

**Square Kilometre Array (SKA)
Main Roads Upgrade
Fauna Assessment**



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Executive summary

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 projects development. Main Roads Western Australia (Main Roads) is co-ordinating a road upgrade for access to the SKA site. This involves the widening of the existing road formation, minor realignments and a single lane seal over approximately 180km of road. Road works will also require road building material, identified from nine potential material sources, ‘borrow material’ being located adjacent to the road formation.

As part of the Environmental Impact Assessment for the project, Bamford Consulting Ecologists (BCE) was commissioned by Parsons Brinckerhoff (on behalf of Main Roads) to conduct a Level 1 fauna assessment of the SKA access road upgrade area. 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 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;
 - 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.

The fauna investigations were based on a desktop assessment, site reconnaissance survey conducted in October 2015 and previous fauna records from the region.

Key **fauna values** are:

Fauna assemblage. The desktop survey identified an assemblage of 287 vertebrate fauna species potentially occurring in the survey area. A total of 120 were recorded during the field survey, including one freshwater fish, 16 reptiles, 92 birds, five native mammals and six

introduced mammals. A total of 26 vertebrate species of conservation significance fauna species are expected to occur in the study area. The assemblage is considered to be relatively intact, within a relatively intact, largely uncleared landscape.

Species of conservation significance. A total of 26 species of conservation significance are expected to be present at least occasionally within the project area. Eight conservation significant species were recorded from the survey area (Western Spiny-tailed Skink, Malleefowl, Shield-backed Trapdoor Spider, Peregrine Falcon, Bush stone-curlew, Major Mitchell's Cockatoo, Rainbow Bee-eater) and several additional species are considered to have resident populations or regularly visit the area (eg. Golden Carp Gudgeon, Gilled Slender Blue-tongue, Australian Bustard, Long-tailed Dunnart and two locally significant birds). Only ancient, inactive mounds of the Western Pebble-mound Mouse were recorded from the site, suggesting the species no longer occurs in the area. Significant species expected to be present regularly within the project area include:

- Western Spiny-tailed Skink – resident in granite outcrops adjacent to development;
- Malleefowl – potential resident / visitor to survey area;
- Shield-backed Trapdoor Spider - resident, likely to be widespread in local area;
- Peregrine Falcon – resident;
- Bush Stone-curlew – resident;
- Major Mitchell's Cockatoo – resident, breeds in mature Eucalypts along major rivers;
- Long-tailed Dunnart; likely resident;
- Australian Bustard: previously recorded nearby – widespread;
- Rainbow Bee-eater: regular migrant – common and widespread,
- Golden Carp Gudgeon – resident;
- Gilled Slender Blue-tongue – resident;
- Grey Honeyeater: likely resident – associated with Mulga dominated VSAs widespread in the region;

These are the species most likely to be impacted by the proposed development, although impacts are expected to be mostly minimal due to the presence of existing roads and widespread occurrence of most habitat types. The Malleefowl and Shield-backed Trapdoor Spider are of significance and in need of consideration and management.

Vegetation and Substrate Associations. 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 project 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 (eg. Major Mitchells

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 *Idiosoma nigrum*.
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:

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

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. The elevated avian assemblage around water also supported avian predators. Temporary waterbodies within the drainage lines will provide some habitat to waterbirds allowing for movement and dispersal. Rocky outcrops support saxicoline fauna, generally restricted to such habitat (eg. Woolley's Pseudantechinus, Western Spiny-tailed Skink).

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.

With respect to fauna values, those parts of the project area of most concern are the southern borrow pits (Borrow Pits 1, 2 and 3) which have more significant species, and sections of the road that cross drainage systems.

Impacts upon fauna include:

Habitat loss and increased roadkill, and there is some concern about the potential of the project to impact on local hydrology, thereby impacting VSAs and consequently impacting fauna. Habitat degradation as a result of weed incursion and/or fire, and the activities of feral fauna may also be of some concern.

Recommendations relate to impacts and include:

Loss of habitat

- Minimise the disturbance footprint – restrict the development corridor to the existing road where possible;
- Avoid disturbances to significant fauna habitats: rocky outcrops; waterholes and gnamma holes; riparian (riverine) vegetation; large, mature, hollow-bearing trees; Malleefowl mounds; Malleefowl habitat (dense Acacia shrublands on gravelly slopes); and locations supporting the Shield-backed Trapdoor Spider.

Increased mortality due to roadkill

- Where possible, restrict SKA related vehicle movements in the early evening when roadkill most likely.

Habitat fragmentation and Hydrology

- Maintain hydrological flows.

Habitat degradation due to weed invasion

- Develop a weed management/hygiene plan.

Changes in fire regime

- Develop a fire management plan;

Environmental Management

- Due to the presence of EPBC listed taxa, the project should be referred to the national Department of the Environment.
- If disturbances to Malleefowl habitat (dense Acacia shrublands) are proposed, mounds (breeding sites) should be left undisturbed by conducting pre-clearance checks. As a result, any proposed vegetation clearance within suitable should be inspected by a qualified zoologist prior to clearance.

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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. This involves the widening of the existing road formation, minor realignments and a single lane seal over approximately 180km of road (see Table 1). Road works will also require road building material, identified from 10 potential material sources ('borrow pits'), 'borrow material' being 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 780ha, and much of the footprint is in pastoral country where existing clearing is minimal.

As part of the Environmental Impact Assessment for the project, Bamford Consulting Ecologists (BCE) was commissioned by Parsons Brinckerhoff (on behalf of Main Roads) to conduct a Level 1 fauna assessment of the SKA access road upgrade area (referred to hereafter as the "survey area"). The function of the fauna assessment, consistent with 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.

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;
 - 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.

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 Parsons Brinckerhoff with the following actions 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 nearby the project 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 project 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 Environmental Protection Authority (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 (DotE). Provide justification of decision as to whether referral to DotE 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

The SKA project is located on Boolardy Station in the Murchison region of Western Australia. The proposed access road upgrade extends over approximately 180km of unsealed roads from near the Greenough River (43 km north of Mullewa, 50, 371110E, 6883135N) to the SKA Access Road at the junction of the Murgoo/Boolardy Rd (50, 468513E, 7040700N). Table 1 summarises the locations of the road upgrade with borrow pit locations listed in Table 2. The SKA survey area included the proposed road upgrade route with a 100 m buffer and the proposed borrow pit areas.

Table 1. Location of Road Upgrade.

Road Name	Road Number	Start SLK	End SLK	Length
Carnarvon Mullewa Road	5050756	0.00	27.80	27.80
Carnarvon Mullewa Road	7050043	230.70	278.86	48.16
Meeberrie – Wooleen Road	7050026	0.00	28.00	28
Twin Peaks – Wooleen Road	7050004	44.34	45.66	1.32
Wooleen – Mt Witte Road	7050027	0.00	13.15	13.15
Boolardy – Wooleen Road	7050032	0.00	19.08	19.08
Beringarra – Pindar Road	7050001	100.00	145.67	85.5
			TOTAL	183.18

Table 2. Location of Borrow Pit survey areas.

Borrow Pit	Location	Easting	Northing	Area Total (ha)
1	Carnarvon Mullewa Road SLK 21.7	371236	6889165	39.9
2	Carnarvon Mullewa Road SLK 166.81	374963	6932902	54.97
3	Carnarvon Mullewa Road SLK 201.13	376754	6941295	56
4	Carnarvon Mullewa Road SLK 235.39	388708	6981512	100
5	Carnarvon Mullewa Road SLK 244.21	392266	7013419	113.93
6	Boogardy Wooleen Road SLK 13.6	429540	6997964	247.64
7	Beringarra Pindar Road SLK 138.55	446757	7008605	59.22
8	Beringarra Pindar Road SLK 129.3	452277	7015611	62.68
9	Beringarra Pindar Road SLK 116.4	461555	7023450	45.01
Total				779.35

2 Background

2.1 Regional Description

The Interim Biogeographic Regionalisation of Australia (IBRA) (Environment Australia, 2000) has identified 26 bioregions in Western Australia (Figure 2). 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 180km 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, 849ha (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 that dominate and characterise the subregion. Areas of hummock grasslands on sandplains, saltbush shrublands on calcareous soils and Halosarcia low shrublands on saline alluvia occur. 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 project area. Landforms are grouped into “Land Types”, which are classified according to similarities in landform, soil, vegetation, geology and geomorphology. Five Land Types have been mapped across the project 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, and traversed by the survey corridor 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
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

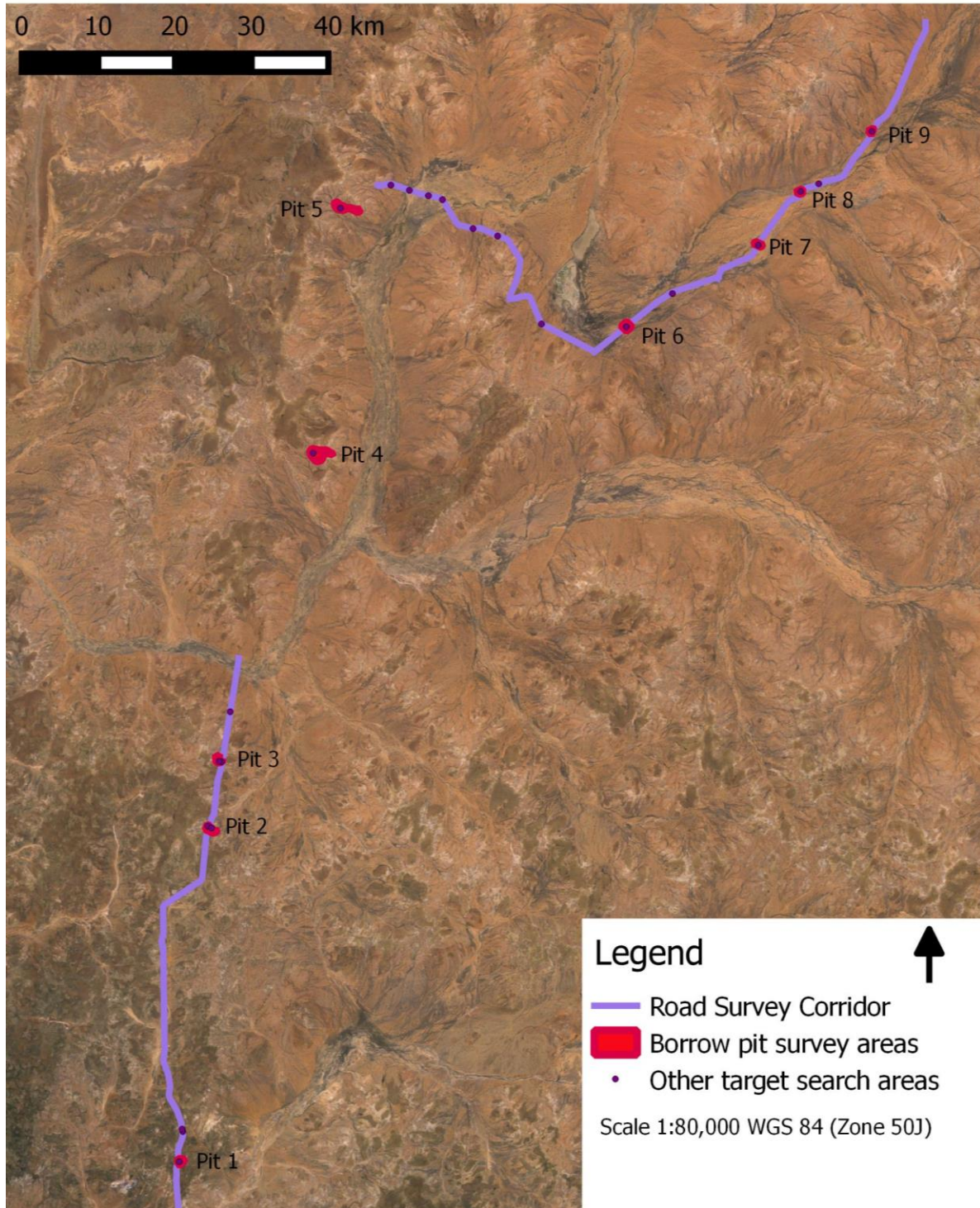
Table 4. Land Systems within the survey area.

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.
Waguin	Sandplains and stripped granite or laterite surfaces with low fringing breakaways and lower plains; supports bowgada and mulga shrublands with wanderrie grasses and minor mixed halophytes.
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 wanderrie banks and weak groving; supporting mulga shrublands and wanderrie grasses on banks.
Beringarra	Major riverine plains with active lower floodplains flanking channelled watercourses; supports mostly halophytic shrublands and mixed acacia shrublands and low woodlands with minor perennial grasses
ERO	Tributary floodplains with shallow, erodible duplex soils on red-brown hardpan, more or less saline and supporting acacia shrublands with halophytic and non-halophytic undershrubs; grazed preferentially and widely degraded and eroded.
Challenge	Gently undulating gritty-surfaced plains, occasional granite hills, tors and low breakaways, with acacia shrublands.
Bayou	Saline alluvial meander plains and river floodplains with anatomising river channels supporting halophytic shrublands with overstorey shrubs and Eucalyptus trees.
Mileura	Saline and non-saline calcreted river plains, with clayey flood plains interrupted by raised calcrete platforms supporting diverse and very variable tall shrublands, mixed halophytic shrublands and shrubby grasslands.

Table 5. Land Systems present within the borrow pit areas (presence denoted with X).

Borrow Pit	Land Systems						
	Kalli	Nerramyne	Waguin	Tindalarra	Narryer	Yanganoo	Beringarra
1	X	X					
2		X					
3	X		X	X			
4	X				X		
5	X				X	X	
6			X			X	
7						X	
8							X
9							X

Figure 1. Location of the survey area.



3 Methods

3.1 Overview

The methods used in this investigation are based upon the general approach to fauna investigations for impact assessment (as outlined in Section 1.2 and EPA Guidance Statement 56, and with reference to Appendices 1 to 4). As such, the impact assessment process involves the identification of fauna values, review of impacting processes and preparation of mitigation recommendations.

In addition, the approach to fauna impact assessment was carried out with reference to guidelines and recommendations set out by the Western Australian Environmental Protection Authority (EPA) on fauna surveys and environmental protection, and Commonwealth biodiversity legislation (EPA 2002; EPA 2004; EPA and DEC, 2010). 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. For the initial investigation, Parsons Brinckerhoff requested a Level 1 fauna assessment of the project. This included:

- 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) 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 6). These included state and federal government databases and results of regional studies (including BCE 2010; BCE 2012; BCE 2014; BCE 2015, Ninox, 2011). 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 2015)	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 cell 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 Level 1 Fauna Assessment conducted in 2007	Boolarly Station adjacent to survey area
Weld Range Fauna Assessments	Fauna Assessment, conducted at Weld Range by Bamford Consulting Ecologists.	2007, 2008, Weld Range (80km east of project)
Boolarly / Murgoo Fauna records	BCE records from Boolardy and Murgoo Stations	Boolarly and Murgoo Stations

3.2.2 Previous Fauna Surveys

BCE conducted the fauna assessment for the initial approval of the SKA project during 2007. Field surveys recorded 63 fauna species (41 bird, 11 reptile, six native mammal species and five introduced mammal species) from the project area. One species of high conservation significance (*Egernia stokesii*) was recorded from the area, and an additional six species have been recorded by BCE in adjacent areas. These include the Malleefowl (recorded at Twin Peaks, Boolardy, Murgoo), Major Mitchell's Cockatoo (Boolardy), Slender-billed Thornbill (Mungada), Peregrine Falcon (Boolardy), Gilled Slender-Bluetongue (Karara) and Shield-backed Trapdoor Spider (Weld Range). Records from previous surveys are summarised in Appendix 5.

3.2.3 Nomenclature and taxonomy

As per the recommendations of EPA (2004a), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's (WAM) *Checklist of the Vertebrates of Western Australia* (WAM, 2015). The authorities used for each vertebrate group were: amphibians (Doughty and Maryan 2014a), reptiles (Doughty and Maryan 2014b), birds (Birdlife Australia, 2014b), and mammals (How *et al.* 2014). English names of species, where available, are used throughout the text; 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 was highly unlikely that these species would be present. Some are also known to be regionally extinct. In general, however, species returned by the desktop review process are considered to be potentially present in the survey area whether or not they were recorded during field surveys, and whether or not the survey area is likely to be important for them. This is because fauna are highly mobile, often seasonal and frequently cryptic. This is particularly important for significant species that are often rare and hard to find. Species returned from databases but excluded from species lists are presented in Appendix 6.

Interpretation of species lists generated through the desktop review included assigning an expected status within the survey area to species of conservation significance. This is particularly important for birds that may naturally be migratory or nomadic, and for some mammals that can also be mobile or irruptive. 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 has not been recently recorded in the local area and therefore is almost certainly no longer present in the survey area.

3.3 October 2015 Field survey

3.3.1 Dates and Personnel

The SKA Main Roads Project was assessed during 4th – 10th October 2015. Personnel involved in the survey included:

- Dr Michael Bamford (B.Sc. Hons. Ph.D.) – field survey and report production; and
- Mr Jeff Turpin (B.Sc) – field survey and report production.

Field work was conducted under Wildlife Conservation Act 1950 Regulation 17 “Licence to Take Fauna for Scientific Purposes”, SF010465 (licensed to J.M. Turpin, valid 1/09/15 – 31/08/2016).

3.3.2 Survey 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 conservation significant fauna and an assessment of their likelihood of occurrence;
- avian census;
- Motion-cameras; and
- Opportunistic fauna observations.

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 (eg. *Idiosoma* sp.): Searching for burrows in suitable habitat;
- Slender-billed Thornbill: bird census 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.

VSA	Easting	Northing	Target Species
Borrow Pit 1: Carnarvon Mullewa Road SLK 21.7	371236	6889165	All
Borrow Pit 2: Carnarvon Mullewa Road SLK 166.81	374963	6932902	All
Borrow Pit 3: Carnarvon Mullewa Road SLK 201.13	376754	6941295	All
Borrow Pit 4: Carnarvon Mullewa Road SLK 235.39	388708	6981512	All
Borrow Pit 5: Carnarvon Mullewa Road SLK 244.21	392266	7013419	All
Borrow Pit 6: Boogardy Wooleen Road SLK 13.6	429540	6997964	All
Borrow Pit 7: Beringarra Pindar Road SLK 138.55	446757	7008605	All
Borrow Pit 8: Beringarra Pindar Road SLK 129.3	452277	7015611	All
Borrow Pit 9: Beringarra Pindar Road SLK 116.4	461555	7023450	All
Samphire low shrubland near Murchison River	398832	7016432	Targeting Slender-billed Thornbill
Samphire low shrubland near Murchison River	403728	7015059	Targeting Slender-billed Thornbill
Samphire low shrubland near Murchison River	401251	7015758	Targeting Slender-billed Thornbill
Murchison River – Eucalypt / Casuarina Woodland	405568	7014540	Major Mitchell's Cockatoo and waterbirds
Drainage line	418488	6998342	Major Mitchell's Cockatoo and waterbirds
Granite Outcrop	435563	7002295	Western Spiny-tailed Skink
Granite Outcrop	412764	7009796	Western Spiny-tailed Skink
Acacia shrubland – Pit 1	371236	6889165	Shield-backed Trapdoor Spider
Acacia shrubland – north of Pit 1	371692	6893113	Shield-backed Trapdoor Spider
Acacia shrubland – north of Pit 1	371607	6893418	Shield-backed Trapdoor Spider
Acacia shrubland – Pit 3	376435	6941350	Shield-backed Trapdoor Spider
Acacia shrubland – north of Pit 3	377880	6947806	Shield-backed Trapdoor Spider
Acacia shrubland – north of Murchison River	409549	7010763	Shield-backed Trapdoor Spider
Gnamma Hole	375453	6932667	Conservation significant birds
Pool adjacent to Murchison River	454646	7016611	Conservation significant birds

3.3.5 Motion Sensitive Cameras

Baited motion-sensitive cameras (Bushnell Trophycam) were set at three sites targeting species of conservation significance (eg. Long-tailed Dunnart). Details for camera locations are provided in Table 8 below. Motion-sensitive cameras are useful for recording a range of species, including conservation significant fauna and feral species.

Table 8. Location and details of motion cameras in operation during the 2015 fauna assessment (Zone 50J).

Camera	Easting	Northing	Description
Bushnell	388954	6981137	Acacia sandplain / drainage line
Bushnell	388739	6982037	Breakaway on eastern margin of project

3.3.6 Bird Census

Bird censuses were conducted at each borrow pit site and along the access road survey area. This included at several seemed deemed suitable to support conservation significant fauna, listed in Table 7. Censussing involved an area search technique with all bird species recorded and some species counted.

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 at the project area 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	The survey focussed on terrestrial vertebrate fauna, although some targeted searching for conservation significant invertebrates was conducted and opportunistic observations on

EPA Survey Limitations	BCE Comment
of constraints?)	freshwater fish. 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 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 2015 during warm and dry conditions. However the survey was conducted after seasonal winter rainfall and as a result several species were observed breeding. This included the Pied Honeyeater, Cockatiel, Little Button-quail, Diamond Dove, Common Bronzewing, Crimson Chat, Red-capped Robin, Bourke's Parrot and Zebra Finch.
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. Habitats likely to support conservation significant fauna were subject to further intensive sampling.
Resources (e.g. degree of expertise available in animal identification).	All species identified to taxon level.
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 DotE (Department of the Environment; 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 detailed fauna investigations;
- Species of conservation significance – based upon desktop assessment and the detailed fauna investigations;
- Recognition of ecotypes or vegetation/substrate associations (VSAs) - based upon desktop assessment and the detailed site investigations;
- Patterns of biodiversity across the landscape - based upon desktop assessment and detailed site investigations;
- Ecological processes upon which the fauna depend - based upon desktop assessment and detailed site investigations.

Impact assessment

This section reviews impacting processes (as described in detail in Appendix 2) with respect to the project and examines the potential effect of these impacts upon biodiversity of the alignment. It thus expands upon Section 1.3 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 15km 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 15km radius or within the Bioregion), whereas a low impact is where the environment is widespread (eg. 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 Results

4.1 Vertebrate Fauna

4.1.1 Overview of fauna assemblage

The desktop study identified 287 vertebrate fauna species as potentially occurring in the survey area (see Table 11 and Appendix 6): four freshwater fish, 10 frogs, 80 reptiles, 158 birds and 25 native and 10 introduced mammals. The presence of 120 species (one freshwater fish, 16 reptiles, 92 birds, five native mammals and six introduced mammals) was confirmed during the October 2015 field survey (see Appendices 5 and 6). Note that the expected species assemblage is based largely on databases and includes species that may occur occasionally, but for which it is not important (such as birds that rarely fly overhead or waterbirds infrequently using temporary or seasonal waterbodies). The vertebrate assemblage includes 26 species of conservation significance (Table 12).

The site's fauna assemblage is expected to be relatively intact, with the main exception being the medium sized mammals which have declined across mainland Australia. The key features of the fauna assemblage expected in the project 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 relatively complete but with the loss of some mammal species. 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 are expected. Bird diversity will be seasonally variable and waterbirds will be restricted to seasonal wetlands and along the Murchison River. Due to the low regional diversity, few 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 11. Composition of vertebrate fauna assemblage expected to occur within the survey area

Taxon	Number of species expected	Number of species recorded	Significant fauna expected		
			CS1	CS2	CS3
Freshwater Fish	4	1	0	1	0
Frogs	10	0	0	0	0
Reptiles	80	16	2	1	0
Birds	158	92	15	1	3
Native Mammals	25	5	0	1	1
Introduced Mammals	10	6	0	0	0
Total	287	120	17	4	4

4.1.2 Species of conservation significance

A total of 26 conservation significant vertebrate fauna species may occur in the study area, based on known distributions and available habitats. Additionally, one listed invertebrate species is known from the region. Conservation significant fauna are discussed below and a summary of their status provided in Table 12.

Table 12. Conservation status of significant fauna species expected to occur in project area. The predicted status of each species is given. See Appendix 1-3 for details of conservation significance.

Common Name	Species Name	Conservation Status			Expected status in project area	Recorded in survey area
		CS1	CS2	CS3		
Shield-backed Trapdoor	<i>Idiosoma nigrum</i>	Vul			Resident	Yes
Golden Carp Gudgeon	<i>Hypseleotris aurea</i>		P2		Resident: Murchison River	
Western Spiny-tailed Skink	<i>Egernia stokesii badia</i>	End			Resident: granite outcrops	Yes
Gilled Slender Blue-tongue	<i>Cyclodomorphus branchialis</i>	Vul			Potential resident	
Good-legged Lerista	<i>Lerista eupoda</i>		P1		Potential resident	
Malleefowl	<i>Leipoa ocellata</i>	S1			Visitor / Resident	Old mound
Slender-billed Thornbill	<i>Acanthiza iredalei</i>	Vul			Potential Resident	
Fork-tailed Swift	<i>Apus pacificus</i>	Mig			Irregular visitor	
Great Egret	<i>Ardea alba</i>	Mig			Visitor	
Grey Falcon	<i>Falco hypoleucos</i>	S1			Visitor	
Peregrine Falcon	<i>Falco peregrinus</i>	S4			Resident	Yes
Common Sandpiper	<i>Acitis hypoleucos</i>	Mig			Visitor	
Common Greenshank	<i>Tringa nebularia</i>	Mig			Visitor	
Marsh Sandpiper	<i>Tringa stagnatalis</i>	Mig			Visitor	
Wood Sandpiper	<i>Tringa glareola</i>	Mig			Visitor	
Red-necked Stint	<i>Calidris ruficollis</i>	Mig			Visitor	
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>	Mig			Visitor	
Curlew Sandpiper	<i>Calidris ferruginea</i>	Mig,Cr			Visitor	
Night Parrot	<i>Pezoporus occidentalis</i>	S1			Vagrant/locally extinct	
Rainbow Bee-eater	<i>Merops ornatus</i>	Mig			Regular migrant	Yes
Major Mitchell's Cockatoo	<i>Cacatua leadbeateri</i>			X	Resident	Yes
Australian Bustard	<i>Ardeotis australis</i>			X	Resident	
Bush Stone-curlew	<i>Burhinus grallarius</i>			X	Resident	Yes
Elegant Parrot	<i>Neophema elegans</i>			X	Occasional visitor	
Grey Honeyeater	<i>Conopohila whitei</i>			X	Resident	
Long-tailed Dunnart	<i>Sminthopsis longicaudata</i>		P4		Resident	
Kultarr	<i>Antechinomys laniger</i>			X	Resident	

Eight conservation significant fauna species were recorded during the October 2015 field survey. These included:

1. Shield-backed Trapdoor Spider, EPBC Vulnerable (burrows recorded at four locations);
2. Malleefowl, EPBC Vulnerable (old, abandoned mound recorded at Pit 1);
3. Western Spiny-tailed Skink, EPBC Vulnerable (latrines recorded at one granite hill);
4. Peregrine Falcon, Schedule 4 (recorded from wetland adjacent to Murchison River);
5. Major Mitchell's Cockatoo, CS3 (recorded at Murchison River);
6. Bush Stone-curlew, CS3 (one observed at Pit 4);
7. Western Pebble-mound Mouse, DPaW Priority 4 (several ancient mounds recorded but species locally extinct);
8. Rainbow Bee-eater, EPBC Migratory (pair observed at the Roderick River).

While not considered conservation significant, an additional three species recorded during the survey were of note due to their presence on the extreme edge of their known range. These are:

1. Australian Raven, recorded along the Murchison River;
2. Plumed Whistling Duck, recorded adjacent to the Murchison River; and
3. Brown Quail. One heard (the call is distinctive and diagnostic) on a small drainage line near the Wooleen Woolshed. This species appears to have recently moved into the Murchison, presumably from the Pilbara where it is common on alluvial grasslands of drainage systems.

The locations of conservation significant fauna recorded from the survey area are listed in Table 13 and shown in Figure 2. Conservation significant fauna recorded or expected to occur within the survey area are discussed below.

Table 13. Conservation Significant Fauna recorded during the field assessment.

Species	Conservation Status	Easting	Northing	Comments
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	Latrine
Western Spiny-tailed Skink	CS1	436132	7001719	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
Western Pebble-mound Mouse	CS2	409500	7010825	Ancient, inactive mound
Western Pebble-mound Mouse	CS2	409514	7010929	Ancient, inactive mound
Western Pebble-mound Mouse	CS2	409540	7010864	Ancient, inactive mound
Rainbow Bee-eater	CS1	462168	7024351	2 observed

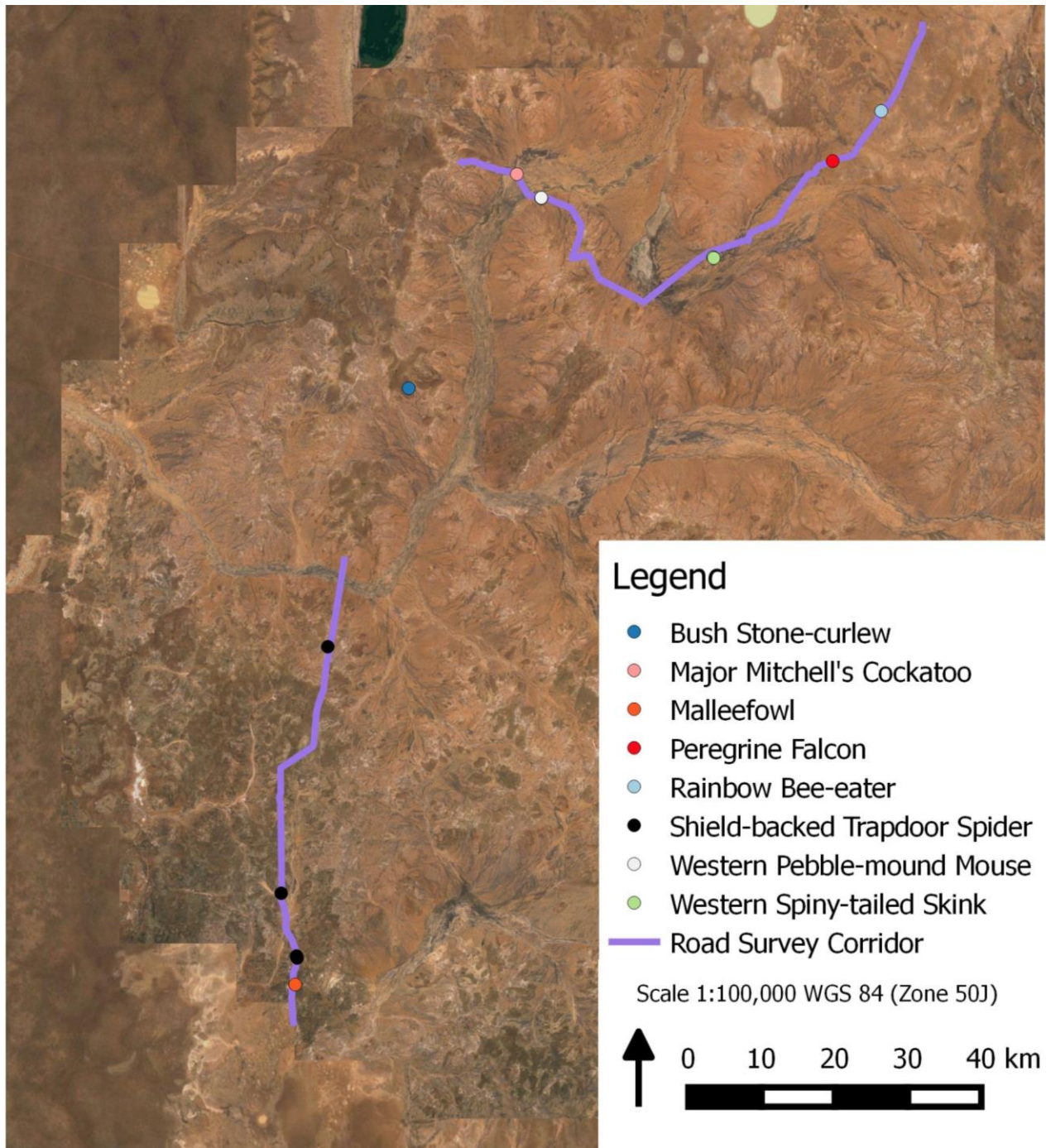


Figure 2. Conservation Significant Fauna recorded from the survey area.

Malleefowl (*Leipoa ocellata*) EPBC Vulnerable

One, ancient, abandoned Malleefowl mound was recorded during the survey, at borrow pit 1 (see Table 13, Figure 2). There are several records of the species in the local area, including from approximately 15km east of Pit 1 and from Talling 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, this species is likely to occur in adjacent areas of suitable habitat (dense Acacia shrublands). Suitable dense Acacia shrublands were observed, particularly in the vicinity of Borrow Pit 1 and along the Carnarvon Mullewa Rd near Talling Peak (from 370891E, 6887646N to 369878E, 6899950N). As the species can move over several kilometres (Benshemsh, 1992), the Malleefowl has the potential to move through the survey area. Additionally, Malleefowl are able to breed in mounds constructed within 20m of the edge of a road (J. Turpin pers. obs.). Therefore, with an increase in road usage and vehicle speed (associated with the road upgrade) the risk of roadkill is increased.

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. The species was recorded from the survey area with several scat latrines located amongst granite boulders on a large granite hill adjacent to the Boolardy – Wooleen Road (near Pia Wadjarri, Table 13, Figures 3 and 4). The skink was also recorded near the SKA project during the original BCE survey (468097E, 7053434N; 455761E, 7043651N) and a few scattered records occur across the local area (DPaW, 2015). The Western Spiny-tailed Skink is restricted to the granite outcrops and boulders, where it lives communally within deep rock crevices (J. Turpin, pers. obs.).



Figure 3. *Egernia stokesii* scat piles recorded during the survey.



Figure 4. *Egernia stokesii* habitat recorded during the survey.

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 at four locations (see Table 13, Figures 5 and 6):

1. Carnarvon – Mullewa Road (four burrows located);
2. Carnarvon – Mullewa Road (three burrows located);
3. Carnarvon – Mullewa Road (one burrow located);
4. Borrow Pit 3 (seven burrows located).

At all locations the spiders were located on the slopes of slight lateritic gravelly rises supporting Acacia shrubland, although at borrow pit 3 the species was recorded on a sandplain overlying and merging with a lateritic rise. 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). Along the survey corridor, the species is likely to occur on the gravelly ironstone and lateritic slopes of Tallering Peak, and its surrounds. Suitable habitat extends from near the Greenough River north to Borrow Pit 3.



Figure 5. Shield-backed Trapdoor Spider burrow recorded near Borrow Pit 1.

Figure 6. Shield-backed Trapdoor Spider burrow in Borrow Pit 3.



Slender-billed Thornbill (*Acanthiza iredalei*) EPBC Vulnerable

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 but surveys in this location failed to find the species.

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 (eg. 15km north of Mullewa and Mount Magnet, DPaW, 2015). South of the survey area, it has been recorded on the slopes of ironstone hills. 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*), Rainbow Bee-eater (*Merops ornatus*) EPBC M, WCA S5

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 project 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 (J. Turpin, pers. obs.). Although this species has declined across parts of its range, it still has a widespread distribution throughout the 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 project area.

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

The Peregrine Falcon is found in a variety of habitats, including rocky ledges, cliffs, watercourses, open woodland and acacia shrublands. The distribution of the Peregrine Falcon is often tied to the abundance of prey as this species predaes heavily on other birds. The Peregrine Falcon lays its eggs in recesses of cliff faces, tree hollows or in large abandoned nests of other birds (Birds Australia 2012). 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 (pair recorded, preying on an abundance of waterbirds, see Table 13). It is likely to occur within 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. 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 Eastern Great Egret has been recorded from the Murchison River near the survey area.

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 Borrow Pit 4 (one adult observed, 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 at the Murchison River crossing east of Murchison settlement. A single adult bird was observed roosting in a eucalypt tree indicating a breeding female occur nearby in a tree hollow. This species is likely to breed within the large, hollow-bearing eucalypt trees fringing the Murchison River and other 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.

Grey Honeyeater (*Conopohila 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.

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

The Long-tailed Dunnart inhabits rocky areas, such as banded ironstone hills and ridges (J. Turpin, pers. obs.). 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.

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.

Western Pebble-mound Mouse (*Pseudomys chapmani*) DPaW Priority 4

The Western Pebble-mound Mouse formerly occurred across the Murchison and Gascoyne regions (DPaW, 2015), however appears restricted now to the Pilbara with only old abandoned mounds recorded to the south. Several old pebble-mounds were recorded in the survey area on low stony hills (Table 13). Old, abandoned mounds are a common feature in the region (BCE records from Boolardy, Andy Well, Robinson Range) and reveal the taxa was formerly widespread in the area.

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.

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.). Due to the presence of a population in the vicinity of the survey area, there is the potential for *Lerista eupoda* to occur.

4.1.3 Conservation significant invertebrates

The Shield-backed Trapdoor Spider was recorded from the survey area and is discussed above. Overall, the project area 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).

4.1.4 Introduced/Feral Species

The desktop study identified nine introduced fauna species as potentially occurring in the survey area (see **Table 14**). Of these, six were recorded during the survey, with the remaining species expected to be resident or occasional visitors to the survey area.

Table 14. Introduced fauna species expected to occur in project area.

Common Name	Latin Name	Expected status in project area
Dingo	<i>Canis lupis</i>	Resident and recorded in project area
House Mouse	<i>Mus musculus</i>	Resident
European Rabbit	<i>Oryctolagus cuniculus</i>	Resident and recorded in project area
Red Fox	<i>Vulpes vulpes</i>	Resident
Cat	<i>Felis catus</i>	Resident and recorded in project area
Goat	<i>Capra hircus</i>	Resident and recorded in project area
Donkey	<i>Equus asinus</i>	Occasional visitor / Resident and recorded
Horse	<i>Equus caballus</i>	Resident
Camel	<i>Camelus dromedarius</i>	Occasional visitor / Resident
Domestic Cattle	<i>Bos taurus</i>	Resident and recorded in project area

4.2 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 alongside 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 is also crossed near the project's northern boundary. A small number of seasonal, 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 Plates 1 - 11):

1. Drainage systems supporting *Eucalyptus camaldulensis*, Acacia shrublands and tussock grasslands. Major drainage support areas of *Casuarina obesa* and contain pools of water with fringing sedgelands 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 wanderrie 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. Granitic breakaways, varying relief, some minor areas with cliff faces up to 3m, supporting *A. aneura* and *A. quadramarginea* shrublands.

A summary of each Borrow Pit is presented below:

Borrow Pit 1

Borrow Pit 1 is situated on a low stony rise supporting dense Acacia shrubland (*A. aneura*, *A. quadramarginea*) with a shrubby understorey of *Eremophila* species. A broad band of sandy loam in the north supports areas mixed Acacia shrubland with an understorey of dense *Eremophilas*. The eastern boundary is fringed with a breakaway system which drops steeply to the surrounding plain to the east.

Borrow Pit 2

The borrow pit is situated on an elevated lateritic, gravelly plateau which drops to the south and east to a low-lying sandplain. Some areas of outcropping occur and a small gnamma hole supporting a locally significant water resource was located at 375453E, 6932667N. Vegetation comprises a mixed Acacia shrubland (*A. aneura*, *A. quadramarginea*), with areas of open *Thryptomene decussata* on the rocky rises.

Borrow Pit 3

The borrow pit is situated on a low lateritic rise surrounded by an Acacia dominated sandplain. The low lateritic plateaux support Acacia and *Thryptomene decussata*. A small lateritic stony rise is situated in the north containing a densely vegetated, Acacia dominated gully and a minor drainage line flanks the southern boundary.

Borrow Pit 4

The borrow pit areas lies on an undulating lateritic upland, dissected by minor drainage lines. The rocky terrain drops steeply where minor areas of breakaway occur. A broad sandy valley and plain flank the borrow pit area. Vegetation comprises *Acacia* and *Eremophila* shrublands (*A. aneura*, *A. quadramarginea* with *Acacia ramulosa* in sandy areas) with *Psyrax latifoila* and *Santalum spicatum* and scattered to open Acacia on stony plains.

Borrow Pit 5.

The borrow pit area is centred on an open stony plain with a slight lateritic gravelly rise. Vegetation is dominated open Acacia shrublands (*A. aneura*, *A. quadramarginea* and *A. grasbyi*).

Borrow Pit 6.

The borrow pit area is situated on a hardpan with scattered Acacia (*A. aneura* and *A. grasbyi*) with an open understorey. A minor lateritic rise occurs on the eastern boundary with small sandplain areas adjacent.

Borrow Pit 7.

The area lies on the outwash plain and hardpan adjacent to the Roderick River. Vegetation comprises open *Acacia* shrublands (*A. aneura* and *A. tetragonophylla*) with an *Eremophila* dominated understorey. A drainage line flanks the western boundary supporting scattered eucalypts and dense tussock grasslands.

Borrow Pit 8.

The area lies on the floodplain adjacent to the Roderick River. Vegetation includes *Acacia* and *Eremo-phila* low shrublands over a rich and dense layer of *Ptilotus* spp., herb and grasses, on red loam. Along the western edge of the area, a small creekline supports scattered River Gums and dense *Acacia* thickets.

Borrow Pit 9.

The area lies on the floodplain adjacent to the Roderick River. Vegetation includes *Acacia* and *Eremophila* shrublands with the Roderick River supporting fringing River Gums and dense *Acacia* thickets.

Plate 1. Drainage systems supporting *Eucalyptus camaldulensis*, Acacia shrublands and tussock grasslands. Major drainages support areas of *Casuarina obesa* and contain pools of water with fringing sedgeland and grasslands. Murchison River.



Plate 2. Drainage systems supporting eucalyptus woodland, Acacia shrublands and tussock grasslands.



Plate 3. Floodplain depressions supporting chenopod shrublands (Samphire, Bluebush, Saltbush). Near Murchison River.



Plate 4. 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.



Plate 5. Hardpan wash plains supporting mulga dominated shrublands.



Plate 6. Sandplains supporting Acacia shrublands (eg. *A. ramulosa*, *A. aneura*)



Plate 7. Stony plains supporting sparse / open Acacia and Eremophila shrublands.



Plate 8. Granite Outcrops, Granite domes and hills supporting scattered Acacia shrublands



Plate 9. Low lateritic stony rises supporting Acacia shrublands (dominated by *A. aneura* and *A. quadramarginea*) with minor areas of outcropping;



Plate 10. Lateritic, gravelly hills and stony rises supporting Mulga shrublands with an *Eremophila* shrub layer. Upper, stony slopes support areas of *Thryptomene decussata*.



Plate 11. Rocky breakaways supporting Acacia shrublands.



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 corridor, significant areas for fauna biodiversity include water sources (providing for a large range and concentration of fauna), linear habitats (allowing for the movement of fauna) and relictual habitats (supporting relictual fauna). This includes:

1. Gnamma holes: support a concentrated fauna assemblage, especially birds;
2. Major drainage lines: the Murchison and Roderick Rivers are fringed with large mature trees providing roosting and breeding sites for several species (eg. Major Mitchell's Cockatoo), contains seasonal and permanent pools supporting freshwater fish, waders and waterbirds, and provides linkage across the landscape;
3. Granite Outcrops: support a highly restricted fauna assemblage including the Western Spiny-tailed Skink.
4. Rocky, lateritic hills supporting dense Acacia shrublands support the conservation significant Malleefowl and *Idiosoma nigrum*.

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 and a pool adjacent to the Roderick River (eg. several ducks and waders). The

riparian vegetation along the rivers and drainage lines also supported elevated numbers of parrots and Eucalypt canopy specialists (such as the Striated Pardalote, Weebill and White-plumed Honeyeater). The Brown Quail was also observed in dense riparian grassland. The elevated avian assemblage around water also supported avian predators such as the Peregrine Falcon and Collared Sparrowhawk.

One gnamma hole was recorded from Borrow Pit 2 (375453E, 6932667N) and additional water sources are expected to be present along the breakaway fringing the eastern margins of Borrow Pit 1, where a high concentration of birds was observed (eg. several parrot species – Bourke’s Parrot, Mulga Parrot and Galah). Permanent and semi-permanent pools were also observed within and adjacent to the Murchison River, supporting several waterbirds and freshwater fish. A significant pool at 454646E, 7016611N supported several waterbird species including a number of Plumed Whistling Ducks occurring in the area at the southern extreme of its known range (others included Pink-eared Duck, Black-tailed Native Hen, Grey Teal, Pacific Black Duck).

The mature eucalypts fringing drainages provide nesting opportunities for many birds. The Cockatiel was observed nesting within tree hollows and the Major Mitchell's Cockatoo was also likely to be nesting along the Murchison River, as a lone adult was flushed from a tree.

In total, 19 species were recorded only in association with drainage lines or water associated VSAs (see Table 15). A further two species were only recorded amongst rock outcrops.

Table 15. VSA restricted fauna recorded during the field assessment.

Water Bodies	Riparian Vegetation	Rock Outcrops
Murchison River hardyhead	Brown Quail	Western Spiny-tailed Skink
Pacific Black Duck	Major Mitchell’s Cockatoo	Woolley's Pseudantechinus
Grey Teal	Little Corella	
Pink-eared Duck	Black-tailed Native-hen	
Plumed Whistle-Duck	Weebill	
White-faced Heron	White-plumed Honeyeater	
White-necked Heron	Striated Pardalote	
Australian Pelican	Long-nosed Dragon	
Little Black Cormorant	Cockatiel (breeding only)	
Black-fronted Dotterel		

An additional VSA of note is the rocky hills and gravelly slopes supporting dense Acacia shrublands, suitable for the Malleefowl and Shield-backed Trapdoor Spider.

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 (runon and runoff). Mulga groves are dependent on sheet flow (eg. 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.

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. The project should be managed to minimise the risk of destructive, high intensity fires.

Feral species and interactions with native species. The fauna assemblage has already been impacted by feral species with the loss of some mammals due to feral predators. Increasing human activity often results in the increasing abundance of feral species (such as the feral Cats and Foxes attracted to work camps). This should be managed to reduce any impact this may have on native fauna 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. Most VSAs that provide habitat for fauna are broad in extent, however the drainage line VSAs are significant in providing connectivity across the landscape. Additionally, the development of the road upgrade may further contribute to habitat fragmentation.

4.5 Summary of fauna values

Fauna values within the study area can be summarised as follows (see Table 16):

Fauna assemblage. Considered to be relatively intact, within a relatively intact, largely uncleared landscape. 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 (eg. Western Spiny-tailed Skink and Woolley's Pseudantechinus). Two species recorded during the survey are at the extreme edge of their known range.

Species of conservation significance. A total of 26 species of conservation significance are expected to be present at least occasionally within the project area. Eight conservation significant species were recorded within the project area. The Shield-backed Trapdoor Spider, Major Mitchell's Cockatoo, Peregrine Falcon and Bush Stone-curlew have resident populations in the project area. While the Malleefowl is a likely resident or visitor, no recently used mounds (breeding sites) were recorded within the areas searched. The Western Spiny-tailed Skink is restricted to granite outcrops adjacent to the project 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 is a regular migrant to the area.

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.

Overall, the more southerly borrow pit locations are likely to support more species of conservation significance than those in the north (Table 16). This relates to the distribution of species and environments, with the Malleefowl and Shield-backed Trapdoor Spider most abundant in the south, and important VSAs such as Mulga on gravelly slopes being present in the south.

Vegetation and Substrate Associations. 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 project 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 (eg. Major Mitchells

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 *Idiosoma nigrum*.
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:

1. Gnamma holes: support a concentrated fauna assemblage, especially birds;
2. Major drainage lines: the Murchison and Roderick Rivers are fringed with large mature trees providing roosting and breeding sites for several species (eg. Major Mitchells Cockatoo), contains seasonal and permanent pools supporting freshwater fish, waders and waterbirds and provides linkage across the landscape;
3. Granite Outcrops: support a highly restricted fauna assemblage including the Western Spiny-tailed Skink.
4. Rocky, lateritic hills supporting dense Acacia shrublands support the conservation significant Malleefowl and the Shield-backed Trapdoor Spider.

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. The elevated avian assemblage around water also supported avian predators. Temporary waterbodies within the drainage lines will provide some habitat to waterbirds allowing for movement and dispersal. Rocky outcrops support saxicoline fauna, generally restricted to such habitat (eg. *Pseudantechinus woolleyae*, Western Spiny-tailed Skink).

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.

Table 16. Summary of Fauna Values at each Borrow Pit location and within the road corridor (split into the northern and southern sections). Those values relevant for each survey area are listed or denoted by X = recorded within area, L = likely to occur (suitable habitat present), V = expected as a visitor only.

Fauna Values	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Pit 7	Pit 8	Pit 9	Road South Section	Road North Section
Restricted Fauna	yes	yes	yes	yes						yes	yes
Shield-backed Trapdoor Spider	L	L	X							X	
Malleefowl	X	L	L	L	L					L	V
Slender-billed Thornbill											L
Bush Stone-curlew	L	L	L	X	L	L	L	L	L	L	X
Major Mitchell's Cockatoo										L	X
Peregrine Falcon	L	L	L	L	L	L	L	L	L	L	X
Western Spiny-tailed Skink											X
Rainbow Bee-eater	L	L	L	L	L	L	L	L	L	L	X
Golden-carp Gudgeon										L	L
Gilled Slender Blue-tongue	L	L								L	
Long-tailed Dunnart	L	L	L	L	L					L	L
Grey Honeyeater	L	L	L	L						L	L
Migratory Waterbirds										V	V
Sensitive / Significant VSAs	X	X	X	X						X	X
Granite Outcrops											X
Drainage lines				X						X	X
Floodplain depressions											X
Gravelly slopes with dense Mulga	X	X	X	X						X	
Gnamma Holes		X									

5 Impact assessment

5.1 Overview of Impacts

As outlined in section 1.1, PB, on behalf of Main Roads WA (MRWA), commissioned Bamford Consulting Ecologists to conduct a Level 1 fauna assessment of the SKA project road upgrade, and identify the fauna values of the area. The following sections examine possible impacts upon these fauna values based upon the impacting or threatening processes outlined in Appendix 2. Impacts are summarised in Table 17. Impact criteria are outlined in Table 10. Recommendations relating to impacts are made in Section 7.

5.1.1 *Loss of habitat leading to population decline*

Some loss of habitat is inevitable but can be minimised through controls during clearing. Minimal vegetation clearance will be required where the project footprint overlays the existing road, but more extensive clearing is required at some borrow pit sites. As such vegetation clearance should be kept to a minimum by retaining the majority of the project footprint over the existing road and strictly defining disturbance areas in borrow pits. Rehabilitation of disturbed areas may also be implemented as soon as possible after clearing. The small areas of impact in relation to the surrounding landscape means that loss of habitat is unlikely to have long-term adverse impacts upon most fauna populations in the region, however disturbances to breeding sites (eg. Malleefowl mounds, tree hollows for Major Mitchell's Cockatoo) or fauna living in restricted colonies (eg. Western Spiny-tailed Skink) require some consideration.

The Malleefowl occurs in the local area and suitable habitat occurs in the vicinity of Borrow Pit 1 and along the Carnarvon Mullewa Rd near Tallering Peak (from 370891E, 6887646N to 369878E, 6899950N). In this area, vegetation clearance should be avoided where possible and if disturbances to Malleefowl habitat (dense Acacia shrublands) is proposed, mounds (breeding sites) should be left undisturbed by conducting pre-clearance checks.

The Western Spiny-tailed Skink is restricted to granite outcrops mostly adjacent to the project footprint. As such, disturbances to granite outcrops should be avoided to minimise disturbance to the isolated and restricted populations. There will be almost no direct impact upon granite outcrops.

Large, mature trees flank several of the drainage lines of the project area, including the Murchison and Roderick Rivers. These provide breeding and roosting sites for many birds (parrots, owls) and bats and are a rare resource in the region. Disturbances to large, mature trees should be avoided where possible.

For each area, the risk to fauna values from loss of habitat is summarised in Table 18. In general, the risk from loss of habitat is low because most VSAs are widespread, and the most restricted VSAs are not being directly impacted.

5.1.2 Loss of habitat leading to population fragmentation

Some landscape features within the project area e.g. drainage lines and associated vegetation, have a connectivity function for fauna, aiding them to move through the landscape. Therefore, impacts upon these features could disrupt this movement, facilitating population fragmentation. Impacts to linear landscape features should be minimised i.e. the drainage lines throughout the project area.

5.1.3 Degradation of habitat due to weed invasion

Weed invasion within the project area is likely to be most significant along the margins of the existing roads, with the worst affected areas expected to be the riverine woodland due to factors including regular soil disturbance associated with grazing and regular water movement. Further impacts from weeds can be minimised by maintaining reasonable hygiene measures.

5.1.4 Ongoing mortality

Increased mortality is inevitable during clearing operations and from ongoing activities, such as roadkill due to animals being struck by vehicles. In general, areas to be cleared are likely to be small within the context of the regional landscape so mortality during clearing is likely to represent only small proportions of regional populations (so long as habitat critical to a species survival is avoided). For common species, levels of mortality are unlikely to be significant in a conservation sense, but there are welfare issues. However, the viability of species that occur at low population densities including in areas adjacent to the project area may be compromised by ongoing mortality. For example, if a population of Malleefowl was present in or nearby to the project area, roadkill could be a concern. The upgrade of the road is likely to result in an increased volume of traffic and increased speed of traffic, which is likely to, in turn, increase the risk of roadkill for Malleefowl. There are anecdotal accounts of high rates of mortality on newly-completed bitumen roads, particularly of reptiles, with a decline in mortality presumably as populations very close to the new road are reduced. Much of this mortality occurs early and late in the day when reptiles move onto the road to bask. This can be very noticeable just after sunset during summer when the road is still warm and nocturnal species bask on the warm bitumen before foraging.

5.1.5 Species interactions

Feral species are a major conservation concern; six introduced species were detected and others are highly likely to be present. Feral fauna are known to use roads and cleared areas to

access habitats and facilitate predation. However, the development of the project (upgrade of the existing road) is unlikely to significantly increase species interactions beyond that currently present within the project area.

5.1.6 Hydroecology

Interruptions of hydroecological processes are a concern where VSAs may be impacted, resulting in impacts to fauna species. Hydrology may be affected in a number of situations within the project area; for example, the interruptions to drainage and sheet flow. The dense shrublands and woodlands associated with drainage lines are likely to be dependent on sheet flow (eg. 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 biodiversity management in the project area.

5.1.7 Altered fire regimes

While the biota of the region is probably adapted to a particular fire regime, it is likely this regime has already been altered since European settlement. The project should be managed to minimise the risk of destructive, high intensity fires.

5.1.8 Disturbance

Impacts of dust, light, disturbance and noise upon fauna are difficult to predict. The impacts of dust may be reduced by upgrading the road to a bitumen surface.

5.1.9 Summary of impacts

Impacts upon key fauna values are summarised in Table 17 and are considered to be Minor or less. This is due to the site's location within a largely intact landscape; a landscape expected to contain large areas of the same VSAs as those present within the survey area and the presence of an existing cleared road, overlying much of the project area. There is some concern about the potential of the project on the local population of the Malleefowl and Shield-backed Trapdoor Spider, loss of breeding sites (mounds and tree hollows) and upon local hydrology, thereby impacting VSAs and consequently impacting fauna. Habitat degradation as a result of weed incursion and/or fire, and the activities of feral fauna may also be of some concern. Recommendations made in this table are expanded in Section 7. A breakdown of impacting processes for each borrow pit location and the road corridor is presented in Table 18.

Table 17. Summary of potential impacts upon key fauna values expected to occur in the project area.

Criteria for significance of impacts are outlined in Section 3.5.1.

Fauna Value	Nature and Significance of Impact		Action required
	Potential Impacts	Significance	
Fauna assemblage	Increased mortality; Loss of habitat; and Species interactions.	Minor as impacts very localized in a regional context	Minimise impact footprint; Restrict footprint to existing road; Manage ongoing mortality if required.
VSAAs	Loss of habitat; Altered hydroecology; Habitat degradation through weed invasion.	Minor as these are widespread in the region	Minimise footprint; and Avoid disturbances to significant habitats – granite outcrops, drainage lines, mature trees, gnamma holes.
Significant fauna	Loss of habitat; and Ongoing mortality.	Mostly minor as if management measures implemented	Minimise impact footprint; Restrict footprint to existing road; Avoid impacts to significant habitats (eg. Malleefowl mounds, granite outcrops, gnamma holes). Conduct pre-clearance inspection to ensure Malleefowl mounds are not disturbed.
Patterns of biodiversity	Loss of habitat; Altered hydroecology; and Habitat degradation through weed invasion.	Minor as impacts very localized	Avoid impacts to watercourses and rocky outcrops where possible; Minimise footprint where possible.
Ecological processes	Potential impacts on hydrology; and Ongoing mortality.	Minor but changes to hydrology could be a concern.	Management to prevent any impacts to local hydrology; and Restrict footprint to existing road;

Table 18. Summary of impacts processes for each survey area.

Impacting Process	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Pit 7	Pit 8	Pit 9	Road South	Road North
Increased mortality	I.n.	I.n.	I.n.							X	X
Ongoing mortality										X, M, R	X, R
Loss of habitat	X, VSA	X, VSA	X, VSA	X	X	X	X	X	X	X, VSA	X, VSA
Hydrological change										X	X
Degradation of habitat - weed invasion										X	X
Species interactions										X	X
Fire										X	X
Dust, light, noise and vibration										X	X

Codes: X = general fauna assemblage, I.n. = *Idiosoma nigrum*, M = Malleefowl, VSA = Sensitive VSAs; R = reptiles

6 EPBC Criteria

As the Malleefowl, Western Spiny-tailed Skink, Slender-billed Thornbill and Shield-backed Trapdoor Spider are Matters of National Environmental Significance (Vulnerable or Endangered under the EPBC Act) management measures should include reducing or avoiding impacts to the local populations. Under the Department of the Environment's Matters of National Significance – Significant Impact Guidelines (DoTE, 2015), an action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

- lead to a long-term decrease in the size of an important population of a species
- reduce the area of occupancy of an important population
- fragment an existing important population into two or more populations
- adversely affect habitat critical to the survival of a species
- disrupt the breeding cycle of an important population
- modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
- result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
- introduce disease that may cause the species to decline, or
- interfere substantially with the recovery of the species.

The EPBC listed species expected to occur within the project footprint are discussed below.

6.1 Malleefowl

A Malleefowl population occurs in the local area, with several recent records in adjacent areas and one old mound recorded at Borrow Pit 1 (Table 13, DPaW, 2015). As the species can move over several kilometres (Benshemsh, 1992), there is the potential for the species to move through the project area. Breeding (mound construction) also may be possible as the species can construct mounds within 20m of existing roads (J. Turpin, pers. obs.). Although no active or recently active mounds were observed, due to the nature of the survey (reconnaissance / Level 1) it was not possible to search the entire project area (road with 100m buffer either side). As some areas of potential habitat were recognised vegetation clearance should be minimised in such areas – in the vicinity of Borrow Pit 1 and along the Carnarvon Mullewa Rd near Tallering Peak (over approximately 15km of road, from 370891E, 6887646N to 369878E, 6899950N). In this area, vegetation clearance should be avoided where possible and if disturbance to Malleefowl habitat (dense Acacia shrublands) is proposed, mounds (breeding sites) should be left undisturbed by conducting pre-clearance checks. As a result, any proposed vegetation clearing within this area should be inspected by a qualified zoologist beforehand.

One old Malleefowl mound was recorded within the survey area, however, due to its ancient age, has little conservation value. While disturbance to this mound is unlikely to result in a significant impact to the local population using the criteria listed above (EPBC Significant

Impacts Guidelines), as the species is of conservation significance, efforts should be made to minimise impacts to the local population, which includes avoiding disturbance to suitable breeding sites (mounds) and habitats (dense Acacia shrublands). The assessment of Malleefowl with regard to the EPBC Significant Impact Criteria are summarised in the Table below. Note, as the Malleefowl population in the vicinity of the project area lies on the arid fringe of the species range, the population is considered important. The assessment concludes that there is some risk from roadkill and borrow pit areas to be cleared should be checked for mounds beforehand, particularly in Borrow Pits 1, 2 and 3.

EPBC Criteria	Comment
Lead to a long-term decrease in the size of an important population of a species	The home ranges of individual Malleefowl can vary from 0.5 to 4.6 km ² , however can overlap considerably and so an overall breeding density of 1.1 pair/ km ² has been recorded (Benshemesh 1992; Booth 1987). The borrow pit areas are thus small relative to a Malleefowl pair's home range. Due to presence of the existing road the clearing footprint for road widening would have only a slight effect on any pair's home range. While no breeding sites were located, there is the potential for the species to breed within the project area, notable in the south (Borrow Pits 1, 2 and 3). Vegetation clearance should be avoided in areas of significant Malleefowl habitat and if disturbance to Malleefowl habitat (dense Acacia shrublands) is proposed, mounds (breeding sites) should be left undisturbed by conducting pre-clearing checks. The development of the project is unlikely to lead to a long-term decrease in the size of an important population of the species if disturbance to Malleefowl mounds is avoided and roadkill does not contribute to the decline of the species.
Reduce the area of occupancy of an important population	Because development areas are small relative to the landscape, the development of the project is unlikely to reduce the area of occupancy of an important population of the species if disturbances to Malleefowl mounds are avoided and roadkill does not contribute to the decline of the species.
Fragment an existing important population into two or more populations	The project corridor overlays an existing road so levels of fragmentation are unlikely to be increased beyond that currently existing.
Adversely affect habitat critical to the survival of a species	Habitat critical to the survival of the Malleefowl includes breeding sites (mounds) and habitat (dense Acacia shrublands). No active or recently used mounds were recorded within the survey area, however, due to the nature of the survey (reconnaissance / Level 1) it was not possible to search the entire project area of every borrow pit. In addition, new mounds could be created between the survey and any planned clearing. Some areas of suitable breeding habitat were recorded in the vicinity of Borrow Pit 1 and Talling Peak, where the species has been previously recorded. As a result, an inspection of proposed clearing footprints in the southern borrow pits should be carried out shortly before clearing takes place.

<p>Disrupt the breeding cycle of an important population</p>	<p>No active or recently used mounds were recorded within the survey area, however, due to the nature of the survey (reconnaissance / Level 1) it was not possible to search the entire project area. Some areas of suitable breeding habitat were recorded in the vicinity of Borrow Pit 1 and Tallering Peak, where the species has been previously recorded. As a result, an inspection of the project footprint should be conducted prior to clearing where the project plans to disturb potential Malleefowl habitat, to ensure Malleefowl mounds are not disturbed.</p>
<p>Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline</p>	<p>The area of impact is small relative to the overall landscape.</p>
<p>Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat</p>	<p>The Malleefowl is vulnerable to predation by feral cats and foxes, and chick mortality is high. The species is also vulnerable to land degradation and competition by feral goats and rabbits. However due to the site's location and the presence of existing threats, the development of the project is unlikely to increase such threatening processes beyond that currently present.</p>
<p>Introduce disease that may cause the species to decline, or</p>	<p>Considered unlikely.</p>
<p>Interfere substantially with the recovery of the species.</p>	<p>In the greater area, there are a few scattered Malleefowl records indicating that the species occurs in low densities. An extant population is yet to be confirmed utilising the survey area (however a precautionary principle is applied here as suitable habitat is present). As the road upgrade will result in an increased traffic volume, the increased risk of roadkill may be of concern for the recovery of the species in the local area.</p>

6.2 Shield-backed Trapdoor Spider

The Shield-backed Trapdoor Spider was recorded from four locations (spaced over approximately 60km, Table 13). Along the survey corridor, the species is likely to occur on the gravelly ironstone and lateritic slopes of Tallering Peak and its surrounds. Suitable habitat extends from near the Greenough River (370891E, 6887646N) north to Borrow Pit 3 (371607E, 6893418N, over a distance of approximately 80km, see Figure 2). Vegetation clearing should be minimised in such areas. Any vegetation clearing within this area may require inspection by a qualified zoologist beforehand.

As suitable habitat is extensive in the region, the proportion of habitat within the project area is likely to represent only a small proportion of local habitat, and therefore a small proportion of the local population. While the development is unlikely to result in a significant impact to the local population using the criteria listed above (EPBC Significant Impacts Guidelines), as the species is of conservation significance, efforts should be made to minimise impacts, which includes avoiding disturbance to suitable habitats (dense Acacia shrublands) and known populations. The assessment of Shield-backed Trapdoor with regard to the EPBC Significant Impact Criteria are summarised in the Table below.

EPBC Criteria	Comment
Lead to a long-term decrease in the size of an important population of a species	<p>The Shield-backed Trapdoor Spider typically inhabits Acacia shrublands with a gravelly loam substrate. The species has been recorded across a wide area from Jack Hills south to the Wheatbelt and there are scattered records across the Murchison, typically associated with the gravelly slopes of rocky hills (eg. Jack Hills, Weld Range, Tallering Peak). Across the region, populations are associated with rocky habitats, primarily in positions with increased moisture retention properties like gullies and drainage lines on southern facing slopes. Within the survey area three populations were recorded on the gravelly slopes of lateritic hills supporting Acacia shrublands, with a fourth recorded on sandplain inter-grading with a lateritic slope. The species has been recorded in densities of 50 - 400 spiders per hectare in suitable habitat on banded ironstone ridges of the Midwest (BCE records). Similar densities may be expected in suitable habitat within the project area.</p> <p>The extent of available habitat within the survey area is patchy but extends over approximately 80km and at most would be approximately 800 hectares of native vegetation. This represents approximately <0.05% of habitat within 15km of the project corridor (potential habitat within 15km of project is estimated to exceed 160km²). Therefore the survey area (and particularly the proposed disturbance area) may at most, form only a very small percentage of the species' local occurrence. However, some populations may be somewhat isolated and therefore disturbances to existing known populations should be avoided. Furthermore, as the species is listed under the EPBC act, vegetation clearance within the species known local range (370891E, 6887646N -</p>
OR	
Reduce the area of occupancy of an important population	
OR	
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	

	371607E, 6893418N) should be minimised and the existing road corridor should be utilised for the development. If habitat clearing is minimised, the development of the project is unlikely to lead to a long-term decrease in the size of an important population of a species
Fragment an existing important population into two or more populations	The project corridor overlays an existing road so levels of fragmentation are unlikely to be increased beyond that currently existing.
Adversely affect habitat critical to the survival of a species	Habitat critical to the survival of the Shield-backed Trapdoor Spider includes Acacia shrublands on gravelly rises. Four important areas were recorded during the survey and disturbances to such areas should be avoided.
Disrupt the breeding cycle of an important population	The project corridor overlays an existing road so levels of disturbance are unlikely to be increased beyond that currently existing.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	Considered unlikely providing weed management measures are implemented.
Introduce disease that may cause the species to decline, or	Considered unlikely.
Interfere substantially with the recovery of the species.	Considered unlikely.

6.3 Western Spiny-tailed Skink

The Western Spiny-tailed Skink was recorded from two locations adjacent to the project corridor (Table 13). Suitable habitat (granite outcrops) is mostly absent from within the project area, with most areas lying outside the 100m buffer. While the development of the project is unlikely to result in a significant impact to the local population using the criteria listed above (EPBC Significant Impacts Guidelines), as the species is of conservation significance, efforts should be made to minimise impacts to the local population, which includes avoiding disturbance to suitable breeding sites and habitats (granite outcrops). The assessment of the Western Spiny-tailed Skink with regard to the EPBC Significant Impact Criteria are summarised in the Table below.

EPBC Criteria	Comment
Lead to a long-term decrease in the size of an important population of a species	In the Murchison region, the Western Spiny-tailed Skink is restricted to rocky areas, generally extensive granite outcrops with a diverse shrub layer (J. Turpin, pers. obs.). Such areas are generally isolated and are sparsely scattered across the region. The Western Spiny-tailed Skink was recorded adjacent to the survey area (at 436232E, 7001582N and 436132E, 7001719N). Suitable

	<p>habitat was recorded within the survey buffer area at two locations (albeit in small areas – at 435563E, 7002295N and 412764E, 7009796N). If disturbances to granite outcrops are avoided, the development of the project will unlikely to lead to a long-term decrease in the size of an important population of a species</p>
<p>Reduce the area of occupancy of an important population</p>	<p>In the Murchison region, the Western Spiny-tailed Skink is restricted to rocky areas, generally extensive granite outcrops with a diverse shrub layer (J. Turpin, pers. obs.). Such areas are generally isolated and are sparsely scattered across the region. The Western Spiny-tailed Skink was recorded adjacent to the survey area (at 436232E, 7001582N and 436132E, 7001719N). Suitable habitat was recorded within the survey buffer area at two locations (albeit in small areas – at 435563E, 7002295N and 412764E, 7009796N). If disturbances to granite outcrops are avoided, the development of the project will unlikely reduce the area of occupancy of an important population.</p>
<p>Fragment an existing important population into two or more populations</p>	<p>The project corridor overlays an existing road so levels of fragmentation are unlikely to be increased beyond that currently existing.</p>
<p>Adversely affect habitat critical to the survival of a species</p>	<p>Habitat critical to the survival of the Western Spiny-tailed Skink includes deeply dissected boulder piles amongst granite outcrops. Such areas are generally isolated and are sparsely scattered across the region. Several large granite outcrops occur in areas adjacent to the project however minimal habitat occurs within the project corridor.</p>
<p>Disrupt the breeding cycle of an important population</p>	<p>No breeding colonies restricted to the project footprint, thus considered unlikely.</p>
<p>Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline</p>	<p>Habitat critical to the survival of the Western Spiny-tailed Skink includes deeply dissected boulder piles amongst granite outcrops. Such areas are generally isolated and are sparsely scattered across the region. Several large granite outcrops occur in areas adjacent to the project however minimal habitat occurs within the project corridor.</p>
<p>Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat</p>	<p>Due to the site's location and the presence of existing threats, the development of the project is unlikely to increase such threatening processes beyond that currently present.</p>
<p>Introduce disease that may cause the species to decline, or</p> <p>Interfere substantially with the recovery of the species.</p>	<p>Considered unlikely.</p> <p>In the greater area, there are a few scattered records indicating that the species occurs in low densities. However as minimal habitat occurs within the project footprint and roadkill is unlikely to be a significant risk (movements across the road considered minimal) the development of the project is unlikely to interfere with the recovery of the species.</p>

6.4 Slender-billed Thornbill

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, and has the potential to occur within the survey corridor (passes through a stretch of approximately 6km of suitable samphire habitat flanking the Murchison River). As suitable habitat is minimal across the project, the species has not been confirmed in the local area and, disturbance to suitable habitat is likely to be >1% of the local habitat available, impacts to the Slender-billed Thornbill are not considered significant. While the development of the project is unlikely to result in a significant impact to the local population using the criteria listed above (EPBC Significant Impacts Guidelines), as the species is of conservation significance, efforts should be made to minimise impacts to the local population, which includes avoiding disturbance to suitable habitats. The assessment of the Slender-billed Thornbill with regard to the EPBC Significant Impact Criteria are summarised in the Table below.

EPBC Criteria	Comment
Lead to a long-term decrease in the size of an important population of a species OR Reduce the area of occupancy of an important population	An extant population is yet to be confirmed utilising the survey area, however a precautionary principle is applied here as suitable habitat is present. Approximately 46km ² of samphire dominated chenopod shrubland occurs adjacent to the Murchison River at the intersection of the survey area. However, less than 60 hectares of suitable habitat is anticipated to lie within the project area (less than 1% of available habitat). Elsewhere across the project, suitable habitat is minimal. Therefore development of the project will unlikely to lead to a long-term decrease in the size of an important population of a species
Fragment an existing important population into two or more populations	The project corridor overlays an existing road so levels of fragmentation are unlikely to be increased beyond that currently existing.
Adversely affect habitat critical to the survival of a species	Habitat critical to the survival of the Slender-billed Thornbill includes samphire dominated chenopod shrublands. Intact habitat is sparsely scattered across the region and minimal habitat occurs within the project corridor.
Disrupt the breeding cycle of an important population	No breeding restricted to the project footprint, there considered unlikely.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	Habitat critical to the survival of the Slender-billed Thornbill includes samphire dominated chenopod shrublands. Intact habitat is sparsely scattered across the region and minimal habitat occurs within the project corridor.
Result in invasive species that are harmful to a vulnerable species becoming	Due to the sites location and the presence of existing threats, the development of the project is unlikely to increase such threatening processes beyond that currently present.

<p>established in the vulnerable species' habitat</p>	
<p>Introduce disease that may cause the species to decline, or Interfere substantially with the recovery of the species.</p>	<p>Considered unlikely. In the greater area, there are a few scattered records indicating that the species occurs in low densities. However as minimal habitat occurs within the project footprint and roadkill is unlikely to be a significant risk (movements across the road considered minimal) the development of the project is unlikely to interfere with the recovery of the species.</p>

7 Recommendations

Section 5 (Impact Assessment) identified several potential adverse impacts that may occur from the disturbance to the survey area. While impacts are expected to be mostly Negligible to Minor, any reduction in impacts is desirable. Management strategies are recommended below to reduce the potential impacts of this development on fauna species.

Loss of habitat

- Minimise the disturbance footprint – restrict the development corridor to the existing road where possible;
- Avoid disturbances to significant fauna habitats -
 - rocky outcrops;
 - waterholes and gnamma holes;
 - riparian (riverine) vegetation;
 - large, mature, hollow-bearing trees;
 - Malleefowl mounds;
 - Malleefowl habitat (dense Acacia shrublands on gravelly slopes); and
 - Locations supporting the Shield-backed Trapdoor Spider.

Increased Mortality

- If possible, SKA related vehicular movements should avoid travel at times when fauna is likely to be basking on the road; this is particularly the case just after sunset in summer. This is also a high risk time for vehicle accidents involving large animals such as kangaroos and goats.

Habitat fragmentation and Hydrology

- Maintain hydrological flows.

Habitat degradation due to weed invasion

- Develop a weed management/hygiene plan. For example, vehicles visiting the site should be clear of weeds and soil.

Changes in fire regime

- Develop a fire management plan; if possible, incorporate a mosaic burning system but include protection of Mulga areas.

Environmental Management

- Due to the presence of EPBC listed taxa, the project should be referred to the national Department of the Environment.
- If disturbances to Malleefowl habitat (dense Acacia shrublands) are proposed, mounds (breeding sites) should be left undisturbed by conducting pre-clearance checks. As a

result, any proposed vegetation clearance within suitable environments should be inspected by a qualified zoologist prior to clearing.

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9 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)

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). In addition, the Western Australian Department of Environment and Conservation (DEC) 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 3.

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. .

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).

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.

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 below are effectively the ecological processes that can be altered to result in impacts upon fauna.

Appendix 2. 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 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*.

Extinct	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild	Taxa known to survive only in captivity.
Critically Endangered	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable	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*

Schedule 1	Fauna that is rare or is likely to become extinct as critically endangered fauna.
Schedule 2	Fauna that is rare or is likely to become extinct as endangered fauna.
Schedule 3	Fauna that is rare or is likely to become extinct as vulnerable fauna.
Schedule 4	Fauna presumed to be extinct.
Schedule 5	Migratory birds protected under an international agreement.
Schedule 6	Fauna that is of special conservation need as conservation dependent fauna.
Schedule 7	Other specially protected fauna.

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

Priority 1	Taxa with few, poorly known populations on threatened lands.
Priority 2	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3	Taxa with several, poorly known populations, some on conservation lands.
Priority 4.	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. Taxa that are close to qualifying for Vulnerable, but are not listed as Conservation Dependent. Taxa that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

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 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 and 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.

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 (Gill *et al.* 1981; Fox 1982; Letnic *et al.* 2004; Bamford and Roberts 2003) *per se* but the fire regime that is important, with evidence that infrequent, extensive and intense fires adversely affect biodiversity, whereas frequent fires that cover small areas and are variable in both season and intensity can enhance biodiversity. 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 and 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 and Longcore 2006).

Appendix 3. 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*.

Extinct	Taxa not definitely located in the wild during the past 50 years.
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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 2014):

- 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, DotE 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?

Appendix 5. Vertebrate fauna assemblage of the study area, based on the October 2015 fauna assessment.

Levels of Conservation Significance (Status) are discussed in the “Assessment of Conservation Significance” section. Data sources include:

- BCE Fauna Assessment of the SKA Project (BCE, 2007);
- BCE Fauna Assessment of Weld Range (BCE, 2010);
- BCE fauna records of Boolardy and Murgoo Stations;
- BCE Fauna Assessment of the SKA Main Roads project – this survey (BCE, 2015).
- Birds recorded on Woolleen Station (Birds Australia, 2009).

FISH

Species	Status	Weld Range	Boolardy	SKA 2007	SKA 2015
<i>Craterocephalus cuneiceps</i>	Murchison River Hardyhead				X
<i>Leiopotherapon unicolor</i>	Spangled Perch				
<i>Hypseleotris aurea</i>	Golden Carp Gudgeon	P2			
<i>Hypseleotris compressa</i>	Empire Gudgeon				
TOTAL	4	0	0	0	1

FROGS

Species	Status	Weld Range	Boolardy	SKA 2007	SKA 2015
HYLIDAE (Tree frogs)					
<i>Cyclorana maini</i>	Main's Frog				
<i>Cyclorana platycephala</i>	Water-holding Frog				
<i>Litoria rubella</i>	Desert Tree Frog	X	X	X	
LIMNODYNASTIDAE (Burrowing frogs)					
<i>Platyplectrum spenceri</i>	Spencer's Frog		X		
<i>Neobatrachus aquilonius</i>	Northern Burrowing Frog				
<i>Neobatrachus sudellae</i>	Trilling Frog				
<i>Neobatrachus kunapalari</i>	Kunapalari Frog				
<i>Neobatrachus sutor</i>	Shoemaker Frog				
<i>Neobatrachus wilsmorei</i>	Wilsmore's Frog				
MYOBATRACHIDAE (Ground frogs)					
<i>Pseudophryne occidentalis</i>	Western Toadlet				
Total Species: 10		1	2	1	0

REPTILES

Species	Status	Weld Range	Booldardy	SKA 2010	SKA 2015
CHELUIDAE (freshwater tortoise)					
<i>Chelodina steindachneri</i>		Flat-shelled Tortoise	X		
CARPHODACTYLIDAE (knob-tailed geckoes)					
<i>Nephrurus vertebralis</i>		Midline Knob-tail	X		
<i>Nephrurus wheeleri</i>		Southern Banded Knob-tail			
<i>Nephrurus (Underwoodisaurus) milii</i>		Barking Gecko			
DIPLODACTYLIDAE (ground geckoes)					
<i>Diplodactylus conspicillatus</i>		Fat-tailed Gecko			
<i>Diplodactylus granariensis</i>		Goldfields Stone Gecko			
<i>Diplodactylus pulcher</i>		Western Saddled Ground	X		
<i>Lucasium squarrosus</i>		Mottled Ground Gecko	X		
<i>Lucasium stenodactylum</i>		Pale-snouted Ground Gecko			
<i>Oedura marmorata</i>		Marbled Velvet Gecko		X	X
<i>Rhynchoedura ornata</i>		Beaked Gecko	X		
<i>Strophurus elderi</i>		Jewelled Gecko			
<i>Strophurus strophurus</i>		Western Ring-tailed Gecko			
<i>Strophurus wellingtonae</i>		Western Shield Spiny-tailed Gecko	X		
GEKKONIDAE (geckoes)					
<i>Gehyra punctata</i>		Spotted Rock Dtella	X	X	X
<i>Gehyra variegata</i>		Variiegated Dtella	X	X	
<i>Heteronotia binoei</i>		Bynoe's Gecko	X		
PYGOPODIDAE (legless lizards)					
<i>Aprasia picturata</i>					
<i>Delma australis</i>		Marble-faced Delma	X		
<i>Delma butleri</i>		Unbanded Delma			
<i>Delma tincta</i>		Excitable Delma			
<i>Lialis burtonis</i>		Burton's Legless Lizard			
<i>Pygopus nigriceps</i>		Western Hooded Scaly-foot	X		

Species	Status	Weld Range	Boolarly	SKA 2010	SKA 2015
AGAMIDAE (dragon lizards)					
<i>Amphibolurus longirostris</i>	Long-nosed Dragon	X			X
<i>Ctenophorus caudicinctus</i>	Ring-tailed Dragon	X	X	X	X
<i>Ctenophorus isolepis</i>	Military Dragon				
<i>Ctenophorus nuchalis</i>	Central Netted Dragon	X			X
<i>Ctenophorus ornatus</i>	Ornate Crevice Dragon				
<i>Ctenophorus reticulatus</i>	Western Netted Dragon	X			X
<i>Ctenophorus salinarum</i>	Claypan Dragon				
<i>Ctenophorus scutulatus</i>	Lozenge-marked Dragon	X	X	X	X
<i>Diporiphora (Caimanops) amphiboluroides</i>	Mulga Dragon	X			
<i>Moloch horridus</i>	Thorny Devil	X			
<i>Pogona minor</i>	Western Bearded Dragon	X			
<i>Tympanocryptis cephalus</i>	Earless Pebble Dragon	X			
VARANIDAE (monitors or goannas)					
<i>Varanus caudolineatus</i>	Stripe-tailed Monitor	X			
<i>Varanus giganteus</i>	Perentie	X			
<i>Varanus gouldii</i>	Sand Goanna				
<i>Varanus panoptes</i>	Yellow-spotted Monitor	X	X	X	X
<i>Varanus tristis</i>	Black-headed Monitor	X			
EGERNIIDAE (part skinks)					
<i>Cyclodomorphus branchialis</i>	Gilled Slender Blue-tongue	CS1			
<i>Egernia depressa</i>	Pygmy Spiny-tailed Skink		X	X	X
<i>Egernia formosa</i>	Goldfields Crevice Skink				
<i>Egernia stokesii badia</i>	Western Spiny-tailed Skink	CS1		X	X
<i>Liopholis inornata</i>	Desert Skink				
<i>Liopholis striata</i>	Night Skink				
<i>Tiliqua occipitalis</i>	Western Blue-tongue				X
<i>Tiliqua multifasciata</i>	Centralian Blue-tongue				

Species	Status	Weld Range	Boolarly	SKA 2010	SKA 2015
EUGONGYLIDAE (part skinks)					
<i>Cryptoblepharus buchananii</i>	Fence Skink	X			
<i>Cryptoblepharus plagiocephal</i>	Fence Skink				
<i>Eremiascincus richardsonii</i>	Broad-banded Sand-swimmer	X			
<i>Menetia greyii</i>	Common Dwarf Skink	X			X
<i>Morethia butleri</i>	Woodland Dark-flecked Morethia				
SPHENOMORPHIDAE (part skinks)					
<i>Ctenotus helenae</i>	Clay Soil Ctenotus				
<i>Ctenotus leonhardii</i>	Leonhardi's Ctenotus	X	X	X	X
<i>Ctenotus pantherinus</i>	Leopard Skink				
<i>Ctenotus schomburgkii</i>	Barred Wedge-snout	X			X
<i>Ctenotus severus</i>	Stern Rock Ctenotus	X		X	X
<i>Ctenotus uber</i>	Spotted Ctenotus	X			
<i>Lerista eupoda</i>		CS2	X		
<i>Lerista macropisthopus</i>					
<i>Lerista nichollsi</i>		X			
<i>Lerista timida</i>		X			
TYPHLOPIDAE (blind snakes)					
<i>Anilius bicolor</i>	Dark-spined Blind snake				
<i>Anilius hamatus</i>	Northern Hook-snouted	X			
<i>Anilius waitii</i>	Beaked Blind Snake				
BOIDAE (pythons)					
<i>Antaresia perthensis</i>	Pygmy Python	X			
<i>Antaresia stimsoni</i>	Stimson's Python				
ELAPIDAE (front-fanged snakes)					
<i>Acanthophis pyrrhus</i>	Desert Death Adder				
<i>Brachyuropis approximans</i>	Northern Shovel-nosed	X			
<i>Brachyuropis semifasciatus</i>	Southern Shovel-nosed				
<i>Demansia psammophis</i>	Yellow-faced Whip-Snake				
<i>Parasuta monachus</i>	Monk Snake	X			

Species	Status	Weld Range	Boolardy	SKA 2010	SKA 2015
<i>Pseudechis australis</i>	Mulga Snake				
<i>Pseudechis butleri</i>	Spotted Mulga Snake	X			
<i>Pseudonaja modesta</i>	Ringed Brown Snake	X			X
<i>Pseudonaja mengdeni</i>	Gwardar				
<i>Simoselaps bertholdi</i>	Jan's Banded Snake	X			
<i>Furina ornata</i>	Moon Snake	X			
<i>Suta fasciata</i>	Rosen's Snake	X			
Total Species: 80		44	4	10	16

BIRDS

Species	Status	Woolleen	Weld Range	Boolarady	SKA 2007	SKA 2015
CASUARIIDAE (Cassowaries and emus)						
<i>Dromaius novaehollandiae</i>	Emu	X	X	X	X	X
MEGAPODIIDAE (Megapodes)						
<i>Leipoa ocellata</i>	Malleefowl	CS1	X			X
PHASIANIDAE (Pheasants and allies)						
<i>Coturnix pectoralis</i>	Stubble Quail	X				
<i>Coturnix ypsilophora</i>	Brown Quail					X
ANATIDAE (swans and ducks)						
<i>Cygnus atratus</i>	Black Swan	X				
<i>Tadorna tadornoides</i>	Australian Shelduck	X				
<i>Anas superciliosa</i>	Pacific Black Duck	X				X
<i>Anas gracilis</i>	Grey Teal	X				X
<i>Chenonetta jubata</i>	Australian Wood Duck	X				
<i>Malacorhynchus membranaceus</i>	Pink-eared Duck	X				X
<i>Aythya australis</i>	Hardhead	X				
<i>Dendrocygna eytoni</i>	Plumed Whistling Duck					X
PODICIPEDIDAE (grebes)						
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe	X				
<i>Poliiocephalus poliocephalus</i>	Hoary-headed Grebe	X				
COLUMBIDAE (Pigeons and doves)						
<i>Phaps chalcoptera</i>	Common Bronzewing	X	X	X	X	X
<i>Ocyphaps lophotes</i>	Crested Pigeon	X	X	X	X	X
<i>Geopelia cuneata</i>	Diamond Dove	X				X
<i>Geopelia striata</i>	Peaceful Dove	X				
PODARGIDAE (Australian frogmouths)						
<i>Podargus strigoides</i>	Tawny Frogmouth	X	X			
CAPRIMULGIDAE (Nightjars and allies)						
<i>Eurostopodus argus</i>	Spotted Nightjar		X		X	

Species	Status	Woolleen	Weld Range	Boolarady	SKA 2007	SKA 2015
AEGOTHELIDAE (Owlet-nightjars)						
<i>Aegotheles cristatus</i> Australian Owlet-nightjar		X	X			
APODIDAE (Typical swifts)						
<i>Apus pacificus</i> Fork-tailed Swift ^a	CS1					
PHALACROCORACIDAE (cormorants)						
<i>Anhinga novaehollandiae</i> Australasian Darter		X				
<i>Microcarbo melanoleucos</i> Little Pied Cormorant		X				
<i>Phalacrocorax varius</i> Pied Cormorant						
<i>Phalacrocorax sulcirostris</i> Little Black Cormorant		X				X
ARDEIDAE (herons and egrets)						
<i>Egretta novaehollandiae</i> White-faced Heron		X	X			X
<i>Ardea pacifica</i> White-necked Heron		X	X	X		X
<i>Ardea alba</i> Great Egret	CS1	X				
<i>Nycticorax caledonicus</i> Nankeen Night Heron		X				
THRESKIORNITHIDAE (ibis and spoonbills)						
<i>Threskiornis molucca</i> Australian White Ibis		X				
<i>Threskiornis spinicollis</i> Straw-necked Ibis		X				X
PELECANIDAE						
<i>Pelecanus conspicillatus</i> Australian Pelican		X				X
ACCIPITRIDAE (Osprey, hawks and eagles)						
<i>Elanus axillaris</i> Black-shouldered Kite		X				
<i>Elanus scriptus</i> Letter-winged Kite						
<i>Lophoictinia isura</i> Square-tailed Kite						X
<i>Hamirostra melanosternon</i> Black-breasted Buzzard		X	X	X		X
<i>Milvus migrans</i> Black Kite		X				
<i>Haliastur sphenurus</i> Whistling Kite		X	X	X	X	X
<i>Circus assimilis</i> Spotted Harrier		X				X
<i>Accipiter fasciatus</i> Brown Goshawk		X	X			
<i>Accipiter cirrhocephalus</i> Collared Sparrowhawk		X	X			X

Species	Status	Woolleen	Weld Range	Boolardy	SKA 2007	SKA 2015
<i>Aquila audax</i> Wedge-tailed Eagle		X	X	X	X	X
<i>Hieraaetus morphnoides</i> Little Eagle		X				
FALCONIDAE (Falcons)						
<i>Falco berigora</i> Brown Falcon		X	X	X	X	X
<i>Falco longipennis</i> Australian Hobby		X	X			
<i>Falco hypoleucos</i> Grey Falcon	CS1	X				
<i>Falco subniger</i> Black Falcon						
<i>Falco peregrinus</i> Peregrine Falcon	CS1	X	X			X
<i>Falco cenchroides</i> Nankeen Kestrel		X	X	X	X	X
RALLIDAE (Rails, gallinules and coots)						
<i>Tribonyx ventralis</i> Black-tailed Native-hen		X				X
<i>Fulica atra</i> Eurasian Coot		X				
OTIDIDAE (Bustards)						
<i>Ardeotis australis</i> Australian Bustard	CS2	X	X			
BURHINIDAE (Stone-curlews)						
<i>Burhinus grallarius</i> Bush Stone-curlew	CS3	X	X	X		X
RECURVIROSTRIDAE (stilts and avocets)						
<i>Himantopus himantopus</i> Black-winged Stilt		X				
<i>Cladorhynchus leucocephalus</i> Banded Stilt						
CHARADRIIDAE (Lapwings, plovers and dotterels)						
<i>Erythronyx cinctus</i> Red-kneed Dotterel		X				
<i>Charadrius ruficapillus</i> Red-capped Plover		X	X			
<i>Elsyornis melanops</i> Black-fronted Dotterel		X		X		X
<i>Charadrius australis</i> Inland Dotterel		X	X			
<i>Vanellus tricolor</i> Banded Lapwing		X		X		X
SCOLOPACIDAE (sandpipers)						
<i>Actitis hypoleucos</i> Common Sandpiper	CS1	X				
<i>Tringa nebularia</i> Common Greenshank	CS1	X				
<i>Tringa stagnatalis</i> Marsh Sandpiper	CS1					

Species		Status	Woolleen	Weld Range	Boolarly	SKA 2007	SKA 2015
<i>Tringa glareola</i>	Wood Sandpiper	CS1	X				
<i>Calidris ruficollis</i>	Red-necked Stint	CS1					
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper	CS1	X				
<i>Calidris ferruginea</i>	Curlew Sandpiper	CS1					
TURNICIDAE (Button-quails)							
<i>Turnix velox</i>	Little Button-quail			X			X
CACATUIDAE (Cockatoos)							
<i>Calyptorhynchus banksii</i>	Red-tailed Black Cockatoo		X				
<i>Eolophus roseicapilla</i>	Galah		X	X	X	X	X
<i>Cacatua sanguinea</i>	Little Corella		X		X		X
<i>Lophochroa leadbeateri</i>	Major Mitchell's Cockatoo	CS1	X			X	X
<i>Nymphicus hollandicus</i>	Cockatiel		X	X			X
PSITTACIDAE (Parrots)							
<i>Barnardius zonarius</i>	Australian Ringneck		X	X	X	X	X
<i>Psephotus varius</i>	Mulga Parrot		X	X	X	X	X
<i>Melopsittacus undulatus</i>	Budgerigar		X	X	X		X
<i>Neosephotus bourkii</i>	Bourke's Parrot		X	X			X
<i>Neophema elegans</i>	Elegant Parrot		X	X			
<i>Neophema splendida</i>	Scarlet-chested Parrot	CS3					
<i>Polytelis anthopeplus</i>	Regent Parrot		X				
<i>Pezoporus occidentalis</i>	Night Parrot	CS1					
CUCULIDAE (Old world cuckoos)							
<i>Cacomantis pallidus</i>	Pallid Cuckoo		X	X			
<i>Chalcites osculans</i>	Black-eared Cuckoo		X	X			
<i>Chalcites basalis</i>	Horsfield's Bronze-Cuckoo		X	X			X
STRIGIDAE (Hawk owls)							
<i>Ninox novaeseelandiae</i>	Southern Boobook		X	X			
TYTONIDAE (Barn owls)							
<i>Tyto alba</i>	Barn Owl		X				

Species	Status	Woolleen	Weld Range	Boolarly	SKA 2007	SKA 2015
HALCYONIDAE (Kingfishers)						
<i>Todiramphus pyrrhopygia</i>	Red-backed Kingfisher	X		X		X
<i>Todiramphus sanctus</i>	Sacred Kingfisher	X				
MEROPIDAE (Bee-eaters)						
<i>Merops ornatus</i>	Rainbow Bee-eater	CS1	X			X
CLIMACTERIDAE (Australo-Papuan treecreepers)						
<i>Climacteris affinis</i>	White-browed Treecreeper		X			
PTILONORHYNCHIDAE (Bowerbirds)						
<i>Ptilonorhynchus guttatus</i>	Western Bowerbird		X	X	X	X
MALURIDAE (Fairy-, emu- and grasswrens)						
<i>Malurus splendens</i>	Splendid Fairy-wren		X	X		X
<i>Malurus lamberti</i>	Variiegated Fairy-wren		X	X	X	X
<i>Malurus leucopterus</i>	White-winged Fairy-wren		X	X	X	X
ACANTHIZIDAE (Thornbills and allies)						
<i>Calamanthus campestris</i>	Rufous Fieldwren					
<i>Pyrrholaemus brunneus</i>	Redthroat		X	X	X	X
<i>Smicrornis brevirostris</i>	Weebill		X	X		X
<i>Gerygone fusca</i>	Western Gerygone		X	X		
<i>Acanthiza apicalis</i>	Inland Thornbill		X	X	X	
<i>Acanthiza uropygialis</i>	Chestnut-rumped Thornbill		X	X	X	X
<i>Acanthiza robustirostris</i>	Slaty-backed Thornbill			X	X	X
<i>Acanthiza iredalei</i>	Slender-billed Thornbill	CS1		X		
<i>Acanthiza chrysorrhoa</i>	Yellow-rumped Thornbill		X	X	X	X
<i>Aphelocephala nigricincta</i>	Banded Whiteface					
<i>Aphelocephala leucopsis</i>	Southern Whiteface		X	X	X	X
PARDALOTIDAE (Pardalotes, thornbills and allies)						
<i>Pardalotus rubricatus</i>	Red-browed Pardalote					
<i>Pardalotus striatus</i>	Striated Pardalote		X	X		X

Species	Status	Woolleen	Weld Range	Boolarady	SKA 2007	SKA 2015
MELIPHAGIDAE (Honeyeaters)						
<i>Certhionyx variegatus</i>	Pied Honeyeater	X	X			X
<i>Lichenostomus virescens</i>	Singing Honeyeater	X	X			X
<i>Lichenostomus plumulus</i>	Grey-fronted Honeyeater					
<i>Lichenostomus penicillatus</i>	White-plumed Honeyeater	X	X			X
<i>Purnella albifrons</i>	White-fronted Honeyeater	X	X			X
<i>Manorina flavigula</i>	Yellow-throated Miner	X	X			X
<i>Acanthagenys rufogularis</i>	Spiny-cheeked Honeyeater	X	X			X
<i>Conopophila whitei</i>	Grey Honeyeater	CS3	X	X		
<i>Epthianura tricolor</i>	Crimson Chat	X	X			X
<i>Epthianura aurifrons</i>	Orange Chat	X	X			X
<i>Epthianura albifrons</i>	White-fronted Chat	X				
<i>Certhionyx niger</i>	Black Honeyeater	X	X			X
<i>Lichmera indistincta</i>	Brown Honeyeater	X	X			X
POMATOSTOMIDAE (Babblers)						
<i>Pomatostomus temporalis</i>	Grey-crowned Babbler	X	X			X
<i>Pomatostomus superciliosus</i>	White-browed Babbler	X	X			X
PSOPHODIDAE (Quail-thrushes and allies)						
<i>Psophodes occidentalis</i>	Chiming Wedgebill	X	X			X
<i>Cinlosoma marginatum</i>	Chestnut-breasted Quail-thrush	X	X			X
NEOSITTIDAE (Sitellas)						
<i>Daphoenositta chrysoptera</i>	Varied Sittella	X				X
CAMPEPHAGIDAE (Cuckoo-shrikes and trillers)						
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike	X	X			X
<i>Coracina maxima</i>	Ground Cuckoo-shrike	X	X			X
<i>Lalage tricolor</i>	White-winged Triller	X	X			X
PACHYCEPHALIDAE (Whistlers and allies)						
<i>Oreoica gutturalis</i>	Crested Bellbird	X	X	X	X	X
<i>Pachycephala rufiventris</i>	Rufous Whistler	X	X	X	X	X

Species	Status	Woolleen	Weld Range	Boolarly	SKA 2007	SKA 2015
<i>Colluricincla harmonica</i> Grey Shrike-thrush		X	X	X	X	X
ARTAMIDAE (Woodswallows and allies)						
<i>Artamus personatus</i> Masked Woodswallow		X	X			X
<i>Artamus cinereus</i> Black-faced Woodswallow		X	X			X
<i>Artamus minor</i> Little Woodswallow		X	X			X
<i>Cracticus torquatus</i> Grey Butcherbird		X	X			X
<i>Cracticus nigrogularis</i> Pied Butcherbird		X	X			X
<i>Cracticus tibicen</i> Australian Magpie		X	X			X
<i>Strepera versicolor</i> Grey Currawong						
RHIPIDURIDAE (Fantails)						
<i>Rhipidura fuliginosa</i> Grey Fantail		X	X			
<i>Rhipidura f. albicauda</i> White-tailed Fantail						
<i>Rhipidura leucophrys</i> Willie Wagtail		X	X			X
CORVIDAE (Crows and allies)						
<i>Corvus coronoides</i> Australian Raven		X				X
<i>Corvus bennetti</i> Little Crow		X	X			X
<i>Corvus orru</i> Torresian Crow		X	X			X
MONARCHIDAE (Monarchs and allies)						
<i>Grallina cyanoleuca</i> Magpie-lark		X	X			X
PETROICIDAE (Robins)						
<i>Microeca leucophaea</i> Jacky Winter		X				
<i>Petroica goodenovii</i> Red-capped Robin		X	X			X
<i>Melanodryas cucullata</i> Hooded Robin		X	X			
MEGALURIDAE (grassbirds)						
<i>Cinclorhamphus mathewsi</i> Rufous Songlark		X	X			X
<i>Cinclorhamphus cruralis</i> Brown Songlark		X				
HIRUNDINIDAE (Swallows and martins)						
<i>Cheramoeca leucosternum</i> White-backed Swallow			X			X
<i>Hirundo neoxena</i> Welcome Swallow		X	X	X		X

Species	Status	Woolleen	Weld Range	Boolardy	SKA 2007	SKA 2015
<i>Petrochelidon nigricans</i> Tree Martin		X		X		X
<i>Petrochelidon ariel</i> Fairy Martin		X	X	X		X
DICAEDAE (Flowerpeckers)						
<i>Dicaeum hirundinaceum</i> Mistletoebird		X	X	X		X
PASSERIDAE (Sparrows, weaverbirds and allies)						
<i>Taeniopygia guttata</i> Zebra Finch		X	X	X		X
MOTACILIDAE (Old world wagtails and pipits)						
<i>Anthus novaeseelandiae</i> Australasian Pipit		X	X	X		X
Total Species: 158		133	89	36	24	92

MAMMALS

Species	Status	Weld Range	Boolarly	SKA 2007	SKA 2015
TACHYGLOSSIDAE (Echidnas)					
<i>Tachyglossus aculeatus</i>	Echidna	X	X		X
DASYURIDAE (Dasyurids)					
<i>Antechinomys laniger</i>	Kultarr	CS3	X		
<i>Ningauai ridei</i>	Wongai Ningauai				
<i>Pseudantechinus woolleyae</i>	Woolley's Pseudantechinus		X	X	X
<i>Sminthopsis crassicaudata</i>	Fat-tailed Dunnart				
<i>Sminthopsis dolichura</i>	Little Long-tailed Dunnart		X		
<i>Sminthopsis longicaudata</i>	Long-tailed Dunnart	CS2	X		
<i>Sminthopsis macroura</i>	Stripe-faced Dunnart		X		
<i>Sminthopsis ooldea</i>	Ooldea Dunnart				
MACROPODIDAE (Kangaroos, wallabies)					
<i>Macropus robustus</i>	Euro, Biggada		X	X	X
<i>Macropus rufus</i>	Red Kangaroo, Marlu		X	X	X
EMBALLONURIDAE (Sheathtail bats)					
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheathtail-Bat				
<i>Taphozous hillii</i>	Hill's Sheathtail-Bat		X	X	
VESPERTILIONIDAE (Vespertillionid bats)					
<i>Chalinolobus gouldii</i>	Gould's Wattled Bat		X		
<i>Nyctophilus geoffroyi</i>	Lesser Long-eared Bat		X		
<i>Nyctophilus major tor</i>	Inland Greater Long-eared Bat	CS2			
<i>Scotorepens balstoni</i>	Inland Broad-nosed Bat		X		
<i>Vespadelus baverstocki</i>	Inland Forest Bat				
<i>Vespadelus finlaysoni</i>	Finlayson's Cave Bat		X	X	
<i>Vespadelus regulus</i>	Southern Forest Bat				
MOLOSSIDAE (Freetail bats)					
<i>Mormopterus</i> sp. 3 (Adams <i>et al.</i> , 1988).	Inland Freetail-bat				
<i>Tadarida saustralis</i>	White-striped Freetail-bat		X		

Species	Status	Weld Range	Boolarly	SKA 2007	SKA 2015
MURIDAE (Rats and mice)					
<i>Mus musculus</i> House Mouse	INT				
<i>Notomys alexis</i> Spinifex Hopping-Mouse		X			X
<i>Pseudomys desertor</i> Desert Mouse					
<i>Pseudomys hermannsburgensis</i> Sandy Inland Mouse		X			
LEPORIDAE (Rabbits and hares)					
<i>Oryctolagus cuniculus</i> Rabbit	INT	X			X
CANIDAE (Dogs and foxes)					
<i>Canis lupus</i> Dog/Dingo		X			X
<i>Vulpes vulpes</i> Red Fox	INT	X			
FELIDAE (Cats)					
<i>Felis catus</i> Cat	INT	X			X
BOVIDAE (Horned ruminants)					
<i>Bos taurus</i> Cattle	INT	X		X	X
<i>Capra hircus</i> Goat	INT	X			X
EQUIDAE (horses)					
<i>Equus asinus</i> Donkey	INT				X
<i>Equus caballus</i> Horse	INT				
CAMELIDAE (camels)					
<i>Camelus dromedarius</i> Camel	INT				
Total Native Species: 25		16	3	3	5
Total Introduced Species: 10		6	0	1	6

Appendix 6. Fauna Recorded at Borrow Pits and other survey locations (G = Granite Outcrops, M = Murchison River).

Species		Borrow Pits					Other Sites					
		1	2	3	4	5	6	7	8	9	G	M
<i>Oedura marmorata</i>	Marbled Velvet Gecko										X	
<i>Gehyra punctata</i>	Spotted Rock Dtella										X	
<i>Amphibolurus longirostris</i>	Long-nosed Dragon									X		X
<i>Ctenophorus caudicinctus</i>	Ring-tailed Dragon					X						
<i>Ctenophorus nuchalis</i>	Central Netted Dragon										X	
<i>Ctenophorus reticulatus</i>	Western Netted Dragon				X		X					
<i>Ctenophorus scutulatus</i>	Lozenge-marked Dragon	X	X	X	X			X				
<i>Varanus panoptes</i>	Yellow-spotted Monitor	X										
<i>Egernia depressa</i>	Pygmy Spiny-tailed Skink		X									
<i>Egernia stokesii badia</i>	Western Spiny-tailed Skink										X	
<i>Tiliqua occipitalis</i>	Western Blue-tongue	X										
<i>Menetia greyii</i>	Common Dwarf Skink	X									X	
<i>Ctenotus leonhardii</i>	Leonhardi's Ctenotus						X					
<i>Ctenotus schomburgkii</i>	Barred Wedge-snout Ctenotus	X										
<i>Ctenotus severus</i>	Stern Rock Ctenotus										X	
<i>Pseudonaja modesta</i>	Ringed Brown Snake				X							
Total Species: 16		5	2	1	3	1	2	1		1	6	1

BIRDS

Note: Bird surveys include along the Murchison River at the river crossing east of Murchison settlement (M1), samphire shrubland flanking the crossing (M2), pool adjacent to Murchison River (M3; 454646E, 7016611N), a tributary on Woolleen Station (M4, 418488E, 6998342) and amongst a granite outcrop (G; 435665E, 7002318N).

Species	Borrow Pits									Other Sites					Total	
	1	2	3	4	5	6	7	8	9	M 1	M2	M3	M4	G		
CASUARIIDAE (Cassowaries and emus)																
<i>Dromaius novaehollandiae</i>	Emu	X	X		X				X						X	X
MEGAPODIIDAE (Megapodes)																
<i>Leipoa ocellata</i>	Malleefowl	X														X
PHASIANIDAE (Pheasants and allies)																
<i>Coturnix pectoralis</i>	Stubble Quail															
<i>Coturnix ypsilophora</i>	Brown Quail													X		X
ANATIDAE (swans and ducks)																
<i>Cygnus atratus</i>	Black Swan															
<i>Tadorna tadornoides</i>	Australian Shelduck															
<i>Anas superciliosa</i>	Pacific Black Duck										X					X
<i>Anas gracilis</i>	Grey Teal										X					X
<i>Chenonetta jubata</i>	Australian Wood Duck															
<i>Malacorhynchus membranaceus</i>	Pink-eared Duck											X				X
<i>Aythya australis</i>	Hardhead															
<i>Dendrocygna eytoni</i>	Plumed Whistling Duck												X			X
PODICIPEDIDAE (grebes)																
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe															
<i>Poliiocephalus poliocephalus</i>	Hoary-headed Grebe															
COLUMBIDAE (Pigeons and doves)																
<i>Phaps chalcoptera</i>	Common Bronzewing	X									X				X	X
<i>Ocyphaps lophotes</i>	Crested Pigeon	X		X							X		X			X
<i>Geopelia cuneata</i>	Diamond Dove			X		X	X	X								X
<i>Geopelia striata</i>	Peaceful Dove															
PODARGIDAE (Australian frogmouths)																
<i>Podargus strigoides</i>	Tawny Frogmouth															

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M 1	M2	M3	M4	G	
CAPRIMULGIDAE (Nightjars and allies)															
<i>Eurostopus argus</i>	Spotted Nightjar														
AEGOTHELIDAE (Owlet-nightjars)															
<i>Aegotheles cristatus</i>	Australian Owlet-nightjar														
APODIDAE (Typical swifts)															
<i>Apus pacificus</i>	Fork-tailed Swift														
PHALACROCORACIDAE (cormorants)															
<i>Microcarbo melanoleucos</i>	Little Pied Cormorant														
<i>Phalacrocorax varius</i>	Pied Cormorant														
<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant														
ARDEIDAE (herons and egrets)															
<i>Egretta novaehollandiae</i>	White-faced Heron														
<i>Ardea pacifica</i>	White-necked Heron														
<i>Ardea alba</i>	Great Egret														
<i>Nycticorax caledonicus</i>	Nankeen Night Heron														
THRESKIORNITHIDAE (ibis and spoonbills)															
<i>Threskiornis molucca</i>	Australian White Ibis														
<i>Threskiornis spinicollis</i>	Straw-necked Ibis														
PELECANIDAE															
<i>Pelecanus conspicillatus</i>	Australian Pelican														
ACCIPITRIDAE (Osprey, hawks and eagles)															
<i>Elanus axillaris</i>	Black-shouldered Kite														
<i>Elanus scriptus</i>	Letter-winged Kite														
<i>Lophoictinia isura</i>	Square-tailed Kite														
<i>Hamirostra melanosternon</i>	Black-breasted Buzzard														
<i>Milvus migrans</i>	Black Kite														
<i>Haliastur sphenurus</i>	Whistling Kite														
<i>Circus assimilis</i>	Spotted Harrier														
<i>Accipiter fasciatus</i>	Brown Goshawk														

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M 1	M2	M3	M4	G	
<i>Accipiter cirrhocephalus</i> Collared Sparrowhawk			X							X				X	X
<i>Aquila audax</i> Wedge-tailed Eagle	X														X
<i>Hieraaetus morphnoides</i> Little Eagle															
FALCONIDAE (Falcons)															
<i>Falco berigora</i> Brown Falcon			X				X	X							X
<i>Falco longipennis</i> Australian Hobby															
<i>Falco hypoleucos</i> Grey Falcon															
<i>Falco subniger</i> Black Falcon															
<i>Falco peregrinus</i> Peregrine Falcon											X		X	X	
<i>Falco cenchroides</i> Nankeen Kestrel	X				X										X
RALLIDAE (Rails, gallinules and coots)															
<i>Tribonyx ventralis</i> Black-tailed Native-hen												X			X
<i>Fulica atra</i> Eurasian Coot															
OTIDIDAE (Bustards)															
<i>Ardeotis australis</i> Australian Bustard															
BURHINIDAE (Stone-curlews)															
<i>Burhinus grallarius</i> Bush Stone-curlew				X											X
RECURVIROSTRIDAE (stilts and avocets)															
<i>Himantopus himantopus</i> Black-winged Stilt															
<i>Cladorhynchus leucocephalus</i> Banded Stilt															
CHARADRIIDAE (Lapwings, plovers and dotterels)															
<i>Erythrogonys cinctus</i> Red-kneed Dotterel															
<i>Charadrius ruficapillus</i> Red-capped Plover															
<i>Elsyornis melanops</i> Black-fronted Dotterel										X					X
<i>Charadrius australis</i> Inland Dotterel															
<i>Vanellus tricolor</i> Banded Lapwing														X	X
SCOLOPACIDAE (sandpipers)															
<i>Actitis hypoleucos</i> Common Sandpiper															
<i>Tringa nebularia</i> Common Greenshank															

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M1	M2	M3	M4	G	
<i>Tringa stagnatalis</i>	Marsh Sandpiper														
<i>Tringa glareola</i>	Wood Sandpiper														
<i>Calidris ruficollis</i>	Red-necked Stint														
<i>Calidris acuminata</i>	Sharp-tailed Sandpiper														
<i>Calidris ferruginea</i>	Curlew Sandpiper														
TURNICIDAE (Button-quails)															
<i>Turnix velox</i>	Little Button-quail														
<i>Eolophus roseicapilla</i>	Galah														
<i>Cacatua sanguinea</i>	Little Corella														
<i>Lophochroa leadbeateri</i>	Major Mitchell's Cockatoo														
<i>Nymphicus hollandicus</i>	Cockatiel														
PSITTACIDAE (Parrots)															
<i>Barnardius zonarius</i>	Australian Ringneck														
<i>Psephotus varius</i>	Mulga Parrot														
<i>Melopsittacus undulatus</i>	Budgerigar														
<i>Neosephotus bourkii</i>	Bourke's Parrot														
<i>Neophema elegans</i>	Elegant Parrot														
<i>Neophema splendida</i>	Scarlet-chested Parrot														
<i>Polytelis anthopeplus</i>	Regent Parrot														
<i>Pezoporus occidentalis</i>	Night Parrot														
CUCULIDAE (Old world cuckoos)															
<i>Cacomantis pallidus</i>	Pallid Cuckoo														
<i>Chalcites osculans</i>	Black-eared Cuckoo														
<i>Chalcites basalis</i>	Horsfield's Bronze-Cuckoo														
STRIGIDAE (Hawk owls)															
<i>Ninox novaeseelandiae</i>	Southern Boobook														
TYTONIDAE (Barn owls)															
<i>Tyto alba</i>	Barn Owl														

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M1	M2	M3	M4	G	
HALCYONIDAE (Kingfishers)															
<i>Todiramphus pyrrhopygia</i>		X		X			X		X						X
<i>Todiramphus sanctus</i>															
MEROPIDAE (Bee-eaters)															
<i>Merops ornatus</i>													X		X
CLIMACTERIDAE (Australo-Papuan treecreepers)															
<i>Climacteris affinis</i>															
PTILONORHYNCHIDAE (Bowerbirds)															
<i>Ptilonorhynchus guttatus</i>										X			X	X	X
MALURIDAE (Fairy-, emu- and grasswrens)															
<i>Malurus splendens</i>	X	X	X	X		X			X						X
<i>Malurus lamberti</i>			X				X								X
<i>Malurus leucopterus</i>									X	X					X
ACANTHIZIDAE (Thornbills and allies)															
<i>Calamanthus campestris</i>															
<i>Pyrrholaemus brunneus</i>	X	X	X	X		X			X						X
<i>Smicrornis brevirostris</i>										X					X
<i>Gerygone fusca</i>															
<i>Acanthiza apicalis</i>															
<i>Acanthiza uropygialis</i>	X	X	X			X	X		X						X
<i>Acanthiza robustirostris</i>				X											X
<i>Acanthiza iredalei</i>															
<i>Acanthiza chrysorrhoa</i>	X													X	X
<i>Aphelocephala nigricincta</i>															
<i>Aphelocephala leucopsis</i>	X	X	X	X	X	X	X		X						X
PARDALOTIDAE (Pardalotes, thornbills and allies)															
<i>Pardalotus rubricatus</i>															
<i>Pardalotus striatus</i>										X					X
MELIPHAGIDAE (Honeyeaters)															

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M 1	M2	M3	M4	G	
<i>Certhionyx variegatus</i> Pied Honeyeater			X						X						X
<i>Lichenostomus virescens</i> Singing Honeyeater		X		X	X	X	X	X	X						X
<i>Lichenostomus plumulus</i> Grey-fronted Honeyeater															
<i>Lichenostomus penicillatus</i> White-plumed Honeyeater									X	X		X	X		X
<i>Purnella albifrons</i> White-fronted Honeyeater		X		X						X					X
<i>Manorina flavigula</i> Yellow-throated Miner				X	X	X				X					X
<i>Acanthagenys rufogularis</i> Spiny-cheeked Honeyeater	X	X			X	X			X					X	X
<i>Conopophila whitei</i> Grey Honeyeater															
<i>Epthianura tricolor</i> Crimson Chat	X	X	X		X	X	X	X	X						X
<i>Epthianura aurifrons</i> Orange Chat											X				X
<i>Epthianura albifrons</i> White-fronted Chat															
<i>Certhionyx niger</i> Black Honeyeater	X	X	X	X	X			X							X
<i>Lichmera indistincta</i> Brown Honeyeater													X		X
POMATOSTOMIDAE (Babblers)															
<i>Pomatostomus temporalis</i> Grey-crowned Babbler	X			X	X					X		X			X
<i>Pomatostomus superciliosus</i> White-browed Babbler	X			X											X
PSOPHODIDAE (Quail-thrushes and allies)															
<i>Psophodes occidentalis</i> Chiming Wedgebill		X	X				X						X		X
<i>Cinlosoma marginatum</i> Chestnut-breasted Quail-thrush	X	X		X					X						X
NEOSITTIDAE (Sittellas)															
<i>Daphoenositta chrysoptera</i> Varied Sittella	X			X			X								X
CAMPEPHAGIDAE (Cuckoo-shrikes and trillers)															
<i>Coracina novaehollandiae</i> Black-faced Cuckoo-shrike				X	X							X			X
<i>Coracina maxima</i> Ground Cuckoo-shrike				X											X
<i>Lalage tricolor</i> White-winged Triller	X	X			X		X							X	X
PACHYCEPHALIDAE (Whistlers and allies)															
<i>Oreoica gutturalis</i> Crested Bellbird	X		X		X	X	X								X
<i>Pachycephala rufiventris</i> Rufous Whistler	X	X	X	X		X	X		X					X	X
<i>Colluricincla harmonica</i> Grey Shrike-thrush	X			X		X									X

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M1	M2	M3	M4	G	
ARTAMIDAE (Woodswallows and allies)															
<i>Artamus personatus</i>				X	X										X
<i>Artamus cinereus</i>			X	X	X	X	X	X							X
<i>Artamus minor</i>	X			X											X
<i>Artamus superciliosus</i>															
<i>Cracticus torquatus</i>	X	X		X											X
<i>Cracticus nigrogularis</i>										X					X
<i>Cracticus tibicen</i>										X					X
<i>Strepera versicolor</i>															
RHIPIDURIDAE (Fantails)															
<i>Rhipidura fuliginosa</i>															
<i>Rhipidura f. albicauda</i>															
<i>Rhipidura leucophrys</i>	X	X		X						X					X
CORVIDAE (Crows and allies)															
<i>Corvus coronoides</i>										X					X
<i>Corvus bennetti</i>	X		X				X				X				X
<i>Corvus orru</i>										X					X
MONARCHIDAE (Monarchs and allies)															
<i>Grallina cyanoleuca</i>										X		X			X
PETROICIDAE (Robins)															
<i>Microeca leucophaea</i>															
<i>Petroica goodenovii</i>	X	X		X		X									X
<i>Melanodryas cucullata</i>															
MEGALURIDAE (grassbirds)															
<i>Cinclorhamphus mathewsi</i>		X			X		X	X	X				X		X
<i>Cinclorhamphus cruralis</i>															
HIRUNDINIDAE (Swallows and martins)															
<i>Cheramoeca leucosternum</i>	X	X	X												X
<i>Hirundo neoxena</i>	X			X								X			X

Species	Borrow Pits									Other Sites					Total
	1	2	3	4	5	6	7	8	9	M 1	M2	M3	M4	G	
<i>Petrochelidon nigricans</i> Tree Martin										X		X	X		X
<i>Petrochelidon ariel</i> Fairy Martin	X											X			X
DICAEIDAE (Flowerpeckers)															
<i>Dicaeum hirundinaceum</i> Mistletoebird										X					X
PASSERIDAE (Sparrows, weaverbirds and allies)															
<i>Taeniopygia guttata</i> Zebra Finch	X	X	X	X	X	X	X		X			X	X	X	X
MOTACILIDAE (Old world wagtails and pipits)															
<i>Anthus novaeseelandiae</i> Australasian Pipit					X				X	X					X
Total Species:	37	23	22	34	19	19	18	7	24	32	2	17	12	11	92

MAMMALS

Species	Borrow Pits									Other		Total
	1	2	3	4	5	6	7	8	9	G	M	SKA 2015
TACHYGLOSSIDAE (Echidnas)												
<i>Tachyglossus aculeatus</i>												
Echidna	X	X	X	X			X				X	X
DASYURIDAE (Dasyurids)												
<i>Antechinomys laniger</i>												
Kultarr												
<i>Ningaui ridei</i>												
Wongai Ningau												
<i>Pseudantechinus woolleyae</i>												
Woolley's Pseudantechinus	X			X								X
<i>Sminthopsis crassicaudata</i>												
Fat-tailed Dunnart												
<i>Sminthopsis dolichura</i>												
Little Long-tailed Dunnart												
<i>Sminthopsis longicaudata</i>												
Long-tailed Dunnart												
<i>Sminthopsis macrura</i>												
Stripe-faced Dunnart												
<i>Sminthopsis ooldea</i>												
Ooldea Dunnart												
MACROPODIDAE (Kangaroos, wallabies)												
<i>Macropus robustus</i>												
Euro, Biggada	X											X
<i>Macropus rufus</i>												
Red Kangaroo, Marlu				X	X							X
EMBALLONURIDAE (Sheathtail bats)												
<i>Saccolaimus flaviventris</i>												
Yellow-bellied Sheathtail-Bat												
<i>Taphozous hillii</i>												
Hill's Sheathtail-Bat												
VESPERTILIONIDAE (Vespertilionid bats)												
<i>Chalinolobus gouldii</i>												
Gould's Wattled Bat												
<i>Nyctophilus geoffroyi</i>												
Lesser Long-eared Bat												
<i>Nyctophilus major tor</i>												
Inland Greater Long-eared Bat												
<i>Scotorepens balstoni</i>												
Inland Broad-nosed Bat												
<i>Vespadelus baverstocki</i>												
Inland Forest Bat												
<i>Vespadelus finlaysoni</i>												
Finlayson's Cave Bat												
<i>Vespadelus regulus</i>												
Southern Forest Bat												
MOLOSSIDAE (Freetail bats)												
<i>Mormopterus</i> sp. 3 (Adams <i>et al.</i> ,1988). Inland Freetail-bat												

		Borrow Pits								Other	Total
<i>Tadarida saustralis</i>	White-striped Freetail-bat										
MURIDAE (Rats and mice)											
<i>Mus musculus</i>	House Mouse										
<i>Notomys alexis</i>	Spinifex Hopping-Mouse		X	X		X					X
<i>Pseudomys desertor</i>	Desert Mouse										
<i>Pseudomys hermannsburgensis</i>	Sandy Inland Mouse										
LEPORIDAE (Rabbits and hares)											
<i>Oryctolagus cuniculus</i>	Rabbit	X	X						X		X
CANIDAE (Dogs and foxes)											
<i>Canis lupus</i>	Dog/Dingo			X		X	X				X
<i>Vulpes vulpes</i>	Red Fox										
FELIDAE (Cats)											
<i>Felis catus</i>	Cat		X						X		X
BOVIDAE (Horned ruminants)											
<i>Bos taurus</i>	Cattle		X	X		X	X		X		X
<i>Capra hircus</i>	Goat	X		X							X
EQUIDAE (horses)											
<i>Equus asinus</i>	Donkey		X								X
<i>Equus caballus</i>	Horse										
CAMELIDAE (camels)											
<i>Camelus dromedarius</i>	Camel										
Total Native Species: 5											
Total Introduced Species: 6											