is an ecological interaction that threatens or may threaten the survival, abundance or evolutionary development of a threatened species or ecological community. There are currently 20 key threatening processes listed by the federal Department of the Environment (DotE 2014b):

- Competition and land degradation by rabbits.
- Competition and land degradation by unmanaged goats.
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*).
- Incidental catch (bycatch) of Sea Turtle during coastal otter-trawling operations within Australian waters north of 28 degrees South.
- Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations.
- Infection of amphibians with chytrid fungus resulting in chytridiomycosis.
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris.
- Invasion of northern Australia by Gamba Grass and other introduced grasses.
- Land clearance.
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.
- Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean.
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.
- Novel biota and their impact on biodiversity.
- Predation by European red fox.
- Predation by exotic rats on Australian offshore islands of less than 1000 km² (100,000 ha).
- Predation by feral cats.
- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs.
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species.
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*).
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta* (fire ant).

General processes that threaten biodiversity across Australia (The National Land and Water Resources Audit):

-
- Vegetation clearing;
 - Increasing fragmentation, loss of remnants and lack of recruitment;
 - Firewood collection;
 - Grazing pressure;
 - Feral animals;
 - Exotic weeds;
 - Changed fire regimes;
 - Pathogens;
 - Changed hydrology—dryland salinity and salt water intrusion;
 - Changed hydrology— such as altered flow regimes affecting riparian vegetation; and
 - Pollution.

In addition to the above processes, DSEWPaC has produced Significant Impact Guidelines that provide criteria for the assessment of the significance of impacts. These criteria provide a framework for the assessment of significant impacts. The criteria are listed below.

- Will the proposed action lead to a long-term decrease in the size of a population?
- Will the proposed action reduce the area of occupancy of the species?
- Will the proposed action fragment an existing population?
- Will the proposed action adversely affect habitat critical to the survival of a species?
- Will the proposed action disrupt the breeding cycle of a population?
- Will the proposed action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?
- Will the proposed action result in introducing invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat?
- Will the proposed action introduce disease that may cause the species to decline?
- Will the proposed action interfere with the recovery of the species?

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Spotted Rock Dtella	<i>Gehyra punctate</i>					Resident	X		X	X	X	X	X
Variiegated Dtella	<i>Gehyra variegata</i>					Resident	X		X	X	X		X
Bynoe's Gecko	<i>Heteronotia binoei</i>					Resident	X		X	X			
PYGOPODIDAE													
Marble-faced Delma	<i>Delma australis</i>					Resident	X			X			
Unbanded Delma	<i>Delma butleri</i>					Resident							
Excitable Delma	<i>Delma tincta</i>					Resident	X		X				
Burton's Legless Lizard	<i>Lialis burtonis</i>					Resident	X						
Western Hooded Scaly-foot	<i>Pygopus nigriceps</i>					Resident				X			
AGAMIDAE													
Long-nosed Dragon	<i>Amphibolurus longirostris</i>					Resident	X		X	X			X
Ring-tailed Dragon	<i>Ctenophorus caudicinctus</i>					Resident	X		X	X	X	X	X
Military Dragon	<i>Ctenophorus isolepis</i>					Resident	X						
Central Netted Dragon	<i>Ctenophorus nuchalis</i>					Resident	X		X	X		X	
Ornate Crevice Dragon	<i>Ctenophorus ornatus</i>					Resident	X						
Western Netted Dragon	<i>Ctenophorus reticulatus</i>					Resident	X		X	X		X	X
Claypan Dragon	<i>Ctenophorus salinarum</i>					Resident							
Lozenge-marked Dragon	<i>Ctenophorus scutulatus</i>					Resident	X		X	X	X	X	X
Mulga Dragon	<i>Diporiphora amphiboluroides</i>					Resident				X			
Thorny Devil	<i>Moloch horridus</i>					Resident	X			X			
Western Bearded Dragon	<i>Pogona minor</i>					Resident	X		X	X			
Earless Pebble Dragon	<i>Tympanocryptis cephalus</i>					Resident				X			
EGERNIIDAE													
Gilled Slender Blue-tongue	<i>Cyclodomorphus branchialis</i>	V				Resident							
Pygmy Spiny-tailed Skink	<i>Egernia depressa</i>					Resident	X		X	X	X	X	X
Goldfields Crevice Skink	<i>Egernia formosa</i>					Resident							
Western Spiny-tailed Skink	<i>Egernia stokesii badia</i>	E				Resident	X				X	X	X
Desert Skink	<i>Liopholis inornata</i>					Resident							
Night Skink	<i>Liopholis striata</i>					Resident							

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Western Blue-tongue	<i>Tiliqua occipitalis</i>					Resident						X	
Centralian Blue-tongue	<i>Tiliqua multifasciata</i>					Resident							
EUGONGYLIDAE													
Buchanan's Fence Skink	<i>Cryptoblepharus buchananii</i>					Resident	X			X			
Common Fence Skink	<i>Cryptoblepharus plagiocephalus</i>					Resident	X						
Broad-banded Sand-swimmer	<i>Eremiascincus richardsonii</i>					Resident	X		X	X			
Common Dwarf Skink	<i>Menetia greyii</i>					Resident	X		X	X		X	
Woodland Morethia	<i>Morethia butleri</i>					Resident	X						X
SPHENOMORPHIDAE													
Clay Soil Ctenotus	<i>Ctenotus helenae</i>					Resident	X						
Leonhard's Ctenotus	<i>Ctenotus leonhardii</i>					Resident	X		X	X	X	X	
Leopard Skink	<i>Ctenotus pantherinus</i>					Resident				X			
Barred Wedge-snout Ctenotus	<i>Ctenotus schomburgkii</i>					Resident	X		X	X		X	
Stern Rock Ctenotus	<i>Ctenotus severus</i>					Resident	X		X	X	X	X	
Spotted Ctenotus	<i>Ctenotus uber</i>					Resident	X		X	X			
Good-legged Slider	<i>Lerista eupoda</i>		P1			Resident				X			
King's Three-toed Slider	<i>Lerista kingi</i>					Resident	X						
Unpatterned robust Slider	<i>Lerista macropisthopus</i>					Resident	X						
Pale broad-blazed Slider	<i>Lerista nichollsi</i>					Resident	X		X	X			
Timid Slider	<i>Lerista timida</i>					Resident	X		X	X			
VARANIDAE													
Stripe-tailed Monitor	<i>Varanus caudolineatus</i>					Resident	X		X	X			
Perentie	<i>Varanus giganteus</i>					Resident	X		X	X			
Sand Goanna	<i>Varanus gouldii</i>					Resident	X						
Yellow-spotted Monitor	<i>Varanus panoptes</i>					Resident	X		X	X	X	X	X
Black-headed Monitor	<i>Varanus tristis</i>					Resident			X	X			
TYPHLOPIDAE													
Dark-spined Blind snake	<i>Anilius bicolor</i>					Resident							
Long-beaked blind snake	<i>Anilius grypus</i>					Resident			X				

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Pale-headed blind snake	<i>Anilius hamatus</i>					Resident				X			
Beaked Blind Snake	<i>Anilius waitii</i>					Resident							
BOIDAE													
Pygmy Python	<i>Antaresia perthensis</i>					Resident	X		X	X			
Stimson's Python	<i>Antaresia stimsoni</i>					Resident							
ELAPIDAE													
Desert Death Adder	<i>Acanthophis pyrrhus</i>					Resident							
Northern Shovel-nosed Snake	<i>Brachyuropis approximans</i>					Resident				X			
Southern Shovel-nosed Snake	<i>Brachyuropis semifasciata</i>					Resident							
Yellow-faced Whip-Snake	<i>Demansia psammophis</i>					Resident			X				
Monk Snake	<i>Parasuta monachus</i>					Resident	X			X			
Mulga Snake	<i>Pseudechis australis</i>					Resident							
Spotted Mulga Snake	<i>Pseudechis butleri</i>					Resident	X			X			
Ringed Brown Snake	<i>Pseudonaja modesta</i>					Resident	X			X		X	
Gwardar	<i>Pseudonaja mengdeni</i>					Resident	X						
Jan's Banded Snake	<i>Simoselaps bertholdi</i>					Resident	X			X			
Moon Snake	<i>Furina ornata</i>					Resident				X			
Rosen's Snake	<i>Suta fasciata</i>					Resident	X			X			
Birds										56	92	65	
DROMAIIDAE													
Emu	<i>Dromaius novaehollandiae</i>					Resident	X	X	X	X	X	X	X
Anatidae													
Black Swan	<i>Cygnus atratus</i>					Regular Visitor	X	X	X	X			
Freckled Duck	<i>Stictonetta naevosa</i>					Vagrant							
Australian Shelduck	<i>Tadorna tadornoides</i>					Regular Visitor	X	X	X	X			
Pink-eared Duck	<i>Malacorhynchus membranaceus</i>					Regular Visitor	X	X	X	X		X	
Australian Wood Duck	<i>Chenonetta jubata</i>					Regular Visitor	X	X	X	X			
Pacific Black Duck	<i>Anas superciliosa</i>					Regular Visitor	X	X	X	X		X	
Australasian Shoveler	<i>Anas rhynchotis</i>					Vagrant		X					

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Grey Teal	<i>Anas gracilis</i>					Regular Visitor	X	X	X	X		X	
Chestnut Teal	<i>Anas castanea</i>					Vagrant		X					
Hardhead	<i>Aythya australis</i>					Regular Visitor	X	X	X	X			
Blue-billed Duck	<i>Oxyura australis</i>		4			Vagrant							
Musk Duck	<i>Biziura lobata</i>					Vagrant	X						
Plumed Whistling Duck	<i>Dendrocygna eytoni</i>					Regular Visitor	X					X	
MEGAPODIIDAE													
Malleefowl	<i>Leipoa ocellata</i>	V				Resident	X		X	X		X	M
PHASIANIDAE													
Stubble Quail	<i>Coturnix pectoralis</i>					Visitor		X					
Brown Quail	<i>Coturnix ypsilophora</i>					Resident						X	
PODICIPEDIDAE													
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>					Regular Visitor		X	X				
Hoary-headed Grebe	<i>Poliocephalus poliocephalus</i>					Regular Visitor		X	X				
Great Crested Grebe	<i>Podiceps cristatus</i>					Vagrant							
THRESKIORNITHIDAE													
Australian White Ibis	<i>Threskiornis moluccus</i>					Irregular Visitor		X					
Straw-necked Ibis	<i>Threskiornis spinicollis</i>					Regular Visitor	X	X				X	
Glossy Ibis	<i>Plegadis falcinellus</i>	M				Irregular Visitor		X	X				
Yellow-billed Spoonbill	<i>Platalea flavipes</i>					Vagrant		X					
ARDEIDAE													
Nankeen Night-Heron	<i>Nycticorax caledonicus</i>					Irregular Visitor		X					
Cattle Egret	<i>Ardea ibis</i>	S5				Vagrant		X					
White-necked Heron	<i>Ardea pacifica</i>					Regular visitor		X	X	X	X	X	
Eastern Great Egret	<i>Ardea modesta</i>	S5				Regular visitor		X					X
White-faced Heron	<i>Ardea novaehollandiae</i>					Regular visitor		X	X	X		X	
PELECANIDAE													
Australian Pelican	<i>Pelecanus conspicillatus</i>					Vagrant		X	X			X	
PHALACROCORACIDAE													

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey							
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey	
Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>					Regular visitor		X						X
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>					Regular visitor		X					X	X
Pied Cormorant	<i>Phalacrocorax varius</i>					Irregular Visitor		X						
Great Cormorant	<i>Phalacrocorax carbo</i>					Irregular Visitor								
ACCIPITRIDAE														
Black-shouldered Kite	<i>Elanus caeruleus</i>					Irregular Visitor		X						
Letter-winged Kite	<i>Elanus scriptus</i>					Vagrant								
Square-tailed Kite	<i>Hamirostra isura</i>					Regular Visitor							X	
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>					Resident		X	X	X			X	
Little Eagle	<i>Hieraaetus morphnoides</i>					Resident		X						
Wedge-tailed Eagle	<i>Aquila audax</i>					Resident		X	X	X	X	X	X	X
Brown Goshawk	<i>Accipiter fasciatus</i>					Resident		X		X				
Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>					Resident		X	X	X			X	X
Swamp Harrier	<i>Circus approximans</i>					Irregular visitor		X						
Spotted Harrier	<i>Circus assimilis</i>					Resident		X					X	
Whistling Kite	<i>Haliastur sphenurus</i>					Resident		X	X	X	X	X	X	
Black Kite	<i>Milvus migrans</i>					Resident/ Visitor		X						
OTIDIDAE														
Australian Bustard	<i>Ardeotis australis</i>			X		Resident	X	X	X	X				X
RALLIDAE														
Black-tailed Native-hen	<i>Tribonyx ventralis</i>					Irregular visitor	X	X					X	
Eurasian Coot	<i>Fulica atra</i>					Irregular visitor	X	X	X					
TURNICIDAE														
Little Button-quail	<i>Turnix velox</i>					Resident	X	X	X	X			X	X
BURHINIDAE														
Bush Stone-curlew	<i>Burhinus grallarius</i>			X		Resident		X	X	X	X	X	X	
RECURVIROSTRIDAE														
Black-winged Stilt	<i>Himantopus himantopus</i>					Regular visitor		X	X					
Banded Stilt	<i>Cladorhynchus leucocephalus</i>					Irregular visitor			X					

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey							
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey	
Red-necked Avocet	<i>Recurvirostra novaehollandiae</i>					Irregular visitor								
CHARADRIIDAE														
Banded Lapwing	<i>Vanellus tricolor</i>					Resident	X	X	X		X	X	X	
Red-kneed Dotterel	<i>Erythrogonys cinctus</i>					Irregular visitor		X	X					
Red-capped Plover	<i>Charadrius ruficapillus</i>					Regular visitor		X	X					
Black-fronted Dotterel	<i>Euseyornis melanops</i>					Resident	X	X	X		X	X	X	
Inland Dotterel	<i>Charadrius australis</i>					Resident/ Visitor		X	X	X				
SCOLOPACIDAE														
Common Greenshank	<i>Tringa nebularia</i>	M				Irregular visitor		X	X					X
Red-necked Stint	<i>Calidris ruficollis</i>	M				Irregular visitor								
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	M				Irregular visitor		X						
Common Sandpiper	<i>Actitis hypoleucos</i>	M				Irregular visitor		X						
Marsh Sandpiper	<i>Tringa stagnatalis</i>	M				Irregular visitor								
Wood Sandpiper	<i>Tringa glareola</i>	M				Irregular visitor		X						
Curlew Sandpiper	<i>Calidris ferruginea</i>	M				Vagrant								
COLUMBIDAE														
Common Bronzewing	<i>Phaps chalcoptera</i>					Resident	X	X	X	X	X	X	X	X
Crested Pigeon	<i>Ocyphaps lophotes</i>					Resident	X	X	X	X	X	X	X	X
Diamond Dove	<i>Geopelia cuneata</i>					Resident		X	X		X	X	X	
Peaceful Dove	<i>Geopelia striata</i>					Irregular visitor		X						
CUCULIDAE														
Horsfield's Bronze-Cuckoo	<i>Chalcites basalus</i>					Visitor	X	X	X	X			X	
Black-eared Cuckoo	<i>Chrysococcyx osculans</i>					Resident	X		X					
Pallid Cuckoo	<i>Cacomantis pallidus</i>					Resident	X	X	X	X				
TYTONIDAE														
Eastern Barn Owl	<i>Tyto alba delicatula</i>					Resident	X	X	X					
STRIGIDAE														
Southern Boobook	<i>Ninox boobook boobook</i>					Resident	X	X		X				
PODARGIDAE														

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Tawny Frogmouth	<i>Podargus strigoides</i>					Resident	X	X		X			
CAPRIMULGIDAE													
Spotted Nightjar	<i>Eurostopodus argus</i>					Resident	X			X	X		X
AEGOTHELIDAE													
Australian Owlet-nightjar	<i>Aegotheles cristatus</i>					Resident	X	X		X			
APODIDAE													
Fork-tailed Swift	<i>Apus pacificus</i>	M				Irregular visitor							
ALCEDINIDAE													
Sacred Kingfisher	<i>Todiramphus sanctus</i>					Irregular visitor	X	X			X		
Red-backed Kingfisher	<i>Todiramphus pyrrhopygia</i>					Resident		X	X		X	X	
MEROPIIDAE													
Rainbow Bee-eater	<i>Merops ornatus</i>	S5				Migrant	X	X	X			X	X
FALCONIDAE													
Nankeen Kestrel	<i>Falco cenchroides</i>					Resident	X	X	X	X	X	X	X
Australian Hobby	<i>Falco longipennis</i>					Resident	X	X	X				X
Brown Falcon	<i>Falco berigora</i>					Resident	X	X	X	X	X	X	X
Peregrine Falcon	<i>Falco peregrinus</i>	S7				Resident	X	X	X	X		X	
Grey Falcon	<i>Falco hypoleucos</i>	V				Irregular visitor		X					
Black Falcon	<i>Falco subniger</i>					Vagrant							
CACATUIDAE													
Red-tailed Black Cockatoo	<i>Calyptorhynchus banksii</i>			X		Irregular visitor		X					
Galah	<i>Eolophus roseicapilla</i>					Resident		X	X	X	X	X	X
Little Corella	<i>Cacatua sanguinea</i>					Resident		X	X		X	X	
Major Mitchell's Cockatoo	<i>Lophochroa leadbeateri</i>			X		Resident		X	X		X	X	
Cockatiel	<i>Nymphicus hollandicus</i>					Resident		X	X	X		X	X
PSITTACIDAE													
Australian Ringneck	<i>Barnardius zonarius</i>					Resident		X	X	X	X	X	X
Mulga Parrot	<i>Psephotus varius</i>					Resident		X	X	X	X	X	X
Budgerigar	<i>Melopsittacus undulatus</i>					Regular visitor		X	X	X		X	X

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Bourke's Parrot	<i>Neosephotus bourkii</i>					Resident		X	X	X		X	X
Elegant Parrot	<i>Neophema elegans</i>					Irregular visitor		X		X			
Scarlet-chested Parrot	<i>Neophema splendida</i>					Vagrant							
Regent Parrot	<i>Polytelis anthopeplus</i>					Vagrant		X					
Night Parrot	<i>Pezoporus occidentalis</i>	E				Vagrant							
CLIMACTERIDAE													
White-browed Treecreeper	<i>Climacteris affinis</i>					Resident		X	X				
PTILONORHYNCHIDAE													
Western Bowerbird	<i>Ptilonorhynchus guttatus</i>					Resident		X	X	X	X	X	X
MALURIDAE													
Splendid Fairy-wren	<i>Malurus splendens</i>					Resident		X	X	X		X	X
Variiegated Fairy-wren	<i>Malurus lamberti</i>					Resident		X	X	X	X	X	X
White-winged Fairy-wren	<i>Malurus leucopterus</i>					Resident		X	X	X	X	X	X
MELIPHAGIDAE													
Pied Honeyeater	<i>Certhionyx variegatus</i>					Regular visitor		X		X		X	
Singing Honeyeater	<i>Lichenostomus virescens</i>					Resident		X	X	X	X	X	X
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>					Resident		X	X	X	X	X	X
White-fronted Honeyeater	<i>Purnella albifrons</i>					Resident		X		X		X	
Yellow-throated Miner	<i>Manorina flavigula</i>					Resident		X	X	X	X	X	X
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>					Resident		X	X	X	X	X	X
Grey Honeyeater	<i>Conopophila whitei</i>			X		Resident		X		X			
Crimson Chat	<i>Epthianura tricolor</i>					Resident		X	X	X	X	X	X
Orange Chat	<i>Epthianura aurifrons</i>					Resident		X		X		X	
White-fronted Chat	<i>Epthianura albifrons</i>					Resident		X					
Black Honeyeater	<i>Sugomel niger</i>					Regular visitor		X		X		X	
Brown Honeyeater	<i>Lichmera indistincta</i>					Resident		X	X	X	X	X	
PARDALOTIDAE													
Red-browed Pardalote	<i>Pardalotus rubricatus</i>					Resident							
Striated Pardalote	<i>Pardalotus striatus</i>					Resident		X	X	X		X	

Common Name	Latin Name	Conservation Status			Int	Expected status in project area	Presence in Previous Literature and Present Survey						
		CS1	CS2	CS3			D	Bird Data	BCE Data	BCE 2007	BCE 2010	BCE 2015	Present survey
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>					Resident		X	X	X	X	X	X
Ground Cuckoo-shrike	<i>Coracina maxima</i>					Resident		X	X	X		X	
White-winged Triller	<i>Lalage tricolor</i>					Resident		X	X	X		X	X
NEOSITTIDAE													
Varied Sittella	<i>Daphoenositta chrysoptera</i>					Resident		X				X	X
OREOICIDAE													
Crested Bellbird	<i>Oreoica gutturalis</i>					Resident		X	X	X	X	X	X
PACHYCEPHALIDAE													
Rufous Whistler	<i>Pachycephala rufiventris</i>					Resident		X	X	X	X	X	X
Grey Shrike-thrush	<i>Colluricincla harmonica</i>					Resident		X	X	X	X	X	X
RHIPIDURIDAE													
Grey Fantail	<i>Rhipidura fuliginosa</i>							X		X			
Willie Wagtail	<i>Rhipidura leucophrys</i>					Resident		X	X	X	X	X	X
MONARCHIDAE													
Magpie-lark	<i>Grallina cyanoleuca</i>					Resident	X	X	X	X	X	X	X
CORVIDAE													
Australian Raven	<i>Corvus coronoides</i>					Resident		X				X	
Little Crow	<i>Corvus bennetti</i>					Resident		X	X	X	X	X	X
Torresian Crow	<i>Corvus orru</i>					Resident		X	X			X	
PETROICIDAE													
Red-capped Robin	<i>Petroica goodenovii</i>					Resident		X	X	X	X	X	X
Hooded Robin	<i>Melanodryas cucullata</i>					Resident		X	X	X	X		X
HIRUNDINIDAE													
White-backed Swallow	<i>Cheramoeca leucosternum</i>					Resident		X				X	
Welcome Swallow	<i>Hirundo neoxena</i>					Resident		X	X	X	X	X	
Tree Martin	<i>Petrochelidon nigricans</i>					Resident		X	X		X	X	X
Fairy Martin	<i>Petrochelidon ariel</i>					Resident		X	X	X	X	X	X
LOCUSTELLIDAE													
Rufous Songlark	<i>Megalurus mathewsi</i>					Resident		X	X	X		X	X

Appendix 6. Annotated list of fauna recorded during the 2016 field survey.

No.	Species	Observational Notes
	Fish	
1	Spangled Grunter	Many in pools on Murchison River at Mullewa-Carnarvon Road.
2	Murchison River Hardyhead	Common at both Murchison River crossings.
	Frogs	
3	Desert Tree Frog	Abundant in and around Murgoo Homestead
	Reptiles	
4	<i>Gehyra variagata</i>	Common on walls of buildings around Murgoo Homestead.
5	<i>Gehyra punctata</i>	In granites at Area 2.
6	<i>Oedura marmorata</i>	Several sloughed skins found in breakaway at Area 7.
7	<i>Ctenophorus reticulatus</i> .	Seen in Areas 8 and 7.
8	<i>Ctenophorus scutullatus</i> .	Seen in Areas 8, 7, 1 and 3.
9	<i>Lophognathus longirostris</i> .	Several along Murchison River at Mullewa-Carnarvon Road crossing. Also at Murgoo Homestead.
10	<i>Ctenotus severus</i>	Seen around Murgoo Homestead.
11	<i>Egernia depressa</i> .	One colony found in dead Gidgee in Area 4.
12	<i>Egernia stokesii badia</i> .	Scat piles in granite outcrops along Twin Peaks-Wooleen Road and near Area 2.
13	<i>Eremiascincus richardsonii</i> .	Several at night around Murgoo Homestead.
14	<i>Morethia butleri</i>	One in breakaway country of Area 7.
15	<i>Varanus panoptes</i>	Tracks and diggings throughout. One seen in Area 6.
	Birds	
16	Emu.	One in Area 8 and two near Twin Peaks. Tracks in Area 6. Two in Area 1.

No.	Species	Observational Notes
17	Malleefowl.	One crossed Mullewa-Carnarvon Road near Area 8 (about 28/10; reported by owner of Pine Grove). Old mound recorded at Area 8 and fresh tracks observed south of Murgoo.
18	Little Button-quail.	Two flushed at Area 6.
19	Little Pied Cormorant.	One on Murchison River at Mullewa-Carnarvon crossing.
20	Little Black Cormorant.	One on Murchison River at Mullewa-Carnarvon crossing.
21	Brown Falcon.	One over Area 8.
22	Australian Hobby.	One seen near Area 8.
23	Nankeen Kestrel.	One at area 4 and one near Area 2. Nest with two mid-sized chicks in old babbler nest in Area 3.
24	Whistling Kite.	Several along Murchison River at both crossings.
25	Wedge-tailed Eagle.	Pair at Area 8 and one at area 7. Old nest in Area 6.
26	Eastern Great Egret.	One in pool of Murchison River at Mullewa-Carnarvon Road crossing.
27	Common Greenshank.	Single bird on Murchison River at Mullewa-Carnarvon crossing and Twin Peaks Road crossing.
28	Black-fronted Dotterel.	Flock of about five on Murchison River at Mullewa-Carnarvon Road crossing.
29	Galah.	Pair over Area 8. Small flocks along Mullewa-Carnarvon Road.
30	Cockatiel.	One over Area 4 in evening and flock of about 50 at sunrise on 1/11. Seven in group at Site 6.
31	Mulga Parrot.	Group of about four in Area 8 and several seen in Area 4, including juveniles. Also seen in Areas 2 and 6.
32	Bourke's Parrot.	Small group in Area 8, several groups (up to 10 birds) in Area 4 and several in area 6. Also a pair in Area 1.
33	Australian Ringneck.	One in Area 7 and heard in Area 2.
34	Budgerigar.	Few along Murchison River. Several in Area 6.
35	Diamond Dove.	Few drinking at Murchison River at Mullewa-Carnarvon Road crossing.

No.	Species	Observational Notes
36	Crested Pigeon.	Few drinking at Murchison River at Mullewa-Carnarvon Road crossing and small numbers seen in Area 4 and Area 6.
37	Common Bronzewing.	Few drinking at Murchison River at Mullewa-Carnarvon Road crossing.
38	Rainbow Bee-eater.	Two in Area 8.
39	Spotted Nightjar.	Two flushed from breakaway on northern edge of Area 1.
40	Splendid Fairy-wren.	Parties in Areas 2, 8 and 7.
41	Variiegated Fairy-wren.	Party in Area 4, including coloured male. Also in Area 1.
42	White-winged Fairy-wren.	Party in chenopod shrubland at Murchison River Twin Peaks Road crossing.
43	Redthroat.	Seen and heard in Areas 8, 7, 4, 2, 1 and 6.
44	Chestnut-rumped Thornbill.	Areas 8, 7, 2, 1 and 6.
45	Slatey-backed Thornbill.	Several parties in areas 8, 7, 4, 2, 5 and 6. Seem to be the most abundant thornbill species.
46	Southern Whiteface.	Areas 8, 7, 2, 1 and 4.
47	Western Gerygone.	One in area 8.
48	Yellow-throated Miner.	Area 4, where adult attending a nest, and in Area 2.
49	Spiny-cheeked Honeyeater.	Few in areas 8, 7, 3, 4, 2 and 6.
50	White-plumed Honeyeater.	Common along Murchison River at crossing of Mullewa to Carnarvon Road, and around Murgoo Homestead.
51	Singing Honeyeater.	Several at Murchison River Crossing and few in Areas 1, 3, 2 and 6.
52	Crimson Chat.	Few along roads throughout. Seen in Areas 6, 3, 2 and 4.
53	Black-faced Cuckoo-shrike.	One in Area 4 and one along the Mullewa-Carnarvon Road.
54	White-winged Triller.	One (male) in area 4, and a female in Area 6.
55	Hooded Robin.	One male in Area 8 and pair seen in Area 2.

No.	Species	Observational Notes
56	Red-capped Robin.	Few in Areas 8 and 6. Pair feeding flying young in Area 4.
57	Varied Sittella.	Party seen near Area 2.
58	Willie Wagtail.	Pairs at both Murchison River Crossings. Also in Areas 1, 2, 4, 5 and 6.
59	Magpie-lark.	Several at Murchison River Mullewa-Carnarvon Road crossing.
60	Chestnut-breasted Quail-thrush	Several in Areas 7 and 4. Party in Area 1.
61	White-browed Babbler.	Several parties in Area 8.
62	Grey-crowned Babbler.	Party in Areas 2 and 4.
63	Chiming Wedgebill.	Several calling at Murchison River crossing Mullewa-Carnarvon Road
64	Crested Bellbird.	Heard in Areas 3, 5 and 8.
65	Rufous Whistler.	Heard in Areas 5, 8, 7, 2 and 6.
66	Grey Shrike-thrush.	Heard in Areas 7 and 6. One seen in Area 1.
67	Black-faced Woodswallow.	Small groups in all areas and occasionally along roads.
68	Masked Woodswallow.	Small group flying high over Murchison River crossing Twin Peaks Road.
69	Little Woodswallow.	Three at breakaway just south of Area 7.
70	Fairy Martin.	Several at Murchison River crossing Mullewa-Carnarvon Road, and nests in breakaway near Area 7.
71	Tree Martin.	Several over Murchison River crossing Twin Peaks Road. Also around Murchison Homestead.
72	Grey Butcherbird.	Heard in Areas 4 and 8.
73	Pied Butcherbird.	Heard at Murchison River crossing Twin Peaks Road.
74	Zebra Finch.	About 20 drinking at Murchison river Mullewa-Carnarvon Road crossing. Small groups in Areas 2 and 6.
75	Little Crow.	Heard in Area 8.

No.	Species	Observational Notes
76	Rufous Songlark.	One calling at granite outcrop along Twin Peaks-Wooleen Road. Seen and heard in Area 1.
	Mammals	
77	Echidna	Diggings abundant in Areas 1, 3, 5, 6 and 7.
78	<i>Pseudantechinus wooleyae</i>	Abundant scats in breakaway near Area 7.
79	Red Kangaroo.	Pair in Area 8. Several near Murgoo Homestead.
80	Euro.	Scats and dead animals in caves in Area 7.
	Boodie	Old warrens in most borrow pit sites
81	<i>Notomys alexis</i>	Burrow in old Boodie mounds in Areas 1, 8 and 7. Also in Area 4.
82	<i>Chalinolobus gouldii</i>	Recorded on bat detector
83	Rabbit.	Tracks, diggings and scats in Area 8.
84	Cat.	Tracks in Area 8, recorded on motion camera in Area 2.
85	Dingo	Tracks recorded in Area 2
87	Cattle	Scats and tracks throughout
88	Goat	Scats recorded in rocky areas
89	Western Pebble-mound Mouse	Ancient, inactive mounds at 370717E, 6912780N and 371048E, 6913337N (Borrow Pit 8) and 409500E, 7010825N; 409514E, 7010929N; 409540E, 7010864N (Main Road).
90	Lesser Stick-nest Rat	Old nesting material recorded at Borrow Pits 5 and 7
91	Brush-tail Possum	Scats recorded in a cave outside project area (432362E, 6961411N)
92	Black-flanked Rock-Wallaby	Scats recorded in a cave outside project area (432362E, 6961411N)