Appendix J1

Ecological impact assessment

Santos
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Narrabri Gas Project

Ecological Impact Assessment

Prepared for
Santos NSW (Eastern) Pty Ltd

November 2016

This report should be cited as 'Eco Logical Australia 2016. *Narrabri Gas Project: Ecological Impact Assessment*. Prepared for Santos NSW (Eastern) Pty Ltd.'

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Abbreviations

Abbreviation	Description
AKF	Australian Koala Foundation
BAR	Biodiversity Assessment Report
BBS	Brigalow Belt South
BNCCA Act	NSW *Brigalow and Nandewar Community Conservation Area Act 2005*
BOM	Bureau of meteorology
BOS	Biodiversity Offset Strategy
BVT	Biometric vegetation type
CCA	Community conservation area
CHM	Canopy height model
CMA	Catchment management authority
CSG	Coal seam gas
DBH	Diameter at breast height
DEC	NSW Department of Conservation (now NSW Office of Environment and Heritage)
DECC	NSW Department of Environment and Climate Change (now NSW Office of Environment and Heritage)
DECCW	NSW Department of Climate Change and Water (now NSW Office of Environment and Heritage)
DEWHA	Australian Department of the Environment, Water, Heritage and the Arts (now Department of the Environment)
DMR	NSW Department of Mineral Resources (now NSW Trade and Investment)
DNG	Derived native grassland
DPI	NSW Department of Primary Industries
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EEC	Endangered ecological community
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
EMP	Environmental Management Plan
ENSW	Energy NSW
EPA Act	NSW *Environmental Planning and Assessment Act 1979*
ESA	Ecological Sensitivity Analysis
FBA	Framework for Biodiversity Assessment

Abbreviation	Description
GDE	Groundwater Dependant Ecosystems
GIS	Geographic Information System
GPS	Global Positioning System
IECA	International Erosion Control Association
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
MNES	Matters of national environmental significance
NICE	Northern Inland Council for the Environment
NPW Act	NSW *National Parks and Wildlife Act 1974*
NPWS	National Parks and Wildlife Service
NSWVCA	NSW Vegetation Classification Assessment
NW Act	NSW *Noxious Weeds Act 1993*
NV Act	NSW *Native Vegetation Act 2003*
OCSG	NSW Office of Coal Seam Gas
OEH	NSW Office of Environment and Heritage
PA	Planning Agreements
PAL	Petroleum Assessment Lease
PCT	Plant community type
PEL	Petroleum Exploration Licence
PPL	Petroleum Production Lease
RPS	RPS Group Plc
RVC	Regional vegetation community
SAT	Spot assessment technique
SCA	State Conservation Area
SEPP	State Environmental Planning Policy
TSC Act	NSW *Threatened Species Conservation Act 1995*
TSSC	Threatened Species Scientific Committee
TWS	The Wilderness Society
WIRES	NSW Wildlife Information Rescue and Education Service Inc

Executive summary

Eco Logical Australia (ELA) was engaged by the Proponent to undertake an Ecological Assessment for inclusion in the Environmental Impact Statement (EIS) for the proposed Narrabri Gas Project (the project). The proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri.

The study area for this Ecological Assessment comprises 95,077 ha with surface infrastructure proposed as part of the project impacting approximately one per cent of the total study area. The study area comprises approximately 75% native vegetation, 10% derived native grassland, 14% agriculture (cropping, improved pasture or areas of previous pasture improvement) and 1% other (including cleared, creek beds and dams).

This report details the ecological survey and assessment undertaken to assess the potential impacts of the project on biodiversity values in the study area. Field surveys were undertaken between November 2010 and September 2014. Surveys were supported by information obtained through a comprehensive database review and literature review. Following field surveys, extensive mapping, modelling and analyses were undertaken using data from field surveys and the database and literature reviews.

The field surveys involved a range of survey techniques to collect data both on the broad species diversity and abundance in the study area, as well as targeted surveys to assess species abundance, distribution, ecology and habitat preferences. Flora surveys involved undertaking full floristic Biometric plots, targeted threatened flora surveys, habitat surveys, rehabilitation monitoring and rapid flora plots for fauna habitat and vegetation mapping. Fauna surveys involved nocturnal and diurnal fauna surveys (trapping, searches and call playback/analysis, hair and image capture), targeted threatened fauna surveys and habitat surveys. Flora and fauna surveys were undertaken over a range of seasons, with targeted surveys undertaken in the optimal season to ensure identification of the target species.

A total of 80,398 ha of native vegetation, 807 flora species and 289 fauna species were identified across 22 Plant Community Types (PCTs) mapped in the study area. Four of the mapped Plant Community Types qualify as endangered ecological communities (with two of these endangered ecological communities being further divided by status under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Threatened Species Conservation Act 1995* (TSC Act) due to condition).

Ten of the flora species recorded are listed as threatened under the TSC Act. Of these, five are also listed as threatened under the EPBC Act. The flora surveys identified 116 exotic flora species of which eight are declared noxious within the Narrabri Local Government Area (LGA).

The 289 fauna species identified to species level in the study area consisted of 17 amphibians, 186 birds, 45 mammals and 41 reptiles. Of these, 16 birds, 10 mammals and one reptile are listed as threatened under the TSC Act, three mammals and one bird are listed as threatened under the EPBC Act and five birds are listed as migratory under the EPBC Act. Five birds and 12 mammals recorded in the study area are feral species.

The direct impacts of the project would result in the removal of up to 988.8 ha of native vegetation which includes 75.9 ha of derived native grassland. This equates to the removal of approximately 1.29% of the native vegetation and 0.80% of the derived native grassland in the study area. The indirect impacts of the project are equivalent to an additional removal of 181.11 ha of native vegetation.

The direct and indirect impacts to vegetation would impact on fauna foraging, breeding and dispersal habitat. For all threatened fauna species considered 'potential' or 'known' to occur in the study area, the direct and indirect impact to habitat would account for less than 2% of the total habitat available in the study area.

The direct removal of threatened flora species has been estimated through modelling and/or mapping where possible. Impacts to the abundance of each threatened flora species is less than 1.6% of the total abundance estimated to occur in the study area.

Cumulative impacts that consider all existing and proposed exploration and production appraisal activities associated with the Energy NSW coal seam gas exploration and appraisal program operated by the Proponent in the study region have been assessed. Additionally, vegetation, fauna habitat and threatened flora directly and indirectly impacted by Narrabri Coal Mine have been included in the cumulative impact assessment as they share similar biodiversity values and are in the same landscape to the study area. A review was undertaken for all other potential developments in the study region, however no other projects were included as they were located in different landscapes and/or had different biodiversity values to those present in the study area.

A total of 1,701.51 ha of native vegetation and derived grassland would be cumulatively impacted with the addition of the project to the study region. This would result in the removal of 1.79% of vegetation in the study area and 0.48% of vegetation in the study region. Less than 3% of fauna habitat would be cumulatively impacted. Additionally, less than 2% of the total abundance for each threatened flora species would be cumulatively impacted.

Assessments of significance under both the TSC Act and EPBC Act were undertaken for all threatened species and communities that are considered 'potential', 'likely' or 'known' to occur in the study area. This involved assessing 32 birds, 14 mammals, one reptile, 10 plants and four ecological communities which are listed as threatened under the TSC Act and/or EPBC Act and nine birds listed as migratory under the EPBC Act.

The design process would ensure that infrastructure minimises vegetation and habitat clearance, fragmentation and additional indirect impacts. This would be achieved through placing infrastructure in existing clearing wherever practicable, aligning infrastructure adjacent to existing clearing wherever practicable and the implementing the Field Development Protocol.

The Field Development Protocol incorporates the Ecological Scouting Framework and Pre-clearing Procedure during the planning, design and construction phases to avoid and minimise impact to ecologically sensitive values. The methods presented have been previously applied to reduce the impact to individual biodiversity values (such as threatened flora individuals or hollow-bearing trees) from between 20% to 80%.

The proposed mitigation measures including the Field Development Protocol will further reduce impacts on threatened and migratory species and ecological communities at a site scale.

It is unlikely that project would have a significant impact on the threatened ecological communities, threatened flora and threatened fauna that are considered 'potential', 'likely' or are known to occur in the study area provided the proposed avoidance, minimisation and mitigation measures are applied.

Residual impacts on threatened species and ecological communities will be offset as part of a Biodiversity Offset Strategy in general accordance with the NSW Biodiversity Offset Policy for Major Projects.

1 Introduction

1.1 Overview

The Proponent is proposing to develop natural gas in the Gunnedah Basin in New South Wales (NSW), southwest of Narrabri (**Figure 1**).

The Narrabri Gas Project (the project) seeks to develop and operate a gas production field, requiring the installation of gas wells, gas and water gathering systems, and supporting infrastructure. The natural gas produced would be treated at a central gas processing facility on a local rural property (Leewood), approximately 25 kilometres south-west of Narrabri. The gas would then be piped via a high-pressure gas transmission pipeline to market. This pipeline would be part of a separate approvals process and is therefore not part of this proposed development.

The primary objective of the project is to commercialise natural gas to be made available to the NSW gas market and to support the energy security needs of NSW. Production of natural gas under the project would deliver economic, environmental and social benefits to the Narrabri region and the broader NSW community. The key benefits of the project can be summarised as follows:

- The Narrabri Gas Project has the capacity to deliver up to 200 terajoules of gas per day which, at the time of EIS submission, represents approximately 50 per cent of NSW's gas demand. The project would therefore provide an important new energy source for NSW, which would contribute to the State's economy through royalties paid, jobs created and infrastructure investment
- The provision of a reduced greenhouse gas emission fuel source for power generation in NSW as compared to traditional power generation.
- The project would create local and regional job opportunities. The investment is forecast to directly create approximately 1,300 jobs during the construction phase and sustain approximately 200 jobs during the operational phase.
- The establishment of a regional community benefit fund of up to $120 million over the next two decades.

1.2 Description of project

The project would involve the construction and operation of a range of exploration and production activities and infrastructure including the continued use of some existing infrastructure. The key components of the project are presented in **Table 1**, and are shown on **Figure 1**.

Table 1: Key project components

Location	Infrastructure or activity
Major facilities	
Leewood	• a central gas processing facility for the compression, dehydration and treatment of gas • a central water management facility including storage and treatment of produced water and brine • optional power generation for the project • a safety flare

Location	Infrastructure or activity
	• treated water management infrastructure to facilitate the transfer of treated water for irrigation, dust suppression, construction and drilling activities • other supporting infrastructure including storage and utility buildings, staff amenities, equipment shelters, car parking, and diesel and chemical storage • continued use of existing facilities such as the brine and produced water ponds • operation of the facility
Bibblewindi	• in-field compression facility • a safety flare • supporting infrastructure including storage and utility areas, treated water holding tank, and a communications tower • upgrades and expansion to the staff amenities and car parking • produced water, brine and construction water storage, including recommissioning of two existing ponds • continued use of existing facilities such as the 5ML water balance tank • operation of the expanded facility
Bibblewindi to Leewood infrastructure corridor	• widening of the existing corridor to allow for construction and operation of an additional buried medium pressure gas pipeline, a water pipeline, underground (up to 132 kV) power, and buried communications transmission lines
Leewood to Wilga Park underground power line	• installation and operation of an underground power line (up to 132 kV) within the existing gas pipeline corridor
Gas field	
Gas exploration, appraisal and production infrastructure	• seismic geophysical survey • installation of up to 850 new wells on a maximum of 425 well pads o new well types would include exploration, appraisal and production wells • installation of water and gas gathering lines and supporting infrastructure • construction of new access tracks where required • water balance tanks • communications towers • conversion of existing exploration and appraisal wells to production

Ancillary	• upgrades to intersections on the Newell Highway
	• expansion of worker accommodation at Westport
	• a treated water pipeline and diffuser from Leewood to Bohena Creek
	• treated water irrigation infrastructure including:
	  o pipeline(s) from Leewood to the irrigation area(s)
	  o treated water storage dam(s) offsite from Leewood
	• operation of the irrigation scheme

The project is expected to generate approximately 1,300 jobs during the construction phase and sustain around 200 jobs during the operational phase; the latter excluding an ongoing drilling workforce comprising approximately 100 jobs.

Subject to obtaining the required regulatory approvals, and a financial investment decision, construction of the project is expected to commence in early 2018, with first gas scheduled for 2019/2020. Progressive construction of the gas processing and water management facilities would take around three years and would be undertaken between approximately early/mid-2018 and early/mid-2021. The gas wells would be progressively drilled during the first 20 or so years of the project. For the purpose of impact assessment, a 25 year construction and operational period has been adopted.

1.2.1 Terminology

Study area

For the purposes of this report, the project area is the study area. It includes areas surveyed as part of this assessment, incorporating the extent of direct and indirect impacts (**Figure 2**).

Study region

The study region is defined as the area within PEL 238 which includes PAL 2 and PPL 3. This area is used to discuss the project within the context of the broader north-east Pilliga Forest.

1.3 Project location

The project would be located in north-western NSW, approximately 20 kilometres south-west of Narrabri, within the Narrabri local government area (LGA) (**Figure 1**).

The project area covers about 950 square kilometres (95,000 hectares), and the project footprint would directly impact about one per cent of that area.

The project area contains a portion of the region known as ‘the Pilliga’; which is an agglomeration of forested area covering more than 500,000 hectares in north-western NSW around Coonabarabran, Baradine and Narrabri. Nearly half of the Pilliga is allocated to conservation, managed under the NSW National Parks and Wildlife Act 1974. The Pilliga has spiritual meaning and cultural significance for the Aboriginal people of the region.

Other parts of the Pilliga were dedicated as State forest, and set aside for the purpose of ‘forestry, recreation and mineral extraction, with a strategic aim to “provide for exploration, mining, petroleum production and extractive industry” under the Brigalow and Nandewar Community Conservation Area Act 2005. The parts of the project area on state land are located within this section of the Pilliga.

The semi-arid climate of the region and general unsuitability of the soils for agriculture have combined to protect the Pilliga from widespread clearing. Commercial timber harvesting activities in the Pilliga were preceded by unsuccessful attempts in the mid-1800s to establish a wool production industry. Resource exploration has been occurring in the area since the 1960s; initially for oil, but more recently for coal and gas.

The ecology of the Pilliga has been fragmented and otherwise impacted by commercial timber harvesting and related activities over the last century through:

- the establishment of more than 5,000 kilometres of roads, tracks and trails
- the introduction of pest species
- the occurrence of drought and wildfire.

The project area avoids the Pilliga National Park, Pilliga State Conservation Area, Pilliga Nature Reserve and Brigalow Nature Reserve. Brigalow State Conservation Area is within the project area but would be protected by a 50 metre surface exclusion zone.

Agriculture is a major land use within the Narrabri LGA; about half of the LGA is used for agriculture, split between cropping and grazing. Although the majority of the project area would be within State forests, much of the remaining area is situated on agricultural land that supports dry-land cropping and livestock. No agricultural land in the project area is mapped by the NSW Government to be biophysical strategic agricultural land (BSAL) and detailed soil analysis has established the absence of BSAL. This has been confirmed by the issue of a BSAL Certificate for the project area by the NSW Government.

1.4 Planning framework and structure of this report

1.4.1 Planning framework

The project is permissible with development consent under the State Environmental Planning Policy (Mining, Petroleum and Extractive Industries) 2007, and is identified as 'State significant development' under section 89C(2) of the Environmental Planning and Assessment Act 1979 (EP&A Act) and the State Environmental Planning Policy (State and Regional Development) 2011.

The project is subject to the assessment and approval provisions of Division 4.1 of Part 4 of the EP&A Act. The Minister for Planning is the consent authority, who is able to delegate the consent authority function to the Planning Assessment Commission, the Secretary of the Department of Planning and Environment or to any other public authority.

The project is also a controlled action under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. The project was declared to be a controlled action on 5 December 2014, to be assessed under the bilateral agreement between the Commonwealth and NSW Governments, and triggering the following controlling provisions:

- listed threatened species and ecological communities
- a water resource, in relation to coal seam gas development and large coal mining development
- Commonwealth land.

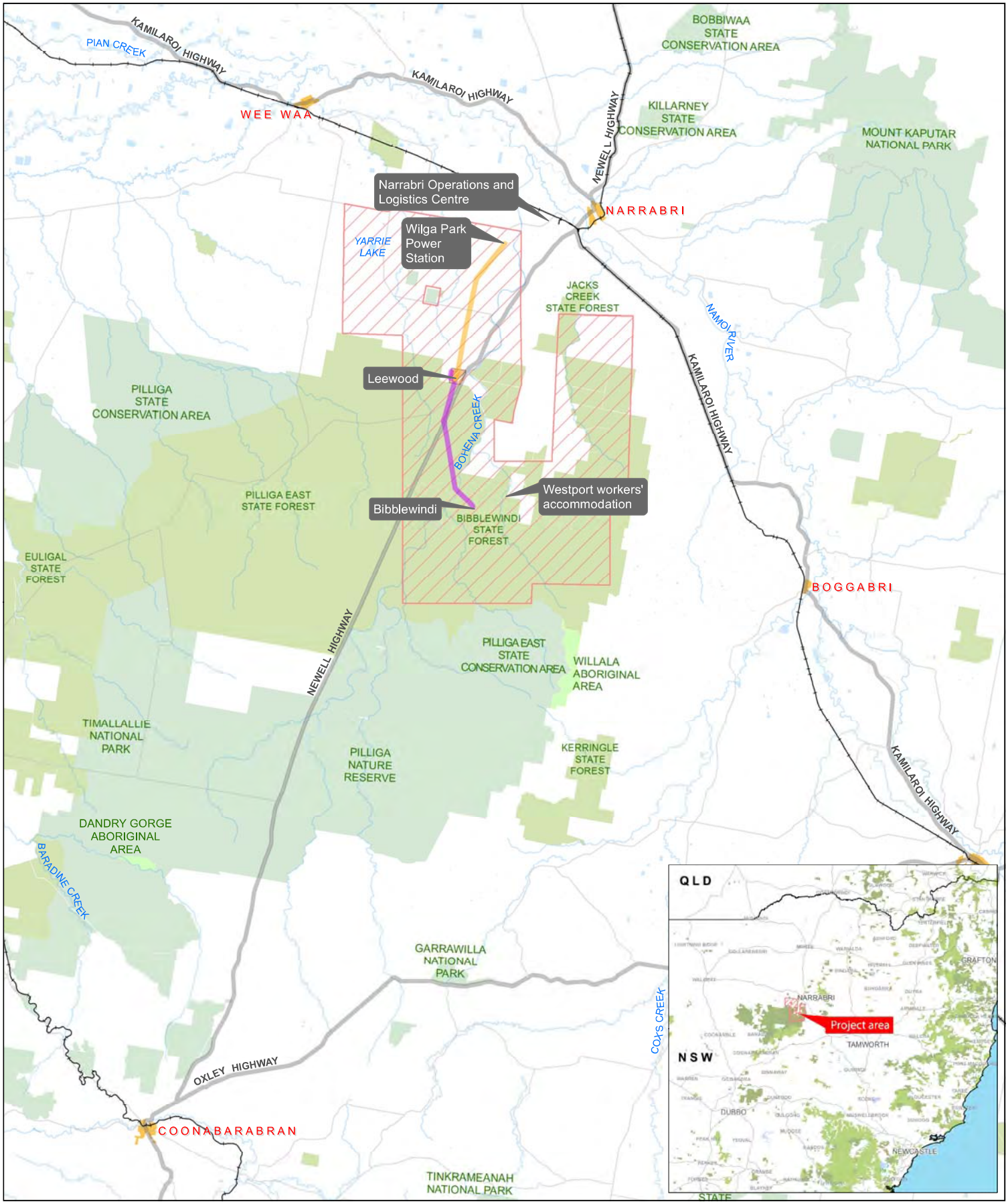
This Ecological Impact Assessment identifies the potential environmental issues associated with construction and operation of the project and addresses the Secretary's environmental assessment requirements for the project (**Section 2.4**). The assessment will be used to support the EIS for the project. The requirements addressed in this report include:

- An assessment of the likely biodiversity impacts of the development, having regard to the principles and strategies in the NSW Biodiversity Offsets Policy for Major Projects, and the OEH's and NSW Trade and Investments' requirements, and using a suitable methodology for credit calculation.
- A detailed description of the proposed regime for minimising, managing and reporting on the biodiversity impacts of the project over time if the project is approved.
- A comprehensive offset strategy for the project, using a suitable methodology for calculating the credits of offsets.

1.4.2 Structure of report

The report is structured as follows:

- **Chapter 1 – Introduction**. This chapter introduces the project and the proponent and describes the study area.
- **Chapter 2 – Legislative context**. This chapter outlines the relevant Commonwealth and State legislation relating to the assessment. Guidelines and assessment criteria (where applicable) relevant to the gas field construction, operation and decommissioning are also identified.
- **Chapter 3 – Existing environment**. This chapter describes the existing biodiversity values of the study area relevant to terrestrial ecology.
- **Chapter 4 – Methodology**. This chapter defines the study area assessed in this report and describes the steps undertaken in the assessment.
- **Chapter 5 – Results**. This chapter outlines the findings of the database searches, literature review and field survey.
- **Chapter 6 – Impact assessment**. This chapter examines the potential environmental impacts associated with the construction and operation of the project.
- **Chapter 7 – Mitigation measures**. This chapter outlines the proposed mitigation strategies to be implemented during the life of the project to manage the potential environmental impacts.
- **Chapter 8 – Biodiversity offset strategy**. This chapter outlines the biodiversity offset strategy proposed for the project.
- **Chapter 9 – Conclusion**. This chapter presents a conclusion to the report and presents the next steps in the advancement of the project.



LEGEND

- Project area
- Leewood
- Urban
- State forest
- Parks and reserves
- Aboriginal areas
- Lakes and dams
- Watercourses
- Highways
- Major Roads
- Train line
- Leewood to Wilga Park infrastructure corridor
- Bibblewindi to Leewood infrastructure corridor

0 5 10 20
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Narrabri Gas Project
EIS Technical Appendix

Regional context and location of key infrastructure

Job Number 21-22463
Revision A
Date 12 Mar 2015

Figure 1

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: NSW Department of Lands: DTDB and DCDB - 2012-13. Santos: Operational and Base Data - 2013. Created by: afoddy

Figure 2: Study area

Brigalow SCA

Brigalow NR

Brigalow SCA

Jacks Creek SF

Jacks Creek SF

NEWELL HIGHWAY

Pilliga Outwash

Bibblewindi SF

Pilliga

Pilliga East SF

Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- IBRA subregions

NPWS Estate

- Brigalow Nature Reserve
- Brigalow State Conservation Area

State Forests

- Bibblewindi
- Jacks Creek
- Pilliga East

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
DSEWPaC
Forestry Corporation of NSW
OEH
Imagery: Bing Maps & Esri

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Prepared by: MS Date: 17/10/16

2 Legislative context

2.1 Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999

The primary objective of the EPBC Act is to 'provide for the protection of the environment, especially those aspects of the environment that are Matters of National Environmental Significance.'

Environmental approvals under the EPBC Act are required for an 'action' that is likely to have a significant impact on matters of national environmental significance (MNES) including:

- World Heritage Areas
- National Heritage Places
- Ramsar wetlands of international importance
- Nationally listed threatened species and ecological communities
- Listed migratory species
- Commonwealth marine areas
- Nuclear actions
- Great Barrier Reef Marine Park
- A water source, in relation to coal seam gas and large coal mining development.

In addition, the EPBC Act confers jurisdiction over actions that have a significant impact on the environment:

- Where the actions affect, or are taken on, Commonwealth land.
- Which are carried out by a Commonwealth agency (even if that significant impact is not on one of the nine matters of 'national environmental significance').

An 'action' is considered to include a project, development, undertaking, activity or series of activities.

Ecological matters of national environmental significance relevant to the study area are nationally listed threatened species, ecological communities and listed migratory species. Ecological matters of national environmental significance that were recorded or have the potential to occur or use the study area are listed in **Appendix K**. An assessment of the potential impacts of the project in accordance with the EPBC Act has been undertaken and provided in **Appendix K**.

The Significant impact guidelines for Matters of National Environmental Significance (DotE, 2013b) were used to assess the potential impact on each ecological matter presented in **Appendix K**. The EPBC Act referral guidelines for the vulnerable Koala (DotE, 2014b) have also been applied to this assessment. The referral guidelines present a process to assess potential impact on the Koala by the project and to decide if it is necessary to prepare a referral under the EPBC Act with relation to the Koala.

The project was referred to the Commonwealth Department of the Environment on 3 November 2014 (2014/7376). The project was determined a 'controlled action' on 1 December 2014 due to potential impacts on listed threatened species and communities, a water resource, in relation to coal seam gas development and large coal mining development and commonwealth land. Assessment of the project has been delegated to the State under the assessment bilateral agreement with the NSW Government.

2.2 New South Wales legislation

Environmental Planning and Assessment Act 1979

The EPA Act is the principal planning legislation for NSW. It provides a framework for land use control and assessment, determination and management of development.

The project is being assessed under Division 4.1 of Part 4 of the EPA Act. The Minister for Planning is the consent authority, who is able to delegate the consent authority function to the Planning Assessment Commission, the Secretary of the Department of Planning and Environment or to any other public authority.

Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act 1995* (TSC Act) aims to protect and encourage the recovery of threatened species, populations and communities listed under the Act. The Act is integrated with the EPA Act. Activities being assessed under the EPA Act require consideration of whether the project is likely to significantly affect threatened species, populations and ecological communities or their habitats listed under the TSC Act.

Threatened species, populations and ecological communities that were recorded or have the potential to be present in or use the study area are listed in **Appendix J**. The impacts to these species have been assessed with consideration to the *Threatened species assessment guidelines: the assessment of significance* (DECC, 2007).

Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) aims to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations. The FM Act defines 'fish' as any marine, estuarine or freshwater fish or other aquatic animal at any stage of their life history, excluding whales, mammals, reptiles, birds, amphibians or other species specifically excluded.

No threatened fish or endangered populations are known or expected to occur within the study area.

Brigalow and Nandewar Community Conservation Area Act 2005

The *Brigalow and Nandewar Community Conservation Area Act 2005* (BNCCA Act) transferred forested land in the Brigalow and Nandewar area to the National Parks and Wildlife Service estate, creating Community Conservation Areas (CCAs). The purpose of CCAs is to reserve land for permanent conservation, protect areas of natural and cultural heritage to the Aboriginal people, and support sustainable forestry and mining. Local communities are involved in the management of CCAs through the Community Conservation Council.

Four CCA zones have been defined:

- Zone 1: Conservation and recreation (National Park)
- Zone 2: Conservation and Aboriginal culture (Aboriginal Area)
- Zone 3: Conservation, recreation and mineral extraction (State Conservation Area)
- Zone 4: Forestry, recreation and mineral extraction (State Forests).

Two CCA zones (Zone 3 and 4) apply to the study area. Zone 4 contains all the State Forests in the study area (Pilliga East, Bibblewindi and Jacks Creek) whilst Zone 3 in the north includes Brigalow State Conservation Area (SCA). Brigalow Nature Reserve (Zone 1) is excluded from the study area. As mineral extraction is a permitted use in Zone 3 and 4, the Project is considered consistent with the zoning in the BNCCA Act.

Noxious Weeds Act 1993

The *Noxious Weeds Act 1993* (NW Act) defines the roles of government, councils, private landholders and public authorities in the management of noxious weeds. The NW Act sets up categorisation and control actions for noxious weeds, according to their potential to cause harm to the local environment.

Under this Act, noxious weeds have been identified for local government areas and assigned Control Classes (**Section 5.3.4**). Part 3 of the NW Act provides that occupiers of land (this includes owners of land) have responsibility for controlling noxious weeds on the land they occupy.

Native Vegetation Act 2003

The *Native Vegetation Act 2003* (NV Act) and Native Vegetation Regulation 2005 are the controlling legislation for native vegetation on rural land in NSW and are administered through Catchment Management Authorities (CMAs).

The project involves clearing of native vegetation, however Section 89J of the EPA Act excludes all approvals required under Section 12 of the NV Act for State Significant Development, namely to clear native vegetation or State protected land.

Water Management Act 2000

The *Water Management Act 2000* (WM Act) provides for the sustainable and integrated management of the water sources of the State for the benefit of both present and future generations.

As part of this study, watercourses in the study area were refined at a 1:15,000 scale, stream orders classified (Strahler, 1952) and riparian corridors mapped in accordance with recommended widths under the WM Act (**Section 4.10** and **5.6**).

The project involves works on waterfront land, however Section 89J of the EPA Act excludes all approvals (other than an aquifer interference approval) required under Section 91 of the WM Act.

2.3 Planning instruments

State Environmental Planning Policy (Mining, Petroleum and Extractive Industries) 2007

State Environmental Planning Policy (Mining, Petroleum and Extractive Industries) 2007 (the Mining SEPP) aims to provide for the proper management and development of mineral, petroleum and extractive material resources for the social and economic welfare of NSW. The Mining SEPP establishes appropriate planning controls to encourage ecologically sustainable development.

The project is permissible with development consent under clause 7(2)(a) of the Mining SEPP.

State Environmental Planning Policy (State and Regional Development) 2011

Section 89C(2) of the EPA Act provides that a SEPP may declare any development or any class or description of development, to be State significant development. State Environmental Planning Policy (State and Regional Development) 2011 (State and Regional Development SEPP) identifies development which is ‘State significant development’ for this purpose.

The project is permissible with development consent, and is development for the purposes of petroleum production, therefore the project is State significant development under clause 8(1) of the State and Regional Development SEPP.

State Environmental Planning Policy 44 (Koala Habitat)

State Environmental Planning Policy 44 (Koala Habitat) (SEPP 44) aims to encourage the proper conservation and management of areas of natural vegetation that provide habitat for *Phascolarctos cinereus* (Koala) to ensure a permanent free-living population over their present range and reverse the current trend of Koala population decline. As the project is over 1 ha in size and SEPP 44 applies to the Narrabri Shire Council local government area, an assessment under SEPP 44 is required. As Koala is listed as a threatened species, impacts to Koalas and their habitat have also been assessed. The assessment follows the three steps below.

Step 1: Is the land potential Koala habitat?

Potential Koala habitat is areas of native vegetation where the trees of types listed in Schedule 2 of the SEPP 44 constitute at least 15% of the total number of trees in the upper of lower strata of the tree component.

Step 2: Is the land core koala habitat?

Core Koala habitat is areas of land with a resident population of Koalas, evidenced by attributes such as breeding females (that is, females with young) and recent sightings of and historical records of a population.

Step 3: Can development consent be granted in relation to core koala habitat?

A plan of management in accordance with Part 3 of SEPP 44 must be prepared. If the action is not inconsistent with the plan of management, then development consent can be granted in relation to core Koala habitat.

Local Environmental Plans (LEPs)

The project is located within the Narrabri LGA and is subject to the Narrabri Local Environmental Plan 2012. This plan indicates that the project is located within the RU1 Primary Production and RU3 Forestry zones.

In the RU1 zone, agriculture is permitted either with or without development consent, depending on the type of agriculture. A range of other uses are permissible with consent in the RU1 Zone including extractive industries, open cut mining and rural industries.

In the RU3 zone, uses authorised under the NSW *Forestry Act 2012* are permitted without development consent. Under section 60 of the *Forestry Act 2012*, forest permits can be issued to use forestry area for non-forestry purposes specified in the permit, including recreational, sporting or commercial activities. Whilst section 60 does not explicitly reference agricultural uses, it allows for any use provided it is specified in the permit. On this basis, the development may be carried out in the RU3 zone without the need for development consent.

2.4 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements (SEARs) for the project were first issued on 25 July 2014 and address the key issues relating to biodiversity presented in **Table 2**. Revised Secretary's environmental assessment requirements for the project were issued on 27 September 2016. The additional requirements have been addressed in this report (**Table 2**) and by the preparation of a Biodiversity Assessment Report (BAR) in accordance with the Framework for Biodiversity Assessment (FBA). For ease of reference, a compliance table between this assessment report and the requirements of the *NSW Biodiversity Offsets Policy for Major Projects* has been included in **Appendix M**.

Table 2: Secretary's environmental assessment requirements

Key issue	Document	Requirement	Relevant section of this document
General requirement	SEARs 25/7/2014	A description of the existing environment likely to be affected by the development, using sufficient baseline data.	Section 3
Biodiversity	SEARs 25/7/2014	An assessment of the likely biodiversity impacts of the development, having regard to the principles and strategies in the draft NSW Biodiversity Offsets Policy for Major Projects, and the OEH's and NSW Trade and Investments' requirements (see Attachment 2), and using a suitable methodology for credit calculation (for instance, BBAM or FBA).	Section 6, Section 8, Appendix L
	SEARs 25/7/2014	A detailed description of the proposed regime for minimising, managing and reporting on the biodiversity impacts of the project over time if the project is approved.	Section 7
	SEARs 25/7/2014	A comprehensive offset strategy for the project, using a suitable methodology for calculating the credits of any offsets.	Section 8, Appendix L
	SEARs 27/9/2016	An assessment of the likely biodiversity impacts of the development, in accordance with the Framework for Biodiversity Assessment (OEH, 2014b), unless otherwise agreed by OEH, and having regard to the OEH's and DPI's requirements.	Details provided in Table 1 of BAR
	SEARs 27/9/2016	A strategy to offset any residual impacts of the development in accordance with the NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014c), unless otherwise agreed by OEH.	Section 8, Appendix L

In forming the above requirements, advice was obtained from relevant government agencies to ensure the potential impacts of the project are adequately addressed. Recommended environmental assessment requirements from relevant government agencies as they relate to biodiversity and where they have been addressed is provided in **Table 3**.

Table 3: Agency input

Agency	Document	Requirement	Relevant section of this document
Office of Environment and Heritage	SEARs 25/7/2014	Map remnant native vegetation within the project area by Plant Community Type (and Biometric Vegetation Type) at a 1: 15,000 scale, including attribution of fauna habitat types based on a combination of targeted survey, field validation and aerial photographic interpretation.	Figure 15, Figure 16

Agency	Document	Requirement	Relevant section of this document
	SEARs 25/7/2014	Undertake targeted field surveys to identify the occurrence of flora and fauna and to assess the biodiversity values present in the project area	Sections 4.4 – 4.7
	SEARs 25/7/2014	For threatened flora species conduct surveys randomly across the project area, i.e. random points are surveyed for presence/absence of the target species in the area of study followed by a binomial probability analysis to determine a 95% confidence interval for the proportion of occurrence of the target species based on the presence/absence results.	Section 4.5.3, Section 6.3, Appendix F4
	SEARs 25/7/2014	Based on vegetation and fauna habitat mapping, assign breeding and foraging habitat for each known or predicted fauna species to each area of habitat.	Figure 19, Appendix A5
	SEARs 25/7/2014	Provide details of the survey methodology employed including survey effort and representativeness for each flora and fauna species targeted.	Sections 4.4 – 4.7
	SEARs 25/7/2014	Map primary and secondary *Pseudomys pilligaensis* (Pilliga Mouse) habitat within the project area at a 1: 15,000 scale based on a combination of targeted survey, field validation and modelling.	Section 4.7.1, Section 5.4.3, Appendix F5, Appendix F6
	SEARs 25/7/2014	Identify and locate important habitat and/or climate refuges for *Phascolarctos cinereus* (Koala) both in the project area and more broadly across the Pilliga including the location of remnant populations.	Section 4.7.4, Section 5.4.3, Appendix F7
	SEARs 25/7/2014	Refine, map and order watercourses within the project area according to the Strahler System based on a high-resolution digital elevation model.	Section 2.1.2, Appendix F8
	SEARs 25/7/2014	Develop an ecological sensitivity analysis digital mapping layer which ranks and weights biodiversity values such as: • Endangered Ecological Communities; • threatened flora; • threatened fauna species habitat; • vegetation of regional significance; • watercourses;	Figure 23, Section 4.9, Section 5.5, Appendix F8

Agency	Document	Requirement	Relevant section of this document
		• vegetation condition based on Biometric scores from plot data; and • patch size.	
	SEARs 25/7/2014	The ecological sensitivity analysis must be supported by robust criteria and (if applied) weightings, and these details must be provided in the EIS.	Section 4.9, Section 5.5, Appendix F8
	SEARs 25/7/2014	Determine upper limits of disturbance against ecological features (Plant Community Types, threatened plants and threatened fauna habitat) using an appropriate robust statistical method.	Section 6.3, Appendix A6, Appendix A7, Appendix F3
	SEARs 25/7/2014	Provide a field development protocol which sets out the detailed environmental criteria and locational principles to be used during the project for selecting the specific location of infrastructure within the project area, having regard to the ·baseline data, to minimise impact on flora and fauna and highly sensitive ecological features within the upper limits of disturbance, accounting for: • limits of disturbance against ecological features; • ecological sensitivity; • proximity to watercourses; • cultural heritage; • land access; and • amenity.	Section 6.2
	SEARs 25/7/2014	Measures proposed to be taken to avoid, minimise or mitigate impacts on biodiversity including a micrositing procedure for all infrastructure.	Section 6.2, Section 7, Appendix G
	SEARs 25/7/2014	Impact quantification and assessment using BBAM • Impacts including the likely direct, indirect and cumulative impacts: • Using the BBAM credit calculator quantify the likely direct, indirect and cumulative impacts of the development on threatened species, populations and communities listed in the TSC Act and matters of national environmental significance under the EPBC Act.	Section 6, Appendix L

Agency	Document	Requirement	Relevant section of this document
		• Assessment of indirect and cumulative impacts of implementation of the project on biodiversity, specifically: • indirect impact zones; • dust and noise; and • habitat fragmentation, fauna mortality, predation, competition and disturbance by vertebrate pests, edge favouring native species, weed invasion and sedimentation and erosion.	
	SEARs 25/7/2014	The offsets package proposed for impacts to biodiversity should be consistent with the seven principles for the use of biodiversity offsets in NSW. In determining offset requirements: a) The project must avoid and minimise impacts, and offset any remaining impacts. b) The project assessment should proceed using BBAM, noting the limitations to that are set out in Tier 2 of the Interim policy on assessing and offsetting biodiversity impacts of Part 3A developments (the "Interim Policy"). c) Where offsets are required, the offset strategy should: a. a. Use the BBAM offset rules, or target any higher conservation priority b. b. Adopt the additionality rules in BBAM c. c. Secure the offset in accordance with section 5.1 of the 2011 Interim Policy d. d. Provide for the use of Supplementary Measures where it can be demonstrated that a land-based offset is not available, subject to the endorsement of OEH. d) Take account of the landscape design principles such as patch size and building onto and connecting existing remnants. e) Include an appropriate Management Plan (such as vegetation or habitat) that has been developed as a key amelioration measure to ensure any proposed compensatory offsets, retained habitat enhancement features within the development footprint and/or impact mitigation measures (including proposed rehabilitation and/or monitoring programs) are appropriately managed and funded.	Section 8, Appendix L

Agency	Document	Requirement	Relevant section of this document
	SEARs 25/7/2014	A comprehensive offset strategy for the development: • The offset strategy is to include all direct, indirect and cumulative impacts associated with existing infrastructure which is to be used as part of the project; • Use the BBAM credit calculator to determine the credits of· any offsets proposed for the development; • Consider of Aboriginal cultural values and cultural activities in the selection and conservation of land as part of the biodiversity offset strategy.	Section 8, Appendix L
	SEARs 25/7/2014	Monitoring: Include a detailed and comprehensive ongoing monitoring and adaptive management plan to detail of how biodiversity impacts would be managed during construction and operation including indirect impact levels and any biodiversity changes throughout the life of the project.	Section 7.6
	SEARs 27/9/2016	Biodiversity impacts related to the proposed Narrabri Gas Project are to be assessed and documented in accordance with the NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014c) and Framework for Biodiversity Assessment (OEH, 2014b), unless otherwise agreed by OEH, by a person accredited in accordance with s142B(1)(c) of the Threatened Species Conservation Act 1995.	Details provided in Table 1 of BAR
	SEARs 27/9/2016	A. Impacts on the species/populations/ecological communities listed in Attachment C will require further consideration and provision of the information specified in s9.2 of the Framework for Biodiversity Assessment.	Covered in BAR
	SEARs 27/9/2016	B. The EIS must identify: a. In the case of a project that adjoins, is in the immediate vicinity or upstream of NPWS estate, the assessment of impacts must address the matters outlined in the Guidelines for developments adjoining land and water managed by DECCW (DECCW, 2010) and include: i. The nature of the impacts, including direct and indirect impacts. ii. The extent of the direct and indirect impacts. iii. The duration of the direct and indirect impacts.	Section 4.12 and Section 6.12

Agency	Document	Requirement	Relevant section of this document
		iv. The objectives of the reservation of the land.	
	SEARs 27/9/2016	b. Measures proposed to prevent, control, abate, minimise and manage the direct and indirect impacts including an evaluation of the effectiveness and reliability of the proposed measures.	Section 6, Section 7
	SEARs 27/9/2016	c. Residual impacts.	Section 8, Appendix L
Forestry Corporation	SEARs 27/9/2016	The EIS should consider the possibility of using offset strategies to improve biodiversity outcomes in the State forests adjacent to the development.	Section 8, Appendix L

3 Existing environment

3.1 The Pilliga

The Pilliga represents the largest block of remnant vegetation in NSW, west of the Great Dividing Range. The Pilliga is comprised primarily of State Forests managed for timber production, as well as conservation reserves and other landholdings. There are 24 State Forests, four National Parks, two Aboriginal Areas, six State Conservation Areas and two Nature Reserves within the study region.

In recognition of the high ecological and landscape value of the Pilliga, over 240,000 ha of conservation reserve have been gazetted under the NPW Act since the 1960s. The Pilliga Nature Reserve (83,000 ha) was first reserved in 1968. 30 years later, regional assessments of the Brigalow and Nandewar Bioregions (NPWS, 2000a, 2000b) culminated in the NSW Government's decision in 2005 to conserve an additional 160,000 ha of the Pilliga under the BNCCA Act. This area focuses on the central, southern and western extents of the Pilliga. Today, approximately half of the Pilliga is now reserved under the NPW Act, with the other half retained as State Forest for commercial timber production, recreation and mineral extraction.

Of the 240,000 ha of conservation reserve, a total of 146,000 ha, including Pilliga Nature Reserve, four Community Conservation Area (CCA) Zone 1 reserves (National Parks) and two CCA Zone 2 reserves (Aboriginal Areas) are precluded from forestry and mineral/petroleum exploration. Three CCA Zone 3 reserves (State Conservation Areas) totalling 94,000 ha, were created for conservation, recreation and mineral extraction.

3.2 Landscape context

The Pilliga and the study region are located within the southern part of the Brigalow Belt South Bioregion. This bioregion extends over NSW and Queensland, with the majority occurring in Queensland. In NSW, the bioregion covers an area of 52,409 km², which represents 18.7% of the total bioregion (NPWS, 2000a).

In NSW, the Brigalow Belt South Bioregion shares its borders with five other bioregions: the Nandewar and North Coast Bioregions to the east, the Sydney Basin and South Western Slopes Bioregions to the south, and the Darling Riverine Plains Bioregion to the west. Within the NSW section of the Brigalow Belt South Bioregion, major towns include Baradine, Binnaway, Coonabarabran, Dubbo, Gunnedah, Merriwa, Moree and Narrabri. Major rivers include the MacIntyre, Gwydir, Namoi, Castlereagh, Goulburn, Talbragar and Macquarie Rivers (NPWS, 2000a; OEH, 2011). The Brigalow Belt South Bioregion also shares its borders with other bioregions in Queensland.

The Brigalow Belt South Bioregion is divided into seven provinces in NSW: Northern Outwash, Liverpool Plains, Pilliga Outwash, Liverpool Range, Northern Basalt, Pilliga, and Talbragar Valley. Of these, the study area is situated in the Pilliga and Pilliga Outwash provinces (**Figure 2**). These provinces are characterised by occurring on Mesozoic bedrock containing extensive sandstone hills and coarse sandy soils (Pilliga), and on the plains of deep sandy texture dominated by alluvial and colluvial sediments (Pilliga Outwash) (NPWS, 2000a, 2000b).

3.3 Land use

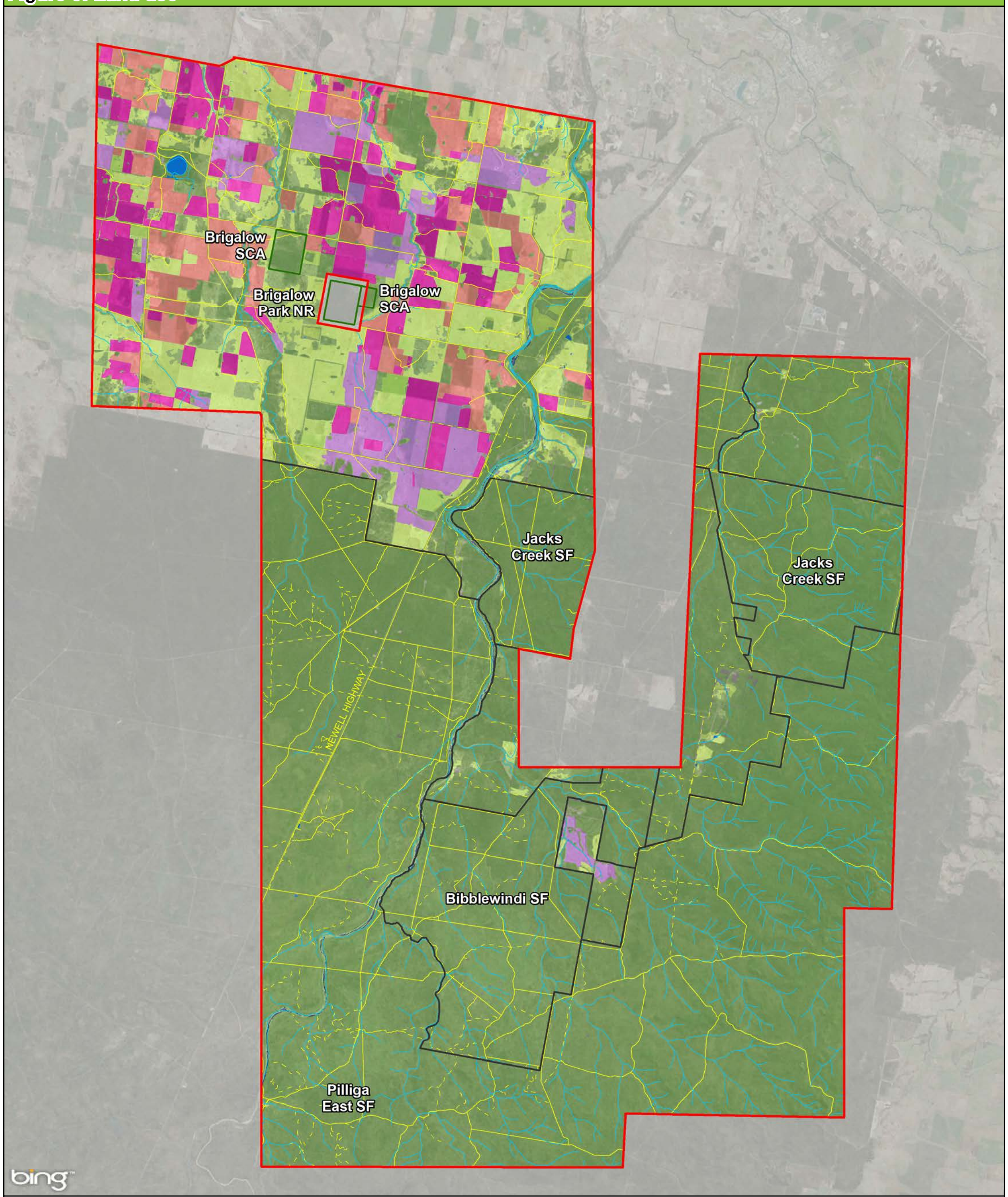
Within the NSW section of the Brigalow Belt South Bioregion, the majority of land (approximately 85%) is freehold land. Much of the freehold land is used for agricultural purposes, where cropping (dryland and irrigation farming) and grazing/pastoral activities dominate (NPWS, 2000a, 2000b).

Approximately 5% of the NSW sections of the bioregion are used by the forestry industry. The Pilliga forests managed by the Forestry Corporation of NSW is the largest area of forestry in the NSW sections of the bioregion. There are many small forest and flora reserves in addition to these forests.

Crown lands and conservation reserves form approximately 4% of the bioregion in NSW. Other land uses within the bioregion include mining and apiary industries (NPWS, 2000a). The mining industry is primarily coal, as the region lies mostly within the Gunnedah Basin, which is a major coal-bearing sedimentary basin. Current mining titles are held for coal and some industrial minerals while exploration titles are held for coal, petroleum, gold, base metals, zeolites and clay minerals (OEH, 2011).

Land use in the study area was mapped by ELA for this assessment (**Figure 3**) and classified into the following categories; cleared, creek bed, dam, derived native grassland, native vegetation, cropping, improved pasture and previous evidence of pasture improvement. This mapping indicates that native vegetation covers approximately 75% of the study area whilst derived native grassland consists approximately 10% of the study area. Agricultural areas of cropping, improved pasture or areas with evidence of previous pasture improvement together consist approximately 14% of the study area.

Figure 3: Land use



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Land use type (ELA 2014)

- Derived native grassland
- Native vegetation
- Other - cropping
- Other - improved pasture
- Other - previous evidence of pasture improvement
- Other - creek bed
- Other - dam
- Other - cleared

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

N

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Prepared by: VH Date: 17/11/2014

3.4 Mitchell landscapes

Mitchell Landscapes are a system of ecosystem classification mapped at the 1:250,000 scale, based on a combination of soils, topography and vegetation (DECC, 2008a). Mitchell Landscapes are used in regional conservation planning in NSW and form a component of the BioBanking Assessment Methodology. Four Mitchell Landscape have been mapped in the study area (**Table 4** and **Figure 4**).

Table 4: Mitchell Landscapes within the study area

Mitchell landscape	Landscape description (DECC, 2008a)	Location
Barradine - Coghill Channels and Floodplains	Sandy incised channels and distributary streams on Quaternary alluvium in fans of Coghill and Baradine Creeks flowing from the sandstones of the Pilliga forest. General elevation 170 to 210m, local relief 10m. Deep texture-contrast soils with harsh clay subsoils, grey clay with gilgai and uniform deep yellow sands. Sediments and soils become finer down valley merging with the Coghill Alluvial Plains ecosystem. Gallery woodland dominated by river red gum along the channels. Other species including; *Eucalyptus populnea* (Poplar box), *E. pilligaensis* (Pilliga box), *E. blakelyi* (Blakely's Red Gum), *Callitris glaucophylla* (*W*hite Cypress Pine) and *E. sideroxylon* (Mugga Ironbark) and occasional *E. melanophloia* (Silver-leaved Ironbark).	Occurs along the main drainage lines within the study area
Bugaldie Uplands	Stepped stony ridges on Jurassic quartz sandstone with some conglomerate, shale and occasional interbedded basaltic volcanic rocks. General elevation 350 to 490m local relief 50 to 150m, extensive joint controlled stream network. Abundant outcrop on ridge tops with thin discontinuous soils with stony, sandy profiles and low nutrients. Down slope texture-contrast soils are more common typically with harsh clay sub-soils and deep uniform or gradational yellow brown sands on the valley floors. Patches of *E. viridis* (Green Mallee) and *E. dwyeri* (Dwyer's Mallee Gum), clumps of *Acacia concurrens* (Curracabah) and *A. cheelii* (Motherumbah) amongst *E. sideroxylon* and *C. endlicheri* (Black Cypress Pine) with shrubby understorey including *Prostanthera ovalifolia* (Mint Bush), *Stypandra glauca* (Nodding Blue Lily) and *Cheilanthes sieberi* (Rock Fern) on ridges and stony slopes. *E. crebra* (Narrow-leaved Ironbark), *E. macrorhyncha* (Red Stringybark), *C. endlicheri*, *Corymbia trachyphloia* (Brown Bloodwood) and *Angophora floribunda* (Rough-Barked Apple) on the sandy flats. *E. albens* (White Box) and *Ficus rubiginosa* (Port Jackson Fig) on the volcanics	Occurs in the eastern and south-eastern part of the study area
Cubbo Uplands	Pilliga horizontal Jurassic quartz sandstones, limited shales, Tertiary basalt caps and plugs plus the sediments derived from these rocks. Stepped sandstone ridges with low cliff faces and high proportion of rock outcrop. Long gentle outwash slopes intersected by sandy streambeds and prior stream channels. A few patches of heavy clay. General elevation 400 to 550m, local relief 50m. On sandstone, the ridge tops have thin discontinuous soils with stony, sandy profiles and low nutrients. Downslope texture-contrast soils are more common	Occurs primarily in the central, eastern and south-eastern sections of

Mitchell landscape	Landscape description (DECC, 2008a)	Location
	typically with harsh clay subsoils and in the valley floors sediments tend to be sorted into deep sands with yellow earthy profiles, harsh grey clays, or more texture-contrast soils with a greater concentration of soluble salts. The sandstone outcrop areas support various forests and woodlands including; *E. nubila* (Blue-leaved Ironbark), *E. rossii* (Inland Scribbly Gum), *C. endlicheri*, *Atalaya hemiglauca* (Whitewood), and *A. floribunda*. Stony hills in the north of the region carry mallee patches with; *E. melanophloia*, *Corymbia maculata* (Spotted Gum) [sic], and *A. leiocarpa* (Smooth-barked Apple). Gentler sandstone slopes over most of the region carry; *E. crebra* (Narrow-leaved Ironbark), *C. glaucophylla*, *E. macrorhyncha*, patches of *E. viridis* and *Melaleuca uncinata* (Broombush) heath. In western and northern sections on texture-contrast or more uniform harsh clay soils forests of *E. pilligaensis*, *E. microcarpa* (Western Grey Box), *E. populnea*, and *E. conica* (Fuzzy Box) are found with stands of *Allocasuarina luehmannii*, *Alectryon oleifolium* (Rosewood), *Atalaya hemiglauca*, *Geijera parviflora* (Wilga), *Casuarina cristata* (Belah), *Acacia homalophylla* (Yarran), and *Eremophila mitchellii* (Budda).	the study area
Coghill Alluvial Plains	Distal parts of the Quaternary alluvial fans largely derived from Jurassic quartz sandstone on streams draining from the Pilliga Forests. Long gentle slopes broken by sandy abandoned stream channels (sand monkeys), patches of heavy grey clay, and contemporary incised stream channels. General elevation 200 to 280m, local relief 5 to 9m. Deep texture-contrast soils with harsh clay subsoils, grey clay with gilgai. Open forest of *C. glaucophylla*, *E. populnea*, *E. pilligaensis*, *E. blakelyi* and *E. sideroxylon*. *C. trachyphloia* and *Xanthorrhoea* sp. (Grass Trees) on sand monkeys (abandoned stream channels). Patches of *Allocasuarina luehmannii* (Bull Oak) or *A. harpophylla* (Brigalow) on gilgai in heavy clay. *E. chloroclada* (Dirty Gum) and *E. camaldulensis* (River Red Gum) in creek lines.	Occurs primarily in the north and central sections of the study area

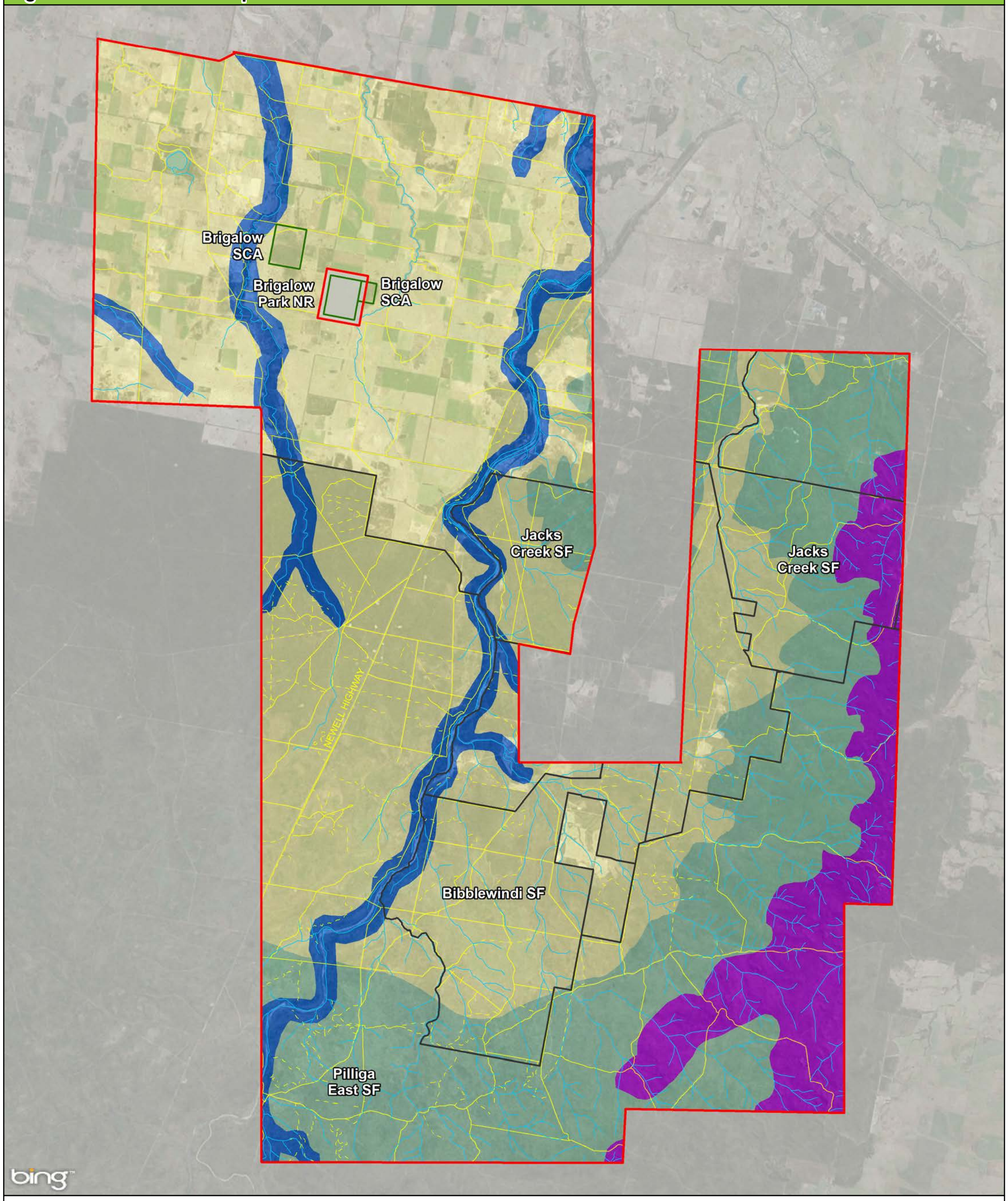
3.5 Climate

The Brigalow Belt South Bioregion is located within an ecological gradient, or ecotone, between the dry inland or Eyrean zone and the wetter coastal or Bassian zone. Within the south eastern section of the bioregion where the study area is located, the climate is classed as subhumid: there is no dry season and the area experiences hot summers (NPWS, 2000b).

Substantial rainfall can occur at any time of the year but there is a peak in summer and a smaller peak in winter. In summer, high intensity rain or thunderstorms can cause significant erosion. Evaporation rates are high in summer and often exceed precipitation rates, so the net penetration of rainfall is greater in winter than in summer (NPWS, 2000a). Mean annual rainfall in the NSW section of the Brigalow Belt South Bioregion varies from 550 mm in the west (in Gilgandra) to 823 mm on the east of the bioregion (at Murrurundi). On the north-south gradient, mean annual rainfall is 587 mm in Dubbo, 651 mm at Narrabri, and 659 mm on the Queensland border (at Texas).

Temperatures vary with altitude throughout the bioregion and have large daily variation (daily maximum can reach 45 °C in summer and stay above 40 °C for several days, and minimum temperatures can be as low as -9 °C). However, mean monthly temperatures (based on 6 weather stations in NSW) range from a maximum of 33 °C in January to a minimum of 3 °C in July (NPWS, 2000b).

Figure 4: Mitchell landscapes



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Mitchell landscapes (DECC 2008)

- Barradine - Coghill Channels and Floodplains
- Bugaldie Uplands
- Coghill Alluvial plains
- Cubbo Uplands

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
DECC
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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Prepared by: VH Date: 17/11/2014

4 Methodology

This section details terrestrial flora and fauna methods for database searches, literature review, and field based surveys. Aquatic ecological survey and assessment for the project are addressed in Appendix I of the EIS.

4.1 Literature review

A number of previous ecological impact assessments, flora and fauna surveys and research studies conducted in the East Pilliga area were reviewed (**Appendix A1**). The review focussed on surveys that have previously been undertaken within the study area. Additionally, all records of threatened species and communities and their associated habitat and / or distribution were reviewed. The review also included relevant previous surveys located outside of the study area.

Two databases were produced from this literature review to help inform the ecological impact assessment. The first database contains all reviewed previous survey effort within the study area. It has been tabulated and is spatially enabled. The spatial component consists of a Geographic Information System (GIS) geodatabase which provides both geographic locations for each survey and attribute information for the report name, survey type and site code relating to the written report. This spatial component cross-references to the tabulated component with each previous survey represented by a unique code. The tabulated component presents all reviewed previous survey effort in the study area, stratified by habitat type surveyed, as per the habitat types presented for this assessment (**Section 4.6.1**). The previous survey effort was calculated by the quantum of effort (number of traps / hours) and survey periods (days / nights) for each survey technique when sufficient information was available.

The second database contains a tabulated form of all threatened flora and fauna species recorded in the additional surveys. The database is stratified by habitat type, as detailed in each survey report and presents an overview of each habitat type that a particular threatened species has been recorded in.

In addition to previous surveys, a number research papers and reviews conducted in the Pilliga or in similar habitats in the region were reviewed as part of this report. These documents were used to gather species specific information for the Pilliga area, the significance of the Pilliga area for threatened species, and species' responses to disturbances, such as logging and fire. These additional reports have been referenced where referred to throughout this report.

4.2 Database review

A number of key datasets and mapping available to determine biodiversity values and constraints within the study area are listed below:

- BioNet Database (Atlas of NSW Wildlife) (OEH, 2016a)
- EPBC Act Protected Matters Search Tool (DotE, 2016a)
- NSW geology mapping (DMR, 2002)
- Watercourse mapping (LPI, 2013)
- Forest Types Mapping (State Forests of NSW, 2007)
- Namoi Catchment Management Authority vegetation mapping (ELA, 2013a)
- Namoi Catchment Management Authority wetland mapping (ELA, 2008)

High resolution aerial photographs and Light Detection and Ranging (LiDAR) data (producing high resolution surface contours, digital terrain models and canopy height models) of the study area were also used to investigate the extent of vegetation cover, landscape features and disturbance patterns in the area. LiDAR data is collected by air using laser light to densely sample the surface of the earth. The data records distances to the Earth from the aircraft, producing an accurate physical layout of terrain and landscape features.

Databases and maps were searched for state and federally listed threatened species, populations and Threatened Ecological Communities (TECs). Searches were conducted for a 100 km area around the centre point of the study area. It is noted that this large search area included regions of different topography, geology and climate, and included species that will not have suitable habitat in the study area. However, due to the relative paucity of records in the study area (and generally western areas of NSW), this large search area was considered necessary to effectively capture all potential target species.

4.3 Assessment of species, populations and communities likely to occur in the study area

The database and literature review was initially used to form the list of threatened and migratory species and ecological communities (that could potentially occur) in the likelihood table (**Appendix I**). This information was used to design the survey methods to target threatened species predicted to occur in the study area. The likelihood table was continually updated as additional data or knowledge became available, either through updated datasets, additional literature or survey results. The final version of the likelihood table was used to determine which threatened species were considered in the impact assessment (i.e. those considered 'potential', 'likely' or 'known' to occur in the study area).

Threatened and migratory species from key datasets and literature reviewed were combined to produce a list of threatened and migratory species that may occur within the study area. The likelihood of occurrence for threatened and migratory species, populations and communities in the study area was then made based on the location of database records, the presence of suitable habitat in the study area, and knowledge of the species' ecology. The likelihood of occurrence was subsequently modified as more information was obtained through field surveys or additional literature (**Appendix I**). The terms for likelihood of occurrence are defined below:

- "Yes" = the species was or has been observed in the study area.
- "Likely" = a medium to high probability that a species uses the study area.
- "Potential" = suitable habitat for a species occurs in the study area, but there is insufficient information to categorise the species as likely to occur, or unlikely to occur.
- "Unlikely" = a very low to low probability that a species uses the study area.
- "No" = habitat in the study area and in the vicinity is unsuitable for the species.

4.4 Field survey – general methods

Over 13,000 hours of survey effort has been undertaken in the study area since 2002, with the majority of the study area covered by one or more of these surveys. The following sections outline the general methods for these surveys, with more detail on techniques provided in the subsequent sections.

4.4.1 Objectives

The primary objectives of the field surveys (in accordance with state and federal survey requirements), were to determine:

- The abundance, distribution, ecology and habitat preferences of each threatened species, ecological communities and migratory species.
- The conservation value of each habitat present in the study area from a local and regional perspective.
- The importance of populations present from a local and regional perspective.

4.4.2 Survey team

Field surveys were conducted by teams comprising of two ecologists; a senior with a specialisation in the appropriate field of study, and a supporting field ecologist. Details of field staff and their qualifications are provided in **Appendix A2**.

4.4.3 Survey guidelines

Field surveys were designed to align with survey methods described in relevant guidelines and previous surveys.

Flora surveys were designed using the BioBanking Assessment Methodology (OEH, 2014a) and the draft *Threatened Biodiversity Survey and Assessment Guidelines* (Working Draft) (DEC, 2004). The federal governments guidelines for orchids (DotE, 2013c) was not available at the time of survey, however the field methods used are consistent with methods prescribed in these guidelines.

Fauna surveys were designed following survey methods and habitat stratification procedures of the *Draft Threatened Biodiversity Survey and Assessment Guidelines* (DEC, 2004), the *NSW Threatened species survey and assessment guidelines for amphibians* (DECC, 2009), relevant federal government survey guidelines as they became available (DEWHA, 2010a, 2010b, 2010c, DSEWPaC, 2011b, 2011c) and *Draft Referral guidelines for the nationally listed Brigalow Belt reptiles* (DSEWPaC, 2011a).

Survey effort was not applied in full accordance with the above guidelines due to the size of the study area (approximately 95,077 ha) because a detailed project design was not available at the time of survey. Surveys were designed to investigate the full suite of vegetation and habitat types present within the study area to determine the threatened species, populations and ecological communities that occur.

4.4.4 Weather conditions

Field surveys were undertaken between 2010 and 2014 over a number of seasons and varying weather conditions. Weather conditions (minimum and maximum temperatures, and total rainfall) across the entire survey period were compared to historical averages (2001 – 2013/14) and presented in **Plates 1 – 3**. The median was used for temporal rainfall statistics as the high variability of daily rainfall has less effect on the median than the arithmetic mean. Data was sourced from Narrabri Airport (station 054038) and gaps in data were filled by records from Narrabri Bowling Club (station 051420) or Narrabri West Post Office (station 053030) where possible (BOM, 2014).

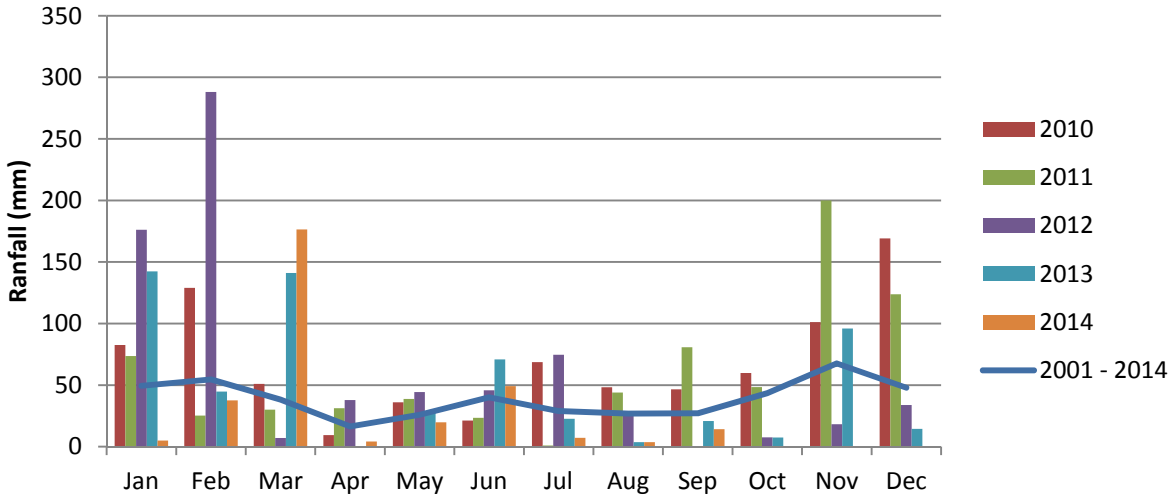


Plate 1: Rainfall over survey period

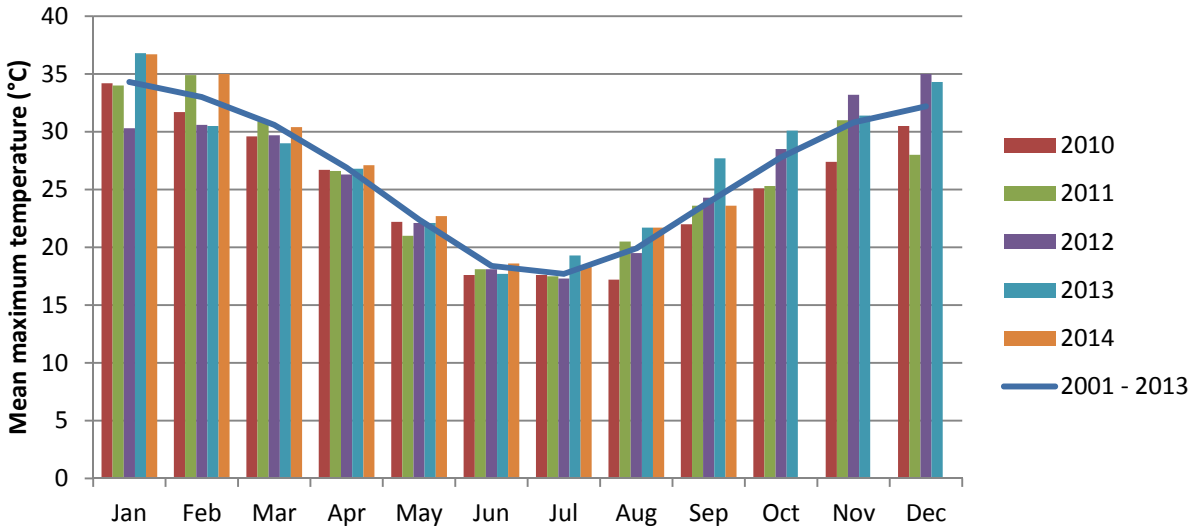


Plate 2: Mean maximum temperature over survey period

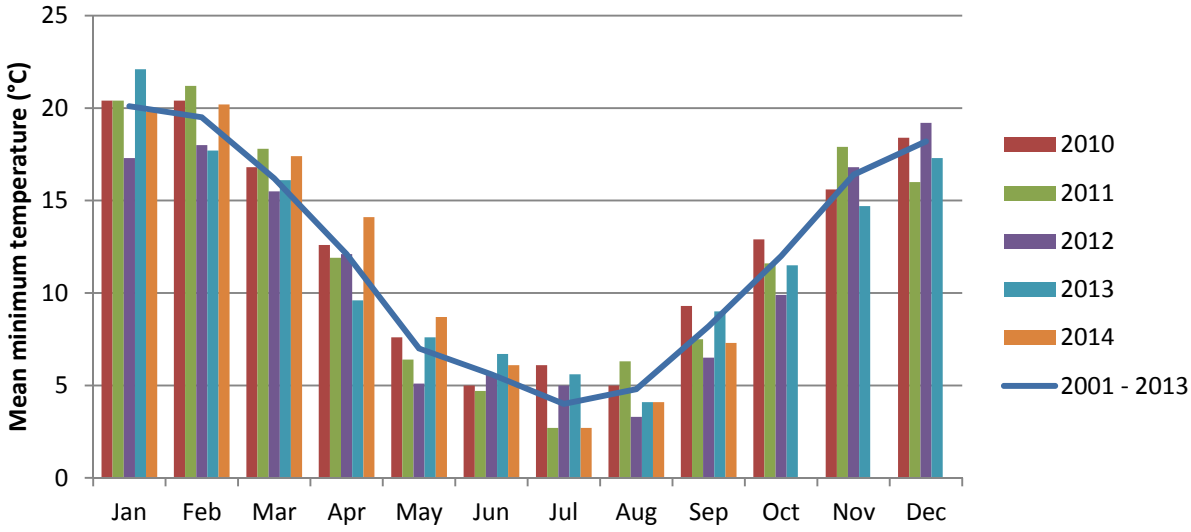


Plate 3: Mean minimum temperature over survey period

4.5 Flora survey

Flora surveys and vegetation mapping for the study area were conducted between 2010 and 2014, and included an initial desktop approach followed by extensive field validation and data collection (**Table 5**). A summary of the flora survey effort across the study area is provided in **Table 6** below and presented in **Figure 5**.

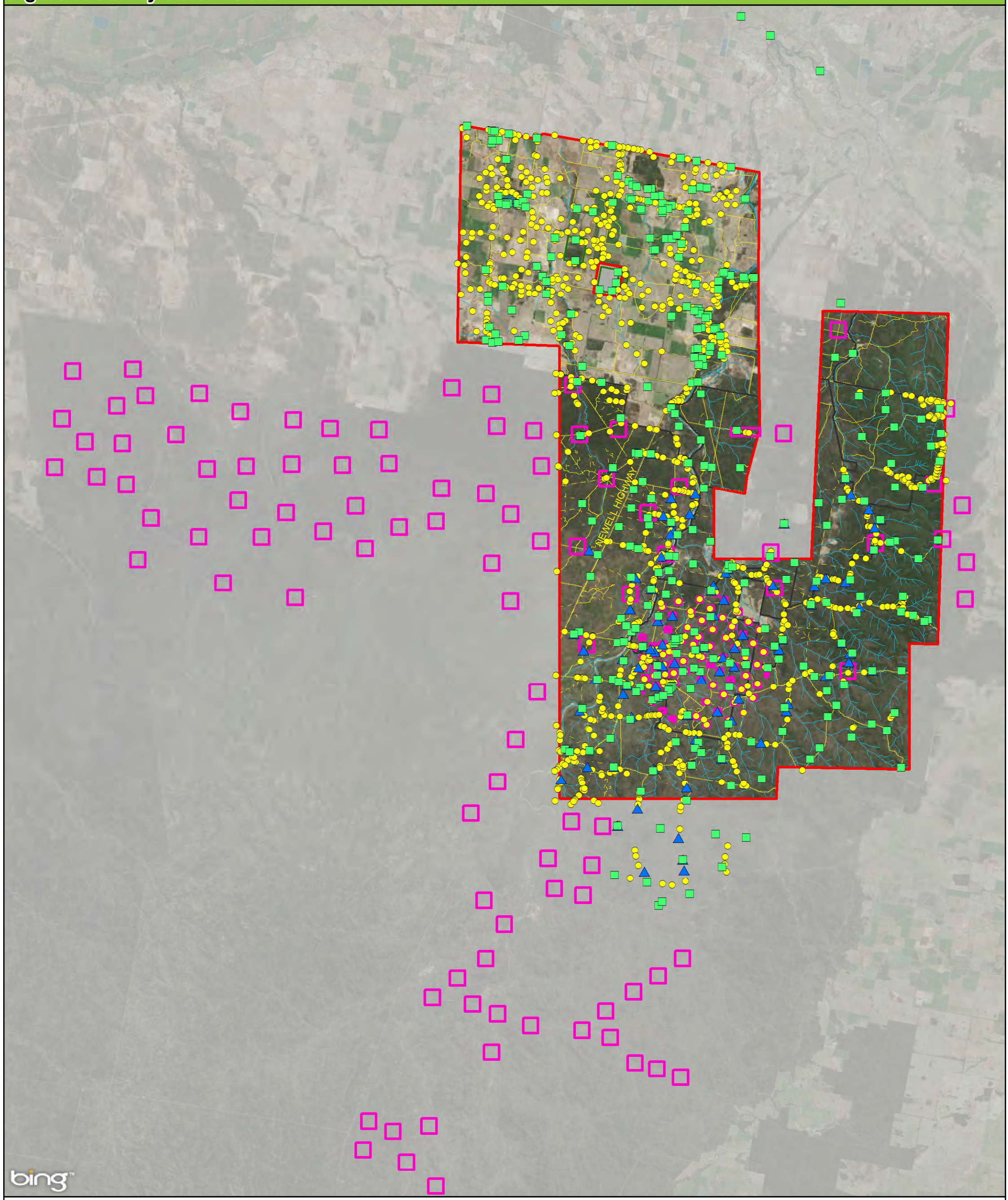
Table 5: Flora survey timing

	2010	2011				2012				2013										2014			
Survey type	November	January	February	April	October	February	March	September	October	March	April	May	June	July	August	September	October	November	December	January	February	March	September
Field reconnaissance																							
Biometric plots																							
Targeted threatened flora surveys																							
Habitat survey																							
Rehabilitation monitoring																							
Rapid flora plots																							

Table 6: ELA field effort for vegetation surveys

Survey method	Survey effort	Approximate field person hours
Flora survey (vegetation validation using BioBanking Assessment Methodology) including targeted Box Gum Woodland survey	327 biometric plots	680 hours
Threatened flora survey (two person transects in 2011 and 2012)	523 km at 10 m width (523 ha)	1,300 hours
Threatened flora survey (population distribution and abundance mapping in 2014)	23 transects at 100 m long and 10 m wide (2.3 ha) and 84 point surveys	100 hours
Vegetation and habitat mapping	Over 1,300 rapid vegetation validation plots	216 hours

Figure 5: Survey effort – flora



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests
- Biometric Plots (ELA)
- Threatened flora survey sites
- Rapid vegetation validation points
- Accuracy assessment points

0 1.25 2.5 5
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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Prepared by: VH Date: 17/11/2014

4.5.1 Stratification

A detailed flora survey implementing the BioBanking Assessment Methodology (OEH, 2014a) was conducted at sampling locations stratified across the entire study area, in lieu of a detailed project design. The spatial distribution of survey effort was not aligned with major facilities as infrastructure locations were not known at the time of the field surveys. Stratification of such a large study area was necessary to ensure that all vegetation types and condition states were systematically sampled. However, some areas in the study area were inaccessible due to restricted access to private land.

Vegetation mapping available at the beginning of the surveys (in 2010) was limited to the regional vegetation community (RVC) mapping of Namoi Catchment Management Authority (CMA) boundary (ELA, 2013a) and the Forest Type mapping of State Forests (State Forests of NSW, 2007). As the Namoi catchment management authority regional vegetation class mapping layer covered the entire study area and regional vegetation classes are easily attributable to Biometric Vegetation Types – the units required to be reported on in NSW, this mapping was used as the original basis for survey stratification.

It's important to note that the regional vegetation class mapping was utilised for stratification purposes only. Fine scale Plant Community Type mapping was specifically developed for the entire study area as part of this project (**Section 4.5.5**). Plant community types, along with Biometric Vegetation Types were used to provide detailed descriptions of vegetation types in the study area (**Appendix D**).

4.5.2 Flora field survey

Flora surveys consisted of biometric plot surveys, threatened flora searches, and vegetation type and condition mapping (rapid vegetation validation plots), the latter of which was used to develop a new vegetation map for the study area (**Section 4.5.5**).

Detailed vegetation surveys were completed by ELA ecologists between 2010 and 2014. Vegetation surveys involved validating the mapped vegetation communities, delineating the boundaries of mapped vegetation and assessing condition. A total of 327 biometric plots following the BioBanking Assessment Methodology and over 1,300 rapid vegetation validation plots were undertaken in the study area (**Appendix A3**). The layout of the biometric plots is provided in **Plate 4**.

Rapid vegetation validation plots involved recording dominant species in each structural layer and site characteristics including soil type, soil colour, fire history and fauna habitat features.

Biometric plots involved a nested 0.04 ha (20 m x 20 m) quadrat to record the presence of visible vascular flora species, along with presence-absence (2011) or cover-abundance (2012 onwards) for each species using a modified Braun-Blanquet scale. Vegetation structure and fauna habitat features were determined over a nested 0.1 ha (50 m x 20 m) quadrat; measures included number of hollow-bearing trees and length of fallen dead timber greater than 10 cm diameter. Within the 0.1 ha quadrat, projected foliage cover of each strata level and exotic flora was assessed along a 50 m line transect.

The physical characteristics (such as aspect, slope and disturbance) at the biometric plots were noted and photos were taken of the quadrat along the 50 m line transect. Species were identified to the lowest taxonomic level possible, following the Flora of NSW (Harden, 1992, 1993, 2002, 2000) and NSW Plantnet (Royal Botanic Gardens and Domain Trust, 2016). Biometric plot locations are shown in **Figure 5**.

Wherever possible, biometric plots were located away from major tracks to reduce bias from edge effects and local disturbances. Biometric plots were located in areas of homogenous vegetation representative of the vegetation community and away from vegetation boundaries. Biometric plots were oriented in the

direction which minimised changes in environmental gradients (e.g. biometric plots along riparian areas were oriented upstream/downstream).

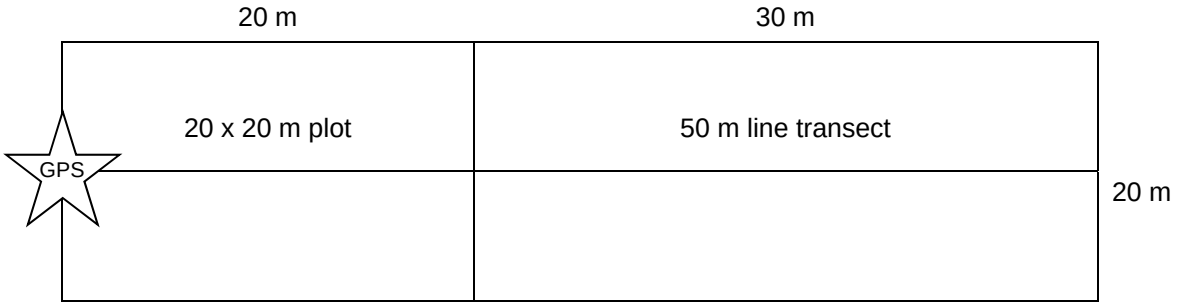


Plate 4: Biometric plot layout

4.5.3 Targeted threatened flora survey

Targeted surveys for threatened flora considered 'potential' or 'likely' to occur were undertaken across the study area between spring 2011 to autumn 2014. Additionally, threatened flora were recorded when observed opportunistically during biometric plot surveys. The initial literature and data review identified 14 species with the potential to occur in the study area (**Table 7**).

2011 surveys

In October 2011, targeted threatened flora surveys were undertaken within a 6,450 ha area (wholly contained with the study area for this assessment) with the purpose of locating threatened plants within a previously proposed development footprint (**Appendix F4**). A total of 79 sites (10 ha each) and an associated network of gathering systems were traversed over a total length of 447 km and a search area of 446 ha with counts for all threatened flora species observed recorded.

The data obtained from the searches was used to model and estimate the threatened species population sizes in the study area.

2012 surveys

In September and October 2012, a broader targeted threatened species survey of the north-east Pilliga (incorporating the study area) was undertaken over a 229,857 ha area (**Appendix F4**). Sites for targeted searches were selected based on the specific habitat requirements for each threatened species. A total of 79 sites were sampled in the 2012 survey. Within each site between one and five strip-quadrats were surveyed (306 in total), with each quadrat being 250 m in length and covering a 10 m width. A total length of 153 km was traversed and a search area of 76.5 ha covered. The surveys were conducted to provide detailed information on population size, distribution and habitat requirements for threatened flora populations within the north-east Pilliga. The data obtained from the searches were used to model and estimate threatened species population sizes in the study area through a stratified survey approach based on areas of suitable habitat (**Appendix F4**).

2014 surveys

Detailed population distribution and abundance mapping was undertaken for *Bertya opponens* (Coolabah Bertya) and *Pomaderris queenslandica* (Scant Pomaderris) in the study area in 2014. The number of individuals of *B. opponens* and *P. queenslandica* within the study area was estimated by defining the distribution of the species within the study area and by determining the density of the species across its distribution. The approximate extent of each species within the study area was determined by locating the limits of the population along existing tracks and by surveying suitable habitat around existing records. Supplementary surveys in areas of suitable habitat were also undertaken to identify new populations of

each species. Once the approximate limits of the distribution of the species within the study area was determined, traverses of areas between known records were conducted to determine if each species formed a single continuous population within the study area, or if discrete populations of the species were present, separated by large areas where the species was absent.

The approximate density of *B. opponens* within its distribution in the study area was then sampled along 23 strip-quadrats of 10 m x 100 m (total area 1,000 m^2). This involved two ecologist walking the transects (each covering an area of 5 m x 100 m) and counting the number of individuals present. These transects were located at regular intervals from a random starting location and distributed across the species extent within the study area. From these transects a mean density for the species across its distribution was determined and an estimate of the total population size was made.

The approximate density of *P. queenslandica* was determined by surveying suitable habitat around existing records of the species and counting the number of individuals of the species encountered within each population. Where large populations of the species were located, the total number of individuals within the population was determined by counting the number of individuals in smaller sub populations (where accurate counts could be performed) or by measuring the density of individuals within a small representative portion of the population, and multiplying this density across the entire area of the population or subpopulation. The density within representative portions of large populations was measured by counting the number of individuals within a fixed area, along transects through the population, or by measuring distances between plants within a population, or by a combination of these methods.

Populations of these two species were mapped as they occurred in defined locations, compared with other species in the study area which occurred across broad areas and vegetation types and could be reliably modelled (**Appendix F4**).

Table 7: Threatened flora species targeted during field survey

Scientific name	Common name	Status	
		TSC Act	EPBC Act
Bertya opponens	Coolabah Bertya	V	V
Cyperus conicus	-	E1	~
Diuris tricolor	Pine Donkey Orchid / Painted Diuris	V	Delisted
Homopholis belsonii	Belson's Panic	E1	V
Lepidium aschersonii	Spiny Peppercress	V	V
Lepidium monoplocoides	Winged Peppercress	E1	E
Monotaxis macrophylla	Large-leafed Monotaxis	E1	~
Myriophyllum implicatum	-	CE	~
Philotheca ericifolia	-	Delisted	V
Polygala linariifolia	Native Milkwort	E1	~
Pomaderris queenslandica	Scant Pomaderris	E1	~
Pterostylis cobarensis	A Greenhood Orchid	V	Delisted
Commersonia procumbens (syn. *Rulingia procumbens* and	-	V	V

Scientific name	Common name	Status	
		TSC Act	EPBC Act
Androclava procumbens as listed in EPBC Act)			
Tylophora linearis	-	V	E

V- vulnerable; E1- endangered under the TSC Act; E- endangered under the EPBC Act and TSC Act; Delisted – no longer listed under relevant legislation (TSC or EPBC Act)

Population estimations

The method used to estimate the number of individuals of each threatened plant species in the study area was determined by whether habitat modelling using Plant Community Types would provide an accurate estimation of population size. Those species with a very patchy or localised distribution that were clearly not consistently associated with occurrences of a particular Plant Community Type/s were not suitable for estimating population numbers based on habitat modelling of Plant Community Types (such as *Bertya opponens* and *Pomaderris queenslandica*).

Population estimations for *Bertya opponens* and *Pomaderris queenslandica* involved:

- Field counts and/or estimates of the number of individuals within mapped population/sub-populations derived from subsamples.
- Supplementary extrapolation to account for sub-populations that are assumed to be present but have not yet been observed. Supplementary extrapolation was based on the total number of observed individuals averaged out across all plant communities where they were known to occur

Habitat modelling based on Plant Community Types was used for those species with a less restrictive distribution and which occur with greater consistency in specific vegetation types. Modelled population estimates were calculated for *Diuris tricolor*, *Polygala linariifolia*, *Pterostylis cobarensis*, *Commersonia procumbens* and *Tylophora linearis* (**Appendix F4**).

Population modelling

Plant density and abundance estimations of threatened plant species were made by combining the 2011 and 2012 targeted survey results and incorporating the data into a population model. An estimate of the area of each vegetation type across the entire study area was required in order to apply the model to habitat present in the study area to estimate of plant abundance with 95% confidence intervals. Vegetation communities mapped at a regional scale (ELA, 2013a) were delineated into ten Biometric Vegetation Types. The total area of each Biometric Vegetation Type within the study area was calculated in a Geographic Information System.

A total of 751 threatened flora quadrats were included in the model dataset. Sampling intensity was at about 0.08% which is low but higher levels are considered difficult to achieve over such a large area. The most common vegetation type, *White Cypress Pine - Bulloak - ironbark woodland of the Pilliga area of the Brigalow Belt South Bioregion*, was sampled the most frequently, and survey effort was generally related to area of vegetation types.

The number of individual plants from vegetation communities was summarised by summing the counts of each threatened plant species by vegetation type. The proportion of quadrats occupied by a species in each vegetation community for both years combined was calculated by assigning the species as present

or absent from a quadrat (using 0 for absent and 1 for present), and then summing the number of quadrats with the species present and presenting as a proportion of total number of quadrats.

Plant densities per quadrat were calculated separately for each species. When sample sizes were low, data were pooled across all vegetation types. Additional distribution models were applied to vegetation types where sample sizes were larger than 10. Finally, plant densities were converted into plants per hectare where plants were present..

The output of the regional modelling data was then applied to the study area and subject site to develop rigorous estimates of threatened species populations.

4.5.4 Targeted Threatened Ecological Community survey and assessment

Data collected in the biometric plots was compared against the final determination and/or corresponding listing advice for each threatened ecological community considered likely to occur in the study area. This was undertaken to confirm that the vegetation present was consistent with legislative descriptions, either under the EPBC Act or TSC Act.

For the Weeping Myall community, restricted land access prevented biometric plots from being completed. Identification of the community was undertaken by visual observation where possible and by through Aerial Photographic Interpretation.

A more detailed assessment of the presence of White Box Yellow Box Blakely's Red Gum Woodland / White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland within the study area was undertaken as detailed below. This ecological community is listed as an endangered ecological community under the TSC Act and as a critically endangered ecological community under the EPBC Act.

Vegetation surveys

Vegetation surveys were undertaken at 16 subject plots (biometric plots specifically located in vegetation that needed clarification of its status) following methods described in **Section 4.5.2**.

Soil classification

Soil texture was measured in the field at eight of the sixteen subject plots. At each site a sample of soil was collected with particles >2 mm (gravel, roots and other organic material) removed. The sample was then moistened and kneaded into a bolus. The bolus was continually worked (adding more soil and water as necessary) for approximately 1-2 minutes until there was no apparent change in plasticity.

A ribbon was then extruded by shearing the sample between thumb and forefinger. The length of the ribbon produced was then measured. The combination of the behaviour of the moist bolus and the ribbon length was then used to give an indication of the field texture grade (McDonald, Isbell, Speight, Walker, & Hopkins, 1998).

Soil colour of each sample was also measured using the Munsell Colour System. A dry soil sample was compared with pages from the Munsell colour book that closely corresponded to the colour of the sample. The closest match was then determined. The soil sample was then moistened and the closest match for the wet sample was determined.

Data analysis

To determine whether the listed community occurs within the study area, the data from 16 subject plots located in vegetation dominated or co-dominated by *Eucalyptus blakelyi* (Blakely's Red Gum) was analysed and compared to the NSW Scientific Committee Final Determination under the TSC Act (NSW

Scientific Committee, 2002) and the listing advice for the community under the EPBC Act (Threatened Species Scientific Committee, 2006).

4.5.5 Vegetation mapping

A vegetation mapping project was conducted to map the vegetation communities occurring within the study area to help inform planning/design decisions for the project. Derived native grassland, cropped and pasture improved land, as well as clearings, roads and trails, and dams were also delineated in the mapping process to help inform infrastructure locations to minimise impacts on biodiversity values.

Vegetation mapping was undertaken using a 'heads-up' on screen digitising approach (utilising high quality aerial photography, Light Detection and Ranging datasets including a Canopy Height Model, contours and drainage) using a Geographic Information System running the software ArcGIS 10.2. The on screen digitising approach and previous vegetation mapping (State Forests of NSW, 2007) were used to compliment field surveys, including over 1,300 rapid vegetation validation plots and 327 biometric plots to form the basis for vegetation community classification.

Vegetation communities were attributed in accordance with the Plant Community Types of the NSW Vegetation Classification Assessment (Benson, Richards, Waller, & Allen, 2010) as they provide the best representation of the vegetation in the study area and are at a useful scale for delineating fauna habitat. The project also mapped Endangered Ecological Communities, classified land use and attributed each Plant Community Type to a Biometric Vegetation Type for use in the assessment and quantifications of suitable offsets for the project

Rapid vegetation validation plots are less comprehensive than biometric plots, however they allow for rapid identification of Plant Community Types and identify boundaries between vegetation communities within the landscape. The data outlined in **Table 8** was recorded at each rapid vegetation validation plot.

Table 8: Data recorded within rapid vegetation validation plots

Category	Description
Dominant canopy	Dominant canopy species (max. 3 species recorded order in dominance)
Dominant midstorey	Dominant midstorey (max. 3 species recorded in order of dominance)
Dominant ground	Either grass, low shrubs (<1m), shrubs (>1m) or a combination
Structure	Structure according to (Specht & Specht, 2002) – e.g. shrubland, low open woodland, woodland or forest. Prefixed with grassy, low shrubby or mid-shrubby depending on structural elements.
Fire History	Three categories – recent (<3 yrs), not recent (3-10 years) and old (>10 years). This category was determined based on visual assessment of fire damage, age of regrowth and presence of fire-sensitive species.
Soil Type	Brief description of soil type – e.g. brown alluvial sand, yellow sand or red sand
Comments	Additional comments pertinent to the location, e.g. presence of old growth trees, threatened species, weeds etc.

Biometric plots were surveyed across the study area. Data recorded at these sites generally included all vascular plant species present, cover abundance of each species in accordance with a modified six-point Braun-Blanquet scale, cover abundance of each structural layer (canopy, midstorey, groundcover), weed abundance, hollow presence and size classification length of fallen logs and a soil classification (colour and texture)

The rapid vegetation validation points were used as an initial guide to identifying vegetation community boundaries. Aerial Photograph Interpretation was then used in combination with the Canopy Height Model to identify distinct patterns in the imagery representing potential vegetation community boundaries. Vegetation community boundaries (polygons) were then digitised at a 1:10,000 scale. Supplementary datasets such as contours, drainage layers and soil classification were used to help inform the Aerial Photograph Interpretation to delineate boundaries between vegetation communities.

Forest Types Mapping (State Forests of NSW, 2007) and the Namoi Catchment Management Area Regional Vegetation Class Mapping (ELA, 2013a) were used to guide and/or validate the allocation and extent of each Plant Community Type mapped. OEH land use mapping (OEH, 2013c) was used to delineate areas of cropping and improved pasture with Aerial Photograph Interpretation undertaken to identify additional areas not mapped by OEH.

Each polygon was assigned a Plant Community Type based on expert opinion on floristic composition, vegetation structure, landscape position and soil type. Vegetation mapping was generally undertaken at a 1:10,000 scale, however areas that were not accessed during vegetation surveys were often inspected carefully at a finer scale. Roads, trails, dams, existing infrastructure and other clearings were also delineated.

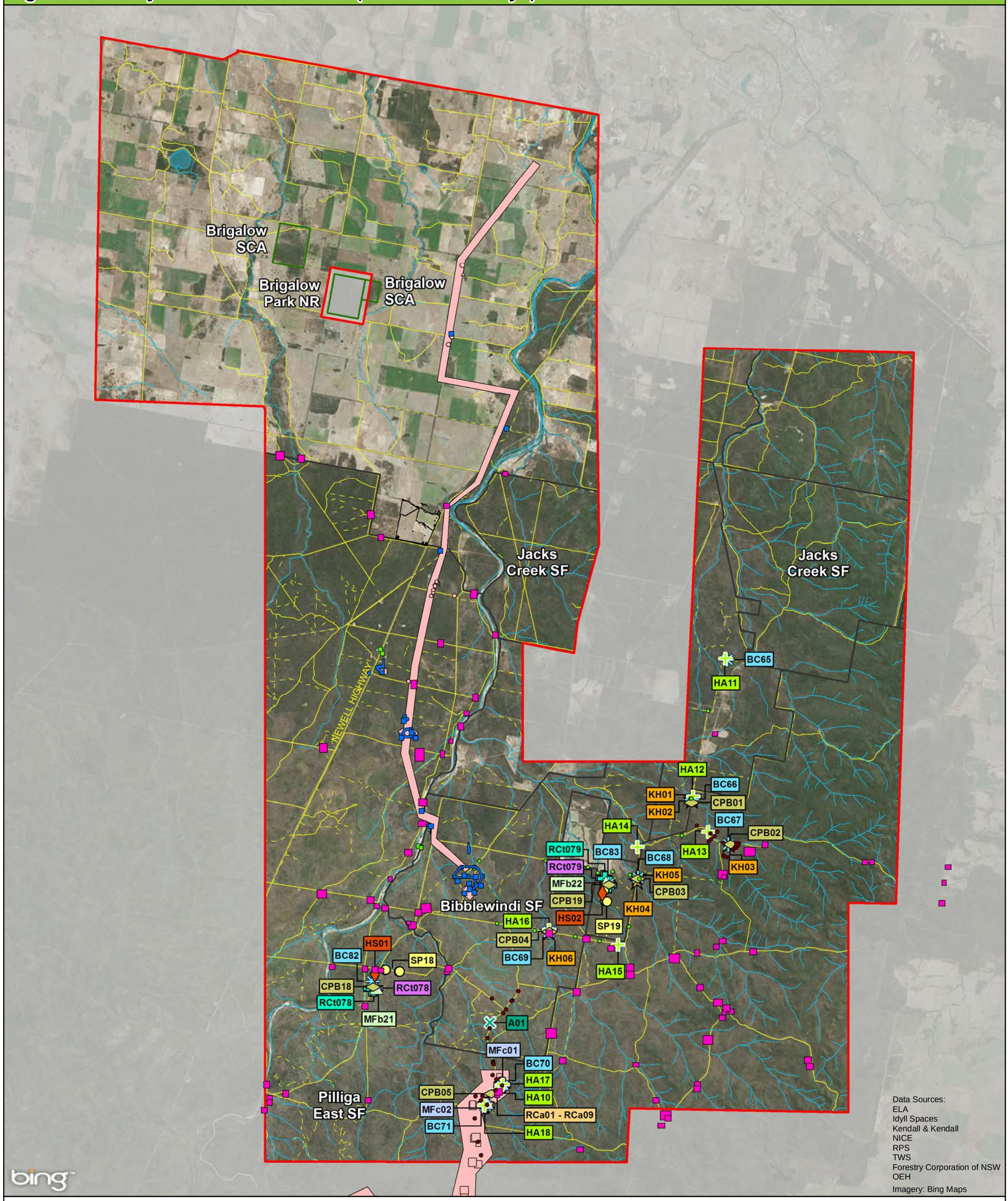
Vegetation mapping validation occurred continuously throughout the field surveys with polygon boundaries and Plant Community Types updated where necessary.

4.5.6 Previous flora surveys

Previous flora surveys conducted by various consultants were reviewed as per **Section 4.1** and **Section 4.2**. A complete list of these surveys is presented in **Appendix A1** and presented in **Figure 6**. Previous flora survey effort reviewed within the study area dates back to 2005 and incorporated a combination of survey methods for site specific impact assessments and general ecology based surveys. These methods included targeted species searches, random meander transects, full floristic plots, rapid assessment plots and road based searches.

Site specific impact assessments conducted by Idyll Spaces Environmental Consultants from 2005 – 2010 incorporated random meander transects and full floristic survey plots. Landmark Ecological Services and the Wilderness Society (TWS) conducted road-based surveys to identify potential endangered ecological communities and habitat for threatened species across the study area, followed by intensive ground based searches where necessary in 2011. Further site specific impact assessments were conducted by RPS from 2012 – 2013 at various sites within the study area which included random meander transects and full floristic and rapid assessment plots. Alison Hunt & Associates undertook full floristic plots, rapid assessments and random meander transect in 2010. The results from these surveys, as detailed in their respective reports, were used where applicable to inform this assessment.

Figure 6: Survey effort – flora & fauna (additional surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Additional survey by company

- RPS (2012)
- RPS (2013)
- Idyll Spaces (2005 - 2010)
- Kendall & Kendall (2005 -2010)
- NICE & TWS (2012)

Additional survey by method (ELA)

- Anabat (A)
- Bird census (BC)
- Call playback (CPB)
- Harp and Anabat (HA)
- Harp and songmeter (HS)
- Koala habitat assessment (KH)
- Multi fauna trapping - design 2 (MFb)
- Multi fauna trapping - design 3 (MFc)
- Remote camera - arboreal / universal (RCa)
- Remote camera - fish (RCt)
- Remote camera - universal (RCt)
- Spotlighting (SP)

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

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4.6 Fauna survey

Eight fauna surveys were undertaken by ELA ecologists between 2011 and 2014, specifically for this assessment (**Table 9**). A regional Koala survey was also undertaken specifically for this assessment by both Niche Environment and Heritage and ELA ecologists. Additional surveys undertaken in the study area both by ELA (for other site specific activities) and other scientists have been included in this report and discussed in **Section 4.8**.

Initial reconnaissance of the study area was undertaken by ELA ecologists (30 November and 1 December 2010) followed by detailed fauna surveys (11 – 20 January 2011). Field work was proposed to commence following initial reconnaissance in 2010, however had to be postponed due to heavy rain and widespread flooding in the region.

From this initial survey, a series of targeted fauna surveys were undertaken. These involved a targeted *Anthochaera phrygia* (Regent Honeyeater) survey (21 – 26 October 2012), targeted *Pseudomys pilligaensis* (Pilliga Mouse) and *Dasyurus maculatus* (Spotted-tailed Quoll) surveys (5 – 11 May 2013 & 26 May – 1 June 2013), a targeted winter migratory bird survey (21 – 26 July 2013) and a targeted amphibian and reptile survey (7 – 11 April 2014). Two subsequent detailed fauna surveys were undertaken targeting habitats within the Pilliga (13 – 18 October 2013 and 3 – 8 November 2013) and north of the Pilliga (8 – 18 December 2013 and 12 – 25 January 2014). The regional Koala survey was undertaken between 28 April and 8 May 2014.

Table 9: Fauna survey timing

Survey number	Survey name	2010	2011	2012	2013						2014		
		December	January	October	May	June	July	October	November	December	January	April	May
1	Initial reconnaissance												
2	Detailed fauna survey												
3	Regent Honeyeater targeted survey												
4	Pilliga Mouse targeted survey												
5	Spotted-tailed Quoll targeted survey												
6	Winter migratory bird targeted survey												
7	Fauna survey – forest												
8	Fauna survey – northern												
9	Amphibian and reptile targeted survey												
10	Regional Koala survey												

A range of fauna survey techniques were used for these surveys and specifics detailing each method are presented in the following sections. The design and methods for targeted surveys are explained in more detail in **Section 4.7**.

4.6.1 Stratification

Site locations were selected through a desktop stratification process in a GIS. Each survey's study area was stratified by habitat type initially using Namoi Catchment Management Authority vegetation mapping (ELA, 2013a). For later surveys (2013 onwards), sites were stratified by Plant Community Types using vegetation mapping produced specifically for this assessment. Plant community types were then assigned fauna habitat types and sites were stratified by either Plant Community Type or habitat type, depending on the habitat features required for each target species. Assigned habitat types per Plant Community Type are presented in **Table 10**.

Site locations were spatially spread throughout the landscape to cover the full breadth of the study area. The spatial distribution of survey effort was not aligned with major facilities as infrastructure locations were not known at the time of the field surveys. Additionally, some areas in the study area were inaccessible due to restricted access to private land.

Once in the field, potential site locations were refined by selecting specific habitat features required by target species. For example, flyways and drainage lines for harp trapping microbats and high fauna activity pathways for remote cameras and hair tubes were targeted.

Table 10: Habitat types

Habitat type	Plant Community Type ID	Corresponding Plant Community Type
Closed Forest	35	Brigalow - Belah open forest / woodland on alluvial often gilgaied clay
	55	Belah woodland on alluvial plains and low rises
Grassland	Many	Derived native grassland
Grassy Woodland	27	Weeping Myall open woodland
	202	Fuzzy Box Woodland on alluvial brown loam soils
	402	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats
	418	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland
Heath	141	Broombush - wattle very tall shrubland
	425	Spur-wing Wattle heath on sandstone substrates
Heathy Woodland	379	Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland
	405	White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland
	406	White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest
	408	Dirty Gum (Baradine Gum) - Black Cypress Pine - White Bloodwood shrubby woodland

Habitat type	Plant Community Type ID	Corresponding Plant Community Type
	40X	White Bloodwood – Dirty Gum – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand
Riparian Woodland	78	River Red Gum riparian tall woodland / open forest wetland
	399	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland)
	401	Rough-barked Apple - red gum - cypress pine woodland on sandy flats
	428	Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand
Shrub Grass Woodland	88	Pilliga Box - White Cypress Pine - Buloke shrubby woodland
	397	Poplar Box - White Cypress Pine shrub grass tall woodland
	398	Narrow-leaved Ironbark - White Cypress Pine - Buloke tall open forest on lower slopes and flats
Shrubby Woodland	256	Green Mallee tall mallee woodland rises
	404	Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil

4.6.2 Survey design

Following the database and literature review, the survey methods were designed to sample both a broad range of taxa, and to specifically target those threatened fauna that were considered 'potential', 'likely' or 'known' to occur in the study area (**Table 11**). Details for each survey method are presented in the following sections.

Table 11: Fauna targeted by each survey method

Survey method	Fauna groups targeted	Species targeted
Arboreal trapping and sampling		
Elliott trapping (tree-mounted)	Arboreal mammals	*Petaurus norfolcensis* (Squirrel Glider), *Cercartetus nanus* (Eastern Pygmy Possum)
Hair sampling (tree-mounted) – universal bait	Arboreal mammals	Squirrel Glider, Eastern Pygmy Possum
Terrestrial trapping and sampling		
Cage trapping	Medium terrestrial mammals	*Aepyprymnus rufescens* (Rufous Bettong), Spotted-tailed Quoll
Elliott trapping	Small terrestrial mammals	Pilliga Mouse
Funnel trapping	Reptiles	*Hoplocephalus bitorquatus* (Pale-headed Snake)
Hair sampling – fish bait	Carnivorous terrestrial mammals	Spotted-tailed Quoll
Hair sampling – universal bait	Terrestrial mammals	*Macropus dorsalis* (Black-striped Wallaby), Pilliga Mouse

Survey method	Fauna groups targeted	Species targeted
Pitfall trapping	Mammals, reptiles	Pilliga Mouse, Eastern Pygmy Possum
Sand plot	Mammals, reptiles	-
Diurnal searches		
Diurnal bird census	Birds	Regent Honeyeater, *Lathamus discolor* (Swift Parrot), *Polytelis swainsonii* (Superb Parrot), *Calyptorhynchus lathami* (Glossy Black-cockatoo), *Glossopsitta pusilla* (Little Lorikeet), *Neophema pulchella* (Turquoise Parrot), *Circus assimilis* (Spotted Harrier), *Falco subniger* (Black Falcon) (once listed), *Hieraaetus morphnoides* (Little Eagle), *Lophoictinia isura* (Square-tailed Kite), *Chthonicola sagittata* (Speckled Warbler), *Daphoenositta chrysoptera* (Varied Sittella), *Melanodryas cucullata cucullata* (Hooded Robin (south-eastern form)), *Pomatostomus temporalis temporalis* (Grey-crowned Babbler (eastern subspecies)), *Stagonopleura guttata* (Diamond Firetail), *Grantiella picta* (Painted Honeyeater), *Apus pacificus* (Fork-tailed Swift), *Ardea modesta* (Great Egret), *Hirundapus caudacutus* (White-throated Needletail), *Merops ornatus* (Rainbow Bee-eater), *Myiagra cyanoleuca* (Satin Flycatcher), *Artamus cyanopterus cyanopterus* (Dusky Woodswallow)
Diurnal reptile search	Reptiles	*Anomalopus mackayi* (Five-clawed Worm-skink)
Microbat surveys		
Echolocation recording (Song Meter and Anabat)	Microbats	*Chalinolobus dwyeri* (Large-eared Pied Bat), *Chalinolobus picatus* (Little Pied Bat), *Saccolaimus flaviventris* (Yellow-bellied Sheathtail-bat), *Miniopterus schreibersii oceanensis* (Eastern Bentwing Bat), *Vespadelus troughtoni* (Eastern Cave Bat)
Harp trapping	Microbats	*Nyctophilus corbeni* (South-eastern Long-eared Bat), Little Pied Bat
Nocturnal surveys		
Call playback	Nocturnal birds and mammals	*Ninox connivens* (Barking Owl), *Tyto novaehollandiae* (Masked Owl), *Burhinus grallarius* (Bush-stone Curlew), Koala, Squirrel Glider
Nocturnal amphibian search	Amphibians	*Crinia Sloanei* (Sloan's Froglet)
Spotlighting	Nocturnal mammals, birds, reptiles	Pale-headed Snake and species targeted in call playback
Stream search	Nocturnal mammals, birds, reptiles	Pale-headed Snake and species targeted in call playback
Remote recording surveys		
Diurnal call recording (Song Meter)	Birds	Regent Honeyeater

Survey method	Fauna groups targeted	Species targeted
Remote camera – fish / chicken bait	Carnivorous terrestrial mammals	Spotted-tailed Quoll
Remote camera – universal bait	Terrestrial mammals	Black-striped Wallaby
Habitat surveys		
Koala habitat assessment	Koala	Koala
Spot assessment technique (SAT) survey	Koala	Koala
Opportunistic surveys		
Scat collection	Carnivorous predator species, prey species	-
Opportunistic observations	All fauna	-

4.6.3 Arboreal trapping and sampling

Elliott trapping

For the initial survey effort (2011), B type Elliott traps (for medium sized mammals) were secured to a wooden platform that was screwed at approximately 90 degrees to a tree 2 m above the ground. Traps were set in trees (with hollows when possible) proximate to every fourth Elliott trap along the terrestrial Elliott transects (**Section 4.6.4**). All traps were baited with a mixture of rolled oats, bird seed, peanut butter, honey and vanilla essence; and leaf litter was placed in Elliotts for bedding. A honey and water mixture (approximately 1:5 ratio) was sprayed on the tree trunks supporting the traps to lure arboreal fauna to the trap. Traps were set from four to eight consecutive nights.

For the subsequent survey effort (2013 – 2014), A type Elliott traps (for small sized mammals) and B type Elliott traps were deployed along two parallel lines of six traps alternating between A and B type Elliotts. Traps were mounted to trees in a similar fashion to the initial survey (2011), and covered with a bag (calico, hessian or pillow slip) for added protection from the weather. Quilt batting was placed inside the trap for bedding along with a bait of rolled oats, peanut butter, honey and truffle oil (3:3:1:trace). A honey and water solution (approximately 1:3 ratio) was sprayed above and below each trap to lure arboreal fauna to the trap. Traps were set for four consecutive nights.

All traps were checked daily by two ecologists within the first three hours of sunlight. All fauna caught were identified to species level and released at the point of capture.

Locations of survey sites are presented in **Figure 7** with all Elliott trapping undertaken at multi fauna trapping sites. The initial survey effort is presented as design 1 and the subsequent survey effort is presented as design 2. Arboreal Elliott trapping survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 12** and a photo of arboreal Elliott trapping is provided in **Plate 5**.

Table 12: Arboreal Elliott survey effort

Habitat	Trap nights per Elliott trap size							
	ELA[1]		ELA[2]		Other[3]		Total	
	A	B	A	B	A	B	A	B
Closed Forest	48	48	-	-	-	24	48	72
Grassy Woodland	72	72	-	-	-	-	72	72
Heathy Woodland	72	112	-	-	-	120	72	232
Riparian Woodland	96	226	-	-	-	40	136	266
Shrub Grass Woodland	120	230	96	96	-	112	216	438
Shrubby Woodland	72	72	-	-	-	-	72	72

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants including RPS and Kendall & Kendall (excluding survey effort from (Kendall and Kendall Ecological Consultants, 2005, 2006) reports as Elliott trapping effort was not distinguished as arboreal or terrestrial). Note A = A sized Elliott trap for small mammals; B = B sized Elliott trap for medium sized mammals.

Hair sampling

For the initial survey effort (2011) large (70 mm x 110 mm) PVC pipe hair tubes were mounted in trees with nails or packing tape proximate (within 5 m) to the terrestrial hair tube transect (**Section 4.6.4**), with the exception of one transect which was placed independent of the terrestrial hair tubes, due to the lack of trees in the heath habitat type. Double sided sticky tape was placed inside the entrance to each tube to collect hair samples. A bait mixture of rolled oats, bird seed, peanut butter, honey and vanilla essence was placed in an inaccessible bait chamber to lure arboreal fauna into the tubes. Hair tubes were deployed in the field for eight nights.

For the subsequent survey effort (2013 – 2014), small (50 mm) and large (70 mm x 110 mm) hair tubes were set up in pairs proximate (within 5 m) to the terrestrial hair tube pairs (**Section 4.6.4**). The hair tubes were mounted using cable ties in trees or in tall shrubs in the absence of trees. Double sided sticky tape was placed inside the entrance to each tube to collect hair samples. A mixture of rolled oats, peanut butter, honey and truffle oil (3:3:1:trace) was placed in an inaccessible bait chamber. Hair tubes were deployed the field for between eight and 21 days.

Hair funnels were mounted in trees proximate (within 5 m radius) to the terrestrial hair funnel stations (**Section 4.6.4**) using screws. A mixture of rolled oats, peanut butter, honey and truffle oil (3:3:1:trace) was placed in an inaccessible bait chamber. The internal surface of the cone was equipped with a 'faunagoo wafer', a removable styrene card coated in a pressure sensitive glue-like substance to collect hair samples. Hair funnels were deployed in the field for six days.

Hair samples collected during all survey effort were identified by Hans Brunner (mammalian hair analysis expert).

Locations of survey sites are presented in **Figure 7** with arboreal hair tube sites at HT01 to HT11 for the initial survey and at HT27 to HT31 and all hair funnel sites for subsequent surveys. Arboreal hair sampling survey effort from this assessment and the literature review is presented in **Table 13** and a photo of an arboreal hair tube and hair funnel is provided in **Plate 5**.

Table 13: Arboreal hair tube and hair funnel survey effort

Habitat	Trap nights per trap type					
	ELA[1]		Other[2]		Total	
	HT	HF	HT	HF	HT	HF
Closed Forest	-	60	-	-		60
Grassy Woodland		-	-	-		-
Heathy Woodland	420	60	300	-	720	60
Riparian Woodland	1160	-	-	-	1160	-
Shrub Grass Woodland	320	60	-	80	320	140
Shrubby Woodland	1000	-	-	-	1000	-

[1] ELA surveys for this assessment; [2]Other consultants includes RPS and Kendall & Kendall; HT – Hair funnel; HF – Hair funnel.

Plate 5: Arboreal Elliott trapping; arboreal hair funnel sampling; arboreal hair tube sampling

4.6.4 Terrestrial trapping and sampling

Elliott trapping

For the initial survey effort (2011) a combination of A and B type Elliott traps were used. Each site consisted of traps set along a transect, with 20 A type Elliotts spaced 10 m – 15 m apart, and five B traps set near every fourth A type Elliott. Traps were baited with a mixture of rolled oats, bird seed, peanut butter, honey, and vanilla essence; and leaf litter was placed in each Elliott trap for bedding. Traps were set from four to eight consecutive nights.

For the subsequent survey effort (2013 – 2014) a combination of A and E type Elliott traps (for small sized mammals) were used. Each site consisted of a grid configuration of six by six traps spaced at approximately 10 m apart, comprising 12 E type Elliotts and 24 A type Elliotts. Traps were baited with a mixture of rolled oats, peanut butter, honey and truffle oil (at a ratio of 3:3:1:trace). Quilt batting was inserted as bedding and traps were covered with a calico or hessian bag. Traps were set from three to five consecutive nights.

All traps were checked daily by two ecologists within the first three hours of sunlight. All fauna caught were identified to species level and released at the point of capture.

Locations of survey sites are presented in **Figure 7** with all Elliott trapping undertaken at multi fauna trapping sites. The initial survey effort is presented as design 1 and the subsequent survey effort is presented as design 2. Terrestrial Elliott trapping survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 14** and a photo of terrestrial Elliott trapping is provided in **Plate 8**.

Table 14: Terrestrial Elliott survey effort

Habitat	Trap nights per Elliott trap size													
	ELA[1]			ELA[2]			Other[3]				Total			
	A	B	E	A	B	E	A	B	E	NS[4]	A	B	E	NS[4]
Closed Forest	240	-	48	-	-	-	100	100	-	-	340	100	48	-
Grassy Woodland	324	-	72	-	-	-	-	-	-	-	324	-	72	-
Heath	208	-	80	-	-	-	150 or 200	-	-	-	358 or 408	-	80	-
Heathy Woodland	1,446	40	406	-	-	-	1,060 or 1260	48	62	700	2,506 or 2,706	88	468	700
Riparian Woodland	1,220	130	128	-	-	-	345	36	40	200	1565	166	168	200
Shrub Grass Woodland	1,020	110	104	288	288	-	521	317	20	300	1829	715	124	300
Shrubby Woodland	466	-	146	-	-	-	750 or 1,000	-	-	-	1,216 or 1,466	-	146	-

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants including RPS, Kendall & Kendall (excluding survey effort from Kendall and Kendall Ecological Consultants, 2005, 2006 reports as Elliott trapping effort was not distinguished as arboreal or terrestrial), NICE & TWS (two possible values are given where Landmark Ecological Services & The Wilderness Society 2012 report only specified number of traps over 3 or 4 nights); [4]Trap size not specified. Note A = A sized Elliott trap for small mammals; B = B sized Elliott trap for medium sized mammals; E = E sized Elliott trap for small mammals.

Cage trapping

For the initial survey effort (2011) five wire cage traps (20 cm x 20 cm x 56 cm) were set at each site. Cage traps were placed at every fourth A type Elliott trap on terrestrial Elliott transects, approximately 30 m – 45 m apart. Traps were baited with a mixture of rolled oats, bird seed, peanut butter, honey and canned sardines. Traps were set from four to eight consecutive nights.

For the subsequent survey effort (2013 – 2014) five to six wire cage traps (20 cm x 20 cm x 56 cm) were set at each site. Each trap was draped in hessian or a pillow case and was spaced at approximately 100 m intervals. During the spring survey, all five traps were baited with rolled oats, peanut butter, honey and

truffle oil (at a ratio of 3:3:1:trace). During the summer survey, three traps were baited with the same bait used in the spring survey, and three traps were baited with fish bait, made of sardines, flour and tuna oil (at a ratio of 2:2:1). Trap transects were established along roads, with traps located approximately 30 m – 50 m from road edge. Traps were set for four consecutive nights.

All traps were checked daily by two ecologists within the first three hours of sunlight. All fauna caught were identified to species level and released at the point of capture.

Locations of survey sites are presented in **Figure 7** with all cage trapping undertaken at multi fauna trapping sites. The initial survey effort is presented as design 1 and the subsequent survey effort is presented as design 2. Cage trapping survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 15** and a photo of cage trapping is provided in **Plate 6**.

Table 15: Terrestrial cage trapping survey effort

Habitat	Trap nights			
	ELA[1]	ELA[2]	Other[3]	Total
Closed Forest	-	-	24	24
Grassy Woodland	20	-	4	24
Heathy Woodland	84	-	36	120
Riparian Woodland	198	-	28	226
Shrub Grass Woodland	174	-	144	318
Shrubby Woodland	60	-	-	60

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants (Kendall and Kendall Ecological Consultants, 2005, 2006, 2007, 2009, RPS, 2012c, 2013d).

Pitfall and funnel trapping

Pitfalls and funnel traps were set along a 30 m x 40 cm dampcourse drift fence transect at each site, comprising two paired funnel traps, two 20 L bucket pitfalls traps and two 150 mm wide x 40 cm deep PVC pipe pitfall traps. A bed of leaf litter was placed in each pitfall. Funnel traps were covered in additional shade cloth. During hot weather events, small 60 ml water baths we also placed in pitfalls. Traps were not baited.

In rocky areas, areas with hard-set clay earths, or sites targeting potential Pale-headed Snake habitat, transects of only funnel traps were set. At these sites, five or six pairs of funnels traps were placed along the 30 m drift fence. Additionally, funnel traps were placed along fallen logs, as the logs performed the same function as a drift fence (i.e. to direct fauna into the traps). Traps were set for three to four consecutive nights.

All traps were checked daily by two ecologists within the first three hours of sunlight. All fauna caught were identified to species level and released at the point of capture. Invertebrates (such as ants or beetles) captured in the pitfall were removed each morning.

Locations of survey sites are presented in **Figure 7** with all pitfall trapping undertaken at multi fauna trapping sites – design 2. Pitfall and funnel trapping survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 16** and photos of pitfall and funnel trapping are provided in **Plates 6 – 8**.

Table 16: Pitfall and funnel trapping survey effort

Habitat	ELA[1]		Trap nights per trap method					
			ELA[2]		Other[3]		Total	
	Pitfall	Funnel	Pitfall	Funnel	Pitfall	Funnel	Pitfall	Funnel
Closed Forest	8	90	-	-	-	-	8	90
Grassy Woodland	40	88	-	-	-	-	40	88
Heath	24		-	-	-	-	24	-
Heathy Woodland	161	144	-	-	133	78	294	222
Riparian Woodland	102	304	-	-	119	54	221	358
Shrub Grass Woodland	72	200	32	32	227	44	331	276
Shrubby Woodland	63	228	-	-	-	-	63	228

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants including (Kendall and Kendall Ecological Consultants, 2005, 2006, 2007, 2009, RPS, 2013d, 2013e, 2013f) (survey effort by Landmark Ecological Services & The Wilderness Society not included as specific survey details were not provided in report).

Hair sampling

For the initial survey effort (2011) ten small (50 mm) PVC pipe hair tubes were placed along a transect at each site, and placed approximately 10 m – 15 m apart. Each hair tube was equipped with double-sided sticky tape at the entrance of the tube to collect hair samples. A mixture of rolled oats, bird seed, peanut butter, honey and vanilla essence was placed in an inaccessible bait chamber to lure fauna to the tubes. Hair tubes were deployed in the field for eight nights.

For the subsequent survey effort (2013 – 2014), hair samples were collected using a combination of small (50 mm) and large (70 mm x 110 mm) PVC pipe hair tubes; and hair funnels.

Small and large hair tubes were placed in pairs along a transect of ten stations, approximately 100 m apart. The paired set of hair tubes at each station was placed in proximity to each other (within a 5 m radius); and were positioned to target areas of high fauna movement. U-shaped wire pegs were used to secure the tubes to the ground. Double sided sticky tape was placed inside the entrance to each tube to collect samples. A mixture of rolled oats, peanut butter, honey and truffle oil (at a ratio of 3:3:1:trace) was placed in an inaccessible bait chamber to lure fauna to the tubes. Hair tubes were deployed in the field for between 21 and 22 days.

Hair funnels were placed in pairs along a transect of ten stations, approximately 100 m apart. The paired set of hair funnels at each station was placed approximately 10 m apart from each other. Each station comprised one funnel baited with a mixture of rolled oats, peanut butter, honey and truffle oil (at a ratio of 3:3:1:trace) and a second funnel baited with a mixture of flour, sardines and tuna oil (at a ratio of 2:2:1). All bait was placed in an inaccessible bait chamber to lure fauna to the funnels. The internal surface of the cone was equipped with a 'faunagoo wafer', a removable styrene card coated in a pressure sensitive glue-like substance to collect hair samples. Tent pegs were used to secure funnels to the ground. Hair funnels remained in the field for six days.

Hair samples collected during all survey effort were identified by Hans Brunner.

Locations of survey sites are presented in **Figure 7** with sites HT01 to HT11 undertaken during the initial survey and HT12 to HT33 and all hair funnel sites undertaken during subsequent surveys. Terrestrial hair sampling survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 17** and a photo of terrestrial hair sampling is provided in **Plate 7**.

In addition to this survey effort, four hair funnels were installed over seven nights at a site with a previous unconfirmed record of Rufous Bettong, south-west of the study area. The hair funnels were baited with rolled oats, peanut butter, honey and truffle oil (3:3:1:trace).

Table 17: Terrestrial hair tube & hair funnel survey effort

Habitat	Trap nights per trap type							
	ELA[1]				Other[2]		Total	
	HT-u	HT-f	HF-u	HF-f	HT	HF	HT	HF
Closed Forest	-	-	60	60	-		-	120
Grassy Woodland	-	420	-	-	-	-	420	-
Heath	1,440	-	-	-	-	-	1,440	-
Heathy Woodland	1,680	400	60	60	300	226	2,380	346
Riparian Woodland	1,170	4,450	-	-	90	186	5,710	186
Shrub Grass Woodland	620	-	60	60	90	246	710	366
Shrubby Woodland	624	464	-	-	-	-	1,088	-

[1] ELA surveys for this assessment; [2]Other consultants includes (Kendall and Kendall Ecological Consultants, 2007, 2009, RPS, 2012c, 2013a, 2013d, 2013e); HT – Hair funnel; HF – Hair funnel; u – universal bait; f – fish bait.

Sand plots

Four sand plots were raked along sandy tracks during the evening and revisited early morning to identify fauna using tracks. The sand plots were approximately three metres long and covered the entire width of the road. All prints and tracks were identified to as low a taxonomic level as possible.

Locations of survey sites are presented in **Figure 7**. A photo of a sand plot is provided in **Plate 9**.

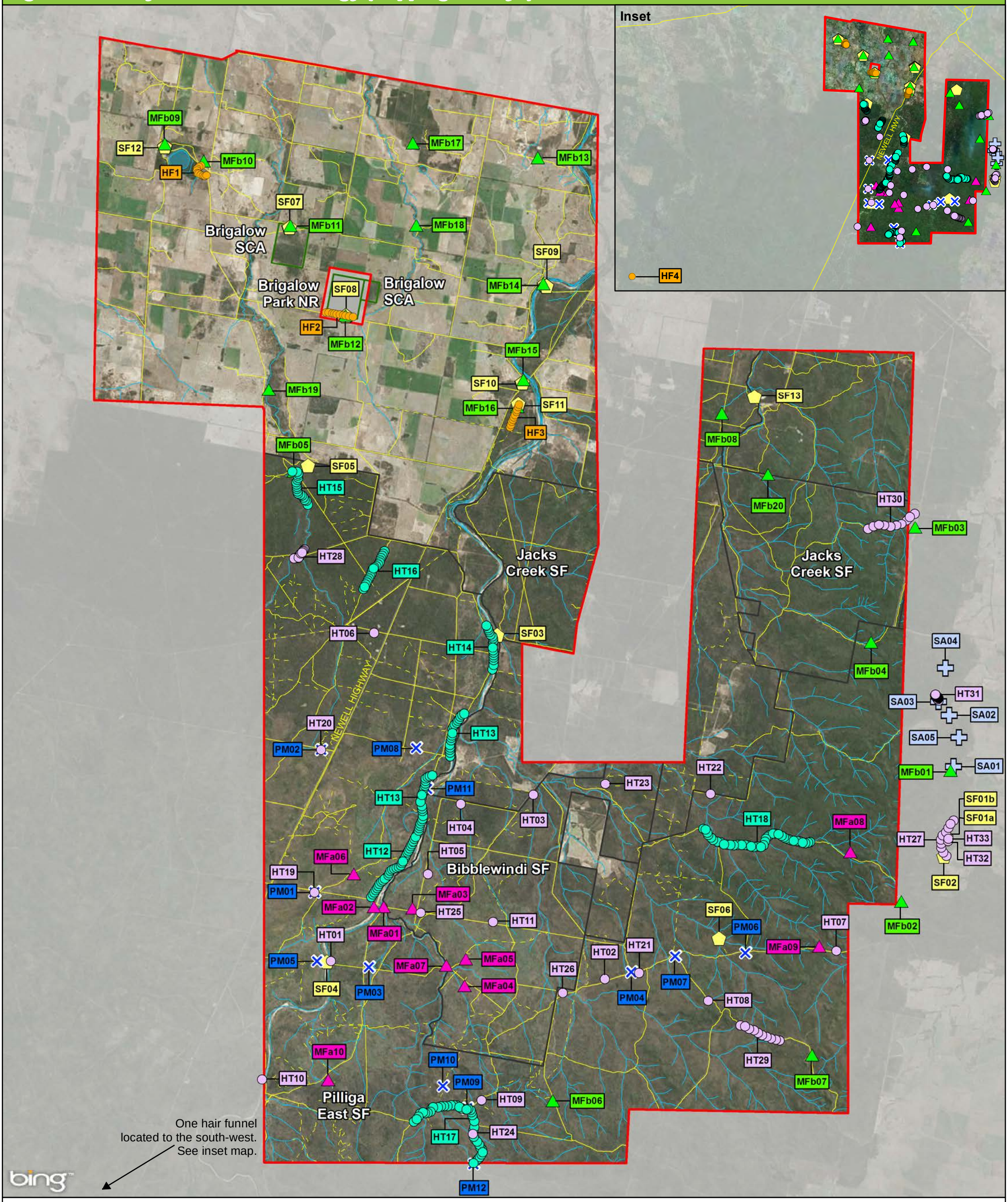

Plate 6: Pitfall traps and funnel traps along drift fence; cage trap


Plate 7: Pilliga Mouse inside a PVC pipe pitfall trap; terrestrial hair tube sampling


Plate 8: Terrestrial Elliott trapping; funnel trapping along drift fence

Plate 9: Sand plot raked across sandy track

Figure 7: Survey effort – fauna ecology (trapping surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Survey by method (ELA 2011 - 2014)

- Hair funnel
- Hair tube - fish
- Hair tube - universal
- Multi fauna trapping - design 1
- Multi fauna trapping - design 2
- Pilliga Mouse targeted trapping
- Sand plot
- Snake funnels

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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4.6.5 Microbat survey

Harp trapping

Microbat species were surveyed using two standard 4.2 m^2 double-bank harp traps coupled with two ultrasonic echolocation recorders (Anabat described below) at each site. Due to the open nature of the mainly woodland habitat types and resultant width of flyways, two harp traps were used together at each site. Harp traps were set prior to dusk for two consecutive nights per survey site and checked each morning before 9.30am. All bats captured were identified to the lowest taxonomic level possible, held in canvas bags during the day prior to and post-identification, for later release at point of capture after dusk.

Echolocation recording

At all standard harp trap sites, two Anabat SD2 Bat Detector units (Titley Electronics) were set up for the two survey nights. Where possible an Anabat unit was aligned within the flyway and the second unit placed perpendicular to the site as the Anabat microphone is directional. Each unit was set with a start time delay for 7pm and finish time of 6am.

Song Meter SM2BAT+ (Wildlife Acoustics Inc.) ultrasonic recorders were also used to record microbat calls and are described in more detail in **Section 4.6.8**

Anabat data from the initial survey was processed by Anna Lloyd (independent bat call analysis expert). Anabat data (including Song Meter data) from the subsequent survey was processed by ELA Ecologist, Peter Knock (spring 2013), ELA Fauna Ecologist Alicia Scanlon (summer 2014) and Dr Anna M^{c}Conville (summer 2014). Peter Knock conducted the majority of microbat field assessments and provided habitat specific knowledge to the data processing team to assist with queries during the call identification process.

Locations of survey sites for harp trapping and Anabat ultrasonic recording are presented in **Figure 8**. Locations of survey sites for Song Meter ultrasonic recording are presented in **Figure 11**, with sites SM02 to SM13 set to record ultrasonic calls. Harp trapping and Anabat recording survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 18** and photos of a harp trap and an Anabat are provided in **Plate 10**.

Table 18: Harp trap and Anabat survey effort

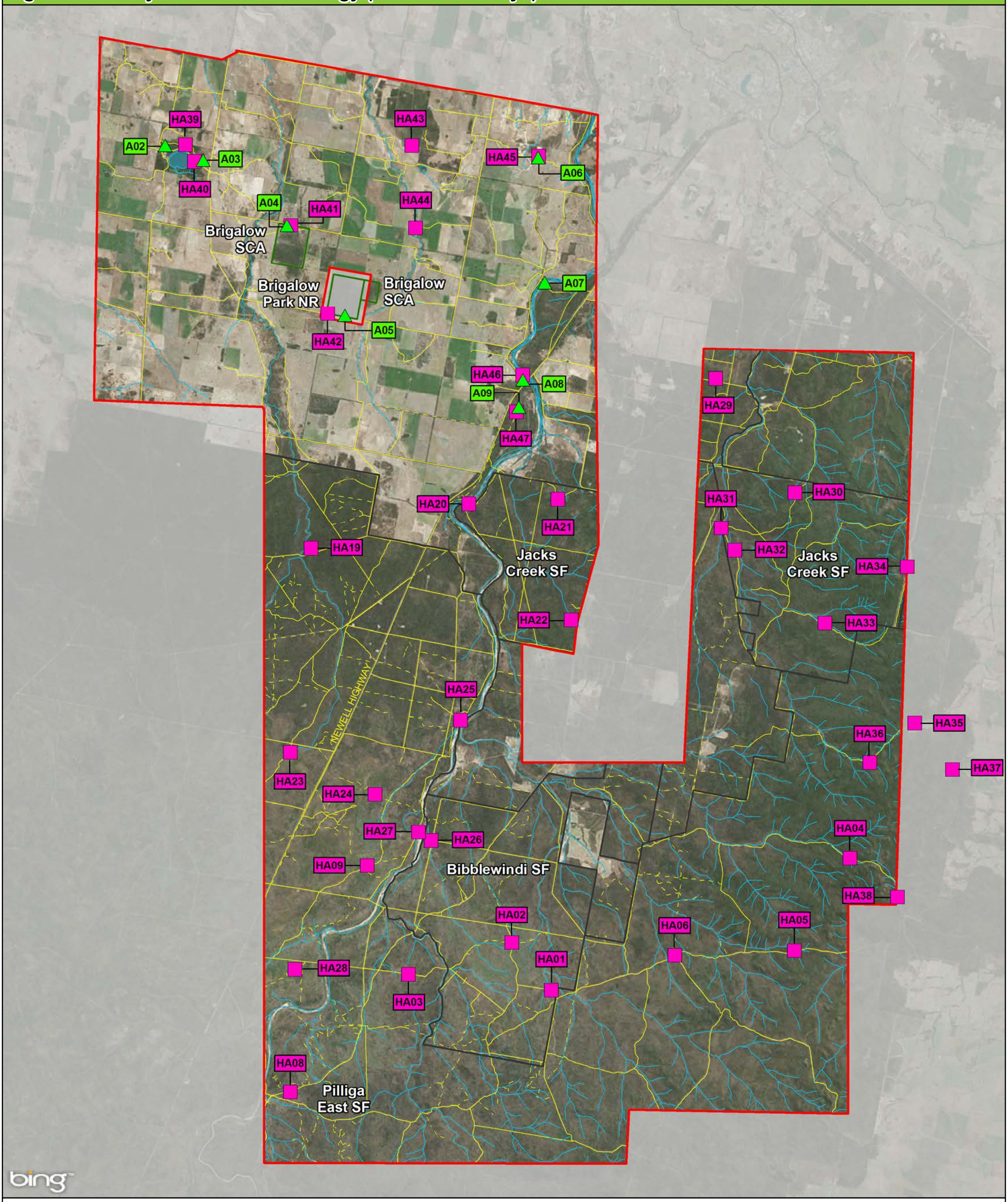
Habitat	Trap nights							
	ELA[1]		ELA[2]		Other[3]		Total	
	H	A	H	A	H	A	H	A
Closed Forest	4	12	-	-	2	6	6	18
Grassland	-	-	-	-	-	4	-	4
Grassy Woodland	8	16	-	-	3 or 6	4	11 or 14	20
Heath	-	-	-	-	-	-	-	-
Heathy Woodland	8	12	2	2	13 or 22	32	23 or 32	46
Riparian Woodland	48	52	4	4	13 or 20	36	65 or 72	92
Shrub Grass Woodland	56	64	28	18	34 or 36	45	118 or 120	127
Shrubby Woodland	24	28	-	-	2 or 4	3	26 or 28	31

H – Harp trap; A – Anabat.

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants including RPS, Kendall & Kendall (excluding Kendall and Kendall Ecological Consultants 2006 and Kendall and Kendall Ecological Consultants 2009 as no specific trap night details were provided in report); and two possible values are given where the Landmark Ecological Services & The Wilderness Society 2012 report only specified number of traps over 3 or 4 nights).

Plate 10: Two harp traps installed in a creek line flyway; Anabat facing a flyway

Figure 8: Survey effort – fauna ecology (microbat surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Survey by method (ELA 2011 - 2014)

- Anabat
- Harp and Anabat

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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4.6.6 Diurnal survey

Bird census

A species time-curve survey technique was applied for this survey method. Each survey was conducted by two ecologists and consisted of an initial 20 minute census, recording all bird calls and observations. After 20 minutes, an extra five minutes was added to the survey for each additional species recorded. This survey technique ensures a maximum number of species is recorded at each site.

Locations of survey sites for bird censuses are presented in **Figure 9**. Diurnal bird survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 19**.

Table 19: Diurnal bird survey effort

Habitat	Person hours			
	ELA[1]	ELA[2]	Other[3]	Total
Closed Forest	2.67	1.33	0.66	4.66
Grassland	4.83			4.83
Grassy Woodland	28.80	-	-	28.80
Heath	17.60	-	-	17.60
Heathy Woodland	7.50	4.17	4.00	15.67
Riparian Woodland	71.83	3.50	4.00	79.33
Shrub Grass Woodland	15.70	6.83	4.32	26.85
Dam	5.00	-		5.00

[1]ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants includes RPS (not including effort from (RPS, 2012a) as no specific survey details were provided.

Diurnal call recording

Song Meter SM2+ (Wildlife Acoustics Inc.) sound recorders were also used to record bird calls and are described in more detail in **Section 4.6.8**. Locations of survey sites for Song Meter bird call recording are presented in **Figure 11** with sites SM01 to SM13 set to record bird calls.

Reptile search

Reptiles were targeted using active diurnal searches in suitable habitat. Diurnal searches involved identifying basking individuals by sight; and searching fallen logs, decorticating and fallen bark, rock outcrops and raking of substrate material to target more cryptic species. Diurnal searches were conducted by two to four ecologists for periods up to an hour.

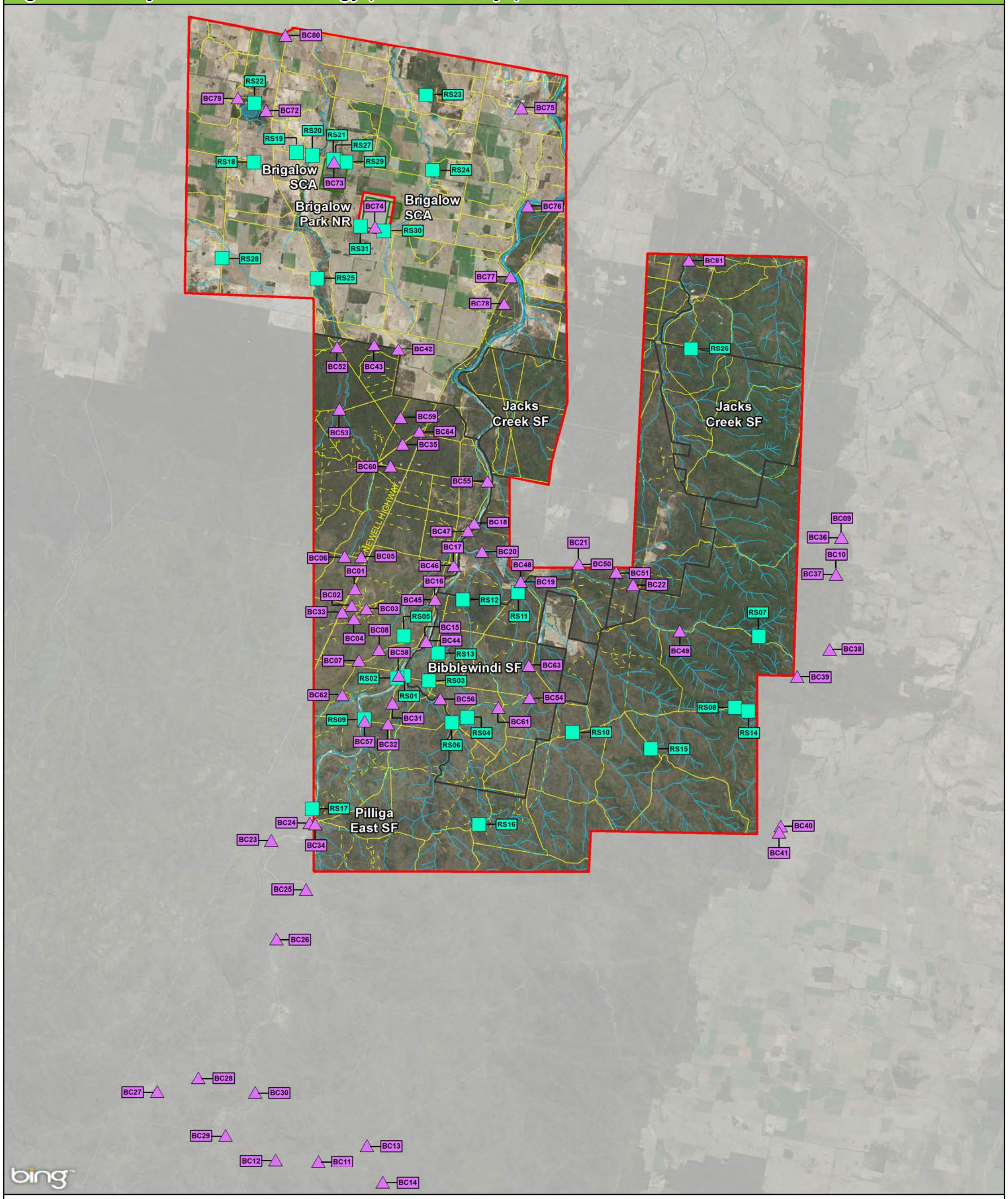
Locations of survey sites for reptile searches are presented in **Figure 9**. Diurnal reptile survey effort from this assessment and the literature review is presented in **Table 20**.

Table 20: Diurnal reptile search effort

Habitat	Person hours		
	ELA[1]	Other[2]	Total
Closed Forest	15.23	-	15.23
Heathy Woodland	2.17	-	2.17
Riparian Woodland	16.80	-	16.80
Shrub Grass Woodland	15.20	9.00	24.20
Shrubby Woodland	7.67	-	7.67

[1]ELA surveys for this assessment; [2]Other consultants includes RPS and Kendall & Kendall (not including (Kendall and Kendall Ecological Consultants, 2007; RPS, 2012a) as no specific survey details were provided).

Figure 9: Survey effort – fauna ecology (diurnal surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Survey by method (ELA 2011 - 2014)

- Bird census
- Reptile search

0 2 4 8
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

N

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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Prepared by: VH Date: 17/11/2014

4.6.7 Nocturnal survey

Spotlighting

For the initial survey effort (2011), spotlighting transects were conducted in vehicles by two ecologists for approximately one hour per transect, travelling at 10 km/h. The search targeted arboreal fauna, concentrating in the canopy and mid-strata levels of vegetation. A hand held spotlight (12 V 100 watt) was used to detect eye shine of nocturnal fauna.

For the subsequent survey effort (2013 – 2014), spotlighting transects were conducted in vehicles and on foot. Spotlighting in vehicles was carried out opportunistically whilst travelling between sites by two ecologists, travelling at 5 km/h. Spotlighting on foot was carried out by two ecologists along a 1 km transect, searching for approximately 30 minutes. Each site was surveyed twice. A hand held spotlight was used to detect eye shine of nocturnal fauna (EagleTac M3C4 920 lumen; LED Lenser P14 200 lumen; or a 12 V 100W spotlight).

Locations of survey sites for spotlighting are presented in **Figure 10**, with SP01 to SP03 undertaken during the initial survey and SP04 to SP19 undertaken during subsequent surveys. Spotlighting survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 21**. Note this table doesn't include the nocturnal survey effort undertaken for the targeted amphibian and reptile survey presented further below.

Table 21: Spotlighting survey effort

Habitat	Person hours			
	ELA[1]	ELA[2]	Other[3]	Total
Closed Forest		-	3.00	3.00
Heathy Woodland		-	6.00	6.00
Riparian Woodland	16.10	-	-	16.10
Shrub Grass Woodland	8.00	2.67	21.00	31.67
Shrubby Woodland	4.00	-	-	4.00
Multiple habitat types	6.00	-	-	6.00

[1]ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants includes (Kendall and Kendall Ecological Consultants, 2005, 2006, 2007, 2009, RPS, 2013a, 2013d, 2013e) (not including effort from Landmark Ecological Services & The Wilderness Society 2012 as no specific spotlight survey details were provided in the report); Opportunistic spotlighting not included.

Stream searches

Two ecologists traversed targeted habitat at night for one hour periods at each site. Ecologists targeted habitat with tree hollows, and carried out searches of upper branches and tree trunks, fallen logs and decorticating and fallen bark. A hand held spotlight was used to detect eye shine of nocturnal fauna (EagleTac M3C4 920 lumen; LED Lenser P14 200 lumen; or a 12 V 100W spotlight).

Locations of survey sites for stream searches are presented in **Figure 10**. Nocturnal stream search survey effort is presented in **Table 22**.

Table 22: Nocturnal stream search effort

Habitat	Person hours		
	ELA[1]	Other[2]	Total
Riparian Woodland	16	-	16

[1] ELA surveys for this assessment; [2]Other consultants

Call playback

Call playback involved listening for fauna vocalisations, spotlighting and broadcasting using a 15W amplifier. All species identified by vocalisation or by sight were recorded. The structure of a full call playback site is presented in **Table 23**. Up to five species were targeted during the call playback survey, however not all sites targeted all five species.

The number of consecutive nights of call playback varied between species. Koala call playback was undertaken over two consecutive nights. Other species were undertaken over a minimum of four consecutive nights, with the aim of surveying Barking Owl for five consecutive nights and Masked Owl for eight consecutive nights (although this was not always possible). If the target species was recorded, call playback for the recorded species ceased at that site.

Locations of survey sites for call playback are presented in **Figure 10**, with only Koala targeted at call playback sites 1-4, 8, 11, 14, 15 and 17. The remainder of the sites targeted all species listed in **Table 22**. Call playback survey effort is presented in **Table 24**. This table has not been classified by habitat type as the call playback technique surveys cover a range of habitat types.

Table 23: Call playback schedule

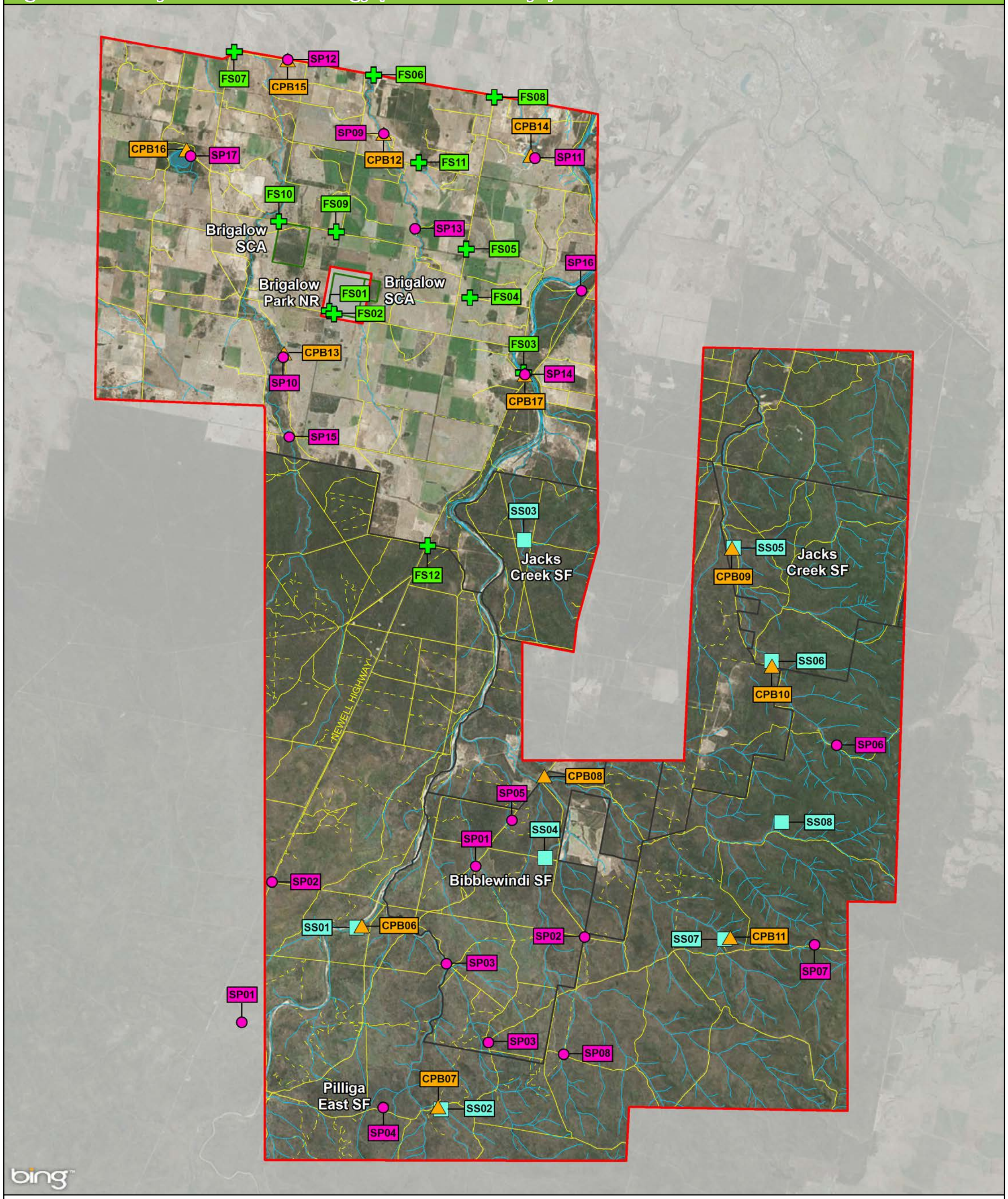
Item	Task	Time (minutes)	Species	Item	Task	Time (minutes)	Species
1	Listen	5	-	10	Listen	5	-
2	Spotlight	5	-	11	Call	0.5	Bush-stone Curlew
3	Call	5	Barking Owl	12	Listen	4.5	-
4	Listen	5	-	13	Call	0.5	Bush-stone Curlew
5	Call	5	Masked Owl	14	Listen	4.5	-
6	Listen	5	-	15	Call	0.5	Bush-stone Curlew
7	Call	5	Koala (2 nights only)	16	Listen	4.5	-
8	Listen	5	-	17	Spotlight	5	-
9	Call	5	Squirrel Glider	**Total**		**70**	**-**

Table 24: Call playback survey effort

Target species	Person hours			
	ELA[1]	ELA[2]	Other[3]	Total
Barking Owl	17	9	76	102
Bush Stone Curlew	25	15	44	84
Koala	27	29	64	120
Masked Owl	33	15	80	128
Powerful Owl	-	-	64	64
Squirrel Glider	25	10	60	95
Yellow-bellied Glider	-	-	20	20

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants includes (Kendall and Kendall Ecological Consultants, 2005, 2006, 2007, 2009; RPS, 2012c) (not including effort from Landmark Ecological Services & The Wilderness Society 2012 as no specific survey details were provided)

Figure 10: Survey effort – fauna ecology (nocturnal surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Survey by method (ELA 2011 - 2014)

- Call playback
- Frog survey
- Spotlighting
- Stream search

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

N

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4.6.8 Remote recording survey

Remote camera surveys

Reconyx infrared and white flash motion detector cameras (remote cameras) (models HC500, HC550, HC600, PC800, PC85 and PC900) were installed in areas where there was evidence of animal activity or where there was likely to be animal activity. Tracks, scats and other signs were used to indicate the presence of other fauna which informed remote camera placement. A combination of methods was used to attract fauna to within the sensors of each remote camera. Some remote cameras simply relied on fauna using possible den or high activity sites, while others were lured with a bait station. Bait used in the bait stations was either a combination of rolled oats, peanut butter, honey and truffle oil (3:3:1:trace), chicken pieces or flour, sardines and tuna oil (at a ratio of 2:2:1). Remote cameras were deployed in the field for between one and 21 days with those remote cameras facing a bait station being deployed in the field for at least eight days.

All photographs were reviewed by an ecologist at the end of the survey period and the fauna photographed were identified to species level where possible.

Locations of survey sites for remote camera surveys are presented in **Figure 11**. Remote camera survey effort from this assessment, additional ELA assessments and the literature review is presented in **Table 25** and a photo of a remote camera site is provided in **Plate 11**.

In addition to this survey effort, four remote cameras were installed at a site with a previous unconfirmed record of Rufous Bettong south-west of the study area. The cameras were installed for seven nights and were facing bait stations with rolled oats, peanut butter, honey and truffle oil (3:3:1:trace).

Table 25: Remote camera survey effort

Habitat	Trap nights by bait type							
	ELA[1]			ELA[2]			Other[3]	Total
	T-u	T-f	T-c	T-u	T-f	A-u		
Closed Forest	39	39	-				-	78
Dam	-	21	-					21
Grassy Woodland	35	16	-				-	51
Heathy Woodland	58	16	-				30	104
Riparian Woodland	234	423	16				12	685
Shrub Grass Woodland	186	88	16	16	16	36	65	423
Shrubby Woodland	112	23	8				-	143

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3] Other consultants including (Kendall and Kendall Ecological Consultants, 2009; RPS, 2013a, 2013d, 2013e), (effort by Landmark Ecological Services & The Wilderness Society 2012 not included as specific trap night details not provided); T-u – Terrestrial universal bait; T-f – Terrestrial fish bait; T-c – Terrestrial chicken bait; A-u – Arboreal universal bait.

Plate 11: Remote camera facing bait station installed along a high use fauna track

Diurnal call recording

Song Meter SM2+ (Wildlife Acoustics Inc.) sound recorders were introduced to the project to record bird calls during the subsequent survey (one unit during winter 2013, one unit during spring 2013 and 11 units during summer 2014). All Song Meters were programmed to record at a sample rate of 44,100 Hz for the first four hours of light each morning. Data were recorded in full frequency wav format.

Song Meter data was analysed by ELA ecologist Kurtis Lindsay using SoundID software. All data was processed for detection of Regent Honeyeater calls by using a library of wav format Regent Honeyeater calls from three different locations in NSW; Widden Valley, Wollombi and Glen Alice Capertee Valley.

Locations of survey sites for Song Meter bird call recording are presented in **Figure 11**, with sites SM01 to SM13 set to record bird calls. Song Meter survey effort from this assessment and additional ELA assessments is presented in **Table 26**.

Table 26: Song Meter survey effort

Habitat	Total recording nights			
	ELA[1]	ELA[2]	Other[3]	Total
Heathy Woodland	7	-	-	7
Riparian Woodland	51	-	-	51
Shrub Grass Woodland	7	8	-	15
Shrubby Woodland	16	-	-	16

[1]ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]All other consultants excluding ELA.

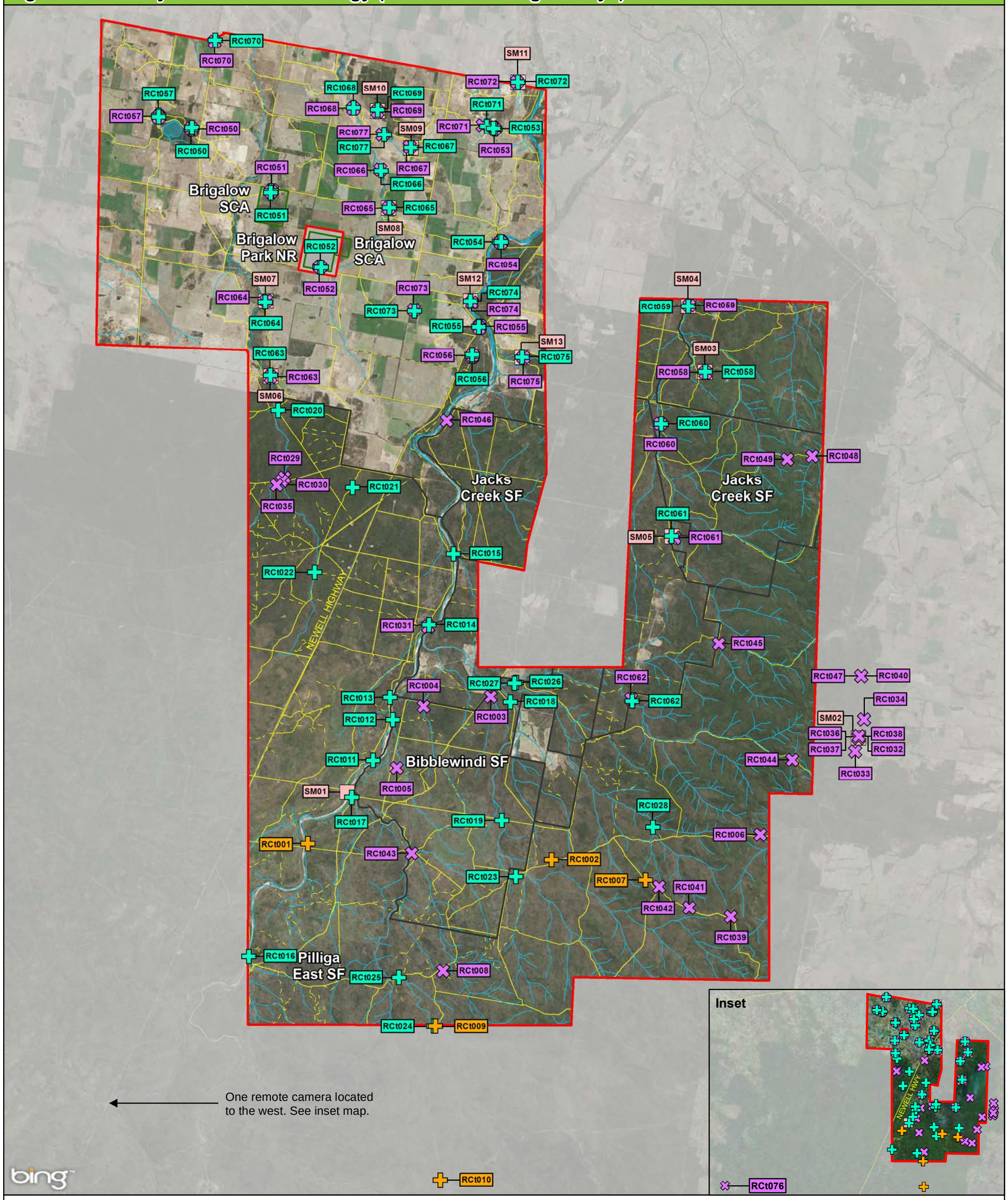
Echolocation recording

Song Meter SM2+ (Wildlife Acoustics Inc.) sound recorders were introduced to the project to record bat calls during the subsequent survey (one unit during spring 2013 and 11 units during summer 2014). They were set up at additional non-harp trap sites. All Song Meters were programmed to record at a sample rate of 192,000 Hz. Settings for the first deployment (spring 2013) was for recording all night. Settings for the second deployment (summer 2014) was for seven nights at four hours of constant recording from 7pm followed by 20 minutes of recording out of each hour for an additional six iterations. Data were recorded in full frequency wav format for later conversion with Song Meter proprietary software *Kaleidoscope* ™ to zero-crossing format to be analysed through AnaLook software as for all Anabat data. The Song Meter units differ from the Anabat system by recording in 16 byte full frequency wav format calls and utilising an omnidirectional microphone recording system.

Additionally Echo Meter EM3+ (Wildlife Acoustics Inc.) handheld bat detector / recorders were utilised when releasing captured bats to confirm identification and to record calls for reference purposes. These handheld units were also used for incidental recording during night survey work.

Locations of survey sites for Song Meter ultrasonic recording are presented in **Figure 11**, with sites SM02 to SM13 set to record ultrasonic calls.

Figure 11: Survey effort – fauna ecology (remote recording surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Survey by method (ELA 2011 - 2014)

- Remote camera - chicken
- Remote camera - fish
- Remote camera - universal
- Song Meter

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

N

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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4.6.9 Opportunistic scat analysis

Predator scats were opportunistically collected in the field. They were analysed by either Hans Brunner or Barbara Triggs (Scat analysis specialist), both for identification of predator and prey species. Prey species were identified by analysing hair, bone or other trace samples in the scat.

4.6.10 Opportunistic surveys

Opportunistic surveys were undertaken for the duration of the field assessment by all ELA field ecologists. The location, count and important ecological observations (i.e. breeding status, behaviour) of all threatened species observed opportunistically was recorded.

4.7 Targeted threatened fauna survey

Targeted surveys were designed to provide additional detail for the primary objectives of the field surveys. Specifically, the surveys targeted gaps in the knowledge of species' presence within the study area and also collected data about the habitat preference, distribution and potential abundance of the targeted fauna species. The survey design, site locations and survey methods are detailed in the following sections and associated technical reports.

4.7.1 Pilliga Mouse

A targeted Pilliga Mouse habitat and trapping field survey was undertaken in May, June, October and November 2013 (**Table 9**) to obtain a more thorough understanding of habitat requirements and distribution of the species in the study area. Two technical reports were prepared, one detailing the habitat assessment and modelling and the other detailing the trapping, tracking and DNA sampling field survey (**Appendix F5** and **F6**). A brief summary of the methodologies for both technical reports are outlined below.

Survey techniques developed for this targeted survey were also applied to the general fauna survey. However, this section only details specific methods and timing for the targeted survey for Pilliga Mouse.

Pilliga Mouse habitat modelling technical report

The aim of this technical study was to develop a habitat model for Pilliga Mouse that identifies areas of primary and secondary habitat within the study area. Primary Pilliga Mouse habitat is considered more likely to be inhabited by the Pilliga Mouse on a more permanent basis (refuge habitat), while secondary habitat is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years.

An initial Pilliga Mouse habitat model was developed followed by a revised model. The models are briefly outlined below with detailed methods in **Appendix F5**.

A number of data sets were used to develop the initial Pilliga Mouse habitat model, including:

- Schlencker Mapping (2010) undertook data acquisition using Airborne Laser Scanning techniques to gather Light Detection and Ranging data for an area of approximately 893 km^2 in the vicinity of the study area.
- RPS (2013h) undertook a second round of data acquisition using Airborne Laser Scanning techniques to gather Light Detection and Ranging data for an area of approximately 95,077 ha across the study area.
- Canopy Height Model data was used to identify areas of low dense shrub cover. The Canopy Height Model was classified into five height range classes that were assigned a red to green colour transition.

The Canopy Height Model was overlayed on the aerial imagery in the Geographic Information System and potential habitat was mapped at a scale of 1:20,000. Potential habitat was initially classified into 5 categories. Categories 1 and 2 represented areas identified in the Canopy Height Model as low dense heath and were considered areas most likely to be potential primary Pilliga Mouse habitat. Categories 3 to 5 were identified as potential Pilliga Mouse habitat that required field validation to determine suitability. A total of 410 unique polygons (patches of potential habitat) were mapped during the development of the initial Pilliga Mouse habitat model.

Field validation was undertaken following development of the initial Pilliga Mouse habitat model. A total of 77 rapid assessments were conducted for the field validation survey. These rapid assessments were undertaken by driving on established forestry roads and trails and recording the start and end points of habitat. For each area confirmed or identified as potential habitat, data was collected on plant community type, soil texture and colour, dominant species at each stratum, low shrub cover, presence/absence and size of burrows and additional site notes (e.g. fire history).

Data collected in the field was then uploaded into the Geographic Information System to inform the development of the revised Pilliga Mouse habitat model. In order to accurately delineate areas of potential habitat a number of resources were used, including the rapid site assessments, the start/end habitat points, existing vegetation mapping (ELA, 2015; State Forests of NSW, 2007), and the initial Pilliga Mouse habitat model, which were overlayed on the Canopy Height Model and aerial images.

The revised model categorised potential habitat as either primary (Category 1) or secondary (Category 2) habitat. Areas of potential habitat, both primary and secondary that were intersected during the field validation survey were given a score of 1 (validated). Areas of potential habitat that were mapped based purely on Canopy Height Model and Aerial Photograph Interpretation were given a score of 2 (not validated).

Supplementary data used to inform the assessment included Pilliga Mouse observational records from field surveys and a number of rapid vegetation validation points.

Pilliga Mouse survey technical report

Targeted Pilliga Mouse surveys were conducted within the study area over a four week period during autumn and a four week period during spring 2013. The abundance, distribution and habitat preferences of the Pilliga Mouse in and adjacent to the study area were determined with reference to the Pilliga Mouse habitat modelling (**Appendix F5**) described above.

Autumn survey sites were selected to include replicate sampling of a range of vegetation structures, shrub densities and soil substrates in primary and secondary habitat identified in the habitat modelling. Autumn surveys were conducted following the breeding season to maximising the chances of trapping the Pilliga Mouse during peak population densities (Tokushima, Green, & Peter, 2008).

Spring survey sites (multi-fauna trapping sites) were not deliberately located in modelled Pilliga Mouse habitat because these surveys consisted of more general fauna surveys in the study area.

Survey effort involved Elliott trapping, pitfall trapping, hair tubes, fluorescent powder tracking and DNA sampling. Trapping at most sites was for four or five nights. However, some sites were closed one night earlier for ethical reasons (to ensure that trapped animals weren't left in the traps beyond four hours after first light on the last day when sites were dismantled). Hair tubes were set up on the first week and pulled in on the fourth week. Fluorescent powder was used on trapped Pilliga Mice to track their movements back to their burrows. Each trapped Pilliga Mouse was also ear notched and the sample was analysed to confirm species identification. Total survey effort and details of techniques are detailed in **Appendix F6**.

The survey design and methodology for the autumn survey was prepared with consultation from Dr Hideyuki Tokushima (Pilliga Mouse expert) who confirmed that the trapping design and survey procedures were well considered and appropriate for detection of the species. Guidance provided by Dr Tokushima was taken into account when designing targeted surveys, when handling the captured Pilliga Mouse and in the discussion of the results of these surveys.

Dr Fred Ford (recognised expert on molecular determination of *Pseudomys* species in Australia) was also consulted regarding the status of the Pilliga Mouse, appropriate methods for DNA analysis and interpretation of results. Dr Ford also provided expert advice to the Australian Centre for Wildlife Genomics at the Australian Museum who completed the DNA analyses for this project.

DNA analyses were conducted as the taxonomic status of the Pilliga Mouse is uncertain in the literature. The Pilliga Mouse is considered a southern population of the widespread *Pseudomys delicatulus* (Delicate Mouse) based on genetic analyses, morphological studies and recent surveys which revealed a continuous distribution of the Delicate Mouse to the Pilliga region (Breed & Ford, 2007; F. Ford, 2008).

4.7.2 Spotted-tail Quoll

The purpose of the targeted Spotted-tailed Quoll survey was primarily to identify whether this species occurs within the study area, since it has not been previously recorded but was considered likely to occur based on previous records within the Pilliga Forest and the presence of suitable habitat.

Survey techniques developed for this targeted survey were also applied to the general fauna survey. However, this section only details specific methods and timing for the targeted survey.

Survey timing

The survey was undertaken by four ELA ecologists over two separate weeks (5 – 11 May 2013 & 26 May – 1 June 2013) with survey equipment deployed during the first week and retrieved during the second week. Surveys were undertaken during the breeding season, a period in which Spotted-tailed Quoll activity is considered high as males roam in search of females (DSEWPaC, 2011b).

Site selection

Site locations were originally selected to survey a range of habitats including riparian corridors, near gullies, rocky escarpments and outcrops. Rocky outcropping was modelled prior to the field survey utilising LiDAR data and aerial photography. However, when assessed in the field, the rocky outcrops initially identified with LiDAR were not considered suitable for Spotted-tailed Quoll due to a lack of significant rock outcropping. The majority of significant rocky outcropping in the region is located outside of the study area, to the east. No escarpments were identified within the study area.

The locations of the sites are presented in **Figure 7** with all the fish baited hair tube transects (HT 12 – HT 18) undertaken during the targeted survey.

Terrestrial hair tubes

Twenty to 40 large (70 mm x 110 mm) PVC pipe hair tubes were placed along a transect at each site, set approximately 100 m apart. Each hair tube was equipped with double-sided sticky tape at the entrance of the tube to collect hair samples. A mixture of flour, sardines and tuna oil (at a ratio of 2:2:1) was placed in an inaccessible bait chamber to lure fauna to the tubes. Hair tubes remained in the field for 19 to 22 days.

Hair samples collected were identified by Hans Brunner.

Remote camera trapping

Eighteen remote cameras (models HC550 and HC600) were established facing bait stations. Bait used in the bait stations was either a pilchard suspended in a stocking inside a closed cage trap, or a hair tube baited with the same fish mixture used in the hair tubes transects. Remote cameras were deployed in the field for 19 to 21 days.

All photographs were reviewed by an ecologist at the end of the survey period and the fauna photographed were identified to species level where possible.

4.7.3 Targeted migratory birds

The potential for Regent Honeyeater, Superb Parrot and Swift Parrot to utilise foraging resources in the study area was not fully understood and hence the purpose of these surveys was to record evidence of the study area being used by these species. As migratory patterns of these species vary annually depending on flowering resources, the habitat present in the study area has potential to support foraging during years where preferred foraging habitat (e.g. Box Gum Woodland outside of the study area) is not abundantly productive.

There are no previous records of these migratory species within the study area, however the absence of records may be due to lack of survey effort, as there are a few scattered records for Regent Honeyeater and Superb Parrot throughout the Pilliga. Swift Parrots have not been recorded in the Pilliga but are known to migrate to the east of the Pilliga.

Survey techniques developed for this targeted survey were also applied to the general fauna survey. However, this section only details specific methods and timing for the targeted survey.

Survey timing

The survey was undertaken by four ELA ecologists over two separate weeks, with the same teams utilised during both surveys. Regent Honeyeaters were targeted in October 2012 and Superb Parrots and Swift Parrots were targeted in July 2013.

Site selection

Site locations were selected based on targeting flowering eucalypts that could provide foraging resources for target species. Sites with previous records outside of the study area were visited where possible. The spring timing for Regent Honeyeaters was aligned with flowering of *Eucalyptus albens, Eucalyptus sideroxylon x Eucalyptus melliodora* and *E. sideroxylon* as these are considered important foraging species for Regent Honeyeater (Damon Oliver, OEH, pers. comm., OEH 2014c). Both Superb Parrots and Swift Parrots migrate north during winter to forage, and the July survey aligned with flowering of red gums along the drainage lines (*E. chloroclada* and *E. blakelyi*), *E. albens* (located outside of the study area to the east) and *E. crebra* which could provide foraging resources during their northerly migration.

The locations of these sites are presented in **Figure 9** with BC01 to BC32 undertaken during the Regent Honeyeater targeted survey in October 2012 and BC33 to BC64 undertaken during the Superb Parrot and Swift Parrot targeted survey in July 2013.

Bird census

A species time-curve survey technique was applied for this survey. Each survey consisted of an initial 20 minute census, recording all bird calls and observations. After 20 minutes, an extra five minutes was added to the survey for each additional species recorded. This survey technique ensures a maximum number of species is recorded at each site.

Car transects were also undertaken between sites and in areas where flowering eucalypts were observed. This involved driving the car at walking pace with the windows open and listening out for calls. All opportunistic identifications of species not yet recorded were also noted during the car transects.

Song Meter

Song Meter SM2+ (Wildlife Acoustics Inc.) sound recorders were introduced to the project to record bird calls during the targeted surveys (one unit during winter 2013, one unit during spring 2013 and 11 units during summer 2014). All Song Meters were programmed to record at a sample rate of 44,100 Hz for the first four hours of light each morning. Data were recorded in full frequency wav format.

Song Meter data was analysed by ELA ecologist Kurtis Lindsay using SoundID software. All data was processed for detection of Regent Honeyeater calls by using a library of wav format Regent Honeyeater calls from three different locations in NSW; Widden Valley, Wollombi and Glen Alice Capertee Valley.

4.7.4 Koala

The potential usage of habitat in the study area by Koalas was not well understood and hence the purpose of the survey was to increase understanding of Koala presence, habitat utilisation and habitat quality in the study area.

Site selection

Prior to conducting field surveys, a desktop assessment was undertaken to stratify the study area into regions of potential Koala habitat, using vegetation mapping (**Figure 15**). Targeted Koala habitat included areas dominated by secondary feed and shelter tree species (DECC, 2008b) listed in **Table 27**.

Table 27: Tree species in targeted Koala habitat

Tree species category	Tree species
Primary	*Eucalyptus camaldulensis**
Secondary	*E. blakelyi*, *E. chloroclada*, *E. conica* (Fuzzy Box), *E. dealbata* (Tumbledown Gum), *E. dwyeri* (Dwyer's red gum), *E. microcarpa* (Western Grey Box), *E. melliodora* (Yellow Box), *E. pilligaensis* (Pilliga box), *E. populnea* (Poplar Box)*
Supplementary	*E. macrorhyncha* (Red Stringybark)
Shelter	*Callitris glaucophylla* (White Cypress Pine)

* Tree species also listed in Schedule 2 of SEPP 44 as feed tree species

Call playback

Call playback involved a five minute listening and a five minute spotlighting session either side of broadcasting a five minute Koala call. The broadcast involved playing a call using a 15W amplifier in an attempt to illicit a response from potential individuals in the surrounding area. All species identified by vocalisation or by sight were recorded. Survey effort is presented in **Table 24**.

Spotlighting

Spotlighting was undertaken on foot by two ecologists along a 1 km transect, searching for approximately 30 minutes. Each site was surveyed twice. A hand held spotlight was used to detect eye shine of nocturnal

fauna (EagleTac M3C4 920 lumen; LED Lenser P14 200 lumen; or a 12 V 100W spotlight). Survey effort is presented in **Table 21**.

Habitat assessment

Koala habitat assessments were undertaken by two ecologists within targeted Koala habitat (**Figure 12)**. The assessments were carried out within a 20 m x 20 m plot (extended to 30 m x 30 m in open woodland) and involved vegetation assessment and a ten minute faecal search. Data collected at each site included the canopy composition (targeting primary and secondary koala feed trees and shelter trees with a diameter at breast height (DBH) greater than 10 cm), groundcover composition (vegetative cover, leaf litter, bare ground, presence of surface water), evidence of introduced species, habitat connectivity, and distance to surface water.

If a Koala or one or more Koala faecal pellets was observed, a spot assessment technique (SAT) survey was to be undertaken. A spot assessment technique survey involves a systematic faecal search of a minimum of 30 trees (diameter at breast height (DBH) >100mm) within the immediate area, with a maximum of two person minutes per tree. The results are then used to determine Koala activity level (Biolink Ecological Consultants, 2008).

All faecal pellets found during Koala habitat surveys were collected and later analysed by Barbara Triggs. Survey effort is presented in **Table 28**.

Table 28: Koala habitat assessment survey effort

Habitat	Number of survey plots			
	ELA[1]	ELA[2]	Other[3]	Total
Grassy Woodland	3	-	-	3
Heathy Woodland	-	3	-	3
Riparian Woodland	18	2	-	20
Shrub Grass Woodland	17	1	-	18

[1] ELA surveys for this assessment; [2]ELA surveys for other site specific assessments; [3]Other consultants

Habitat mapping

Koala habitat was considered under both SEPP 44 and Koala recovery plan (DECC, 2008b) requirements. The specifications for each habitat category are provided below.

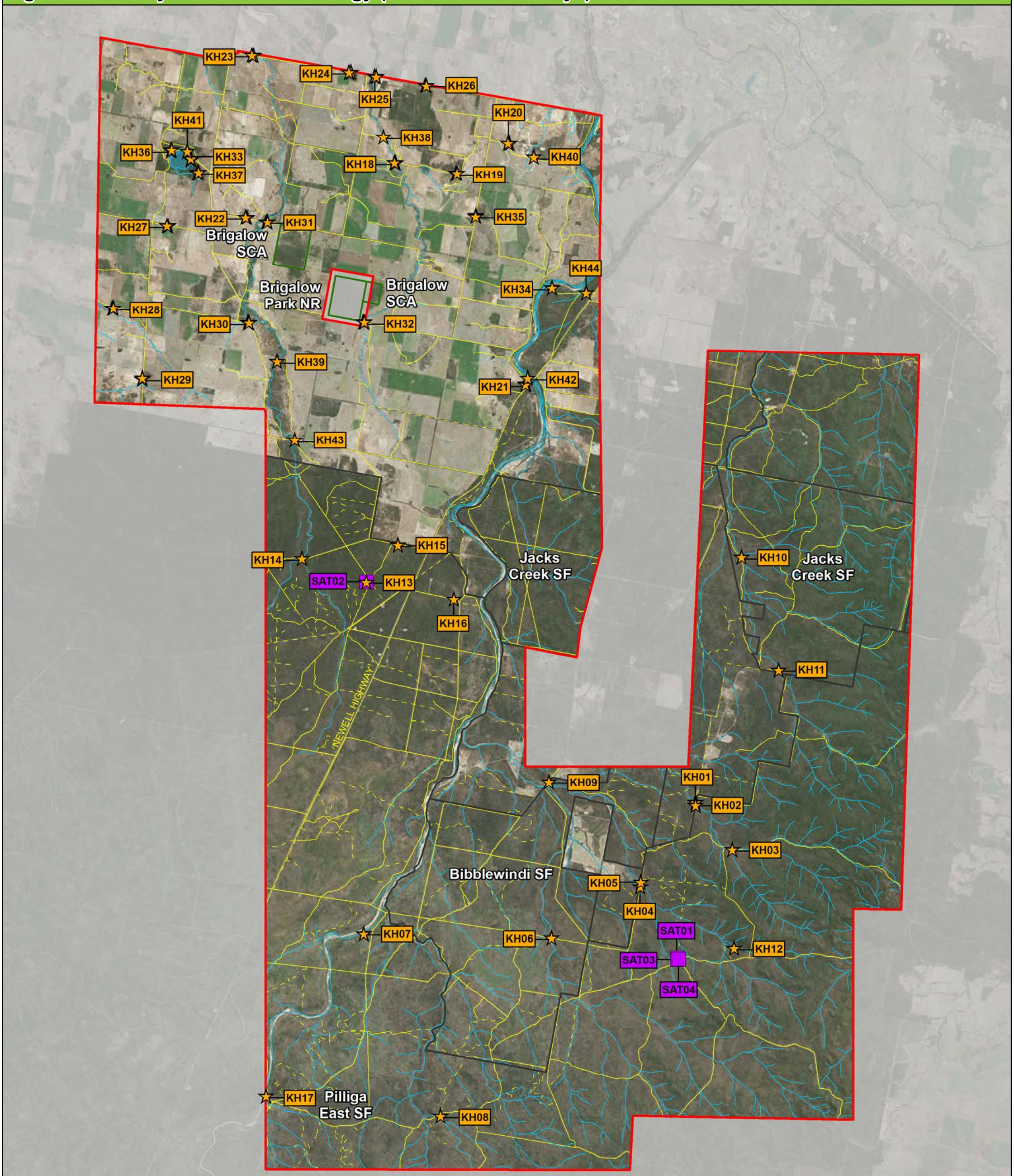
Two options for categorising Koala habitat are provided in the Approved Koala recovery plan. Option 2 is considered to be more robust, and considers distinctions for lesser habitat values that are still considered important for Koalas (AKF, 2012). The habitat categories for Option 2 (Callaghan unpublished as cited in DECC, 2008c) are:

- **Primary habitat**: Areas of forest or woodland where primary Koala food tree species comprise at least 50% of the overstorey trees.
- **Secondary habitat (class A)** (either of the following):
    - Areas of forest or woodland where primary Koala food tree species comprise less than 50% but at least 30% of the overstorey trees.
    - Areas of forest or woodland where primary Koala food tree species comprise less than 30% of the overstorey trees, but together with secondary food tree species comprise at least 50% of the overstorey trees.

    - Areas of forest or woodland where secondary food tree species alone comprise at least 50% of the overstorey trees (primary Koala food tree species absent).
- **Secondary habitat (class B)** (either of the following):
    - Areas of forest or woodland where primary Koala food tree species comprise less than 30% of the overstorey trees.
    - Areas of forest or woodland where primary Koala food tree species together with secondary food tree species comprise at least 30% (but less than 50%) of the overstorey trees.
    - Areas of forest or woodland where secondary food tree species alone comprise at least 30% (but less than 50%) of the overstorey trees (primary Koala food tree species absent).
- **Secondary habitat (class C)**:
    - Areas of forest or woodland where Koala habitat is comprised of secondary and supplementary food tree species (primary Koala food tree species absent), where secondary food tree species comprise less than 30% of the overstorey trees.
- **Tertiary habitat**:
    - Areas of forest or woodland where primary and secondary Koala food tree species are absent, but which have important supplementary Koala habitat values such as habitat buffers and habitat linking areas. Such areas are considered to be necessary components of habitat for the overall conservation of Koala populations.

Potential Koala habitat under SEPP 44 is '*areas of native vegetation where the trees of the types listed in Schedule 2 constitute at least 15% of the total number of trees in the upper or lower strata of the tree component.*' To those sites in the study area that constituted potential Koala habitat, the assessment proceeded to identify if they also constituted core Koala habitat. Core Koala habitat under SEPP 44 is an '*area of land with resident populations of Koalas, evidenced by attributes such as breeding females (that is females with young) and recent sightings of and historical records of a population.'*

Figure 12: Survey effort – fauna ecology (Koala habitat surveys)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Survey by method (ELA 2011 - 2014)

- Koala habitat assessment
- SAT assessment

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

N

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

ecological AUSTRALIA
www.ecoaus.com.au

Prepared by: VH Date: 17/11/2014

4.7.5 Regional Koala survey

In addition to the targeted Koala surveys in the study area, a regional survey of Koalas in the Pilliga was undertaken by Niche Environment and Heritage and ELA ecologists. The survey was designed to locate areas of important habitat and/or climate refuges for Koala across the Pilliga forests. Specifically, the aim of the regional Koala survey was to:

- Survey a number of riparian forest locations that were expected to be among those areas most resilient to drought and high temperatures, based on recent (2013) survey results and ecological understanding of koala habitat requirements, and thus most likely to be where relict Koala populations may occur; and to,
- Document the locations that are found to currently, or have been recently occupied by Koalas.

A summary is provided below with the detailed report presented in **Appendix F7**.

Survey timing

The survey was undertaken by six personnel in teams of three, over 11 evenings and nights from 28 April to 8 May 2014. It was undertaken during a particularly dry period and many waterholes which are normally considered permanent were observed to be dry.

Site selection

Site selection was based on an analysis of priority areas for Koalas in the Pilliga. The priority analysis used two principal vegetation mapping systems and data layers covering the Pilliga forests, known records, and knowledge of Koala habitat preferences to delineate preferred vegetation types that represent favourable habitat. The priority analysis identified areas for targeted survey that contained previous records along major creek systems (e.g. Baradine Creek on the edge of west Pilliga, Etoo Creek in central Pilliga and Borah Creek in east Pilliga), semi-permanent waterholes and forest dams. A subset of these priority areas was surveyed, ensuring a broad spatial coverage.

Diurnal searches

At approximately half of the identified sites, diurnal searches were undertaken to provide an indicator of Koala activity. These involved searching for Koala faecal pellets and scratches at most red gum trees and shelter trees lining the banks of the drainage lines or water source. Additionally, all canopy trees in the site were searched for the presence of Koalas. The searches were predominantly confined to approximately 100 m wide buffers either side of the selected drainage lines.

Nocturnal searches

Nocturnal searches were undertaken at all sites, with preferences given to sites with recent activity identified from the diurnal searches. These searches involved a spotlighting transect for individuals and passive listening for calling Koalas along an approximately 3-4 km stretch of the riparian woodland lining the selected drainage lines. An inspection was also undertaken along the sandy creek-bed below over-hanging trees for Koala faecal pellets. Koala remains were also searched for.

4.7.6 Amphibian and reptile survey

Targeted surveys were undertaken to address the relatively small amount of information available on possible distribution and habitat in the study area of the Five-clawed Worm-skink and Sloan's Froglet.

Survey techniques developed for this targeted survey were also applied to the general fauna survey. However, this section only details specific methods and timing for the targeted survey.

Survey timing

Targeted amphibian and reptile searches were undertaken during a survey in April 2014, following a significant rainfall event. Additionally, amphibians were surveyed continuously throughout the initial survey period by active listening and searching (2010 – 2011) as the wet weather provided suitable conditions for amphibian activity. Reptiles were also surveyed as part of the fauna surveys for this assessment with details provided in **Section 4.6.6**.

Site selection

The amphibian targeted searches involved an initial diurnal habitat assessment to determine habitat potential in the study area and potential survey sites. This involved finding areas of pooling water across different habitat types including grassland, forested areas and pre-existing water bodies.

For the targeted reptile survey, a desktop assessment was undertaken to locate closed forest habitat in the study area that would have suitable clay soils.

Amphibian surveys

Visual and aural nocturnal amphibian searches were undertaken at each site. Amphibian searches were conducted by two ecologists over one to two nights for periods up to an hour (**Figure 10**).

Locations of survey sites for amphibian searches are presented in **Figure 10**. Survey effort is presented in **Table 29**.

Diurnal reptile searches

Targeted reptile searches were also undertaken with methods and survey effort detailed in **Section 4.6.6**.

Locations of survey sites for reptile searches are presented in **Figure 9**. Sites R21 and RS27 to RS31 were in potential habitat for the Five-clawed Worm-skink.

Table 29: Targeted amphibian survey effort

Habitat	Number of person hours		
	ELA[1]	Other[2]	Total
Closed Forest	10		10
Grassland	2.5		2.5
Riparian Woodland	1.60		1.60
Shrub Grass Woodland	3.40		3.40

[1]ELA surveys for this assessment; [2]Other consultants excluding ELA (excluding spotlighting survey effort by (Kendall and Kendall Ecological Consultants, 2007, 2009, 2010, RPS, 2012a, 2012c) as no survey length details were provided).

4.8 Additional fauna surveys

Additional fauna surveys conducted by various consultants were reviewed as outlined in **Section 4.1** and **Section 4.2**. A complete list of these surveys is presented in **Appendix A1** and presented in **Figure 6**. Additional fauna survey effort includes general fauna surveys across different habitat types and site specific impact assessments for various exploration and development activities.

Consultants involved in additional fauna survey include Kendall & Kendall Ecological Consultants (2005 – 2010), Landmark Ecological Services & The Wilderness Society (2012), RPS (2012 – 2013) and ELA (2013 – 2014). The rationale behind separating between ELA survey effort relates to the reason that the

survey was undertaken. All fauna survey undertaken for specific footprints for exploration and appraisal activities have been included in with the additional survey effort as they did not specifically follow the aims outlined in **Section 4.4**.

Survey design varied depending on targeted species and habitats. Fauna trapping techniques included Elliott trapping (A, B, and E type traps); pitfall and snake funnels set on drift fences; harp trapping and baited cage trapping. Remote survey techniques included baited hair tubes and hair funnels; arboreal and terrestrial remote sensing cameras; and ultrasonic Anabat recording. Active searches and timed observational surveys included diurnal bird surveys; spotlighting and call playback; amphibian and reptile searches (log-turning and aural); stag watching and track (print) searches. Random meander habitat assessments were conducted for site specific impact assessments that did not undertake fauna trapping. Alison Hunt & Associates also conducted a suite of fauna surveys although it was not possible to categorise by habitat type.

Additional fauna survey effort and design by consultants other than ELA was used to inform spatial gaps and has been presented alongside the ELA fauna effort in this report.

Threatened species recorded during these additional surveys have also been incorporated into the results section of this report.

4.9 Ecological sensitivity analysis

The potential constraints of the study area from an ecological perspective are complex and involve a number of unique ecological components including threatened flora, threatened fauna habitat, Endangered Ecological Communities (EECs), high quality vegetation, regional vegetation significance and large patch size. To present these constraints in a meaningful manner, an Ecological Sensitivity Analysis (ESA) was developed for the study area to identify the degree of ecological sensitivity and constraint to development.

The primary purpose of the ecological sensitivity analysis is to inform the selection of locations for well sets and associated infrastructure (such as access tracks and gas and water gathering systems) to maximise avoidance on areas of higher ecological sensitivity.

The full methodology for the ecological sensitivity analysis is outlined in **Appendix F8**. The ecological sensitivity analysis used available spatial data as well as data collected through field investigations and spatial data developed specifically for the project to identify areas of sensitivity. Ecological criteria were identified and assigned ranking and weightings in an internal workshop (attended by ecologists and conservation planners) and based on key indicators of biodiversity values and available information. The sensitivity analysis then combined scores for the data, applied weightings, and modelled sensitivity indices. Five relative sensitivity classes based on identified trends (clustering) in the sensitivity index were modelled:

- **Low** – Areas that include a high degree of disturbance which impact on long term viability. Impacts should be directed to these areas wherever possible.
- **Low - Moderate** – Areas that exhibit effects of disturbance, or habitat values which are of lower sensitivity in the regional context. Impacts on these areas should be minimised at the site scale.
- **Moderate** – Areas that exhibit some effects of disturbance, or habitat values which are of moderate sensitivity in the regional context. Impacts on these areas should be minimised at the site scale.
- **Moderate - High** – Areas that include a range of biodiversity values, including those listed under State or Federal legislation. Maximise avoidance on these areas.

- **High** – Areas which contain a combination of significant biodiversity values, including those listed under State or Federal legislation. Maximise avoidance on these areas.

4.10 Watercourse mapping

As part of this study, watercourses in the study area were refined at a 1:15,000 scale, stream orders classified (Strahler, 1952) and riparian corridors mapped in accordance with recommended widths under the WM Act.

In line with WM Act guidelines, the existing watercourse mapping layer based on the 1:50 000 scale topographic maps was used as the base watercourses dataset. This data was updated at a scale of 1:15 000 by utilising a high-resolution digital elevation model (1 m) and contour data (25 cm) derived from LiDAR.

Strahler stream order classification is an essential component of determining required riparian corridor widths as part of the protection of waterfront land under the WM Act. Stream order was assigned to each watercourse according to the (Strahler, 1952) methodology.

The final watercourse layer classified with Strahler stream order was used to identify the necessary vegetated riparian zone buffer required as part of the WM Act. To account for the need to include channel widths as part of the total riparian corridor width, top of bank was digitized for watercourses with larger channels that could easily be identified at a scale of 1:15 000 (including all 5th and 6th order watercourses). For all other watercourses, an average channel width was applied based on their stream order.

4.11 Impact calculations

The potential impacts of the project have been categorised into direct, indirect and cumulative impacts. The magnitude of the potential impacts has been calculated and a description of these calculations is provided below.

4.11.1 Direct impacts

Direct impacts are those impacts that directly affect habitat and individuals (DECC, 2007). Direct impacts considered for this assessment are vegetation removal, habitat removal and removal of threatened flora individuals. Direct impacts are discussed in more detail in **Section 6**.

It is important to note that the calculation of direct impacts is based on the upper disturbance limit for each Plant Community Type and is inherently conservative. The upper disturbance limits allow for flexibility of infrastructure placement within the study area (depending on the viability of the resource, proximity to existing infrastructure, landholder feedback and constraints) and it is unlikely that total upper disturbance limit will be reached.

Direct impact calculations have been used in the impact assessments provided in **Appendix J** and **Appendix K**.

Vegetation removal

For major facilities (except the Leewood to Wilga Park underground power line), the amount of each Plant Community Type directly impacted was calculated in a Geographic Information System. The rationale to not include the Leewood to Wilga Park underground power line was due to all disturbances being within the existing gas pipeline easement which is a previously assessed cleared corridor.

Due to the progressive nature of the project where exploration and appraisal informs development, the exact footprint for vegetation removal (the subject site) is not known at this stage. To address this

uncertainty for gas field infrastructure, the potential impact to each Plant Community Type was modelled and an upper disturbance limit determined.

A vegetation impact model was developed to assess the potential impacts or disturbance of well pads and associated linear infrastructure (roads, access tracks and gathering line easements) from the project on native vegetation. The model utilised the vegetation map for the study area and a probabilistic approach to predict the number of hectares of each Plant Community Type to be removed (**Appendix F3**). To facilitate integration of the probabilistic assessment with the vegetation mapping, the model impact area was divided into standard 1 km^2 blocks, into which well and linear infrastructure (of differing densities) potentially could be placed. Each block was furthered divided into four hundred 0.25 ha squares for the analysis to replicate the potential size of infrastructure that would be constructed in the field. The 0.25 ha squares allowed for statistical assessment and to develop a system that can be used to assess the potential impacts of a multitude of development scenarios. The model grid sizes were selected based on the size of petroleum infrastructure and to allow for assessment of the impact of percent vegetation coverage/habitat within each 0.25 ha cell and the 1 km^2 development area on the magnitude of disturbance.

For the model to assess the maximum probable disturbance associated with various development scenarios, an algorithm was applied to the standard grid system described above. The implementation of the algorithm for maximum probable disturbance utilised the following methodology with the infrastructure considered fixed and the distribution of vegetation and habitat considered an independent variable:

1. Develop the infrastructure footprint by designating the fraction of each 0.25 ha block that potentially could contain infrastructure for a series of standard development scenarios (well densities and associated linear infrastructure).

2. Assess the impact of different densities of vegetation on the probability of disturbance by randomly selecting the appropriate number of 0.25 ha squares (i.e. for 30% of vegetation coverage, select 30 out of the 100 squares) for each discrete ‘percentage’ of vegetation communities and habitat.

3. For the squares with vegetation communities overlaid by infrastructure, sum the area of infrastructure footprints – this is the total vegetation communities or habitat impacted area.

4. Repeat steps 2 and 3 thousands of times and record the impacted area for each ‘realization’

5. Process the recorded values from the realizations to determine the median, 25th and 75th percentile values

Modelling was conducted for 21 separate scenarios utilising the methodology described above, the 21 scenarios consisted of seven separate development scenarios run over three well pad avoidance area assessments: avoiding riparian corridors only; avoiding riparian corridors and high ecological sensitivity areas; and avoiding riparian corridors, high and moderate-high ecological sensitivity areas. The development scenarios differed by the spatial location of infrastructure around the study area. The modelling assessed the impact of 425 well sets and associated linear infrastructure and an additional 5 water balance tanks to account for the potential worse case impact of the project.

The amount of clearing for each Plant Community Type under each scenario was modelled to determine an upper disturbance limit against each Plant Community Type. A qualitative assessment was then undertaken to review the modelled outputs and determine the final upper disturbance limit for each Plant Community Type through the consideration a range of factors including: conservation status; percent remaining in NSW; potential offset availability; sensitivity classification; and extent. The qualitative

assessment considered where concentrated development may result in higher impacts to specific Plant Community Types and ensures that the upper disturbance limits account for the most likely development scenarios.

The upper disturbance limits selected were most often the maximum value generated out of all of the scenarios. Where the upper limit deviated from this value was when a decision was made to have no impact to a vegetation community (based on small size or location), or where a particular scenario was having an adverse effect on the maximum value generated (i.e. highly unlikely to occur). Specific instances where this occurred are outlined in **Table 30**.

Table 30: Deviations from the modelled upper disturbance limit

Plant Comm. ID	Plant Community Type	Maximum modelled disturbance (ha)	Upper disturbance limit (ha)	Rationale
78	River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	0.03	0	The restricted distribution of this community and low overall area allows for complete avoidance of this community.
404	Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	100.04	84.3	Second highest modelled disturbance scenario selected. The upper disturbance limit selected accounts for the most likely development scenarios.
405	White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	125.33	105.88	Upper disturbance limit selected is for the scenario with the maximum modelled disturbance, but driven by a higher level of avoidance.
428	Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	0.08	0	The restricted distribution of this community and low overall area allows for complete avoidance of this community.

The values used in the direct impact assessment are upper disturbance limits and hence considered 'worst case' for each Plant Community Type. Greater detail on impact modelling process is presented in **Appendix F3**.

Habitat removal

Determination of the habitat categories (foraging, breeding, other) for individual threatened fauna species was made by using information obtained during this study, including from the literature and data review and field surveys. Each Plant Community Type was allocated a fauna habitat type based on habitat features present. For most threatened fauna assessed, the fauna habitat types could be assigned to foraging, breeding or other habitat. For some species that require specific habitat components (e.g. Koala has known canopy species as feed trees), the Plant Community Types were directly assigned to foraging, breeding or other habitat. The areas impacted for each Plant Community Type were then summed for all

threatened fauna species, to calculate area of foraging, breeding and other habitat impacted for each threatened fauna species.

The area of each fauna habitat type was then calculated both within the study area and the study region. For the study region, Biometric Vegetation Types were used based on regional mapping (ELA, 2013a) with the equivalent Plant Community Types being matched with Biometric Vegetation Types. This allowed for a calculation of percentage impact to the habitat used by each threatened fauna species, both in comparison to habitat available in the study area and in the study region.

Pilliga Mouse habitat

As Pilliga Mouse habitat has been mapped for the study area, the area of Primary and Secondary habitat mapped was used to calculate the direct impact to Primary and Secondary Pilliga Mouse Habitat. Plant Community Type mapping was used to calculate the direct impact to Dispersal Pilliga Mouse habitat.

For major facilities, the amount of mapped Pilliga Mouse habitat impacted was directly calculated in the Geographic Information System. For gas field infrastructure, the maximum value generated for Primary and Secondary habitat out of all of the scenarios modelled above was selected.

Removal of flora individuals

Flora population estimations and population modelling were utilised in combination with the upper disturbance limits for each Plant Community Type to determine total number of threatened flora individuals that would be impacted. For *Bertya opponens* and *Pomaderris queenslandica* (population estimations), the maximum value generated out of all of the scenarios modelled above was selected. For threatened flora species that were modelled, the direct impact to each species was calculated in proportion to the area of each Plant Community Type impacted.

4.11.2 Indirect impacts

Indirect impacts are those impacts that do not directly affect habitat and individuals but that have the potential to interfere through indirect action. Indirect impacts considered for this assessment are site impacts (fragmentation, noise, traffic, fencing, light, weed invasion, increased feral fauna, fire), downstream or downwind impacts (sedimentation, erosion, dust, hydrological change, accidental spills and leaks) and facilitated impacts (hunting). These indirect impacts are discussed in more detail in **Section 6**.

Indirect impacts have been quantified to provide values for the area of vegetation and habitat that would have potential to be indirectly impacted. Operational indirect impacts have been assessed with a duration of 35 years (25 years during the construction and operational period and an additional 10 years for rehabilitation to become established). In order to quantify the amount of indirect impact that would be required to be offset, the level of indirect impact was correlated with an equivalent area of direct impact. As such, a proportionate amount of vegetation removal can be calculated to correspond with the direct impact calculations presented above.

To undertake this calculation, all site, downstream and facilitated impacts were compared and quantified where possible, firstly without mitigation measures, and then with proposed mitigation measures. A buffer surrounding infrastructure was calculated that would contain all indirect impacts, pre-mitigation. Within the indirect impact buffer, the level of impact is not linear as it will be generally greater closer to the impact source and as such the vegetation within the buffer is not considered to be 100% affected. To account for these factors, a formula was applied to the buffered area to account for the reduction in habitat quality within the indirect impact buffer. This formula was applied to two scenarios; without and with mitigation measures in place. Details of the calculations are presented in **Table 31** and **Table 32** below.

The indirect impact values were then applied to each Plant Community Type, based on the ratio of direct impacts to each Plant Community Type (**Appendix A6**). This allowed for a value of indirect impact to each Plant Community Type which could then be subsequently applied to fauna habitat types and threatened flora individuals.

This method was adapted for the calculations of the Pilliga Mouse habitat. To calculate the indirect impact to Pilliga Mouse habitat, the proportion of indirect impact to native vegetation in the study area was applied to the area of direct impact to Pilliga Mouse habitat.

Table 31: Indirect impact buffer rationale

Infrastructure	Indirect impact buffer	Proportion of indirect impact buffer affected (without mitigation) (25%)	Proportion of indirect impact buffer affected (with mitigation) (10%)
Well pads	50 m	12.5 m	5 m
Gathering system / access tracks	10 m	2.5 m	1 m
Bibblewindi to Leewood infrastructure corridor	10 m	2.5 m	1 m
The Bibblewindi site	50 m	12.5 m	5 m
Workers accommodation at Westport	50 m	12.5 m	5 m
The Leewood property	As the majority of the indirect impacts would be contained within the Leewood boundary, the indirect impacts have only been calculated where the modelled 45 dB(A) noise boundary crosses the Leewood boundary.		
Seismic lines	Seismic lines are to be largely undertaken in previously cleared areas (e.g. roadsides) or in pasture/grassland. Seismic survey generally only require slashing of shrub and mid-storey layers and will minimise removal of canopy species. Due to nature of works (maximum width 3 m, slashing, short duration), no indirect impacts have been calculated.		
Leewood to Wilga Park power line	The underground power line would be installed within the existing gas pipeline easement. As no disturbance would occur outside of the easement, no indirect impacts have been calculated.		

Table 32: Indirect impact calculations

Infrastructure	Direct impact	Direct and indirect impact	Indirect impact
Well pads and balance tanks	1 ha x 430 = 430 ha	110 m x 110 m x 430 = 520.3 ha	90.3 ha

Infrastructure	Direct impact	Direct and indirect impact	Indirect impact
Gathering system / access tracks	10 m x 430 km = 430 ha	(10m + (1m x 2)) x 430 km = 516 ha	86 ha
Bibblewindi to Leewood infrastructure corridor	20 m width x 15.8 km length = 31.6 ha (construction footprint) Note that the actual vegetation disturbance is 26.7 ha due to previously cleared areas in corridor.	22 m width x 15.8 km length = 34.76 ha	3.16 ha
The Bibblewindi site	283 m x 565 m (approx.) = 16 ha	293 m x 575 m = 16.85 ha	0.85 ha
Workers accommodation at Westport	100 m x 300 m = 3 ha	110 m x 310 m = 1.41 ha	3.41 ha
The Leewood property	N/A	0.36 ha	0.36 ha
Total indirect impact			181.1 ha

Fragmentation calculations

To conceptualise fragmentation in the study area, an intactness analysis was performed. Intactness of a landscape is its 'naturalness' and is influenced by the proportion of native vegetation remaining and its patchiness (number of patches). An intactness input layer was developed by first dissecting all extant native vegetation patches with existing linear infrastructure (roads, easements and other cleared areas). Then, the equation below was applied to a 10 m gridcell layer at every point in the landscape. In each gridcell, all surrounding vegetation within a 5 km buffer was considered. Intactness was modelled for two scenarios; before development and with all development complete.

$$Intactness = [[(Native\ vegetation)_{Area}\ ] / [(Total)_{Area}]\ ]^{[1\ +\ (0.01\ *\ (no.\ patches)]}$$

Where:

$(Native\ vegetation)_{Area}$ = combined area of all native vegetation within the 5 km buffer

$(Total)_{Area}$ = area of a circle of 5 km radius

No. patches = number of patches in the 5 km radius (including those divided by existing linear infrastructure)

4.11.3 Cumulative impacts

Cumulative impacts of existing and proposed exploration and production appraisal activities associated with the Energy NSW coal seam gas exploration and appraisal program operated by the Proponent in the study region have been assessed under the TSC Act (ELA, 2013d) and the EPBC Act (ELA, 2013c). Further impact assessments have added to these reports to record subsequent impacts (ELA, 2014b, 2014c). The total cumulative impact from existing and proposed operations has been included in this assessment.

As the Pilliga is a unique biological, geological and geographic unit, most existing and proposed impacts in the study region by other companies or industries were not considered in the cumulative impact, except for Narrabri Coal Mine which adjoins the eastern edge of the Pilliga. Biodiversity values impacted by other activities in the study region are not equivalent to the values in the study area. Hence there is unlikely to be cumulative impacts from other activities on the biodiversity values that would be impacted in the study area.

The direct and indirect impacts of Narrabri Coal Mine were considered in the cumulative impact assessment for those biodiversity values that are present in the study area (ELA, 2014d). The Narrabri Coal Mine has directly and indirectly impacted on the Biometric Vegetation Type *Red Ironbark – Brown Bloodwood shrubby woodland of the Brigalow Belt South Bioregion* and the threatened flora species *Bertya opponens*. Both of these biodiversity values have been included in the cumulative impact assessment for this project, however they have not been included in the cumulative offset calculations as they do not directly relate to the project.

The direct and indirect impacts calculated for the project were added to the current cumulative impact values. As the direct and indirect impacts for the project are categorised by Plant Community Type, they were reassigned to the equivalent Biometric Vegetation Type in order to assess the impact in the study region (as Biometric Vegetation Types were the base unit used at the regional scale).

The Namoi regional vegetation mapping used in the cumulative impact assessment has been recently updated (ELA, 2013a) and was used to inform the cumulative impact assessments. Due to minor changes in the regional mapping unit areas, the existing impact values used for this assessment are slightly different to those published in previous cumulative impact reports (ELA, 2013d, 2014a).

The cumulative impact presented is a 'worst case' scenario as it uses the upper disturbance limits against each Plant Community Type as a base for direct impacts of the project which, as previously stated, are conservative.

4.12 Impacts to OEH estate

The study area adjoins Brigalow Nature Reserve, Brigalow State Conservation Area and Pilliga East CCA Zone 3 State Conservation Area and hence an assessment was undertaken using the Guidelines for developments adjoining land and water managed by DECCW (DECCW, 2010) to specifically address:

- The objectives of the reservation of the land.
- The nature of the impacts, including direct and indirect impacts.
- The extent of the direct and indirect impacts.
- The duration of the direct and indirect impacts.

The nature, extent and duration of impacts are assessed in **Section 6.12**.

4.12.1 Objectives of the reservation of the land

Brigalow Nature Reserve

The Brigalow Nature Reserve was established in December 1986. Nature Reserves were originally created for the purpose of protection of fauna, as they are considered to be areas of special scientific interest containing wildlife or natural environments or natural phenomena (NPWS, 2002). The Brigalow Nature Reserve is considered to be an important area as it was once part of an extensive conservation system of small nature reserves scattered throughout what is considered a 'transition zone' between the wet east and the arid western areas of eastern Australia (NPWS, 2002). The Brigalow Nature Reserve

has been subject to historical clearing, but now that it has been conserved, it is undergoing natural regeneration.

The Brigalow Nature Reserve is located approximately 20 kilometres from the township of Narrabri, and covers an area of 202 hectares. The area reserved contains significant remnant stands of *Acacia harpophylla* (Brigalow). The flora species *Lepidium aschersonii* (Spiny Peppercress), listed under the TSC Act and EPBC Act as vulnerable was identified within the Brigalow Nature Reserve in 1994. In addition to this, *Macropus dorsalis* (Black-striped Wallaby) was identified within the area in low numbers. This species is listed under the TSC Act as endangered. Field survey completed for this EIA identified a number of threatened birds and mammals within the Brigalow Nature Reserve (**Section 5.4.2**).

Pilliga East CCA Zone 3 State Conservation Area

The Pilliga East SCA was reserved in December 2005 and covers an area of approximately 24,000 ha.

The Pilliga East SCA was set aside under the NSW *Brigalow and Nandewar Community Conservation Area Act 2005.* This Act transferred the ownership of particular land within the Brigalow and Nandewar bioregions to the National Parks and Wildlife Service estate, a part of the Community Conservation Areas (CCAs). The purpose of CCAs are to reserve land for permanent conservation, protect areas of natural and cultural heritage to the Aboriginal people, and support sustainable forestry and mining.

Four CCA zones have been defined within the region, each with a different management emphasis. These zones are:

- Zone 1: Conservation and recreation (National Park)
- Zone 2: Conservation and Aboriginal culture (Aboriginal Area)
- Zone 3: Conservation, recreation and mineral extraction (State Conservation Area)
- Zone 4: Forestry, recreation and mineral extraction (State Forests)

The Pilliga East SCA within this impact assessment is reserved as a Zone 3 CCA (as defined above).

The Pilliga East SCA is contiguous with the Pilliga Nature Reserve, and the Willala Aboriginal Area which, as a whole, conserves significant examples of the largest intact native forest west of the Great Diving Range (NPWS, 2014). Important habitat for a number of threatened animal species is located within the Pilliga East SCA. Threatened animal species which uses the habitat available includes the Glossy Black-Cockatoo, Turquoise Parrot, Koala, Squirrel Glider and the Pilliga Mouse. A number of regionally significant birds and endemic Pilliga invertebrates are also present within the Pilliga East SCA.

Brigalow State Conservation Area

The Brigalow SCA was established in 2011, and covers an area of approximately 250 ha. It was reserved as an SCA to a depth of 100 m under the NPW Act. The Brigalow SCA is a surface development exclusion zone (including a buffer of at least 50 m) for the project. No surface infrastructure will be located within the Brigalow SCA or buffer. Wells drilled under from outside of the buffer must be at least 110 m deep under the Brigalow SCA.

4.13 Nomenclature

Botanical nomenclature in this report follows (Harden, 1992, 1993, 2002, 2000), with subsequent taxonomic updates from PlantNET (Royal Botanic Gardens and Domain Trust, 2016). Both scientific and common names (where available) are provided in this report and flora species lists can be found in **Appendix B**.

Names of Plant Community Types used in this report follow those listed in the NSW Vegetation Classification – Western Slopes Section (Benson et al., 2010) and the Biometric vegetation types database (OEH, 2012). Biometric vegetation types are a uniform set of vegetation descriptions which cover all of NSW. Biometric vegetation types are the foundation for assessment under BioBanking, BioCertification and the NV Act. Note that Biometric Vegetation Types for the Namoi CMA were updated in October 2014. Vegetation stratification, habitat stratification, population modelling and cumulative impacts are reported on for Biometric Vegetation Types October 2008, while offset calculations have been undertaken using Biometric Vegetation Types October 2014 in accordance with the NSW Biodiversity Offset Policy for Major Projects.

Vertebrate names used in this report follow the *Census of Australian Vertebrate Species* (database maintained by DotE) (DotE, 2013a) and the NSW BioNet Atlas of NSW Wildlife (OEH, 2016a). Common names and scientific names for fauna species are used throughout this report. Detailed fauna lists can be found in **Appendix C**.

4.14 Ethics

ELA holds a current Animal Research Licence, administered by the Animal Welfare Unit of NSW Department of Primary Industries. Variations to the current licence were required in order to undertake trapping for additional nights, use of fluorescent powder and ear notching.

The standard Animal Research Licence permits trapping up to a maximum of four consecutive nights. To improve trap success in an area of low density small mammal populations (such as western NSW), the number of trap nights in each trap location was increased up to eight nights during some surveys.

Fluorescent powder tracking provides an effective, efficient and non-invasive method to measure fine scale fauna movements, micro-habitat use, foraging behaviour, and to identify the locations of burrow/nest/shelters (Longland & Clements, 1995; McShea & Gilles, 1992; Stapp, Young, VandeWoude, & Horne, 1994). This method has been applied across a broad range of fauna guilds including mammals, reptiles, birds and amphibians and has been identified as safer, less invasive and less technical alternative to radio tracking. Further, this technique is inexpensive and easy to use, and the powder has been shown to have very low levels of toxicity (Stapp et al., 1994). Previous experience and published reports have shown that the powder tends to remain within the fur for no longer than 12 – 24 hours (Stapp et al. 1994, R. Armistead pers. comm.).

Ear notching involves the permanent removal of a 1 mm ear notch. It was undertaken by a suitably qualified and competent ecologist in accordance with the standard operating procedures outlined in *Permanent marking of mammals using ear notching* (DEC, 2009). An assessment of alternative methods to ear notching identified the removal and collection of hair root material. However, hair roots produce lower yields of DNA when compared to using ear notches (Peter Spencer pers. comm.).

4.15 Limitations

Surveys for this ecological assessment were undertaken over multiple seasons and years. However, the size of the study area (95,077 ha) precludes the ability to completely identify all species that occur in the study area. For many species already known to occur in the study area, the survey effort undertaken is justified given the assumed presence of these species.

It is likely that some species that utilise the study area were not recorded during field surveys due to the life cycle and behaviour of species, duration or timing of the survey and other environmental factors. In particular, environmental and season factors were observed to play a large role in the number of

threatened flora recorded during each year. In dry years, the number of orchids recorded was a small portion of the number recorded in previous, wetter seasons.

The list of species recorded from this study provides an indication of the species present at the time of the surveys. A precautionary approach has been implemented to satisfactorily address the potential presence of threatened species. Those species which had been previously recorded in or near the study area during other surveys were assumed to be present for the purposes of this assessment.

The locations of field surveys were also restricted by site access, either by access to private property, or avoidance of active forestry areas. In particular, it was not possible to complete biometric plots in the Weeping Myall community in the north of the study area due to restricted access to private property.

5 Results

5.1 Literature review

The literature review provided substantial data on threatened species and their associated habitats in the study area. The additional survey effort was undertaken during all seasons and across multiple years, contributing to a more thorough understanding of temporal and spatial variation of biodiversity values. The timing of additional flora and fauna survey effort included in the literature review is presented in **Appendix A4**.

Habitat associations for those threatened species that were identified as being recorded in the study area were obtained by either reviewing the habitat types or habitat features found to be utilised by each recorded threatened species. This was either through habitat descriptions provided in reports, or correlation with spatial data when the accuracy of the species location was sufficient. Habitats in which a species was found were recorded as 'known habitat' and habitats that have features that could support a species were recorded as 'predicted habitat'. Threatened species identified as being recorded in the study area during the literature review have been included in the overall fauna habitat assessment and are presented in **Figure 13** and **Figure 14**.

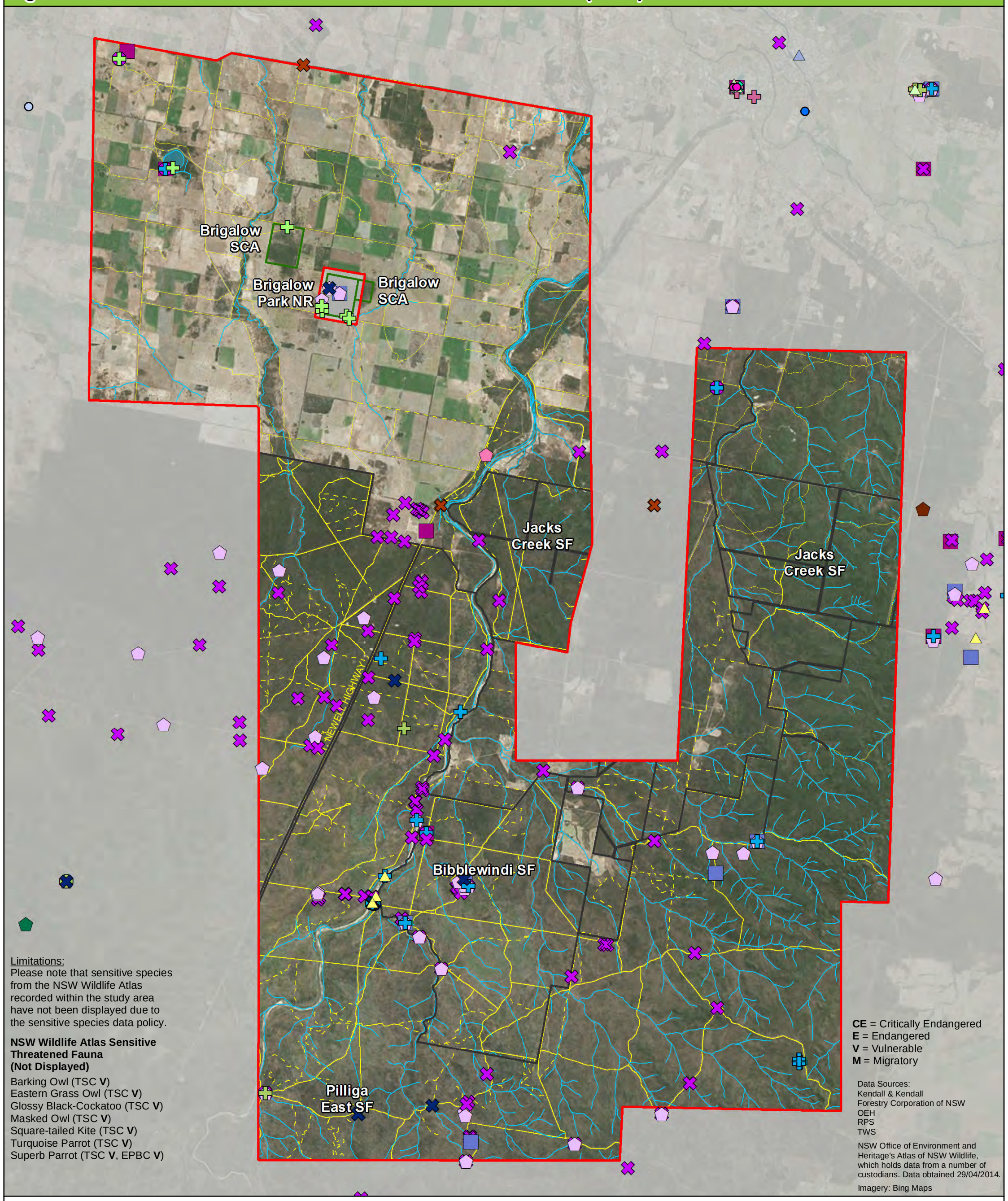
5.2 Database review

The likelihood table (**Appendix I**) includes 95 fauna species, 28 flora species and 11 threatened ecological communities. The database review also provided spatial data on vegetation mapping, geological features and geographical features to assess habitat potential in the study area. Spatial data was used to locate survey sites, and to build vegetation, habitat and sensitivity mapping for the study area.

5.3 Flora survey

A total of 807 species from 93 plant families were recorded from the 327 biometric plots surveyed across the study area (**Appendix B**). Of these, 116 (14%) were exotic. The families which have the greatest representation in the study area include Poaceae (144 species), Asteraceae (94 species), Fabaceae Faboideae (46 species), Myrtaceae (39 species), Cyperaceae (31 species), Fabaceae Mimosoideae (30 species), Chenopodiaceae (25 species), Orchidaceae (24 species) and Goodeniaceae (16 species).103

Figure 13: Threatened fauna - literature and data review results (birds)



Limitations:
Please note that sensitive species from the NSW Wildlife Atlas recorded within the study area have not been displayed due to the sensitive species data policy.

NSW Wildlife Atlas Sensitive Threatened Fauna (Not Displayed)

Barking Owl (TSC **V**)
Eastern Grass Owl (TSC **V**)
Glossy Black-Cockatoo (TSC **V**)
Masked Owl (TSC **V**)
Square-tailed Kite (TSC **V**)
Turquoise Parrot (TSC **V**)
Superb Parrot (TSC **V**, EPBC **V**)

CE = Critically Endangered
E = Endangered
V = Vulnerable
M = Migratory

Data Sources:
Kendall & Kendall
Forestry Corporation of NSW
OEH
RPS
TWS

NSW Office of Environment and Heritage's Atlas of NSW Wildlife, which holds data from a number of custodians. Data obtained 29/04/2014.

Imagery: Bing Maps

Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Threatened birds
TSC & EPBC Act Listing
(Kendall & Kendall, OEH, RPS and TWS)

- Australasian Bittern (TSC **E**, EPBC **E**)
- Australian Painted Snipe (TSC **E**, EPBC **E**)
- Bush Stone-curlew (TSC **E**)
- Cattle Egret (EPBC **M**)
- Diamond Firetail (TSC **V**)
- Freckled Duck (TSC **V**)
- Glossy Ibis (EPBC **M**)
- Grey-crowned Babbler (eastern subspecies) (TSC **V**)
- Hooded Robin (SE form) (TSC **V**)
- Latham's Snipe (EPBC **M**)
- Little Eagle (TSC **V**)
- Little Lorikeet (TSC **V**)
- Magpie Goose (TSC **V**)
- Painted Honeyeater (TSC **V**, EPBC **V**)
- Rainbow Bee-eater (EPBC **M**)
- Red-tailed Black-Cockatoo (inland subsp.) (TSC **V**)
- Regent Honeyeater (TSC **CE**, EPBC **CE**)
- Speckled Warbler (TSC **V**)
- Spotted Harrier (TSC **V**)
- Varied Sittella (TSC **V**)
- White-throated Needletail (EPBC **M**)

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

N

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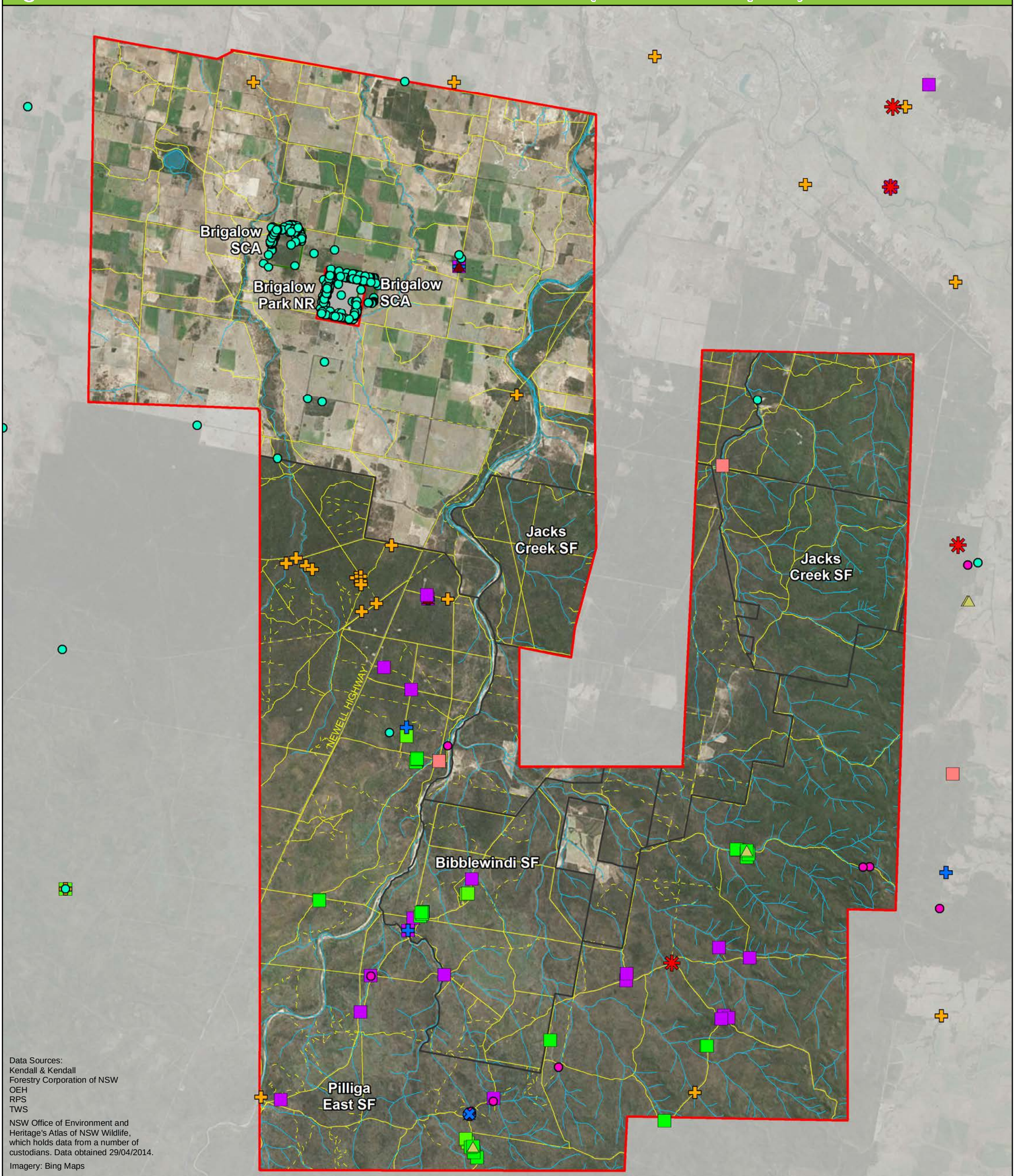
Figure 14: Threatened fauna - literature and data review results (mammals and reptiles)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Threatened mammals
TSC & EPBC Act Listing
(Kendall & Kendall, OEH, RPS and TWS)

- Black-striped Wallaby (TSC **E**)
- Corben's Long-eared Bat(TSC **V**, EPBC **V**)
- Eastern Cave Bat (TSC **V**)
- Eastern Cave Bat - probable (TSC **V**)
- Eastern Pygmy-possum (TSC **V**)
- Koala (TSC **V**, EPBC **V**)
- Little Pied Bat (TSC **V**)
- Little Pied Bat - probable (TSC **V**)
- Pilliga Mouse (TSC **V**, EPBC **V**)
- Squirrel Glider (TSC **V**)
- Yellow-bellied Sheathtail-bat (TSC **V**)

Threatened reptiles
TSC & EPBC Act Listing (OEH and TWS)

- Pale-headed Snake (TSC **V**)

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

E = Endangered
V = Vulnerable

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5.3.1 Plant community types

A total of 22 Plant Community Types (totalling 80,398 ha of native vegetation) including one previously undescribed vegetation community were mapped in the study area (**Table 33** and **Figure 15**). The corresponding Biometric Vegetation Types (2008 and 2014) are also included in **Table 33** and the Biometric Vegetation Types (2008) are shown on **Figure 16**.

Plant community type ID40X (*White Bloodwood – Dirty Gum (Baradine Gum) – Rough Barked Apple – Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests*) does not correspond with the Plant Community Types of the NSW Vegetation Classification Assessment, however this community is most closely related to Plant Community Type ID405 (*White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions*). A supplementary description of this community has been developed based on the cover-abundance of species recorded within biometric plots. The plant community type ID379 *Inland Scribbly Gum - White Bloodwood – Red Stringybark – Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion* is considered a variation of ID 405 and has been presented that way in the descriptions (**Appendix D**).

A detailed report on the identification and mapping of vegetation is contained within **Appendix F2**.

Table 33: Summary of Plant Community Types identified in the study area

Plant Comm. ID	BVT ID (Oct 2008)	BVT ID (Oct 2014)	Plant community type	Total area mapped (ha)
27	NA219	NA219	Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions	209.26
35	NA117	NA117	Brigalow – Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion	6,695.19
55	NA102	NA102	Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions	678.94
78	NA193	NA193	River Red Gum riparian tall woodland / open forest wetland in the Nandewar and Brigalow Belt South Bioregions	10.49
88	NA179	NA179	Pilliga Box - White Cypress Pine - Buloke shrubby woodland in the Brigalow Belt South Bioregion	5,946.61
141	NA121	NA121	Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion	1,034.76
202	NA141	NA141	Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South (including Pilliga) and Nandewar Bioregions	589.82
256	NA143	NA292	Green Mallee tall mallee woodland on rises in the Pilliga - Goonoo regions, southern BBS Bioeregion	20.33

Plant Comm. ID	BVT ID (Oct 2008)	BVT ID (Oct 2014)	Plant community type	Total area mapped (ha)
379	NA124	NA294	Inland Scribbly Gum - White Bloodwood – Red Stringybark – Black Cypress Pine shrubby sandstone woodland mainly of the Warrumbungle NP - Pilliga region in the BBS Bioregion. (See vegetation description for ID405).	103.56
397	NA179	NA324	Poplar Box – White Cypress Pine shrub grass tall woodland of the Pilliga - Warialda region, BBS Bioregion	762.80
398	NA227	NA314	Narrow-leaved Ironbark – White Cypress Pine - Buloke tall open forest on lower slopes and flats in the Pilliga Scrub and surrounding forests in the central north BBS Bioregion	23,975.35
399	NA197	NA255	Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, BBS Bioregion	1,093.46
401	NA197	NA338	Rough-barked Apple - red gum - cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region	7,580.41
402	NA160	NA307	Mugga Ironbark - White Cypress Pine - gum tall woodland on flats in the Pilliga forests and surrounding regions, BBS Bioregion	358.20
404	NA124	NA326	Red Ironbark - White Bloodwood -/+ Burrows Wattle heathy woodland on sandy soil in the Pilliga forests	9,982.48
405	NA124	NA390	White Bloodwood - Red Ironbark - cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions	6,650.54
406	NA124	NA389	White Bloodwood – Motherumbah - Red Ironbark shrubby sandstone hill woodland / open forest mainly in east Pilliga forests	3,232.39
408	NA124	NA279	Dirty Gum (Baradine Gum) –Black Cypress Pine - White Bloodwood shrubby woodland on of the Pilliga forests and surrounding region	3,188.25
418	NA179	NA409	White Cypress Pine - Silver-leaved Ironbark - Wilga shrub grass woodland of the Narrabri-Yetman region, BBS Bioregion	131.59
425	NA121	NA363	Spur-wing Wattle heath on sandstone substrates in the Goonoo – Pilliga forests Brigalow Belt South Bioregion	366.69
428	NA126	NA267	Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion	15.03

Plant Comm. ID	BVT ID (Oct 2008)	BVT ID (Oct 2014)	Plant community type	Total area mapped (ha)
40X	NA124	NA390	White Bloodwood – Dirty Gum (Baradine Gum) – Rough Barked Apple –Black Cypress Pine heathy open woodland on deep sand in the Pilliga forests	7,772.16
Other			Includes cleared, creek bed, dams and improved pasture	14,678.37
Total				**95,076.68**

5.3.2 Threatened ecological communities

Four of the mapped Plant Community Types qualify as endangered ecological communities (with two of these endangered ecological communities being further divided by status under the EPBC Act and TSC Act due to condition). **Table 34** provides a summary of the area of each endangered ecological community in the study area and **Figure 17** shows endangered ecological communities in relation to the study area.

- ID27 Weeping Myall open woodland of the Darling Riverine Plains and Brigalow Belt South Bioregions. Remnant patches that are > 5 ha in size and have > 5% canopy cover qualify as 'Weeping Myall Woodlands' under the EPBC Act and 'Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions' under the TSC Act (DotE, 2014c; OEH, 2014c). Areas of ID27 with scattered trees also qualify as the TSC Act listed community. Areas of derived native grassland attributed with ID27 do not qualify as an endangered ecological community.
- ID35 Brigalow – Belah open forest / woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion. Remnant patches of ID35 that have not been cleared for over 15 years qualify as 'Brigalow (*Acacia harpophylla* dominant and co-dominant)' under EPBC Act and as 'Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions' under the TSC Act. Areas of ID35 that do not meet this requirement may still be considered the TSC Act listed community provided there is regenerating Brigalow present. Areas of derived native grassland attributed with ID35 do not generally qualify as an endangered ecological community.
- ID 202 Fuzzy Box woodland on colluvium and alluvial flats in the Brigalow Belt South (including Pilliga) and Nandewar Bioregions is listed as 'Fuzzy Box Woodland on alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions' under TSC Act (OEH, 2016b).
- ID428 Carbeen - White Cypress Pine - Curracabah - White Box tall woodland on sand in the Narrabri - Warialda region of the Brigalow Belt South Bioregion is listed as 'Carbeen Open Forest community in the Darling Riverine Plains and Brigalow Belt South Bioregions' under the TSC Act (OEH, 2016b).

Table 34: Endangered Ecological Communities

Plant Comm. ID	Endangered ecological community	TSC Act area (ha)[#]	EPBC Act area (ha)
27	Weeping Myall Woodlands (EPBC Act)	36.00	32.52

Plant Comm. ID	Endangered ecological community	TSC Act area (ha)#	EPBC Act area (ha)
	Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions (TSC Act)		
35	Brigalow (*Acacia harpophylla* dominant and co-dominant) (EPBC Act) Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions (TSC Act)	2,467.97	2,447.35
202	Fuzzy Box Woodland on alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions (TSC Act)	588.4	N/A
428	Carbeen Open Forest community in the Darling Riverine Plains and Brigalow Belt South Bioregions (TSC Act)	15.03	N/A
Total		3,107.40	2,479.87

TSC Act area includes the EPBC Act area

White Box Yellow Box Blakely's Red Gum Woodland (TSC Act) was not found to be present in the study area because the assemblage of species and soil type was not consistent with that found in the Final Determination. Specifically, the subject plots investigated contained a low number and frequency of characteristic species. In addition, most of the characteristic species recorded in the subject plots also occurred in higher frequencies in other vegetation communities in the study area. The *E. blakelyi* woodland as assessed by the subject plot data conformed to Red gum – Rough barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga – Goonoo sandstone forests, BBS Bioregion which is restricted in extent but not threatened (Benson et al., 2010).

White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (EPBC Act) was also found not identified in the study area because the assemblage of species and soil type was not consistent with the general description of this community in the listing advice.

Details of this assessment are presented in **Appendix F1**.

5.3.3 Noxious weeds

Only eight of the 116 exotic species recorded in the study area are declared noxious weeds within the Narrabri Local Government Area (DPI, 2014a). Noxious weed species recorded are included in **Table 35**.

Table 35: Noxious weeds in the Narrabri Local Government Area

Species	Common Name	Class	Legal Requirement
Argemone ochroleuca	Mexican Poppy	5	The requirements for a notifiable weed must be complied with
Cestrum parqui	Green Cestrum	3	The plant must be fully and continuously suppressed and destroyed
Heliotropium amplexicaule	Blue Heliotrope	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread

Species	Common Name	Class	Legal Requirement
Lycium ferocissimum	African Boxthorn	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread and the plant must not be sold, propagated or knowingly distributed
Opuntia aurantiaca, O. stricta and *O. tomentosa*	Prickly Pear	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread and the plant must not be sold, propagated or knowingly distributed
Phyla canescens	Lippia	4	The plant must not be sold, propagated or knowingly distributed except incidentally in hay or lucerne

5.3.4 Threatened flora species

The majority of threatened plant species recorded during the course of fieldwork for this assessment were either not known or poorly known in the study area prior to the surveys that commenced in late 2010. Detailed surveys and additional population modelling, where appropriate, indicate that some of these species are relatively common in the study area and broader region. Specific details for each species are discussed below and locations of records in the study area are presented in **Figure 18**.

Bertya opponens (TSC –V; EPBC – V)

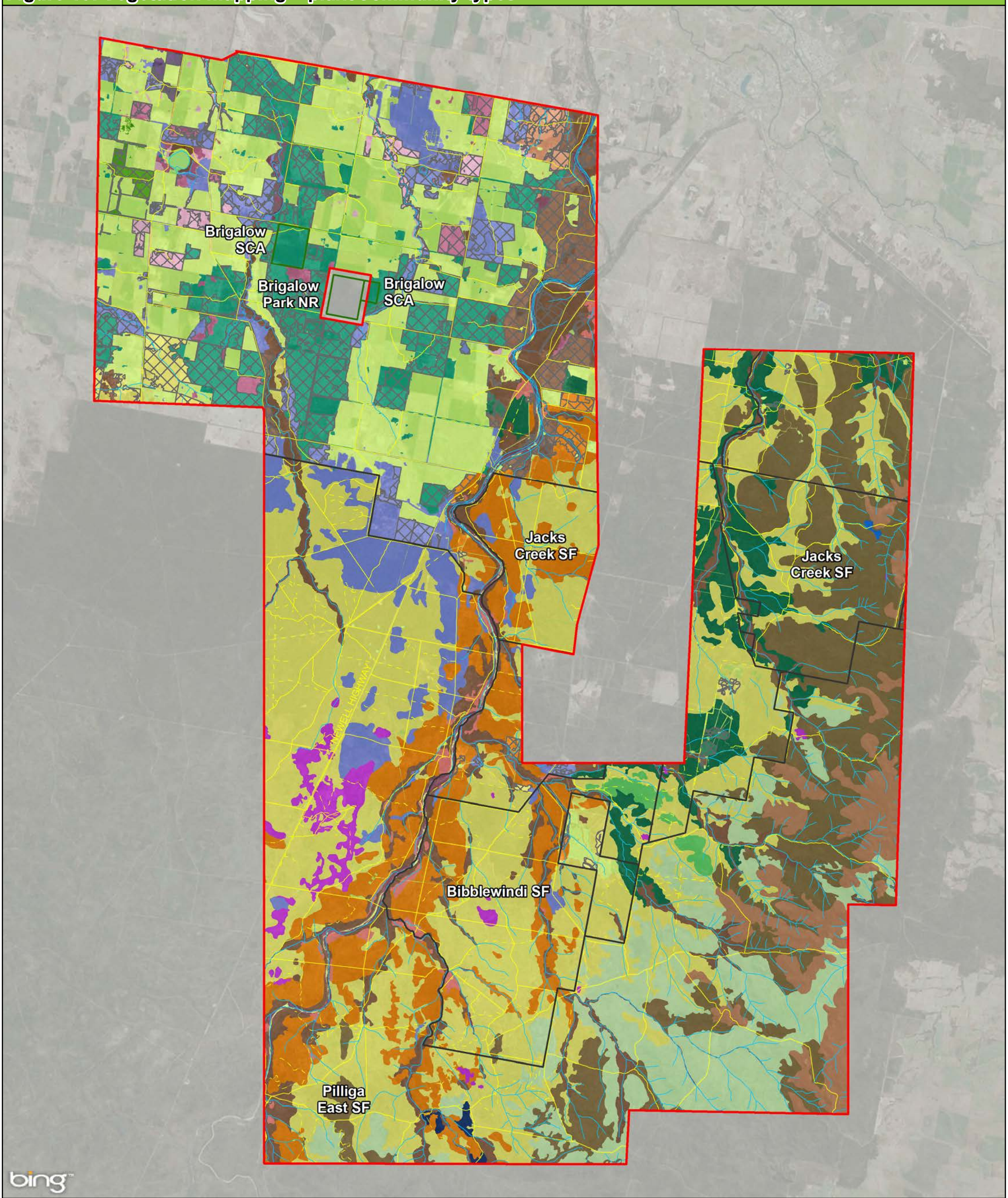
Bertya opponens was moderately well known from the study area prior commencing survey work. The species had been recorded on six occasions, mostly from just within or just outside the eastern boundary of the study area, and an isolated collection had been made along the Newell Highway approximately 12 km to the north-west of those records (Council of Heads of Australasian Herbaria, 2014; OEH, 2016a). A study of population numbers had also been undertaken, with Austen (1999) estimating the Jacks Creek State Forest population to consist of at least 5,000,000 plants scattered over several square kilometres. This estimate was made after counting the number of individuals in 10 quadrats and extrapolating the average number over the entire area of occupancy.

As only part of the population surveyed by Austen (1999) occurs in the study area ELA botanists undertook a targeted survey of *Bertya opponens* with the aim of estimating the population size within the study area and determining the spatial characteristics of the population. The targeted survey confirmed that the largest occurrence of *B. opponens* towards the eastern edge of the study area does appear to form one large contiguous population of varying density rather than a series of discrete populations. The variation in density calculated at each strip transect was high and fluctuated from 0 to 601 individuals per 0.1 ha (average 258) with the highest number of individuals located along existing tracks and associated with disturbance. A slight outlier record to the west (OEH, 2016a), for which there is no available population data, was not included in the population surveyed. The isolated occurrence of *B. opponens* along the Newell Highway comprises only about five adults plants (L. Copeland pers. comm.). From the targeted surveys a total estimated population size of 956,861 individuals for the study area was calculated.

Other than the Pilliga forest population, only two additional populations are known to occur in NSW, both near Cobar. When last assessed in 1999 the population on 'Nurrungal' consisted of 500-600 adult plants, whilst the population on 'Windera Station' is now believed to be extinct (NPWS, 2002). The population within Jacks Creek State Forest and adjoining private land is the most significant population of *Bertya opponens* in NSW and critical to the long term persistence of the species in the state. If the estimated 5,000,000 plants occurring in Jacks Creek State Forest is accurate, approximately 20% of the the main

population occurs within the study area. The species is known from numerous locations in central Queensland.

Figure 15: Vegetation mapping – plant community types



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Plant community types (ELA 2014)

- 0 (other)
- 27
- 35
- 55
- 78
- 88
- 141
- 202
- 256
- 379
- 397
- 398
- 399
- 401
- 402
- 404
- 405
- 406
- 408
- 40X
- 418
- 425
- 428
- DNG

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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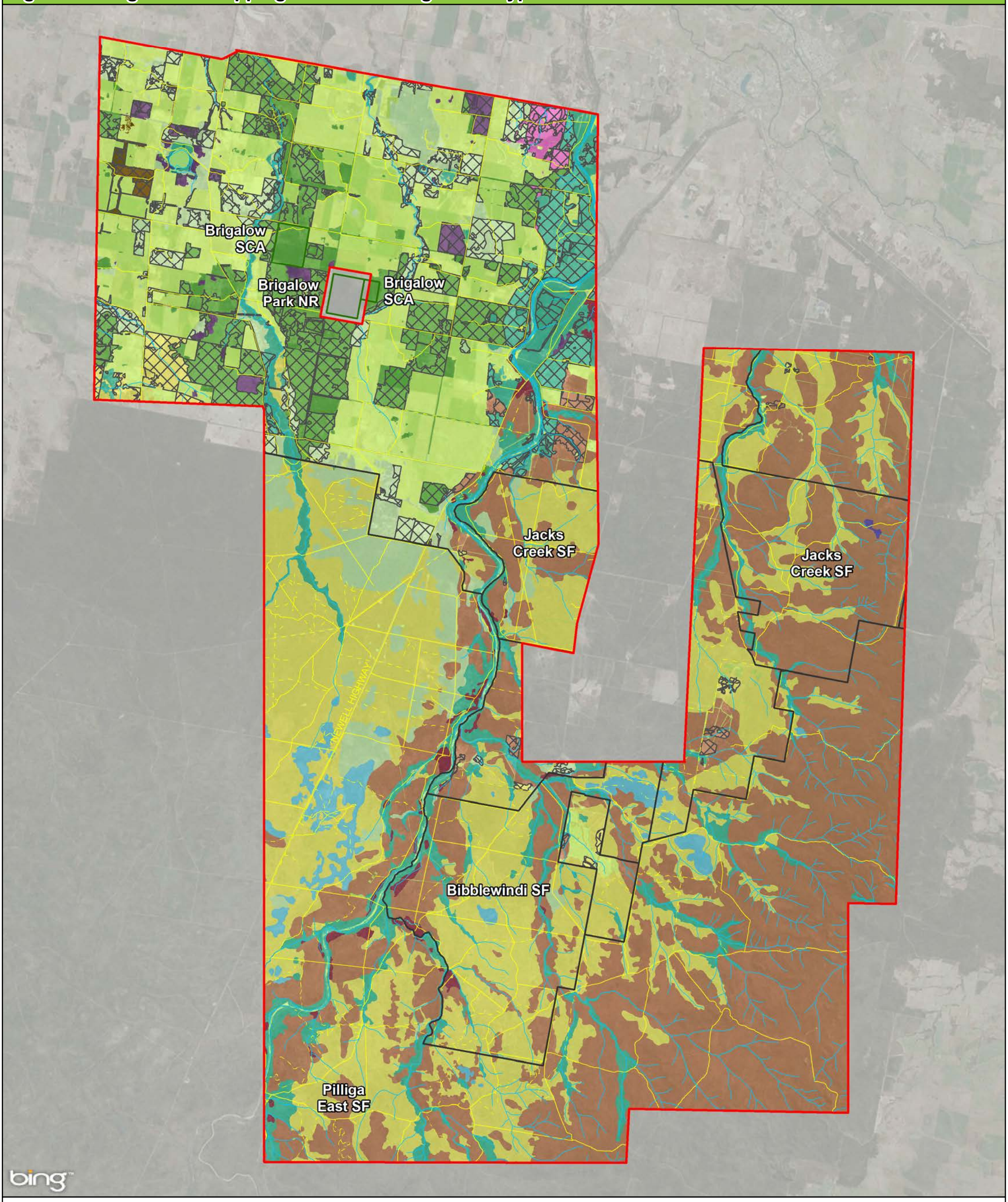
Figure 16: Vegetation mapping – biometric vegetation types



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Biometric vegetation types (ELA 2014)

- 0 (other)
- NA102
- NA117
- NA121
- NA124
- NA126
- NA141
- NA143
- NA160
- NA179
- NA193
- NA197
- NA219
- NA227
- DNG

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH

Imagery: Bing Maps

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Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions (TSC Act)

Carbeen Open Forest community in the Darling Riverine Plains and Brigalow Belt South Bioregions (TSC Act)

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Diuris tricolor (Pine Donkey Orchid, Painted Diuris) (TSC – V)

According to data from the Atlas of NSW Wildlife supplied by OEH at the commencement of surveys, the nearest record to the study area was approximately 150 km to the south west. However, recent review of the Australian Virtual Herbarium has identified a single pre-2010 collection of *Diuris tricolor* within or near the boundary of the study area (Council of Heads of Australasian Herbaria, 2014). Three unvouchered pre-2010 records had also been made nearby to the west (OEH, 2016a). The species was initially located in the study area opportunistically by ELA botanists in late 2011. Random meanders and fixed transects were undertaken during the 2010/11 phase of fieldwork and further transects surveyed in potential habitat at peak flowering in spring 2012. During that period of fieldwork nine individuals were recorded within the southern third of the study area, and two outside the study area to the south-west and west. The low numbers of *D. tricolor* located indicates a scattered occurrence in the locality. The modelled population estimate for the study area is 3,353 individuals (lower 95% confidence interval 1,743 individuals, upper 95% confidence interval 6,444 individuals).

Diuris tricolor is sporadically distributed on the western slopes of NSW, extending from south of Narrandera to the far north of NSW (OEH, 2016b). Based on current records (OEH, 2016a) the Pilliga forest population is separated from the nearest population to the south by approximately 100 km, and inter-population gene flow is likely to be absent or very limited. The broader Pilliga forest population of *D. tricolor* (including the study area occurrences) is regarded as significant because of its geographic separation and small number of individuals recorded. . Throughout the range of the species in NSW it is usually recorded as common and locally frequent in populations (OEH, 2016a), however in the study area only solitary plants were observed at sites. *D. tricolor* also occurs in Queensland and has a very restricted occurrence in Victoria where it is listed as endangered.

Lepidium aschersonii (Spiny Peppercress) (TSC – V; EPBC – V)

Prior to commencing survey work for this assessment there were 29 records (from approximately 9 subpopulations) for the species in the study area (OEH, 2016a). All of these records were concentrated within and around Brigalow Nature Reserve and Brigalow State Conservation Area. Although the dry conditions were not favourable for detection of the species during fieldwork in the north-western part of the study area in 2013 and 2014, 208 individuals (from four sub-populations) were recorded by ELA botanists. Two of these subpopulations were from within Brigalow Nature Reserve, one from 3 km north and another from 4 km south east of Brigalow Nature Reserve. These additional records have added considerably to the knowledge of the species in the study area.

Lepidium aschersonii has two main centres of distribution in NSW, one in the south near West Wyalong, Barmedman and Temora, and another in the north, which includes the populations within the study area. A population near Dubbo lies between these two main centres of distribution. Based on information provided in the National Recovery Plan (Carter, 2010) the occurrences within the study area are highly significant as they are likely to be the largest known extant populations. They constitute the major proportion of extant records from the northern centre of distribution of the species in NSW. Most of the records from the southern centre of distribution in NSW are old (OEH, 2016b), underlining the importance of the northern populations. The species also occurs in Victoria and Western Australia, though it is not known whether it is extant in the latter (Carter, 2010).

Lepidium monoplocoides (Winged Peppercress) (TSC – E; EPBC – E)

Lepidium monoplocoides was not known from the study area prior to commencing survey work, however it was recorded from nearby in the Pilliga National Park and adjoining Pilliga State Conservation Area soon after (Bell, Hunter, & Montgomery, 2012; ELA, 2012c). During the course of vegetation sampling 258 individuals (from three subpopulations) were recorded by ELA botanists within the study area towards the northern boundary, south west of Narrabri. The species is difficult to detect and given the dry

conditions at the time when suitable habitat was surveyed, it is possible that the species is more frequent in the north-western section of the study area than current records indicate.

Lepidium monoplocoides occurs in north-western Victoria and South Australia, southern Queensland, and is widely distributed in semi-arid plains regions of NSW. The populations in the Pilliga region are located some 200 km distant from the nearest population. Although it has been recorded from a considerable number of sites, populations are often localised. In addition some populations are extinct or their status uncertain. The National Recovery Plan (DSE, 2010) estimates that the total population size is less than 3,000 plants each in Victoria and New South Wales, though populations from the Pilliga region were not known at that time. Although the population within the study area may not be large, it should be regarded as significant until further data clarifies the extent and size of populations in the greater Pilliga region.

Myriophyllum implicatum (TSC – CE)

Myriophyllum implicatum was considered possibly extinct in NSW until it was rediscovered in Pilliga National Park by NSW Herbarium botanists in 2008. Subsequent surveys of ephemeral wetlands in the Pilliga National Park and adjoining Pilliga State Conservation Area undertaken in spring-summer 2010-2011 (Bell et al., 2012) found the species at four sites. A further NSW herbarium record from this general area was made in 2012 (Council of Heads of Australasian Herbaria, 2014). All of these records are to the west or south west of the study area. The first record for the study area was made opportunistically by ELA botanists in January 2014 on private property approximately 18 km south west of Narrabri. The plants were dead and partially disintegrated at the time of survey due to the prevailing drought conditions. As identification of specimens was not possible in the field, population estimates were not made, though potential habitat for the species at the collection locality has been mapped. Appropriately timed targeted survey following adequate rainfall events would enable population estimates to be made.

The population of *Myriophyllum implicatum* in the study area, along with those in the Pilliga National Park and adjoining Pilliga State Conservation Area, and one from near Brewarrina located in 2010 are the only known extant populations in NSW. A historical record from the NSW north coast region has not been recollected in recent years. Within the general Pilliga region *Myriophyllum implicatum* has a highly specialised habitat, occurring in shallow basin wetlands (sensu (Bell et al., 2012)), though the original 2008 collection was noted as occurring in a tank gilgai wetland. More extensive areas of potentially suitable habitat occur to the west of the study area between Pilliga National Park and Pilliga (Bell et al., 2012), and further survey work within this area, particularly to the west of the area surveyed by Bell et al. (2012), would help to clarify the abundance of *Myriophyllum implicatum* in the general Pilliga region. Until there is greater clarity the record from within the study area should be treated as highly significant. The species is not threatened in Queensland, where it is known from scattered near-coastal and inland locations from the NSW border northward to Cape York and the Gulf of Carpentaria (Council of Heads of Australasian Herbaria, 2014).

Polygala linariifolia (TSC – E)

According to data from the Atlas of NSW Wildlife supplied by OEH at the commencement of surveys, the nearest record to the study area was 122 km to the north-east. However, recent review of the Australian Virtual Herbarium and BioNet has identified several pre-2010 records of *Polygala linariifolia* in the vicinity of the study area. Specifically, an unvouchered record of *Polygala linariifolia* had been made in the south west corner of the study area, several unvouchered records had been made to the west-south west of the study area and a specimen had been collected from approximately 15 km north-east of Narrabri (Council of Heads of Australasian Herbaria, 2014; OEH, 2016a).

The species was initially opportunistically located in the study area by ELA botanists in late 2010. Random meanders and fixed transects were undertaken during the 2010/11 phase of fieldwork and further

transects surveyed in potential habitat in 2012. During the fieldwork it became apparent that rainfall history has a major influence on the detection of the species, with much larger numbers being located following significant rainfall events. A total of 1,475 plants were recorded within the study area from scattered locations predominantly in the southern third of the study area. The modelled population estimate for the study area is 16,317 individuals (lower 95% confidence interval 8,187 individuals, upper 95% confidence interval 28,095 individuals). The species was also recorded at eight locations outside the study area, each consisting of one to many individuals.

The broader Pilliga forest population of *Polygala linariifolia*, (including the study area occurrences) is significant because it is at the southern limit of the geographic range of the species. The species extends northward as scattered populations in the north-western slopes and north coast (mostly north of Grafton) divisions of NSW. There is also an isolated occurrence in far western NSW near Weebah Gate (OEH, 2016b). The NSW populations link up with those in Queensland where it is widely distributed and not listed as threatened.

Pomaderris queenslandica (Scant Pomaderris) (TSC – E)

Pomaderris queenslandica had not been recorded from the study area at the commencement of surveys, however there were records from within approximately 20 km of the north-east boundary of the study area (Council of Heads of Australasian Herbaria, 2014; OEH, 2016a). Opportunistic records of the species were made by ELA botanists in the north-eastern section of study area in 2012. Subsequently in 2014 a targeted survey of *P. queenslandica* was undertaken within the study area to determine the spatial characteristics of the population and to estimate the overall population size. Through this survey work it has become apparent that the species is restricted to north-eastern section of study area where it occurs in three separate areas. Within these areas the species occurs predominantly as small scattered subpopulations. From the targeted surveys a total estimated population size of 45,518 individuals for the study area was calculated.

Most NSW populations of *Pomaderris queenslandica* occur towards the Queensland border, north and north-west of Armidale, in near-coastal areas between Newcastle and Coffs Harbour, north and south of Dubbo, and between Muswellbrook and Gulgong (OEH, 2016a). The populations in the study area and others occurring approximately 20 km to the north-east towards Mt Kaputar and near Boggabri form a loose cluster separated from the nearest population by a significant distance of over 100 km. Until further information on the size of populations near Mt Kaputar and Boggabri is available, the population within the study area should be regarded as significant due to its considerable size and habitat quality. The species also occurs in Queensland, however it is not listed as threatened in that state.

Pterostylis cobarensis (Cobar Rustyhood) (TSC – V; EPBC – delisted)

A solitary record of *Pterostylis cobarensis* was known from just north of the study area when ELA commence survey work. Although the collection was made by a reliable source it was treated with some uncertainty as it was an old record, over 200 km from the nearest record of the species and outside of the known distribution of the species as understood at that time. The species was initially opportunistically located in the study area by ELA botanists in spring 2011. Random meanders and fixed transects were undertaken during the 2011 phase of fieldwork and further transects surveyed in potential habitat during the peak flowering period in 2012. During that period of intensive fieldwork 240 individuals were recorded within the study area. Almost all records were made in the southern third of the study area, with few isolated records near the north-western edge of the forested section of the study area. The modelled population estimate for the study area is 431,718 individuals (lower 95% confidence interval 338,850 individuals, upper 95% confidence interval 549,833 individuals). The species was also recorded on 170 occasions to the west and south of the study area boundary, each record consisting of one to many individuals.

The relationship of *P. cobarensis* to some related species and anomalous populations is still unresolved and opinions differ on the morphological limits of the species. OEH (2014a, 2014c) consider the species to be restricted to three main areas of distribution in NSW – north-east of Broken Hill, within approximately 100 km of Cobar, and in the Pilliga forest. However, Council of Heads of Australasian Herbaria (2014) include additional collections (many of which have been determined by orchid taxonomist David Jones) under *P. cobarensis*, such as those scattered between Mildura and Sydney and south of Wagga Wagga. Beyond NSW the species extends westward into semi-arid South Australia and northward into southern Queensland. Although initially listed as threatened under the EPBC Act, the species was delisted in 2013 on the basis of its geographic distribution not being limited and no evidence of decline (TSSC, 2010). Further taxonomic resolution is required before there can be clarity about the distribution and conservation status of the species. The population occurring in the Pilliga region (including the study area) is of significance because of its size and the quality of the habitat in which it occurs.

Commersonia procumbens (TSC – V; EPBC – V)

Commersonia procumbens was not known from the study area prior to commencing survey work, however it had been recorded just south in Pilliga Nature Reserve (OEH, 2016a). Several other pre-2010 records had been made to the south and west within 50 km of the study area boundary. The species was initially opportunistically located in the study area by ELA botanists in early 2011 and population counts and random meanders in suitable habitat were made at that time. Targeted transect surveys were undertaken in spring 2012 and additional population counts made opportunistically in late 2013 and early 2014. All records are from the far south eastern corner of study area, where they were found predominantly along the edge of tracks and recently burnt areas. A total of 359 individuals were recorded within the study area and the modelled population estimate for the study area is 240,274 individuals (lower 95% confidence interval 90,799 individuals, upper 95% confidence interval 857,601 individuals). ELA botanists also recorded *R. procumbens* at 37 sites (comprising seven sub-populations) to the south of the study area boundary.

Commersonia procumbens is endemic to NSW. Beyond the Pilliga area populations are known from north-east of Narrabri, the Dubbo–Medooran–Gilgandra region, south of Cobar, and the upper Hunter Valley (OEH, 2016a; TSSC, 2008). The broader Pilliga region population of *R. procumbens* (including the study area occurrences) is regarded as significant on the basis of its considerable size, habitat quality and lack of population size data for other known sites in NSW.

Tylophora linearis (TSC – V; EPBC – E)

Tylophora linearis had not been recorded from the study area prior to commencing survey work, however it had been recorded at three sites within approximately 50 km south and south west of the study area (OEH, 2016a). The species was initially opportunistically located in the study area by ELA botanists in 2011. Targeted transect surveys for the species were undertaken in 2011 and 2012, and additional records were made as part of other studies between 2012 and 2014. A total of 376 individuals were recorded, all within the southern half study area. The total population estimate for the study area is 33,154 individuals (lower 95% confidence interval 25,739 individuals, upper 95% confidence interval 44,712 individuals). On the basis of population data presented by the NSW Scientific Committee (NSW Scientific Committee, 2008) and the technical report, this would be the largest population known in NSW. ELA botanists also recorded *T. linearis* at 30 sites (mostly comprising individual plants) to the west and south of the study area boundary. During survey work plants were commonly observed to be clonal, with numerous stems arising within an radius of up to 5 m. These clonal masses were assumed to be individual plants, rather than each stem representing an individual plant, a view supported by NSW Scientific Committee (NSW Scientific Committee, 2008). A greater understanding of the ecology of the species was gained through work in the Pilliga region, which revealed that although *T. linearis* occurs in a broad range

of vegetation types in the area; it was most often found in areas heavily burnt by the 2007 wildfire, along track edges and in recently cut road drains.

In NSW *Tylophora linearis* is known from relatively few scattered populations in the western slopes division, from Temora in the south to near Yetman in the north (OEH, 2016a). The cryptic nature of the species, and its preference for growing in areas of little agricultural value, suggest that it may be still present in numerous areas which are currently considered gaps for the species (NSW Scientific Committee, 2008). The broader Pilliga region population of *T. linearis* (including the study area occurrences) is regarded as significant on the basis of its estimated large size and habitat quality. The species also occurs in the Glenmorgan district in southern Queensland, where it is very rare and poorly known.

5.4 Fauna survey

A total of 17 amphibians, 186 birds, 45 mammals and 41 reptiles were recorded in the study area to species level (**Appendix C**). An additional three microbats were recorded to a 'possible' confidence level and one amphibian, eight birds, nine mammals and eight reptiles were recorded to genus level. Of those species recorded to genus level, it is likely that there is duplication in the list of records and subsequently the total values have not been combined.

Of those species recorded confidently to species level, 16 birds, 10 mammals and one reptile are listed as threatened under the TSC Act, three mammals and one bird are listed as threatened under the EPBC Act and five birds are listed as migratory under the EPBC Act. Five birds and 12 mammals recorded in the study area are feral species.

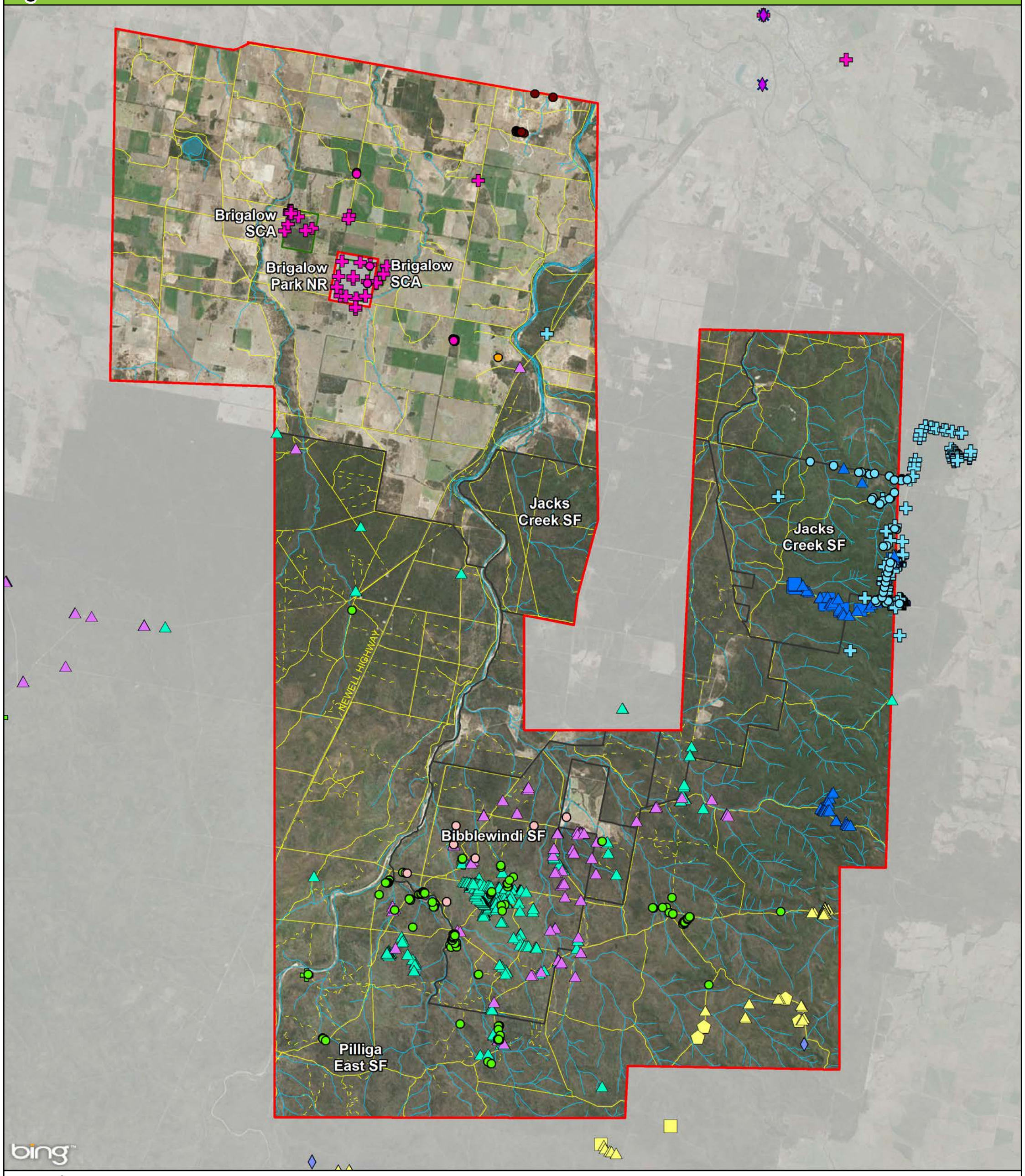
5.4.1 Terrestrial fauna habitat

The study area supports a range of fauna habitats which have been categorised into nine habitat types for the purpose this assessment (**Table 36**; **Appendix E**). These habitat types have been mapped at a landscape scale based on fine scale Plant Community Type mapping (**Figure 19**). Each habitat type has a range of habitat features that support threatened fauna species (**Appendix A5**), either for breeding, foraging, roosting or dispersal. The habitat types associated with each threatened species have also been incorporated into the ecological sensitivity analysis (**Section 4.9**) and have been quantified by each species and their corresponding habitat types (i.e. breeding, foraging) for the impact assessment (**Section 6**).

Table 36: Fauna habitat mapped in the study area

Habitat type	Area mapped in study area (ha)	Habitat type	Area mapped in study area (ha)
Water bodies	100	Riparian Woodland	7,011
Closed Forest	2,827	Shrub Grass Woodland	28,225
Grassland	9,465	Shrubby Woodland	10,002
Grassy Woodland	862		
Heath	1,401		
Heathy Woodland	20,604		

Figure 18: Threatened flora



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Threatened flora records
TSC & EPBC Act Listing (ELA)

- *Bertya opponens* (TSC **V**, EPBC **V**)
- *Diuris tricolor* (TSC **V**)
- *Lepidium aschersonii* (TSC **V**, EPBC **V**)
- *Lepidium monoplocoides* (TSC **E**, EPBC **E**)
- *Myriophyllum implicatum* (TSC **CE**)
- *Polygala linariifolia* (TSC **E**)
- *Pomaderris queenslandica* (TSC **E**)
- *Pterostylis cobarensis* (TSC **V**, EPBC **V**)
- *Rulingia procumbens* (TSC **V**, EPBC **V**)
- *Tylophora linearis* (TSC **V**, EPBC **E**)

Threatened flora records
TSC & EPBC Act Listing (NICE & TWS 2012)

- *Rulingia procumbens* (TSC **V**, EPBC **V**)

Threatened flora records
TSC & EPBC Act Listing (OEH)

- *Bertya opponens* (TSC **V**, EPBC **V**)
- *Dichanthium setosum* (TSC **V**, EPBC **V**)
- *Lepidium aschersonii* (TSC **V**, EPBC **V**)
- *Philotheca ericifolia* (EPBC **V**)
- *Polygala linariifolia* (TSC **E**)
- *Pomaderris queenslandica* (TSC **E**)
- *Rulingia procumbens* (TSC **V**, EPBC **V**)
- *Swainsona murrayana* (TSC **V**, EPBC **V**)

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

CE = Critically Endangered
E = Endangered
V = Vulnerable

NSW Office of Environment and Heritage's Atlas of NSW Wildlife, which holds data from a number of custodians. Data obtained 29/04/2014.

Data Sources:
ELA
Forestry Corporation of NSW
NICE & TWS
OEH
Imagery: Bing Maps

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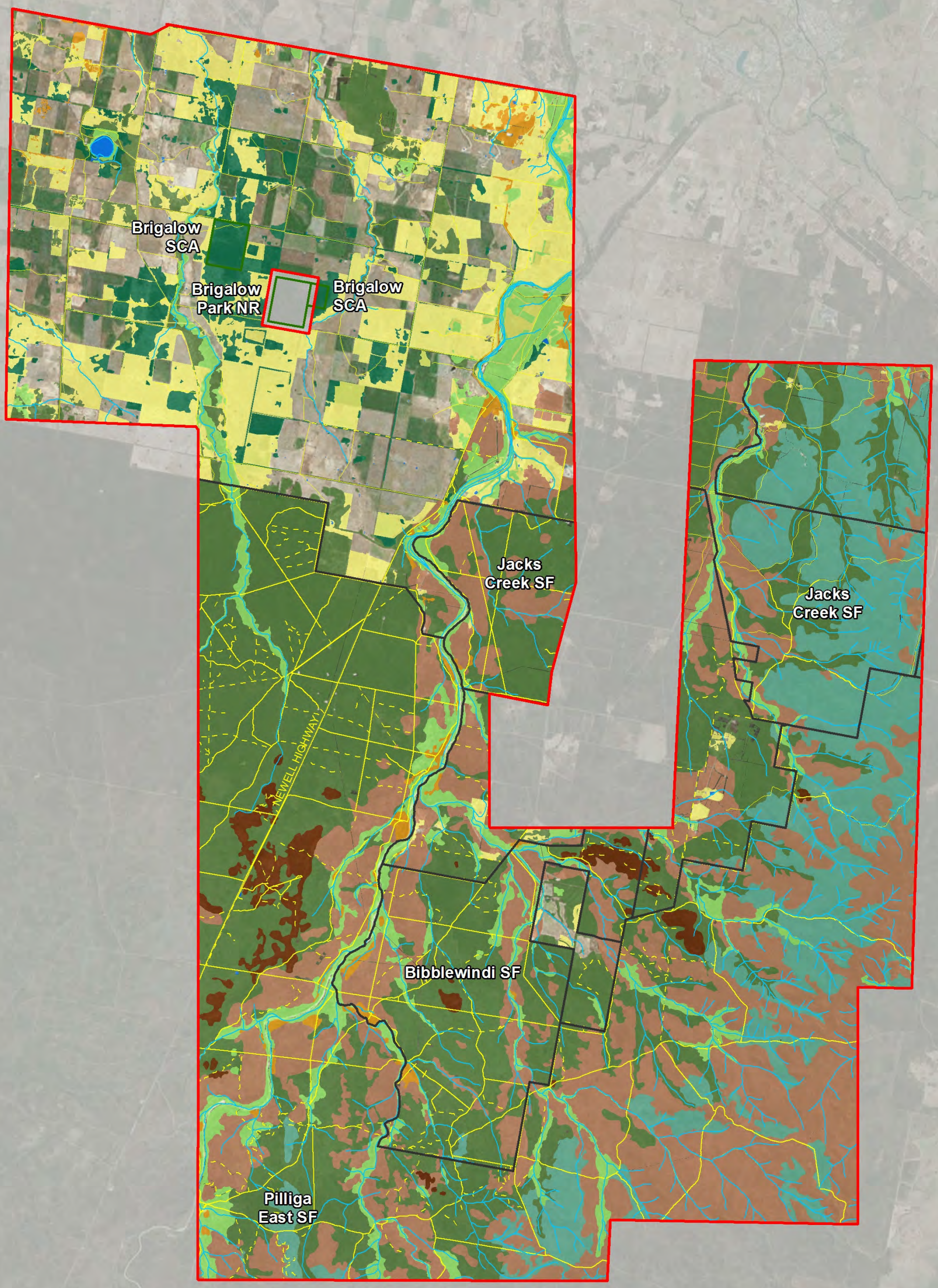
Prepared by: VH Date: 17/11/2014

Figure 19: Fauna habitat mapping



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Habitat (ELA 2014)

- Closed forest
- Grassland
- Grassy woodland
- Heath
- Heathy woodland
- Riparian woodland
- Shrub grass woodland
- Shrubby woodland
- Water bodies

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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5.4.2 Threatened terrestrial fauna species recorded

In the study area, 16 birds, 10 mammals and one reptile listed as threatened under the TSC Act, three mammals and one bird listed as threatened under the EPBC Act and five birds listed as migratory under the EPBC Act were recorded during this assessment (**Figure 20** and **Figure 21**). Additionally, the literature review identified *Ardea ibis* (Cattle Egret), *Ephippiorhynchus asiaticus* (Black-necked Stork) and *Plegadis falcinellus* (Glossy Ibis) in the study area. Note that Koala has been included in this list as Koala scats (Landmark Ecological Services & The Wilderness Society, 2012) and a Koala skull was also recorded during survey for this assessment in 2011. Due to the similarity between Brushtail Possum and Koala scats, and the fact that no Koala sightings in the study area can support these records, the current evidence does not indicate presence of a current population in the study area.

The impact assessments (**Appendix J** and **Appendix K**) provide more detailed information on distribution, habitat preferences and known presence of each threatened species recorded. The potential breeding, foraging and other habitat types were assigned to each threatened fauna species based on information obtained through the literature and data reviews and the field surveys. This information has been used to group threatened fauna recorded in the study area for the impact assessment where multiple species use similar habitat types and features. The list below presents all threatened fauna recorded in the study area, and categorised into the habitat groups.

Birds

- **Parrots** – Glossy Black-cockatoo, Little Lorikeet, Turquoise Parrot (all TSC – V)
- **Owls** – Barking Owl, Masked Owl (both TSC – V)
- **Birds of Prey** – Spotted Harrier, Black Falcon, Little Eagle, Square-tailed Kite (all TSC – V)
- **Woodland birds (ground and midstorey foraging) –** Dusky Woodswallow, Speckled Warbler, Varied Sittella, Hooded Robin (south-eastern form), Grey-crowned Babbler (eastern subspecies), Diamond Firetail, (all TSC – V)
- **Woodland birds (canopy foraging) –** Painted Honeyeater (TSC – V; EPBC – V)
- **Migratory birds** – Fork-tailed Swift, Great Egret, White-throated Needletail, Rainbow Bee-eater, Satin Flycatcher (all EPBC – M).

Mammals

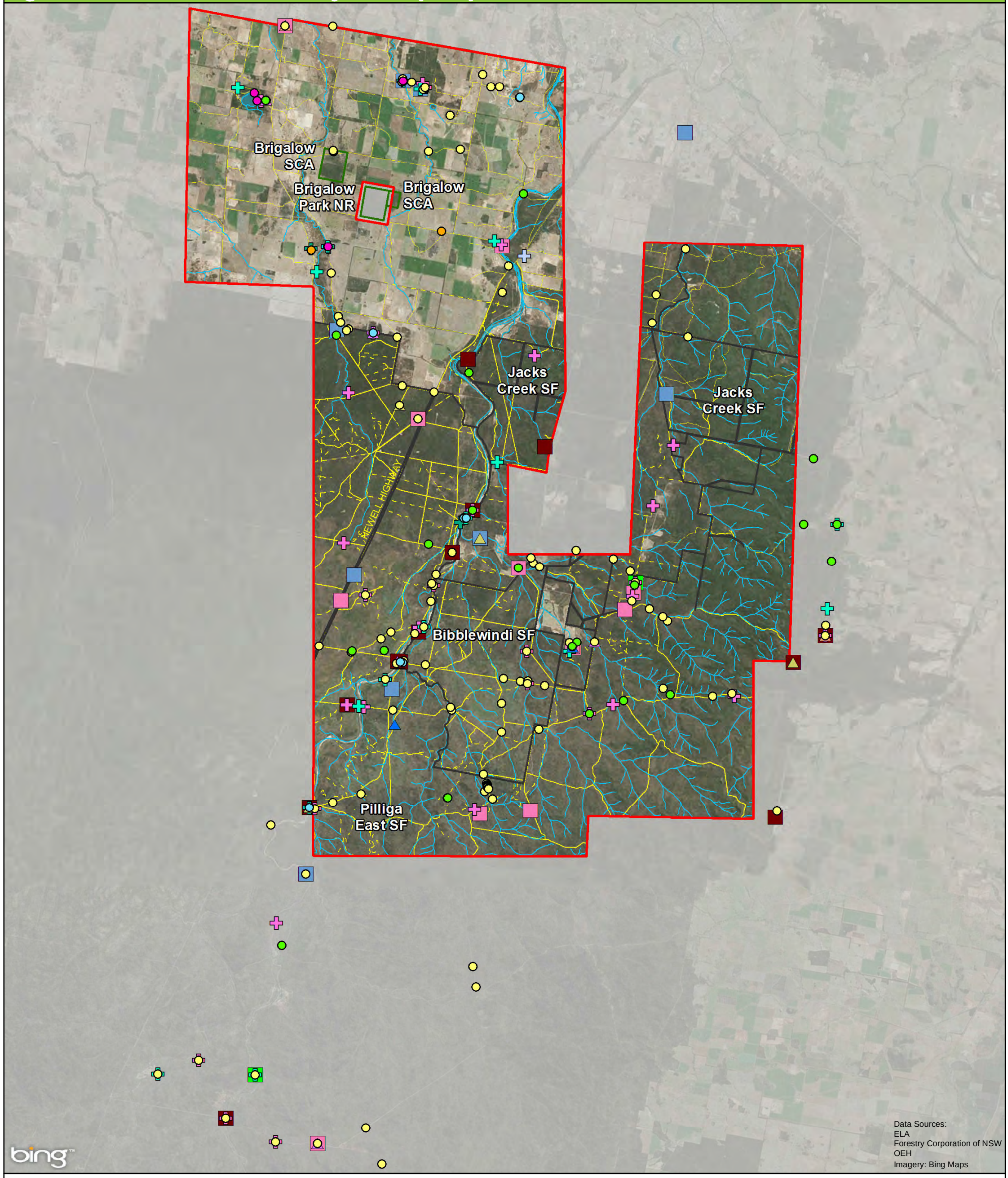
- Black-striped Wallaby (TSC – E)
- Koala (indirect evidence only) (TSC – V; EPBC – V)
- Pilliga Mouse (TSC – V; EPBC – V)
- **Arboreal hollow-dependent mammals** – Eastern Pygmy-possum, Squirrel Glider (both TSC – V)
- **Predominantly tree-roosting bats** – Little Pied Bat (TSC – V), South-eastern Long-eared Bat (TSC – V; EPBC – V), Yellow-bellied Sheathtail-bat (TSC – V),
- **Predominantly cave-roosting bats** – Eastern Bentwing Bat (TSC – V), Eastern Cave Bat (TSC – V).

Large-eared Pied Bat was recorded only to a ‘possible’ confidence level and also recorded in the literature review but has not been included in this list.

Reptiles

- Pale-headed Snake (TSC – V)

Figure 20: Threatened fauna - survey results (birds)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Threatened birds
TSC & EPBC Act Listing (ELA)

- Barking Owl (TSC **V**)
- Black Falcon (TSC **V**)
- Diamond Firetail (TSC **V**)
- Glossy Black-cockatoo (TSC **V**)
- Grey-crowned Babbler (eastern subspecies) (TSC **V**)
- Hooded Robin (south-eastern form) (TSC **V**)
- Little Eagle (TSC **V**)
- Little Lorikeet (TSC **V**)
- Masked Owl (TSC **V**)
- Painted Honeyeater (TSC **V**, EPBC **V**)
- Rainbow Bee-eater (EPBC **M**)
- Speckled Warbler (TSC **V**)
- Spotted Harrier (TSC **V**)
- Square-tailed Kite (TSC **V**)
- Dusky Woodswallow (TSC **V**)
- Turquoise Parrot (TSC **V**)
- Varied Sittella (TSC **V**)
- White-throated Needletail (EPBC **M**)

0 2 4 8
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

V = Vulnerable
M = Migratory

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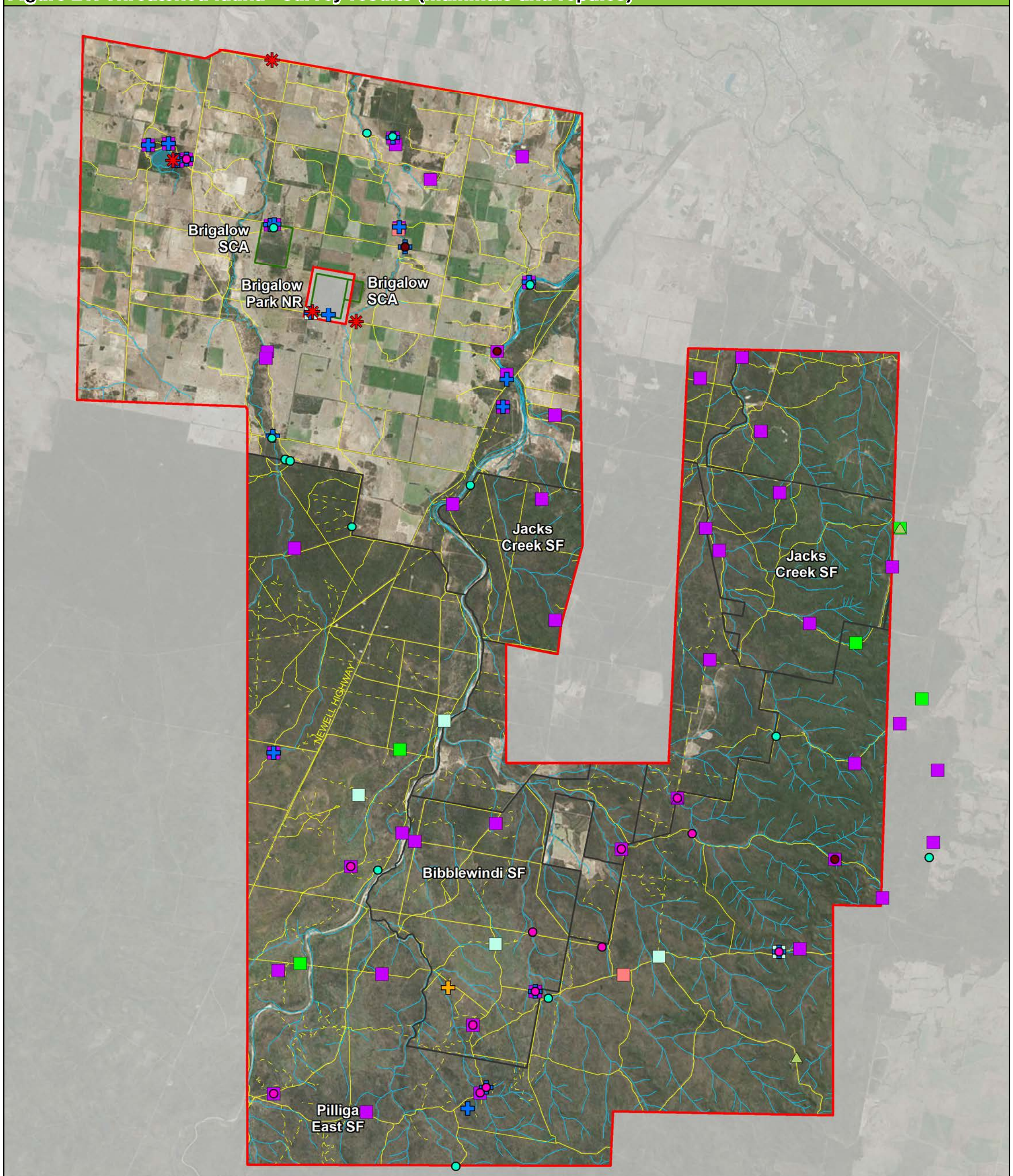
Figure 21: Threatened fauna - survey results (mammals and reptiles)



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Threatened mammals
TSC & EPBC Act Listing (ELA)

- Black-striped Wallaby (TSC **E**)
- Eastern Bentwing Bat (TSC **V**)
- Eastern Cave Bat (TSC **V**)
- Eastern Pygmy-possum (TSC **V**)
- Greater Broad-nosed Bat (TSC **V**)
- Koala (TSC **V**, EPBC **V**)
- Little Pied Bat (TSC **V**)
- Pilliga Mouse (TSC **V**, EPBC **V**)
- South-eastern Long-eared Bat (TSC **V**, EPBC **V**)
- Squirrel Glider (TSC **V**)
- Yellow-bellied Sheathtail-bat (TSC **V**)

Threatened reptiles
TSC & EPBC Act Listing (ELA)

- Pale-headed Snake (TSC **V**)

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

E = Endangered
V = Vulnerable

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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5.4.3 Targeted threatened fauna survey

Information on species and habitat presence in the study area has been compiled from the literature and data reviews and the field surveys. For all threatened fauna considered 'potential', 'likely' or 'known' to occur in the study area, information on presence, distribution and habitat is presented in the impact assessments in **Appendix J** and **Appendix K**. For those fauna species that were specifically targeted as part of the broader field surveys more information is provided below.

Pilliga Mouse – habitat model

The Pilliga Mouse habitat model was developed to provide a greater understanding of the potential distribution of Pilliga Mouse habitat. By incorporating the habitat model into the Geographic Information System, as well as updating the model within the Ecological Sensitivity Analysis, impacts to the Pilliga Mouse can be minimised through design.

Primary Pilliga Mouse habitat is more likely to be inhabited by the Pilliga Mouse on a more permanent basis, while the secondary habitat is less likely to be readily inhabited or is likely to be more suitable after fire and/or during successful breeding years. Secondary habitat has been allocated a higher weighting in the Ecological Sensitivity Analysis (than non-potential Pilliga Mouse habitat) as it provides a buffer to and provides connections between primary habitat. There is potential for all remaining vegetation connecting to primary and secondary habitat to be used as dispersal habitat by the Pilliga Mouse.

Additional discussion on Pilliga Mouse habitat modelling and population in the study area is provided in **Appendix F5**.

Pilliga Mouse – survey

A total of seven Pilliga Mice were detected at five different sites using all types of targeted survey techniques for this assessment. Five Pilliga Mice were recorded at three sites in the study area and an additional two Pilliga Mice were recorded at two sites to the east of the study area.

Almost all the sites in which the Pilliga Mouse was captured or detected supported habitat features that are consistent with habitat descriptions in the literature. These features include a low, diverse shrub cover and suitable burrowing substrate (Paull, 2009; Tokushima et al., 2008). Four of the sites were within heathy woodland and one was in shrubby woodland. All sites had deep sandy soil conducive to burrowing and a diverse shrub layer less than one metre high.

The lack of captures at other sites that had a relatively high cover of low, diverse shrubs could be explained by the fact that the substrate at these sites was not optimal for burrowing. The soil at these other sites was clay loam, which extended to a depth of about 40 cm to 50 cm, after which the soil changed to hard clay. This substrate is not suitable for burrowing for the Pilliga Mouse and the Pilliga Mouse is only considered likely to occur in these low-suitability habitats in irruption phases

Based on the results of field surveys and habitat modelling, the distribution of the Pilliga Mouse in the study area is likely to be confined to primary and secondary habitat in the south and east of the study area. These habitats included patches of woodland along Bohena Creek, Bibblewindi Creek and Cowallah Creek and a mosaic of primary and secondary habitats in the south and east of the study area (Figure 2 of **Appendix F6**). The abundance of Pilliga Mouse in these areas is likely to fluctuate depending on seasonal conditions and fire history.

Survey techniques and conditions were considered conducive to capturing this species but a relatively low capture rate suggests that this species was not in irruption phase at the time of the surveys in 2013. This is supported by the low level of spring rainfall during 2012. Low capture rates meant that the density of this species in the study area at the time of surveys could not be accurately identified.

Estimates of population dynamics in the literature specify peak density (during population irruption) at between 15 to 90 mice per hectare, in comparison to low density (during normal times) which has been calculated at below 5 mice per hectare (Tokushima et al., 2008). Based on existing population size estimates, the study area has the potential to carry up to 45,655 individuals in primary habitat alone (low density at up to 5 individuals per hectare). However it should be noted that not all primary habitat patches have been surveyed, nor will the Pilliga Mouse occur in all patches of primary habitat at all times. Potential Pilliga Mouse populations in the study area during irruption phases are expected to be an order of magnitude higher.

The Pilliga Mouse is not restricted to the study area, with a large number of existing records to the south, south-west and west of the study area within the Pilliga region. Individuals on the edges of the study area are likely to interact with other individuals by moving across these habitats outside of the study area, especially in irruption phases. The habitats in the study area form part of a wider area of habitat for the Pilliga Mouse that occurs within the Pilliga region. The literature review obtained at least 203 records of Pilliga Mouse, with at least 56 individuals from 31 sites recorded within the study area (Kendall and Kendall Ecological Consultants, 2005, 2006, 2009; Landmark Ecological Services & The Wilderness Society, 2012; OEH, 2016a). These records were from both boom and bust periods for the Pilliga Mouse and are from areas of both primary and secondary habitat. The majority of records are rom heath (Broombush dominated) or heathy woodland with some records also from shrubby woodland, riparian woodland and shrub grass woodland. Additional records could not be assigned to a habitat type due to lack of information obtained from the reports.

The habitat model is incorporated in the Ecological Scouting Framework (**Appendix G**) and the Ecological Sensitivity Analysis (**Appendix F8**) to minimise the impacts to the Pilliga Mouse. Additional discussion on Pilliga Mouse habitat and population in the study area is provided in **Appendix F6**. A photo of two Pilliga Mice captured during this survey is provided in **Plate 12**.

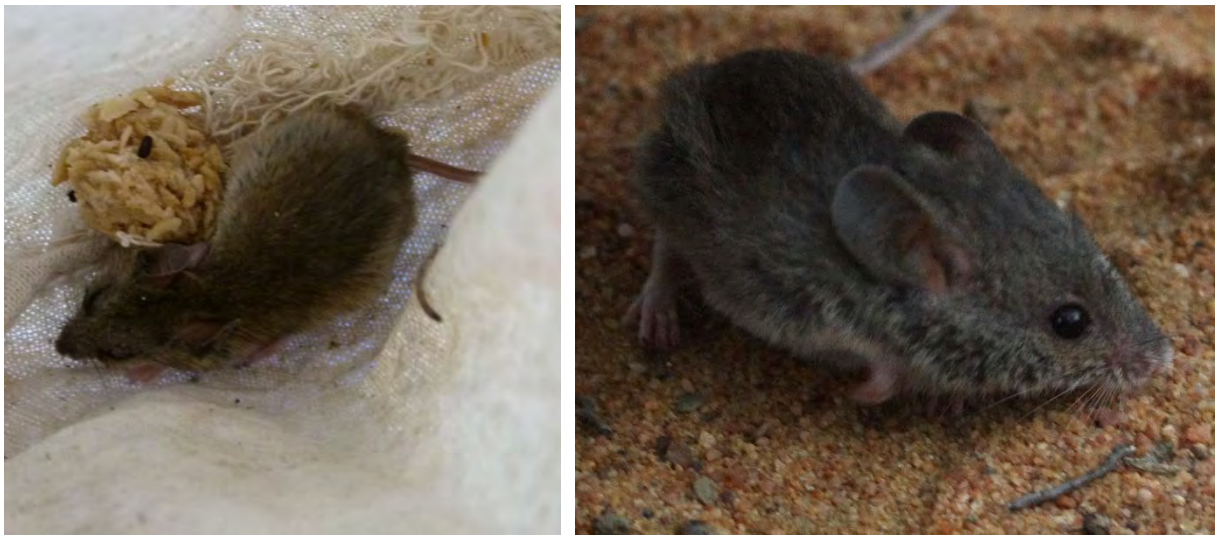


Plate 12: Pilliga Mouse in calico bag; Pilliga Mouse on sand

Spotted-tailed Quoll

No Spotted-tailed Quolls were recorded during the targeted survey. The survey methods utilised during targeted surveys were applied to subsequent surveys of the northern portion of the study area. No Spotted-tailed Quolls were recorded during subsequent surveys.

There are no previous records of Spotted-tailed Quoll in the study area. The closest record is from approximately 15 km south of the study area in the Pilliga Nature Reserve. This record was from a Spotted-tailed Quoll that was captured in a snare in 2006.

The lack of results for Spotted-tailed Quoll in either hair tubes or remote cameras coupled with the lack of previous records of Spotted-tailed Quoll in or adjacent to the study area suggests that the habitat in the study area is unlikely to be important for this species.

Despite the lack of records in the study area, it is still possible that Spotted-tailed Quoll could move through and utilise habitat in the study area for breeding and foraging. All habitat types in the study area are potential habitat for the Spotted-tailed Quoll (**Appendix A5**).

Targeted migratory birds

None of the target species were recorded during these surveys. Many survey sites recorded honeyeaters, lorikeets and parrots which would imply that foraging resources suitable for the target species are present in the study area.

Flowering in the study area was observed to be sporadic and much less profuse than the flowering observed in *Eucalyptus albens* to the east of the study area and in other habitat in coastal areas.

There is potential for the study area to support foraging habitat for the target species during their migration. In particular, areas with flowering *Eucalyptus sideroxylon x Eucalyptus melliodora* and *Eucalyptus sideroxylon* in the west and north-west of the study area are potential foraging resources for Regent Honeyeater. Areas of winter flowering eucalypts including *Eucalyptus chloroclada, Eucalyptus blakelyi* and *Eucalyptus crebra* could provide a foraging resource for both Superb Parrots and Swift Parrots, but were only observed to flower sporadically in the study area. Due to the low number of records in the Pilliga, it is probable that the study area does not provide important habitat for these species. Instead, it may provide an alternative foraging resource when more favourable foraging habitat is not available or when flowering in the study area is more profuse.

Koala – study area

No Koalas were observed in the study area during surveys for this assessment. A Koala skull was found in shrub grass woodland adjacent to Cowallah Creek during the initial fauna survey in 2011 (**Figure 21**).

The literature review obtained one record of Koala inside the study area (Landmark Ecological Services & The Wilderness Society, 2012). This record was of two scats located at the base of a red gum stag on a tributary to Bibblewindi Creek in the south of the study area (**Figure 14**). Due to the similarity between Brushtail Possum and Koala scats, and the fact that no Koala sightings in the study area can support these records, the current evidence does not indicate presence of a current population in the study area.

Previous records of Koala in the study area are concentrated in the north-western forested portion of the study area, along Reedy Creek, Bundock Creek and in adjoining shrub grass woodland with an overstorey including *Eucalyptus pilligaensis* and *Eucalyptus populnea* (**Figure 14**). These records range from 1980 to 2004 (OEH, 2016a).

Koala habitat in the study area is more accurately delineated by Plant Community Types than by habitat types as Koalas require specific canopy species as feed trees (**Figure 22**). Koala feed trees present in the study area are presented in **Table 27** and these trees are present in the following Plant Community Types; ID78, ID399 and ID401 (riparian woodland), ID88 and ID397 (shrub grass woodland), and ID408 and ID40X (heathy woodland) (**Figure 15**). All other vegetated areas in the study area have potential to

provide either shelter habitat, provide buffers to Koala habitat or allow linkages between patches of Koala habitat in which Koalas can move through to access feed trees.

The results of the Koala habitat assessment were used to assess habitat based on the habitat guidelines presented in the approved recovery plan for the Koala (DECC, 2008b) (**Figure 22**). Of the 44 assessments, two sites constituted primary Koala habitat (KH33 and KH41). These two sites are dominated by *Eucalyptus camaldulensis* which is a primary Koala food tree species. The remaining 42 sites constituted secondary habitat, with 31 Secondary A sites, two Secondary B sites and nine Secondary C sites.

The results of these assessments indicate that the study area supports areas of primary and secondary habitat. In particular, areas mapped at ID78 are considered to largely constitute primary koala habitat. There are approximately 10.5 ha of this Plant Community Type mapped in the study area, and it is distributed around Yarrie Lake in the northern portion of the study area.

Habitat in the study area would be considered secondary Koala habitat if it contains secondary Koala food tree species listed in **Table 27**. Plant community types in the study area that would fit this requirement are ID88, ID202, ID397, ID399, ID401, ID408 and ID40X. Depending on the proportion of these trees present, the habitat may fall under either Secondary A, B or C Koala habitat.

While primary and secondary Koala habitat has been identified in accordance with the approved recovery plan for the Koala (DECC, 2008b), there are no recent sightings of Koala in the study area and the study area is unlikely to have historically supported a large population of Koala.

Koala – regional

The regional Koala survey located ten Koalas, which were distributed along Baradine Creek and Etoo Creek and their tributaries in the west of the Pilliga, outside of the project study area. None of the ten Koalas observed were young or sub-adult koalas. In addition, none of the koalas appeared to be displaying symptoms of old age. Over 1,654 ha were searched on foot covering approximately 112 km of preferred habitat dominated drainage lines and water sources.

Koala faecal pellets were observed at an additional 81 sites. Recent signs of Koala activity were found in Talluba and Rocky (Nth) creeks. No Koalas or signs (pellets of scratching's) of their recent activity were found along creek lines of the Pilliga East State Forests or Pilliga East State Conservation Area. Compared with previous population numbers, these results indicate that the Koala population in the Pilliga has declined substantially. With these small numbers, it is difficult to draw conclusions on population status, however the most resilient areas of habitat for the koala appear to be along the two main drainage lines surveyed (i.e. Etoo Creek and Baradine Creek).

The characteristics of habitat that is supporting the population in its restricted size include the presence of red gums and *Callitris glaucophylla* and areas proximal to wide stream beds. Of the 10 Koalas observed, nine were seen in red gums and one in a *C. glaucophylla*. This pattern was similar for the tree species that faecal pellets were found under. However, no Koalas were observed along Bohena Creek (within the study area) which is also consistent with these habitat characteristics.

Evidence of wildfire was seen to have a negative relationship with Koala presence. No Koalas were located at sites that had evidence of large wildfires that had killed canopy trees. Sites that had been burnt by large wildfires had immature regeneration, averaging only a few metres in height.

Presence of water was not observed to have a strong relationship with Koala presence. Only two of the ten observed Koalas were within 500 m of a permanent water body. Furthermore, three waterholes were

inspected along Etoo Creek and none had signs of Koala habitation within 400 m. However rainfall just prior to the surveys is likely to have replenished some dry waterholes so was not considered a good indication of presence of longstanding water. Despite some rainfall during autumn, the forest areas searched were still showing the signs of significant water stress (i.e. many trees were heavily defoliated or showed recent epicormic growth), almost certainly resulting from a rainfall deficit over spring and summer and the lack of significant wet periods since March 2012 (BOM, 2014). Normally permanent waterholes were dry during the 2013/14 summer, and even after the 2014 autumn rains many contained no standing water.

The factors leading to the decline in Koala numbers in the Pilliga have not yet been determined but it has been postulated that the drought conditions together with the 2006 wildfires throughout the central Pilliga would have significantly reduced the available suitable habitat for Koalas. More detail is presented in **Appendix F7**.

Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide core Koala habitat.

Amphibians and reptiles

Neither of the target species were recorded during the April survey.

The Five-clawed Work-skink is known to occur on the floodplains of the Namoi river, and its likely distribution within the Namoi River catchment extends to just north of the study area (North West Ecological Services, 2010). It's preferred habitat of native vegetation on deep cracking clay soils is not present in the study area. The northern portion of the study area supports limited potential habitat in closed forest habitat.

There is one record of Slone's Froglet approximately 25 km west of the study area in Pilliga East State Forest. This record is from 1996 and is of an individual observed in pooled water after recent rainfall. There is potential habitat for Slone's Froglet in grassland and woodland that becomes periodically inundated in the study area.

5.4.4 Feral fauna

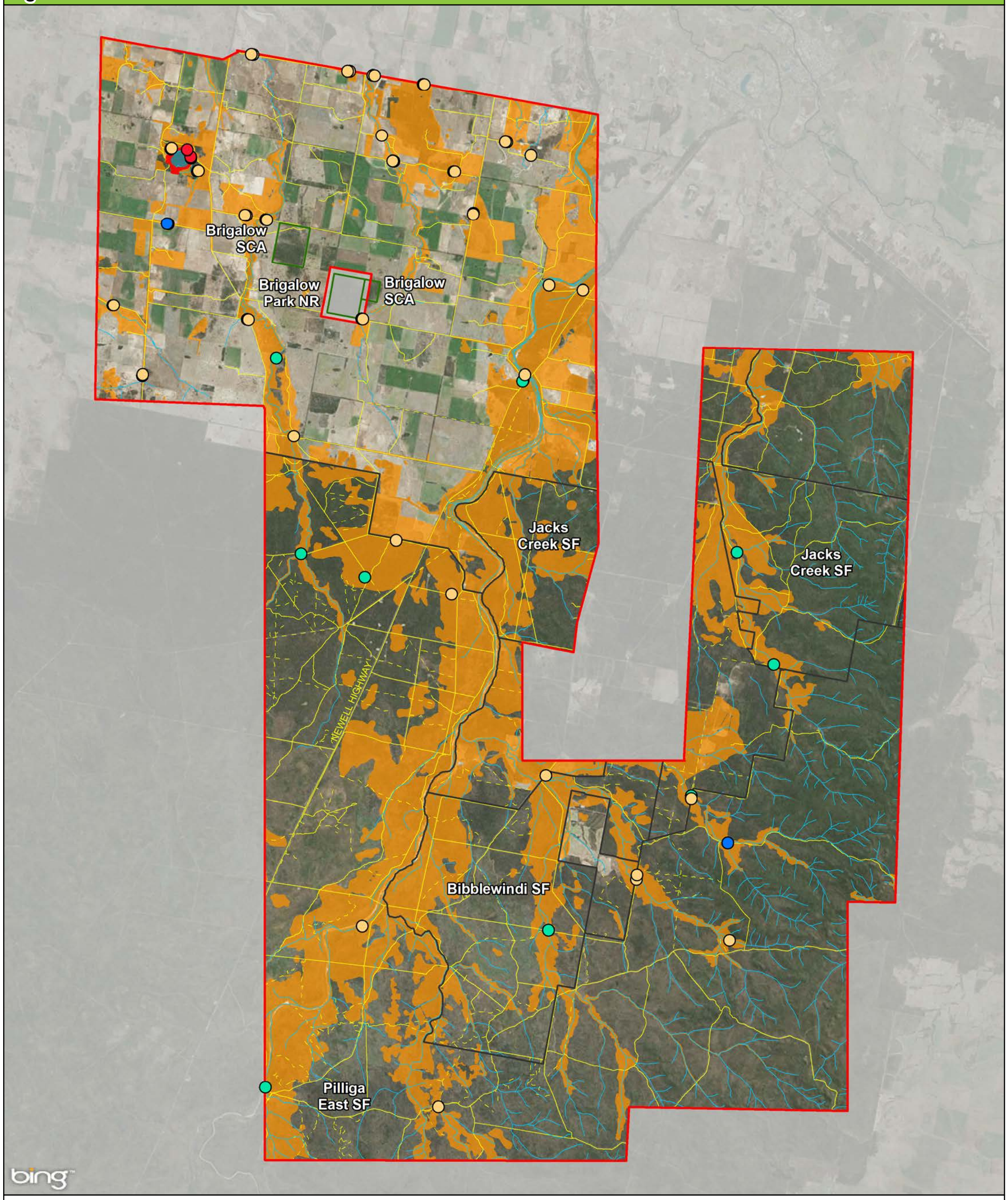
Five feral birds and 12 feral mammals were recorded in the study area. These species impact on biodiversity values through a range of functions including predation, herbivory, competition, habitat modification and destruction. Feral fauna were observed in all habitat types, with scats and tracks frequently observed along the sandy roads and creek beds. The majority of records obtained from remote camera images were of feral fauna.

Predatory species recorded in the study area are *Canis lupus familiaris* (Dog), *Felis catus* (Cat) and *Vulpes vulpes* (Fox). These species can prey on a range of native fauna species including small and medium sized mammals, birds and reptiles. Herbivorous species recorded in the study area are *Bos taurus* (Cow), *Capra hircus* (Goat), *Equus* sp. (Horse), *Lepus capensis* (Hare), *Sus scrofa* (Pig), *Oryctolagus cuniculus* (Rabbit) and *Ovis aries* (Sheep). These species can browse on native flora, changing the composition of the groundcover and shrub layer and removing threatened flora species. Other feral fauna species recorded in the study area were *Mus musculus* (House Mouse), *Rattus rattus* (Black Rat), *Streptopelia chinensis* (Spotted Turtle-dove), *Sturnus tristis* (Common Myna), *Sturnus vulgaris* (Common Starling), *Passer domesticus* (House Sparrow) and *Turdus merula* (Eurasian Blackbird).

All feral fauna recorded in the study area increase the competition pressures and impact on biodiversity values to differing degrees. Competition pressures can reduce breeding and foraging habitat availability,

force native species out of their preferred habitat and can lead to decreases in native species diversity, abundance and distribution. Herbivorous species modify the structure of vegetation by preferentially foraging on certain species, digging and altering the groundcover and soil and altering water flow and erosion.

Figure 22: Koala habitat assessment



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Potential Koala habitat survey results

- Primary
- Secondary A
- Secondary B
- Secondary C

Mapped potential Koala habitat

- Primary
- Secondary

(Koala habitat classification adopted from DECC 2008. This is not indicative of current Koala distribution.)

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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Prepared by: VH Date: 18/11/2014

5.5 Ecological sensitivity analysis

The Ecological sensitivity analysis categorised the study area into the five classes as presented in **Table 37**. The ecological sensitivity classes are mapped in **Figure 23**. This analysis provides a meaningful way to maximise avoidance on areas of 'Moderate - High' to 'High' ecological sensitivity. More detail on the applications of this analysis is provided in **Appendix F8**.

Table 37: Ecological sensitivity classes across the study area

Ecological Sensitivity	Area (ha)	% Area
Low	23,984	25%
Low - Moderate	26,009	27%
Moderate	28,481	30%
Moderate - High	12,620	13%
High	3,983	4%
Total	**95,077**	**100%**

*It is noted that although the high resolution analysis (10m raster based) improves the accuracy of spatial statistics there must be allowance for a small degree of discrepancy in calculated areas due to the way linear features are represented in rasters. This is particularly with respect to the many narrow (<10m) tracks and trails in the study area.

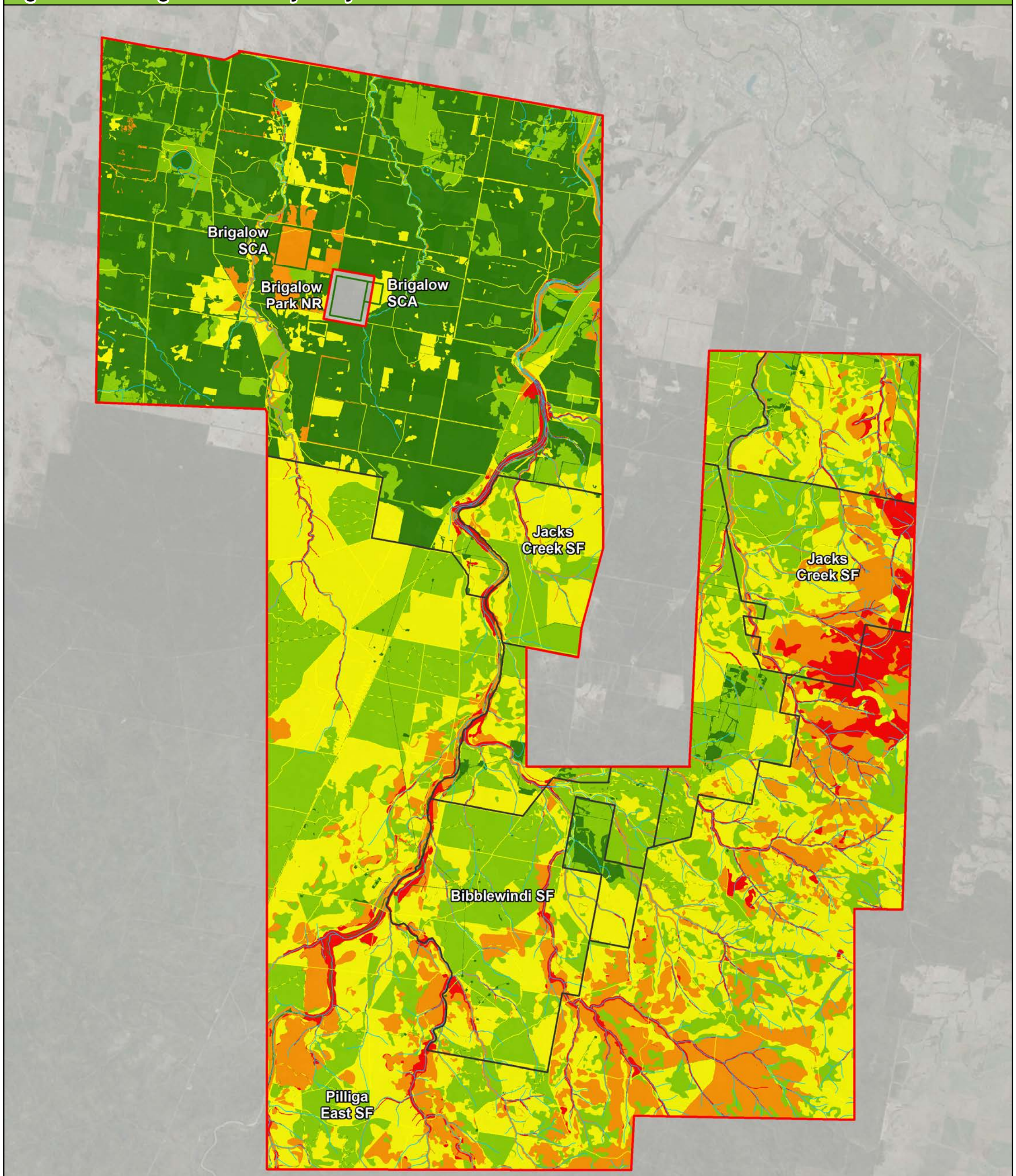
5.6 Watercourse mapping

A total of 717 km of watercourses were mapped in the study area across six Strahler stream orders. The lower order streams (i.e. those in the upper catchments) had the greatest length (319 km) while the higher order streams (4 to 6) were an order of magnitude lower (average length 42 km).

Based on the Strahler stream order classification and designation of vegetated riparian zone buffer widths in accordance with the WM Act a total of 5,298 ha of land is included within mapped Riparian Corridors.

The resulting watercourse layer including Strahler stream order and Riparian Corridors is shown in **Figure 24**.

Figure 23: Ecological sensitivity analysis



Legend

- Study area
- Roads
- Tracks
- Drainage lines (1:50k)
- NPWS Estate
- State Forests

Ecological sensitivity analysis (ELA 2014)

- Low
- Low - Moderate
- Moderate
- Moderate - High
- High

0 1 2 4
Kilometres
Datum/Projection:
GDA 1994 MGA Zone 55

N

Data Sources:
ELA
Forestry Corporation of NSW
OEH
Imagery: Bing Maps

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Figure 24: Riparian Corridors

Map inset

Legend

- Study area
- State Forests
- Roads
- Tracks

Strahler Stream Order

- 1
- 2
- 3
- 4
- 5
- 6
- Riparian corridors (to scale)

0 1,800 3,600 7,200

Metres

Datum/Projection:
GDA 1994 MGA Zone 55

N

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5.7 SEPP 44 Koala Habitat Protection

The data collected from the Koala habitat assessments have been used to address the criteria of SEPP 44.

Step 1: Is the land potential Koala habitat?

Five out of the 41 Koala habitat assessments fit the criteria for potential Koala habitat (KH23, KH25, KH33; KH40 and KH41) (**Figure 12**). These seven assessments are all located in the north of the study area in habitat either dominated by *Eucalyptus camaldulensis* (mostly Plant Community Type ID78) or *Eucalyptus populnea* (Plant Community Type ID397).

The results from these assessments indicate that habitat in other locations of the study area in these two Plant Community Types could also constitute potential Koala habitat as defined by SEPP 44. There are approximately 10.5 ha of Plant Community Type 78 and 763 ha of Plant Community Type 397 mapped in the study area. Both these Plant Community Types are distributed in the northern portion of the study area.

Step 2: Is the land core koala habitat?

There are no recent sightings of Koala in the study area and the study area is unlikely to have historically supported a large population of Koala. The study area is unlikely to support an important population of Koala and does not provide key breeding habitat.

Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide core Koala habitat. Additionally, habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.

The Koala population in the Pilliga has contracted and Koalas are located only in select refuges (Niche Environment and Heritage, 2014).

As the study area does not constitute core Koala habitat as defined in SEPP 44, Step 3 of the SEPP assessment is not required.

6 Impact assessment

This section of the assessment outlines the anticipated impacts from the project on the biodiversity values of the study area following avoidance and minimisation. It also provides information on the cumulative impacts and outlines key threatening processes. The direct and indirect impacts outlined below have been calculated conservatively and have been determined before the ecological scouting framework has been applied which will further minimise impacts on a site scale.

The direct and indirect impacts have been correlated to each type of infrastructure as presented below. It is important to note that at the time of the field surveys, the locations of major facilities were not known and therefore survey effort was not directed towards these locations.

When assessing the impacts, the upper disturbance limits for each Plant Community Type, habitat type and flora species are conservative due to the potential biases in infrastructure locations which may result in the development. The overall upper disturbance limit is unlikely to be reached.

When assessing the indirect impacts, the nature, extent and duration of the impacts were considered. Those impacts that are considered to be long-term (i.e. operational impacts) were weighted heavier than those impacts with an acute, short-term nature (i.e., construction impacts). The staging of the project was also considered, to account for the movement of impacts through the study area over time (i.e. construction impacts were considered as localised but would spread to different locations throughout the study area as the project develops).

- **Well pads (gas field):**
    - Direct impacts: vegetation removal, habitat removal, removal of threatened flora individuals (construction and operation)
    - Indirect site impacts: fragmentation, noise, traffic, fencing, light, weed invasion, increased feral fauna, fire (construction and operation)
    - Indirect downstream or downwind impacts: sedimentation, erosion, dust, hydrological change, accidental spills and leaks (construction and operation)

- **Gathering system / access tracks (gas field):**
    - Direct impacts: vegetation removal, habitat removal, removal of threatened flora individuals
    - Indirect site impacts: fragmentation, noise, traffic, light, weed invasion, increased feral fauna)
    - Indirect downstream or downwind impacts: sedimentation, erosion, dust, hydrological change, accidental spills and leaks)
    - Facilitated impacts: hunting

- **The Leewood property (major facility):**
    - Direct impacts: no direct impacts expected as a result of the project
    - Indirect site impacts: noise, traffic, light, weed invasion, increased feral fauna (construction and operation)
    - Indirect downstream or downwind impacts: sedimentation, erosion, dust, hydrological change, accidental spills and leaks (construction and operation)

- **The Bibblewindi site (major facility):**

  - Direct impacts: vegetation removal, habitat removal, removal of threatened flora individuals
  - Indirect site impacts: fragmentation, noise, traffic, fencing, light, weed invasion, increased feral fauna, fire (construction and operation)
  - Indirect downstream or downwind impacts: sedimentation, erosion, dust, hydrological change, accidental spills and leaks (construction and operation)

- **Bibblewindi to Leewood infrastructure corridor (major facility):**
  - Direct impacts: vegetation removal, habitat removal, removal of threatened flora individuals
  - Indirect site impacts: fragmentation, noise, traffic, light, weed invasion, increased feral fauna
  - Indirect downstream or downwind impacts: sedimentation, erosion, dust, hydrological change, accidental spills and leaks

- **Leewood to Wilga Park underground power line (major facility):**
  - Direct impacts: no direct impacts expected as a result of the project as the power line is being installed in an existing disturbed infrastructure easement
  - Indirect impacts: indirect impacts are expected to be minima as a result of the project as the power line is being installed in an existing disturbed infrastructure easement.

- **Worker accommodation at Westport (ancillary):**
  - Direct impacts: vegetation removal, habitat removal, removal of threatened flora individuals
  - Indirect site impacts: fragmentation, noise, traffic, fencing, light, weed invasion, increased feral fauna
  - Indirect downstream or downwind impacts: sedimentation, erosion, dust, hydrological change

6.1 Biodiversity values

A number of threatened species and communities listed under the TSC Act and/or EPBC Act have been identified as having the potential to be impacted by the project. These species have been identified based on the database and literature reviews, vegetation and habitat mapping, results of flora and fauna surveys and the ecological sensitivity analysis. The likelihood of presence or absence of species and ecological communities has been assessed with full details provided in **Appendix I**.

Thirty-two birds, 14 mammals, one reptile, 10 plants and four ecological communities which are listed as threatened under the TSC Act and/or EPBC Act are determined to have a likelihood of occurrence of ‘known’, ‘likely’ or ‘potential’ within the study area. An additional nine birds listed as migratory under the EPBC Act are determined to have a likelihood of occurrence of ‘known’ or ‘potential’ within the study area.

A number of additional species have also been considered in relation to their likelihood of occurrence within the study area and determined to be unlikely to occur, as the study area is outside of their distribution, and/or suitable habitat is not present. These species are not addressed in detail in this report, but have been considered and are outlined in a full likelihood of occurrence table in **Appendix I**.

Assessments of Significance under the EPA Act and/or EPBC Act have been carried out for those species and ecological communities considered ‘potential’, ‘likely’ or ‘known’ to occur in the study area (**Appendix J** (EPA Act) and **Appendix K** (EPBC Act))**.**

6.2 Avoidance and minimisation

A number of avoidance and minimisation measures are included in the design of the project in order to minimise potential impacts to threatened species and communities and significant ecological features in the study area.

6.2.1 Design alterations

The design and location of infrastructure for the project will make maximum use of areas within or adjacent to existing disturbance or with lower ecological sensitivity. This strategy will continue to reduce the overall extent of clearing required and will minimise additional fragmentation and additional edge effects within the landscape. This strategy includes:

- Implementation of the Field Development Protocol
- Preparation of an ecological scouting framework which considers biodiversity values such as threatened species, ecological communities and their potential habitats and prioritising them for avoidance. This will ensure that infrastructure is appropriately located for minimal ecological impact.
- The placement of seismic infrastructure in previously cleared areas where practicable to avoid vegetation clearing.
- The placement of the central water and gas processing facilities at the Leewood site, outside of the forest to minimise vegetation clearing.
- Co-location of linear infrastructure such as gas and water gathering systems and access tracks with existing roads, access tracks and disturbance corridors wherever possible. Additionally, when new access tracks are required, the construction of gathering system would be aligned with the access tracks where possible. Further micro-alignment may be undertaken to minimise impacts on known ecological constraints such as threatened species and hollow-bearing trees, if practicable.
- Linear infrastructure, tracks and the gathering system, will be an average of 10 m wide during construction (up to a maximum of 12 m wide).
- Construction of the gas and water gathering systems will use a ‘plough-in’ technique where possible as this reduces the width of the corridor required for construction, minimises disruption to topsoil, and minimises the need for traditional trenching and dewatering of open trenches. This would also reduce the risk to fauna falling into trenches.

Field development protocol

A Field Development Protocol has been prepared to ensure the planning, design and construction phases of the project are undertaken in accordance with mitigations and commitments in the EIS, consent conditions and management plans. In relation to ecological matters, it addresses the avoidance and minimisation of direct and indirect impacts by implementing the steps outlined in **Table 38**.

Table 38: Field development protocol outline

Step	Components	Relevant section of this document
Desktop review	Design development plan following procedures described in Step 1 of the Ecological Scouting Framework. Review cumulative disturbance figures against upper clearing limits.	Detail provided below on Ecological Scouting Framework. Clearing limits presented in **Section 6.3**

Micro-siting	Undertake field scouting following procedures described in Step 2 of the Ecological Scouting Framework.	Detail provided below on Ecological Scouting Framework.
Design	Complete detailed design, implementing results from desktop assessment and micro-siting stages following procedures in Step 3 of the Ecological Scouting Framework.	Detail provided below on Ecological Scouting Framework.
Implementation (Management Controls and Auditing)	Implement pre-clearance protocols and relocate fauna out of the construction area	Pre-clearing procedure detailed in **Section 7.2**

Ecological scouting framework

The Ecological Scouting Framework has been incorporated into the Field Development Protocol. It identifies the most suitable areas for proposed infrastructure to be positioned in order to cause the least environmental impact. Full details are provided in **Appendix G**. This process involves:

1. Desktop assessment: a preliminary constraints analysis using spatial layers to highlight areas of ecological sensitivity.
2. In-field micro-siting: a field survey within a buffered area, collecting spatial data for biodiversity values which allows infrastructure micro-siting to be undertaken post-fieldwork.
3. Post-field micro-siting: infrastructure is positioned in the areas of lowest environmental impact following a set of design principles.

6.3 Direct impacts

The direct impacts of the project by infrastructure element are outlined in **Table 39** with detail on specific direct impacts to vegetation, fauna habitat, threatened flora and threatened fauna contained in **Section 6.3.1** to **Section 6.3.4**.

Table 39: Direct impacts by infrastructure element

Location	Leewood	Bibblewindi	Bibblewindi to Leewood infrastructure corridor	Leewood to Wilga Park underground power line	The gas field	Ancillary	Total
Clearing required (ha)	0	16	26.7	0	920.6	25.5	988.8

6.3.1 Vegetation

The project would result in the removal of up to 988.8 ha of native vegetation in the study area which includes 75.9 ha of derived native grassland. This equates to the removal of approximately 1.29% of native vegetation and 0.80% of derived native grassland in the study area.

The impact on each vegetation community has been assessed by both Plant Community Types and Biometric Vegetation Types (**Appendix A6**). The direct impact has been shown both as a value of hectares removed and also a percentage of the Plant Community Type to be removed in the study area.

The largest direct impact is on Narrow-leaved Ironbark – White Cypress Pine – Buloke tall open forest (up to 323.40 ha) which constitutes a direct impact to the community of 1.38% in the study area. Two more Plant Community Types would have direct impact over 100 ha, namely White Bloodwood – Dirty Gum – Rough-barked Apple heathy open woodland (up to 138.40 ha) and White Bloodwood – Red Ironbark – cypress pine shrubby woodland (up to 108.7 ha). Eight additional Plant Community Types would have direct impact between 10 ha and 100 ha with the remaining 12 Plant Community Types having direct impact between 0 ha and 10 ha which includes no direct impact on Carbeen – White Cypress Pine – Curracabah – White Box tall woodland or River Red Gum riparian tall woodland.

All Plant Community Types would be impacted by less than 3% of their occurrence in the study area. The Plant Community Types with the highest percentage impact in the study area are Inland Scribbly Gum - White Bloodwood - Red Stringybark - Black Cypress Pine shrubby sandstone woodland (2.61%), Spur-wing Wattle heath (2.29%) and White Bloodwood - Motherumbah - Red Ironbark shrubby sandstone hill woodland/open forest (2.13%).

Threatened ecological communities

All threatened ecological communities would be impacted by 1% or less of their occurrence in the study area. The largest direct impact would be on Brigalow (up to 19.3 ha). Approximately 2,468.0 ha of this threatened ecological community occurs in the study area which constitutes a direct impact to the community of 0.78% in the study area. The second largest direct impact would be on Fuzzy Box Woodland (up to 5.9 ha). Approximately 588.4 ha of this threatened ecological community occurs in the study area which constitutes a direct impact to the community of 1 % in the study area. Weeping Myall Woodlands would only have up to 0.1 ha removed and Carbeen Open Forest would not be directly impacted.

6.3.2 Fauna habitat

The study area provides habitat for a range of threatened fauna species. The direct vegetation removal outlined in **Section 6.3.1** would result in the removal of known or potential fauna foraging, breeding, roosting, sheltering and dispersal habitat. **Appendix A7** provides the upper limits for direct impact to fauna habitat, categorised into foraging, breeding and other. It also assesses the percentage of habitat loss in the study area. The data provided shows that less than two percent of habitat would be directly impacted for all threatened fauna species assessed.

Loss of hollows

The number of hollow-bearing trees likely to be cleared as a result of the project is based on hollow size class data collected in the 327 biometric plots surveyed across the study area (**Appendix A8**), averaged out across each Plant Community Type. A total of 10,143 hollow-bearing trees will potentially be removed as a result of the project. This estimation is pre-avoidance and does not take into account the Ecological Scouting Framework which will facilitate avoidance of significant hollow-bearing trees where possible. Previous assessments have shown that between a 20% and 80% reduction in clearing of significant hollow-bearing trees can be achieved by following the Ecological Scouting Framework and micro-siting infrastructure.

Koala EPBC Act referral assessment

The koala habitat assessment tool (DotE, 2014b) was applied to the study area to assess if the study area constitutes habitat critical to the survival of the koala. The study area scored a habitat score of 6 and results of this assessment are presented in **Table 40**.

Table 40: Koala habitat assessment tool results

Attribute	Score	Assessment criteria (inland)	Assessment details
Koala occurrence	+1 (medium)	Evidence of one or more koalas within 5 km of the edge of the impact area within the last 10 years.*	Koala scats (Landmark Ecological Services & The Wilderness Society, 2012) and a Koala skull have were recorded in the study area in 2011. Due to the similarity between Brushtail Possum and Koala scats, and the fact that no Koala sightings in the study area can support these records, the current evidence does not indicate presence of a current population in the study area. Previous records of Koala in the study area range from 1980 to 2004 (OEH, 2016a).
Vegetation composition	+2 (high)	Has forest, woodland or shrubland with emerging trees with two or more known koala food tree species in the canopy.	The study area supports one primary, 10 secondary and one supplementary canopy food tree.
Habitat connectivity	+2 (high)	Area is part of a contiguous landscape ≥ 1000 ha.	The study area is part of the Pilliga Forests which is greater than 1,000 ha of contiguous vegetation.
Key existing threats	+1 (medium)	Evidence of infrequent or irregular koala mortality from vehicle strike or dog attack at present in areas that score 1 or 2 for koala occurrence.	Anecdotal records of vehicle strikes have been recorded in the Pilliga Forests. The existing population of foxes, cats and dogs in the Pilliga Forests creates a threat of koala mortality from attack.
Recovery value	0 (low)	Habitat is unlikely to be important for achieving the interim recovery objectives for the relevant context	Results from the regional koala survey indicate that the study area does not provide refuge for the persistence of the species during droughts. The study area does not provide reliable soil moisture and fertility.

The assessment on adverse effects on habitat critical to the survival of the koala was then undertaken (DotE, 2014b) and is outlined below:

- Does your impact area contain habitat critical to the survival of the koala (habitat score ≥ 5)? YES
- Do the area(s) proposed to be cleared contain known koala food trees? YES
- Are you proposing to clear ≤ 2 ha of habitat containing known koala food trees in an area with a habitat score of 5? NO

- Are you proposing to clear ≥ 20 ha of habitat containing known koala food trees in an area with a habitat score ≥ 8? NO
- Referral recommended. Assess characteristics that contribute to adverse effects to habitat critical to the survival of the koala. These have been listed below as either high (contributing to adverse effects) or low (reduce adverse effects)
    - The habitat score is lower (low)
    - A larger area of potential koala habitat is being cleared (high)
    - The method of clearing is clear-felling (high).
    - The density of koalas is considered to be ≤ 0.01 koalas per ha (low)
    - The clearing is fragmenting the habitat (high)

The outcome indicated that a referral is recommended as there is potential for the project to adversely affect habitat critical to the survival of the koala. The project was referred to the Commonwealth Department of the Environment on 3 November 2014 (2014/7376). The project was determined a 'controlled action' on 1 December 2014 due to potential impacts on listed threatened species and communities, a water resource, in relation to coal seam gas development and large coal mining development and commonwealth land. Assessment of the project has been delegated to the State under the assessment bilateral agreement with the NSW Government.

Detailed assessment of the potential impacts of the project on the Koala (as listed under the EPBC Act) is included in **Appendix K**. The assessment found that the project is unlikely to significant impact the Koala as:

- There have been no recent sightings of Koala in the study area and the study area is unlikely to have historically supported a large population of Koala.
- Local and regional studies of the Koala population in the Pilliga forests indicate that the study area does not provide core Koala habitat.
- The small proportion of habitat loss in the study area (less than 2%) is unlikely to adversely affect the long-term survival of Koala in the study area.
- Habitat in the study area is not contributing to the maintenance of genetic diversity or allowing the species to exist at the limit of its range.
- The project is not considered likely to interfere substantially with the recovery of the Koala, as it is unlikely to result in:
    - increased Koala fatalities due to dog attack or vehicle strike
    - the spread of disease or pathogens
    - the creation of barriers to movement to, between or within habitat critical to the survival of the Koala
    - changes to the hydrology of the study area.
- Mitigation measures such as progressive rehabilitation, staged construction and the avoidance of access outside of the disturbance footprint will be implemented.
- The residual impacts of the project on Koala will be offset in general accordance with the NSW Biodiversity Offset Policy for Major Projects.

6.3.3 Threatened flora

The study area is known to support 10 threatened flora species. Direct impacts on numbers of individuals removed have been calculated and presented in **Table 41** below. For those species where a population model was run, the lower and upper 95% confidence intervals are presented to account for the variability in the data.

In order to reduce the likelihood of a significant impact on populations of the flora species *Lepidium aschersonii* and *Lepidium monoplocoides* in the study area, a clearing limit of 1.55% of the population in the study area was assessed which currently equates to three *Lepidium aschersonii* and four *Lepidium monoplocoides* individuals. Should surveys increase the known abundance of these species during the project, then the number of impacted individuals can increase but must stay below 1.55% of the population in the study area.

Table 41: Direct impacts: threatened flora individuals

Species	Study area			Direct and indirect impact			Proportion		
	Estimated mean abundance	Lower 95% CI	Upper 95% CI	Impact (number of individuals)	Lower 95% CI	Upper 95% CI	Impact (%)	Lower 95% CI	Upper 95% CI
Bertya opponens	956,861	861,791	1,051,932	10,309	N/A	N/A	1.08%	N/A	N/A
Diuris tricolor	3,353	1,743	6,444	52	27	100	1.55%	1.55%	1.55%
Lepidium aschersonii	208	N/A	N/A	3	N/A	N/A	1.55%	N/A	N/A
Lepidium monoplocoides	258	N/A	N/A	4	N/A	N/A	1.55%	N/A	N/A
Myriophyllum implicatum	1	N/A	N/A	0	N/A	N/A	0	N/A	N/A
Polygala linariifolia	16,317	8,187	28,095	252	127	435	1.54%	1.55%	1.55%
Pomaderris queenslandica	45,518	44,124	46,913	467	N/A	N/A	1.03%	N/A	N/A
Pterostylis cobarensis	431,718	338,850	549,833	6,658	5,220	8,477	1.54%	1.54%	1.54%
Commersonia procumbens	240,274	90,799	857,601	3,716	1,404	13,265	1.55%	1.55%	1.55%
Tylophora linearis	33,154	25,739	43,712	513	398	676	1.55%	1.55%	1.55%

The area of occupancy for *Bertya opponens* and *Pomaderris queenslandica* was calculated based on patches of the species recorded in the study area. For all modelled flora populations, potential habitat in the study area was calculated. These values are presented in **Table 42** below.

Table 42: Direct impacts: threatened flora habitat

Species	Area of occupancy (ha)	Predicted habitat (ha)	Direct and indirect impact (ha)	Proportion
Bertya opponens	456.02	N/A	6.37	1.40%
Diuris tricolor	N/A	70,036.44	1,081.78	1.54%
Myriophyllum implicatum	10.27	N/A	0	0%
Polygala linariifolia	N/A	70,036.44	1,081.78	1.54%
Pomaderris queenslandica	90.11	N/A	1.44	1.60%
Pterostylis cobarensis	N/A	70,036.44	1,081.78	1.54%

Species	Area of occupancy (ha)	Predicted habitat (ha)	Direct and indirect impact (ha)	Proportion
Commersonia procumbens	N/A	70,036.44	1,081.78	1.54%
Tylophora linearis	N/A	70,036.44	1,081.78	1.54%

6.3.4 Threatened fauna

There is a risk of death to threatened fauna during the removal of habitat. Fauna death can occur from impact during tree felling, stress or loss of breeding sites during the critical growth phase for juveniles. This risk cannot be quantified but has been incorporated into the avoidance, minimisation and mitigation measures.

6.4 Indirect impacts

Indirect impacts have been calculated to equate to the removal of an additional 181.11 ha of vegetation in the study area as outlined in **Table 43** with detail on specific indirect site, downstream and facilitated impacts contained in **Section 6.4.1** to **Section 6.4.3**.

Table 43: Indirect impacts by infrastructure element

Location	Leewood	Bibblewindi	Bibblewindi to Leewood infrastructure corridor	Leewood to Wilga Park underground power line	The gas field	Ancillary	Total
Clearing required (ha)	0.36	.88	3.16	0	176.3	0.41	181.11

When combined with direct impacts, this equates to a total impact of 1,169.91 ha of vegetation and removal of approximately 1.46% of native vegetation in the study area (**Appendix A6**).

The indirect impact on fauna habitat equates to less than 0.3% of additional foraging or breeding habitat for the threatened fauna assessed (**Appendix A7**). Coupled with the proposed direct impacts, there would be less than two percent total impact on habitat for the threatened fauna assessed.

6.4.1 Site impacts

Fragmentation

Fragmentation is the division of a single area of habitat into two or more smaller areas, with a new habitat type occurring in the area between the fragments. Fragmentation can impact on flora and fauna species by creating barriers to movement and dispersal, which can result in genetic isolation of populations. If movement is still possible between fragments, the more an individual is forced to cross open areas between habitat fragments, the greater risk that individual faces and the more energy spent on dispersal and foraging. Fragmentation can also increase edge effects which impact those species that are 'core sensitive' rather than 'edge' species if habitats are heavily fragmented by a series of new habitat types (i.e. a network of roads compared to a single road) (Forman et al., 2003). It also facilitates movement of feral animals which has been discussed below.

The impact of fragmentation can vary depending on the resolution at which the fragmentation occurs, the intensity at which the habitat is removed and the strength of habitat selection (Cattarino, McAlpine, & Rhodes, 2013). As habitat declines, fragmentation at a fine scale forces more crossings of open area than fragmentation at a coarse scale. This impact varies among species, depending on the size of their home range in comparison to the scale and extent of fragmentation (Cattarino et al., 2013). It is therefore important to assess the scale of the fragmentation, the width of open space created and compare these to the dispersal potential and home ranges of the targeted species.

Patches of woody habitat are considered to be linked if they are separated by less than 100 m (or less than 30 m for grassy ecosystems) under the BioBanking assessment methodology (OEH, 2014a), provided the habitat is in moderate to good condition, the patch size is greater than 1 ha and the separation is not a dual carriageway or wider highway.

The project will increase fragmentation in the study area by removing vegetation for infrastructure. This would include linear clearing for the gathering system, road network and the Bibblewindi to Leewood infrastructure corridor and block clearing for well pads, the construction of the Bibblewindi Site and the worker accommodation at Westport.

Fragmentation has been considered for this assessment based on a staged process during construction, to account for the time taken to construct the entire project. However, once constructed, infrastructure has been considered to remain operational during the 25 construction and operational period of the project. Hence, operational fragmentation has considered all infrastructure mentioned in **Section 1.2**.

Linear clearing for gathering systems would be an average of 10 m wide during construction (up to 12 m wide in some cases), and rehabilitated to approximately 5 m wide during operation. Infrastructure will be co-located with existing access roads, tracks or other existing linear features wherever possible which would decrease the number of smaller fragments created, but would increase the width of the fragmentation. The Bibblewindi to Leewood infrastructure corridor would be cleared to a maximum of 30 m width.

The well pads would be approximately one hectare. Following well installation, the majority of the pad would be rehabilitated leaving an area of approximately one quarter of a hectare for surface infrastructure and an additional 0.2 ha to use as a laydown area. The Bibblewindi site would be within a 16 ha approximately rectangular clearing that would be situated adjacent to current infrastructure. The worker accommodation at Westport would be located in an area already partially cleared and an additional 3 ha of habitat would be cleared. The layout of well pads and access tracks would mean that it is unlikely that patches of habitat would be isolated, but instead the distance to move through the habitat would be increased if an individual is to avoid crossing open spaces.

The intactness analysis indicated that the number of patches of habitat in the study area would increase from 387 to 721, almost doubling the number of patches. This would reduce the intactness index (a measure of zero to one, with one being full intactness) from 0.446 to 0.232. The area with lowest intactness is in the north of the study area, where the landscape is currently highly cleared. Due to the nature of the fragmentation caused by the project (by narrow linear features), the removal of habitat is not considered to be at a scale likely to result in the permanent isolation or fragmentation of populations with species still able to disperse between patches.

The impact of fragmentation has been considered for each threatened species considered potentially or known to occur in the study area. Calculating the ability of each flora species to continue to pollinate and of each fauna species to move through the habitat with the additional fragmentation required

understanding on the dispersal potential of each species and the magnitude of the clearing in comparison to this dispersal potential.

Noise

Little is known of the impacts of noise disturbance on fauna and the thresholds of noise they would tolerate. Some species are likely to tolerate noise generated by the project, whilst others will not, causing them to leave the affected area or making the area less desirable for breeding or foraging.

Given the reliance on the noise modelling to assist in the calculations of indirect impacts, a detailed review of noise impacts to fauna was undertaken to investigate a level of noise to be considered the limit of 'safe' noise levels for fauna. The results indicated that a level of 45dB(A) would be a conservative level to ensure that all fauna would not be indirectly impacted if noise was maintained below this level. While few studies have determined noise levels tolerated by fauna species, numbers of woodland bird species and owls in overseas studies decline between 42-48 dB (Delaney, Grubb, & Beier, 1999; Reijnen, Foppen, Braak, & Thissen, 1995).

A number of overseas studies have been conducted, which give an indication of how related species could respond. These studies indicate that many threatened fauna species that occur or have the potential to occur in the study area would be impacted by noise to some degree.

Regarding owls, a study of *Strix occidentalis lucida* (Mexican Spotted Owl) found that the owls flushed at noises such as those from aircraft overflights at levels of 92 dB(A) or greater, and were more disturbed by the sound of chainsaws (only 46dB(A)) compared to overflights (Delaney et al., 1999). Observations showed that noise sources on the ground were of greater concern than noise sources in the air. Noise could also affect foraging behaviour as some owls listen for their prey (Konishi, 2003). Thus, owls, including threatened owl species, could be sensitive to temporary noises as well as ongoing noise while foraging, particularly when the source of noise emanated from the ground.

Noise has been suggested as a disturbance to *Burhinus oedicnemus* (Stone-curlew) at distances up to 3 km (Green, Tyler, & Bowden, 2000). Bush Stone-curlew could be similarly sensitive to disturbance from noise.

Studies of how birds of prey respond to disturbance have indicated that that disturbance types may affect the response of birds of prey, with times of year influencing their responses. Further, the history of disturbance can influence individual bird responses, with some birds able to habituate to particular disturbance types. To illustrate this, human activities disturb wintering *Haliaeetus leucocephalus* (Bald Eagles) in America more so than normally occurring sounds, although gunshots elicited escape behaviour (Stalmaster & Newman, 1978). While *Falco peregrinus* (Peregrine Falcon) tolerated aircraft noise levels from 85-141 dB, low-level jet flights caused a flight response in some pairs, nest abandonment or reproductive failure (Ellis, Ellis, & Mindell, 1991). *Circus cyaneus* (Hen Harrier) displayed extreme tolerance to aircraft and missile bombing in North America (Jackson, Schardien, & McDaniel, 1977). The noise levels were within the range of 80-87 dB and the closest explosives occurred at 60 m from the foraging bird. There have been no reports of reduced reproductive success or physiological risks to Bald Eagles exposed to aircraft overflights or other types of military noise (Brown et al., 1999; Stalmaster & Kaiser, 1998). There were no observable effects to *Falco mexicanus* (Prairie Falcon) to blasts of 140 dB in the range of 560 m – 1,000 m (Holthuijzen et al., 1990). Some birds of prey e.g. Goshawks, have become tolerant of human-altered landscapes and have begun occupying urban habitats with relatively successful productivity (Rutz, Bijlsma, Marquiss, & Kenward, 2006) (Rutz, 2006). Ospreys appear to habituate to regular aircraft overflights (Trimper et al., 1998). However, pairs of birds in disturbed areas have been recorded to respond differently to other pairs of the same species in remote areas, with different responses during various stages of their life cycles (Ruddock & Whitfield, 2007).

Bats, particularly those that listen for their prey in addition to echolocating (e.g. Greater Long-eared Bat), may also be impacted by noise. Overseas studies on Greater Mouse-eared Bats (*Myotis myotis*) have found that these bats avoid areas with noise disturbance while foraging (Schaub, Ostwald, & Siemers, 2008; Siemers & Schaub, 2011). However, Greater Mouse-eared Bats have been recorded roosting in areas with high ambient noise (Schaub et al., 2008). Thus, responses to noise may be dependent on activities.

In overseas investigations of woodland birds and noise, Brotons & Herrando (2001) found reduced bird occurrence, breeding density and breeding success in fragments associated with road proximity in a Mediterranean agricultural area, attributing these results to a response to noise. Reijnen, Foppen, Braak, & Thissen (1995) found about 60% of woodland birds were found in lower densities adjacent to highways with higher noise levels compared with areas further away from highways. While it could be that other effects or interactions might contribute to these results (e.g. patch size or resource availability), there is evidence that habitat may be as or more important than noise in determining use of areas impacted by noise disturbances by some bird species (Warner, 1992). These studies indicate a trend of avoidance to noise disturbance for woodland bird species.

The project would result in increased noise levels in the study area as modelled (Appendix M of the EIS). During operation, at a given well pad, a small turbo charged generator and two PCP electric motors have been modelled to have a 45dB(A) radius of 48 m in calm conditions and 55 m in adverse conditions. The pilot flare at pilot wells have been modelled to have a 45dB(A) radius of 322 m in calm conditions and 437 m in adverse conditions. As some pilot wells will link into the gathering network and will therefore not have flares, it has been assessed that half of the pilots will need a flare. As one flare is required per set of four pilot wells, this equates to five flares at five different pilot well sets which would operate for a maximum of three years at each set.

At Leewood, noise impacts are considered under adverse conditions as they will be emitted 24h per day, with noise travelling further during the evening. Noise impacts have been calculated assuming the existence of a power station at Leewood. Without the power station, these calculations would be conservative. Noise at Leewood will be mitigated which would reduce the 45dB(A) radius to largely within the Leewood property boundary. The model shows a small area of vegetation to the east of the Newell Highway that would be subjected to levels of 45 dB(A) to 50 dB(A).

Noise mitigation at Bibblewindi has not been confirmed and this assessment considers no mitigation in place. The 45dB(A) radius under no mitigation would extend over 600 m (with mitigation the 45dB(A) radius would extend to approximately 100 m). The mitigated radius would be entirely within the direct impact boundary but the unmitigated buffer would not. It is important to note that the noise buffers at Bibblewindi have been calculated based on full flare conditions which are unlikely to occur frequently.

Noise during construction and different weather conditions are likely to alter the noise produced in these locations. However, they would be short term and it is the long term displacement due to noise that has been considered as the greater impact as part of this assessment.

Although most of the threatened fauna within the study area are considered to be impacted by noise to some degree, based on findings in the literature, there may be species that are particularly sensitive to increased noise. It is considered that Barking Owl and Bush Stone Curlew when breeding, nesting Glossy Black-cockatoo, nesting birds of prey, and bats that listen for their prey as well as detecting prey via echolocation, would be susceptible to disturbance from noise, and that disturbance from noise could impact on their behaviours and potentially their reproductive success or fitness. The extent to which these species would be impacted is not clear.

Indirect impacts from noise are considered to be contained within the calculated indirect impact buffer.

Traffic

Increased traffic flow could potentially impact flora via raised dust levels. Fauna could be impacted by increased chances of vehicle strike, and habitat degradation by increased edge effects and disturbance levels (light, noise, dust). The disturbance would be variable and coupled with the added impact of temporary visual and physical disturbance.

Little is known on the impacts of disturbance from increased traffic flow on fauna and the thresholds of disturbance they would tolerate. Collisions with vehicles have been identified as threats for threatened fauna species including Superb and Swift Parrot, Masked Owl, Koala, and Pale-headed Snake (OEH, 2016b). Those species that forage on the ground (including Turquoise Parrot, Diamond Firetail and Hooded Robin) would also be susceptible.

The project would result in construction of additional roads and hence increased traffic movement in the study area. During construction, there will be a short term increase in traffic, including light vehicles and construction machinery.

During construction, traffic is estimated to peak at approximately 350 vehicles per day across the study area. Ongoing construction of each production well is estimated to generate approximately 200 vehicles per day, across several locations in the study area. A conservative estimate of daily traffic during operations and maintenance is approximately 95 vehicles on non-forested roads and 125 vehicles within forested areas in the study area.

The speed limit for vehicle movement in the study area will be controlled, with a limit of 60 km/h throughout most areas in the study area, being reduced in construction or high activity areas to 40 km/h or as signposted.

Indirect impacts from traffic is considered to be contained within the calculated indirect impact buffer.

Fencing

Fencing can be a hazard to fauna through entanglement in barbs, usually on the top strand. A range of fauna are known to be impacted by fencing entanglement, especially nocturnal species such as bats, gliders and owls. Macropods can also get caught in the fencing if it is too high, with or without barbed wire, with the risk of capture increasing if the bottom strand is too low. Fencing close to a wetland can also hinder water birds from landing or taking off.

Fencing for the project would be installed around well pads and other infrastructure sites. All fencing would consist of ‘Fauna friendly’ exclusion fencing (without barbed wire).

It was not possible to quantify the indirect impacts of fencing so this indirect impact has been considered for each individual species in the impact assessments.

Light

Light would be increased in the study area both due to artificial light sources and by vegetation clearance opening up gaps in intact canopy cover. Artificial light sources are most likely to impact nocturnal fauna, potentially impacting movement and behaviour. This could cause changes such as increased predation, disorientation of individuals and reduced fitness. Increased sunlight reaching through the canopy would have the most impact on flora species, and could change the species composition to favour species that are more tolerant of increased light conditions.

During construction, artificial light would be emitted from a maximum of six drilling rigs and two completion rigs at one time. During operation, the Leewood property would be operational 24 hours per day, and would be a constant source of artificial light. Other sources of artificial light including from vehicles and machinery would be short term sources during both construction and operation.

Indirect impacts from light is considered to be contained within the calculated indirect impact buffer.

Weed invasion

There is potential for weeds to increase in the study area, particularly adjacent to roads (both existing and proposed) and gas pad areas. This may be due to weeds being transported by vehicles or personnel or by changes in environmental conditions resulting from clearing of vegetation.

The increase in weeds in cleared areas could result in weeds invading adjacent vegetation communities, impacting on the composition of these communities and the habitat for flora and fauna species. The majority of threatened species are threatened by habitat degradation through weed invasion.

Indirect impacts from weed invasion are considered to be contained within the calculated indirect impact buffer.

Increased feral fauna

Some predators such as foxes, dogs and cats use roads as movement corridors through the landscape. Roads that are more heavily used by predators tend to be unsealed rather than sealed, although it also depends on the structure of the surrounding landscape and the traffic volume.

The project would result in the creation of additional linear clearing for roads and gathering systems (taking into consideration that the gathering system will be co-located with existing roads where possible). The additional linear clearing would open up areas of the landscape to predators, allowing easier access to these areas and their prey. This would impact on all threatened fauna species to a degree, but particularly those that are favoured as prey for foxes, dogs and cats including ground foraging species such as Black-striped Wallaby, Pilliga Mouse, Diamond Firetail, Bush-stone Curlew and Speckled Warbler.

Increased numbers of feral fauna in areas previously less accessible would also introduce added competition stress on native species. This would occur across fauna assemblages and examples include increased completion for prey between Spotted-tailed Quoll and introduced predators such as cats and foxes, increased competition for habitat and foraging resources between Pilliga Mouse and House Mouse and hollow-dependent fauna competing for hollows with *Apis mellifera* (Feral Honeybee).

It was not possible to quantify impacts by increased feral fauna so this indirect impact has been considered for each individual species in the impact assessments (**Appendix J** and **Appendix K**).

Fire

Fire risk in the study area is related to bushfire prevalence and use of flaring. The study area is prone to bushfires that are severe and of high intensity. This is due to the existing landscape, vegetation structure and climatic conditions.

The extraction of natural gas which is a highly flammable could potentially cause fire should leaks and ignition occur simultaneously. The accidental lighting of fire would alter the fire regime in the study area.

Three types of flaring would operate in the study area: infield flaring, maintenance flaring and emergency flaring. Infield flaring would occur during early stages of the project, until the Leewood property was

operational (approximately 12 months). Once operational, the flaring would occur within the Leewood property only.

Infield flaring would have an average height of up to four metres from the top of the stack, with the stack height up to six metres. The flare stack at the Bibblewindi site and the Leewood property would be up to 50 m to the flare stack tip and the flare height would be up to 30 m from the flare tip. Maintenance flaring at the Leewood property is estimated to occur over four weeks every four years, while emergency flaring would be conducted on an as required basis.

The risk of bushfire in the study area is not considered likely to increase following implementation of mitigation measures.

6.4.2 Downstream or downwind impacts

Sedimentation, erosion and dust

Clearing of vegetation would increase the mobility of soil and lead to increased dust creation, erosion and sedimentation. Increased particulate matter can negatively impact on the habitat and growth of communities and species.

During construction, there will be high levels of dust created during vegetation removal and site preparation. The vegetation removal at one site will occur over a short timeframe (a few days per well pad and comparable timeframes for other infrastructure) and it is not considered that dust will be built up over a sustained timeframe. Dust loading on vegetation would be short term and removed by rain and wind, thereby not having a prolonged effect on plant physiology. Construction at Bibblewindi will occur over a longer timeframe (approximately two years) although the vegetation clearing will only be one phase of this construction plan and will be undertaken over a short timeframe (four to six weeks). Sedimentation loss during the long-term construction phase of at Bibblewindi will be managed through mitigation measures.

X-line road will be sealed from the Newell Highway to Bibblewindi which will carry the most traffic in the study area. During operations, if additional roads are highly utilised, they will also be sealed to manage dust creation.

Dust suppression will be applied along unsealed roads which will involve watering the roads. Treated water will be used that has elevated salt levels to assist in suppressing dust. Areas of environmental sensitivity will be watered using fresh water without elevated salt levels.

Partial rehabilitation of well pads and the gathering system will also minimise the area of exposed soil in the study area, thereby reducing dust during operation.

Indirect impacts from sedimentation, erosion and dust are considered to be contained within the calculated indirect impact buffer.

Hydrological change

Modifications to the surface layout in the study area has the potential to impact on the hydrology in the study area through altering water flow and filtration. The impact of these changes to the aquatic ecosystem have not been addressed in this assessment.

The sealing of X-line road would introduce a long section of impervious surface, potentially decreasing infiltration and groundwater recharge in the study area. Additionally, the gathering system and new roads constructed may cross creek lines in the study area, with potential to alter the hydrology.

No new road crossings will be installed across Bohena Creek, with crossings required to follow existing crossings. Additionally, the gathering system will be bored underneath the Bohena Creek riparian buffer and creek crossings to avoid vegetation impact within the riparian buffer.

Due to the design of non-linear infrastructure avoiding riparian buffers and following existing creek crossings, the impact to hydrology in the study area is considered to be minor.

Accidental spills and leaks

A range of chemicals would be used in the study area, including drilling fluid, cement (used during drilling phase and preparation of gas wells), hydrocarbons (used as lubricating oils, diesel and hydraulic oil), Oxyacetylene (used in welding), compressed Nitrogen, Triethylene glycol (TEG) (used for gas dehydration), Amines (aMDEA, MEA or DEA) (used for CO_2 removal from gas) and heat transfer oil (used for boilers). During the water treatment phase, a selection of water treatment chemicals would be used for operation and maintenance (Sodium Hypochlorite, Aqueous Ammonia, Sodium Bisulphite, Hydrochloric Acid, Sulphuric Acid, Anti Scalant, Biocide, Calcium).

Drilling fluid contains various additives designed to alter the physical characteristics of the fluid and seal the well shaft. The drilling fluids have high concentrations of chlorides that would also have a slightly elevated pH. These fluids would be present at gas wells until the drilling process is complete, after which fluids would be removed from the sumps and transported via tankers to the Leewood property for treatment.

These chemicals could potentially impact on threatened fauna species if ingested, or if habitat was degraded from spills or leakages. Fencing would be installed around the hardstand area at each well pad which would limit the ability for non-flying fauna to access the sumps. The additional disturbance at the well head (including noise) would also deter fauna from approaching the gas wells to ingest water from the sumps.

The fluids could also damage the surrounding environment should they leak from the sump. Provided adequate casing, bunding and erosion and sediment control protection is installed, the fluids are unlikely to significantly affect surrounding flora, fauna and vegetation. All chemical use in the study are would be controlled to ensure that spills and leakages are minimised.

6.4.3 Facilitated impacts

Hunting

The increase in the number of access tracks through the study area as a result of the project would increase the accessibility of the study area to hunters and illegal collectors. Glossy Black-cockatoo, Superb Parrot and Turquoise Parrot are threatened by illegal bird smuggling and egg collecting. Similarly, illegal egg collection and/or shooting are listed as key threats to *Hamirostra melanosternon* (Black-breasted Buzzard), *Falco hypoleucos* (Grey Falcon) and Square-tailed Kite. The Pale-headed Snake is also threatened by illegal collections from its natural habitat (OEH, 2016b).

It was not possible to quantify impacts by increased hunting so this indirect impact has been considered for each individual species in the impact assessments.

6.5 Cumulative impacts

6.5.1 Vegetation

A total of 1701.51 ha of native vegetation and grassland would be cumulatively impacted with the addition of the project to the study region (**Appendix A10**). This constitutes 253.4 ha of derived native grassland

and 1,448.11 ha of native vegetation. This would result in the removal of 0.57% of vegetation in the study region.

The cumulative impact on native vegetation is predominately made up of two Biometric Vegetation Types as these two types are the most commonly occurring in the study area. Brown Bloodwood – cypress – ironbark heathy woodland would have the greatest cumulative impact (722.11 ha) although this Biometric Vegetation Type is equivalent to five Plant Community Types mapped in the study area. This represents 1.96% of this Biometric Vegetation Type in the study region. White Cypress Pine – Bulloak – ironbark woodland will have the second greatest cumulative impact (506.05 ha). This represents 0.47% of this Biometric Vegetation Type in the study region.

6.5.2 Fauna habitat

The cumulative impact on foraging, breeding and other habitat for all threatened fauna species considered potential or known in the study area has been calculated (**Appendix A11**). Cumulative impact ranges from 0.25 ha to 1,701.51 ha for foraging habitat and from 0 ha to 1,701.51 ha for breeding habitat. Those species with the broadest habitat preferences are also those that have the greatest habitat loss calculated and as such, the impact is more specifically analysed by percentage loss.

The greatest percentage loss of foraging habitat in the study region is 0.76% and the greatest percentage loss of breeding habitat in the study region is 0.76%. Cumulative impacts exceed 0.5% of foraging habitat for 13 fauna species and breeding habitat for four fauna species in the study region. Cumulative impacts exceed 0.4% of foraging habitat for an additional twenty-eight fauna species and breeding habitat for an additional twenty-two fauna species in the study region.

6.5.3 Flora

The cumulative impact on threatened flora individuals known in the study area has been calculated (**Table 44**). The greatest cumulative loss of a threatened flora species in the study area is 1.79% and the average is 1.33%.

Table 44: Cumulative impact: threatened flora

Species	Impact (number of individuals)	Impact in study area (%)
Bertya opponens	10,309	1.07%
Diuris tricolor	52	1.55%
Lepidium aschersonii	3	1.55%
Lepidium monoplocoides	4	1.55%
Myriophyllum implicatum	0	0
Polygala linariifolia	252	1.54%
Pomaderris queenslandica	467	1.03%
Pterostylis cobarensis	7,364	1.70%
Commersonia procumbens	3,716	1.54%
Tylophora linearis	594	1.79%

6.6 Impact on aquatic ecology

Potential impacts on aquatic ecology within the study area are assessed in Appendix I of the EIS.

6.7 Impact on groundwater dependant ecosystems

Potential impacts to Groundwater Dependent Ecosystems (GDEs) within the study area are assessed in Appendix G of the EIS.

6.8 Threat abatement plans

Threat abatement plans are written with aims on research, management and other actions in order to reduce the impact of listed key threatening processes on native species and ecological communities. They are listed under the TSC Act (OEH, 2014e), FM Act (DPI, 2014b) and EPBC Act (DotE, 2014d). Not all key threatening processes have a corresponding threat abatement plan. Those key threatening processes with threat abatement plans that are relevant to this project are listed below with an asterisk (*).

6.9 Key threatening processes

Key threatening processes threaten or have the potential to threaten the survival or evolutionary development of a species, population or ecological community. They are listed under the TSC Act (OEH, 2013b), FM Act (DPI, 2014d) and EPBC Act (DotE, 2009) and are listed below if relevant to the project. Key threatening processes listed with an asterisk (*) have a threat abatement plan prepared.

A database has been prepared as part of this assessment that links all threatened species considered potential or known to occur in the study area with all listed key threatening processes. This database has been used to inform which management techniques will have the greatest impact in improving biodiversity values relevant to the project.

There is evidence of the majority of the key threatening processes listed below already in the study area (with the exception of the presence of *Phytophthora cinnamomi* and no research on loss of climatic habitat in the study area). The magnitude to which these key threatening processes may be exasperated by the project is addressed in the assessments of significance in **Appendix J** and **Appendix K**.

6.9.1 TSC Act key threatening processes

Direct impacts

- Clearing of native vegetation
- Loss of hollow-bearing trees
- Removal of dead wood and dead trees.

Invasive species

- Competition and grazing by the feral European rabbit (*Oryctolagus cuniculus*)
- Competition and habitat degradation by feral goats (*Capra hircus*)
- Competition from feral honey bees (*Apis mellifera*)
- Invasion of native plant communities by exotic perennial grasses
- Predation and hybridisation of feral dogs (*Canis lupus familiaris*)
- Predation by the European red fox (*Vulpes vulpes*)*
- Predation by the feral cat (*Felis catus*)
- Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*).

Environmental modification

- Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands
- Anthropogenic climate change

- High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.

6.9.2 FM Act key threatening processes

Direct impacts

- The removal of large woody debris from NSW rivers and streams*
- The degradation of native riparian vegetation along New South Wales water courses.

Invasive species

- Introduction of fish to fresh waters within a river catchment outside their natural range.

Environmental modification

- Human-caused climate change
- Instream structures and other mechanisms that alter natural flow.

6.9.3 EPBC Act key threatening processes

Direct impacts

- Land clearance

Invasive species

- Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala*)
- Competition and land degradation by rabbits*
- Competition and land degradation by unmanaged goats*
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)
- Novel biota and their impact on biodiversity
- Predation by European red fox*
- Predation by feral cats*
- Predation, habitat degradation, competition and disease transmission by feral pigs*.

Environmental modification

- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases.

6.10 Critical habitat register

Critical habitat is an area of land that is crucial to the survival of particular threatened species, populations and ecological communities. There are no critical habitat declarations that are considered relevant to this assessment. Critical habitat registers are maintained under the TSC Act (OEH, 2013a) EPBC Act (DotE, 2014c) and FM Act (DPI, 2014c).

6.11 Significance of impact

Assessments of Significance under the EPA Act and/or EPBC Act have been carried out for those species and ecological communities considered ‘potential’, ‘likely’ or ‘known’ to occur in the study area and a summary is provided in **Table 45**. Assessment of significance for these species can be found in **Appendix J** (EPA Act) and **Appendix K** (EPBC Act).

The assessments of significance concluded that the project is unlikely to have a significant impact on threatened and migratory species and ecological communities as the magnitude of direct, indirect and cumulative impacts are considered unlikely to effect the long-term survival of the species or ecological

communities in the study area. This is primarily due to the small proportion of habitat being removed relative to that retained in the study area; the removal of habitat not being at a scale likely to result in the isolation or fragmentation of populations; that the project is unlikely to result in invasive species or diseases becoming established; and that progressive rehabilitation of disturbed areas will be implemented as part of the project.

An EPBC referral (ref 2014/7376) was prepared for the project which identified and assessed a wide range of threatened and migratory species and ecological communities that could be potentially be impacted by the project. The EPBC referral was prepared prior to the development of detailed project design and took a precautionary approach when assessing the potential impacts of the project and hence in determining significance. The EPBC referral identified that the project may have a significant impact on a range of species which have been assessed in detail in this assessment and found to be unlikely to be significantly impacted by the project.

Despite this conclusion, residual impacts of the project (including matters of national environmental significance) will be offset in general accordance with the NSW Biodiversity Offset Policy for Major Projects.

Table 45: Threatened ecological communities, flora, fauna and migratory species known, considered likely or have potential to be in the study area

Scientific name	Common name	Status		Occurrence in study area	Conclusion of Assessment of Significance	
		TSC Act	EPBC Act		TSC Act	EPBC Act
Ecological communities						
TSC: Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions EPBC: Brigalow (Acacia harpophylla dominant and co-dominant)		E	E	Known	No significant impact	No significant impact
Carbeen Open Forest Community in the Darling Riverine Plains and Brigalow Belt South Bioregions		E	~	Known	No significant impact	~
TSC: Myall Woodlands in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW south western slopes bioregions EPBC: Weeping Myall Woodlands		E	E	Known	No significant impact	No significant impact
Fuzzy Box Woodland on alluvial soils of the south western slopes, Darling Riverine Plains and Brigalow Belt South bioregions		E	~	Known	No significant impact	~=
Flora						
Bertya opponens	Coolabah Bertya	V	V	Known	No significant impact	No significant impact
Diuris tricolor	Painted Diuris	V	~	Known	No significant impact	~
Lepidium aschersonii	Spiny Peppercress	V	V	Known	No significant impact	No significant impact
Lepidium monoplocoides	Winged Peppercress	E1	E	Known	No significant impact	No significant impact

Scientific name	Common name	Status		Occurrence in study area	Conclusion of Assessment of Significance	
		TSC Act	EPBC Act		TSC Act	EPBC Act
Myriophyllum implicatum	~	CE	~	Known	No significant impact	~
Polygala linariifolia	Native Milkwort	E1	~	Known	No significant impact	~
Pomaderris queenslandica	Scant Pomaderris	E1	~	Known	No significant impact	~
Pterostylis cobarensis	Greenhood Orchid	V	~	Known	No significant impact	~
Commersonia procumbens	~	V	V	Known	No significant impact	No significant impact
Tylophora linearis	~	V	E	Known	No significant impact	No significant impact
Birds						
Anseranas semipalmata	Magpie Goose	V	Mar	Potential	No significant impact	No significant impact
Anthochaera phrygia	Regent Honeyeater	CE	CE, M	Potential	No significant impact	No significant impact
Apus pacificus	Fork-tailed Swift	~	M, Mar	Known	~	No significant impact
Ardea ibis	Cattle Egret	~	M, Mar	Known	~	No significant impact
Ardea modesta (syn. *Ardea alba*)	Great Egret, White Egret	~	M, Mar	Known	~	No significant impact
Ardeotis australis	Australian Bustard	E1	~	Potential	No significant impact	~
Artamus cyanopterus cyanopterus	Dusky Woodswallow	V	~	Known	No significant impact	~
Botaurus poiciloptilus	Australasian Bittern	E1	E	Potential	No significant impact	No significant impact
Burhinus grallarius	Bush Stone-curlew	E1	~	Potential	No significant impact	~
Calidris acuminata	Sharp-tailed Sandpiper	~	M, Mar	Potential	~	No significant impact
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	~	Known	No significant impact	~
Chthonicola sagittata	Speckled Warbler	V	~	Known	No significant impact	~
Circus assimilis	Spotted Harrier	V	~	Known	No significant impact	~
Daphoenositta chrysoptera	Varied Sittella	V	~	Known	No significant impact	~
Ephippiorhynchus asiaticus	Black-necked Stork	E1	~	Known	No significant impact	~
Falco hypoleucos	Grey Falcon	E1	~	Potential	No significant impact	~

Scientific name	Common name	Status		Occurrence in study area	Conclusion of Assessment of Significance	
		TSC Act	EPBC Act		TSC Act	EPBC Act
Falco subniger	Black Falcon	V	~	Known	No significant impact	~
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	~	M, Mar	Potential	~	No significant impact
Glossopsitta pusilla	Little Lorikeet	V	~	Known	No significant impact	~
Grantiella picta	Painted Honeyeater	V	V	Known	No significant impact	No significant impact
Grus rubicunda	Brolga	V	~	Potential	No significant impact	~
Hamirostra melanosternon	Black-breasted Buzzard	V	~	Potential	No significant impact	~
Hieraaetus morphnoides	Little Eagle	V	~	Known	No significant impact	~
Hirundapus caudacutus	White-throated Needletail	~	M, Mar	Known	~	No significant impact
Lathamus discolor	Swift Parrot	E1	CE, Mar	Potential	No significant impact	No significant impact
Lophoictinia isura	Square-tailed Kite	V	~	Known	No significant impact	~
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	V	~	Known	No significant impact	~
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	~	Potential	No significant impact	~
Merops ornatus	Rainbow Bee-eater	~	M, Mar	Known	~	No significant impact
Myiagra cyanoleuca	Satin Flycatcher	~	M, Mar	Known	~	No significant impact
Neophema pulchella	Turquoise Parrot	V	~	Known	No significant impact	~
Ninox connivens	Barking Owl	V	~	Known	No significant impact	~
Oxyura australis	Blue-billed Duck	V	~	Potential	No significant impact	~
Pachycephala inornata	Gilbert's Whistler	V	~	Potential	No significant impact	~
Petroica boodang	Scarlet Robin	V	~	Potential	No significant impact	~
Plegadis falcinellus	Glossy Ibis	~	M, Mar	Known	~	No significant impact
Polytelis swainsonii	Superb Parrot	V	V	Potential	No significant impact	No significant impact
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	V	~	Known	No significant impact	~

Scientific name	Common name	Status		Occurrence in study area	Conclusion of Assessment of Significance	
		TSC Act	EPBC Act		TSC Act	EPBC Act
Rostratula australis (*syn. Rostratula benghalensis australis*)	Australian Painted Snipe	E1	E, Mar	Potential	No significant impact	No significant impact
Stagonopleura guttata	Diamond Firetail	V	~	Known	No significant impact	~
Stictonetta naevosa	Freckled Duck	V	~	Potential	No significant impact	~
Tyto novaehollandiae	Masked Owl	V	~	Known	No significant impact	~
Mammals						
Aepyprymnus rufescens	Rufous Bettong	V	~	Potential	No significant impact	~
Cercartetus nanus	Eastern Pygmy Possum	V	~	Known	No significant impact	~
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Potential	No significant impact	No significant impact
Chalinolobus picatus	Little Pied Bat	V	~	Known	No significant impact	~
Dasyurus maculatus	Spotted-tailed Quoll	V	E	Potential	No significant impact	No significant impact
Macropus dorsalis	Black-striped Wallaby	E1	~	Known	No significant impact	~
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V	~	Known	No significant impact	~
Nyctophilus corbeni	South-eastern Long eared Bat	V	V	Known	No significant impact	No significant impact
Petaurus norfolcensis	Squirrel Glider	V	~	Known	No significant impact	~
Phascolarctos cinereus	Koala	V	V	Likely	No significant impact	No significant impact
Pseudomys pilligaensis	Pilliga Mouse	V	V	Known	No significant impact	No significant impact
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	~	Known	No significant impact	~
Sminthopsis macroura	Stripe-faced Dunnart	V	~	Potential	No significant impact	~
Vespadelus troughtoni	Eastern Cave Bat	V	~	Known	No significant impact	~
Reptiles						
Hoplocephalus bitorquatus	Pale-headed Snake	V	~	Known	No significant impact	~

V- vulnerable; E1- endangered under the TSC Act; CE-critically endangered under the TSC Act; E- endangered under the EPBC Act; M- migratory under the EPBC Act and Mar – Marine under the EPBC Act

6.12 Impacts to OEH estate

6.12.1 Direct impacts

There will be no direct impacts to occur within the OEH estate discussed in this assessment.

Brigalow Nature Reserve is wholly excluded from the study area by a variable buffer greater than 180 meters in width. Therefore, no direct impacts will occur to this reserve, and indirect impacts are not expected to be significant.

The Brigalow SCA is located within the study area but is protected by a 50-metre surface exclusion zone, and a 110-metre subsurface exclusion zone. While underground infrastructure may be constructed beneath the surface exclusion zone, no direct surface or subsurface impacts will occur to the Brigalow SCA. Indirect impacts to this area may occur and have been addressed below.

The study area avoids any disturbance within the Pilliga East State Conservation Area. It is located upslope of the proposed development, with the closest point 50 m from the study area.

6.12.2 Management implications relating to pests, weeds and edge effects

Feral pests

Five feral birds and 12 feral mammals were recorded in the study area and the Brigalow Nature Reserve during surveys undertaken for the project. Feral species impact on biodiversity values through a range of functions including predation, herbivory, competition, habitat modification and destruction. Feral fauna were observed in all habitat types within the study area and the Brigalow Nature Reserve, with scats and tracks frequently observed along the sandy roads and creek beds.

Linear vegetation clearing is required for the construction of roads and gathering systems (taking into consideration that the gathering system will be co-located with existing roads where possible) within the wider study area. This would expose areas of the landscape to predators, allowing easier access to these areas and their prey. However, within the OEH estate that is the subject of this impact assessment, no direct impacts such as linear clearing will occur.

All feral fauna recorded in the study area increase the competition pressures and impact on biodiversity values to differing degrees. Competition pressures can reduce breeding and foraging habitat availability, force native species out of their preferred habitat and can lead to decreases in native species diversity, abundance and distribution. Herbivorous species modify the structure of vegetation by preferentially foraging on certain species, digging and altering the groundcover and soil and altering water flow and erosion. Some predators such as foxes, dogs and cats use roads as movement corridors through the landscape.

Feral animal control activities are planned to occur within the study area through implementation of a Pest Plant and Animal Management Plan that would be developed for the project. Strategies for management of feral fauna will be implemented during all phases of the project including construction, operation and rehabilitation. This management plan will be used to ensure that feral fauna present within the study area are managed effectively, thus resulting in no additional impacts from feral fauna within OEH estate.

The Proponent has committed to the development of a nil-tenure feral animal control strategy which will initially focus on the study area (including a 5 – 10 km buffer) and will be implemented over a 20 year period. This strategy will target feral fauna that have been identified as presenting a high risk to the survival of native flora and fauna within the Pilliga. The strategy will provide control strategies for management along with monitoring that should be undertaken to detect changes to feral fauna abundance

and impacts to non-target species. No domestic pets (including cats or dogs) will be allowed within the study area.

The OEH estate addressed in this assessment is unlikely to be affected by increased impacts from feral fauna than those currently experienced. This is due to the fact that no direct impacts will occur within the reserved properties, as well as the presence of buffers and exclusion zones around these areas. Feral animal control activities and implementation of the Pest Plant and Animal Management Plan will ensure that feral fauna populations that are present within the wider study area are managed, thus reducing impacts to the OEH estate.

The duration of indirect impacts is discussed in **Section 4.11.2**.

Weeds

116 exotic species were identified within the study area and the Brigalow Nature Reserve, with eight of these declared noxious weeds within the Narrabri Local Government Area (DPI, 2014).

During the implementation of the project, potential exists for the presence of weeds to increase within the study area, particularly adjacent to roads (both existing and proposed) and gas pad areas. This is generally due to transport of weeds into areas with vehicles, equipment or personnel or through changes in environmental conditions resulting from clearing of vegetation. Access to and use of the study area will be managed by the proponent through the use of site inductions. These will ensure that there is no unmanaged visitation to the OEH estate as a result of project related activities.

An increase in weeds in cleared areas could result in weeds invading adjacent vegetation communities, impacting on the composition of these communities and the habitat for flora and fauna species. The majority of threatened species are threatened by habitat degradation including through weed invasion. However, within the OEH estate that is the subject of this impact assessment, no direct impacts such as vegetation clearing for development of the project will occur.

A Pest Plant and Animal Management Plan will be developed for the project. The management plan would provide measures to minimise weed transportation, monitor invasive species and ensure that weeds are managed effectively. Mitigation measures to be implemented for management of weed invasion will ensure that the impacts to the reserved areas are managed effectively.

The OEH estate addressed in this assessment is unlikely to be affected by increased impacts from exotic species than those currently experienced. This is due to the fact that the areas will remain intact with no direct impacts to occur within the OEH estate, along with buffers and exclusion zones around the reserves provided within the study area. Implementation of the Pest Plant and Animal Management Plan will also ensure that weeds are managed effectively.

Strategies for management of weeds will be implemented during all phases of the project including construction, operation and rehabilitation.

The duration of indirect impacts is discussed in **Section 4.11.2**.

Edge Effects

Vegetation present within the study area provides a link between the study area and OEH estate, and therefore allows maintenance of biodiversity. Clearing of vegetation causes fragmentation of these areas, and therefore increases the potential for edge effects to occur along the perimeter of the cleared areas. Vegetation with a minimal edge to area ratio will be more likely to withstand impacts that may occur as a result of edge effects such as weed invasion, wind damage and desiccation (OEH, 2013).

Fragmentation is the division of a single area of habitat into two or more smaller areas, with a new habitat type occurring in the area between the fragments. Fragmentation can impact on flora and fauna species by creating barriers to movement and dispersal, which can result in genetic isolation of populations. Fragmentation can also increase edge effects which impact upon those species that are 'core sensitive' rather than 'edge' species if habitats are heavily fragmented by a series of new habitat types (i.e. a network of roads compared to a single road) (Forman et al., 2003).

Fauna may be impacted by habitat degradation by increased edge effects. Vegetation and habitat areas present within the study area provide a range of support values to reduce the effects of indirect impacts such as edge effects through increasing vegetation patch size, buffering and providing corridor connections between patches of vegetation.

Fragmentation (and therefore increased edge effects) will occur within the wider study area as a result of the development of the project including construction of well pads and the gathering system/access tracks within the gas field, the Bibblewindi site, the infrastructure corridor from Bibblewindi to Leewood and construction of the workers accommodation at Westport. The design and location of infrastructure for the project maximise the use of areas within or adjacent to existing disturbance or with lower ecological sensitivity. This strategy will continue to reduce the overall extent of clearing required and minimise additional fragmentation and edge effects within the landscape.

Buffers are present around two of the OEH estates addressed within this assessment (the Brigalow Nature Reserve (180 m) and the Brigalow SCA (50 m)), and will provide protection from edge effects within these areas. The Pilliga East SCA is 50 m from the boundary of the project at the closest point, therefore no edge effects will occur as a result of vegetation clearing or disturbance.

The impacts of the project (including fragmentation and edge effects) have been shown to be unlikely to significantly impact threatened species or ecological communities. This is primarily due to the small proportion of habitat being removed relative to that retained in the wider study area; the removal of habitat not being at a scale likely to result in the isolation or fragmentation of populations; that the project is unlikely to result in invasive species or diseases becoming established; and that progressive rehabilitation of disturbed areas will be implemented as part of the project.

Strategies for management of edge effects will be implemented during all phases of the project including construction, operation and rehabilitation.

The duration of indirect impacts is discussed in **Section 4.11.2**.

6.12.3Noise impacts

Noise

Noise impacts will occur during the construction, operation and rehabilitation phases of the project. Noise will occur as a result of the construction of well pads and the gathering system/access tracks within the gas field, the Leewood and Bibblewindi sites, the infrastructure corridor from Bibblewindi to Leewood and construction of the workers accommodation at Westport. The project would result in increased noise levels in the study area as modelled (Appendix M of the EIS).

Little is known of the impacts of noise disturbance on fauna and the thresholds of noise they would tolerate. Some species are likely to tolerate noise generated by the project, whilst others will not, causing them to leave the affected area or making the area less desirable for breeding or foraging. A number of overseas studies have been conducted, which give an indication of how related species could respond.

These studies indicate that many threatened fauna species that occur or have the potential to occur in the study area would be impacted by noise to some degree.

Given the reliance of noise modelling to assist in the calculations of indirect impacts, a detailed review of noise impacts to fauna was undertaken to investigate a level of noise to be considered the limit of 'safe' noise levels for fauna. The results indicated that a level of 45dB(A) would be a conservative level to ensure that all fauna would not be indirectly impacted if noise was maintained below this level. While few studies have determined noise levels tolerated by fauna species, numbers of woodland bird species and owls in overseas studies decline between 42-48 dB (Delaney, Grubb, & Beier, 1999; Reijnen, Foppen, Braak, & Thissen, 1995).

Although most of the threatened fauna within the study area are considered to be impacted by noise to some degree, based on findings in the literature, there may be species that are particularly sensitive to increased noise. It is considered that Barking Owl and Bush Stone Curlew when breeding, nesting Glossy Black-cockatoo, nesting birds of prey, and bats that listen for their prey as well as detecting prey via echolocation, would be susceptible to disturbance from noise, and that disturbance from noise could impact on their behaviours and potentially their reproductive success or fitness. The extent to which these species would be impacted is not clear.

The duration of indirect impacts are discussed in **Section 4.11.2**. During operation, at a given well pad, a small turbo charged generator and two PCP electric motors have been modelled to have a 45dB(A) radius of 48 m in calm conditions and 55 m in adverse conditions. The pilot flare at pilot wells have been modelled to have a 45dB(A) radius of 322 m in calm conditions and 437 m in adverse conditions. It has been assumed that only half of the pilots will need a flare. As one flare is required per set of four pilot wells, this equates to five flares at five different pilot well sets which would operate for a maximum of three years at each set.

At Leewood, noise impacts are considered under adverse conditions as they will be emitted 24 hours per day, with noise travelling further during the evening. Noise impacts have been calculated assuming the existence of a power station at Leewood. Without the power station, these calculations would be conservative. Noise at Leewood will be mitigated which would reduce the 45dB(A) radius to largely within the Leewood property boundary. The model shows a small area of vegetation to the east of the Newell Highway that would be subjected to levels of 45 dB(A) to 50 dB(A).

Noise generated from the operation of the well heads would deter fauna from approaching the gas wells, and therefore protect them from hazards present at these locations.

Buffers are present around two of the OEH estates addressed within this assessment (the Brigalow Nature Reserve (180 m) and the Brigalow SCA (50 m)), and the Pilliga East SCA is 50 m from the boundary of the project at the closest point providing some protection from noise impacts within these areas..

Strategies for management of noise will be implemented during all phases of the project including construction, operation and rehabilitation. Noise mitigation design and engineering measures have been provided within Appendix M of the EIS.

6.12.4Threats to ecological connectivity and groundwater-dependent ecosystems

Ecological Connectivity

The study area is located within the Pilliga Forests region, which has greater than 500,000 hectares of contiguous vegetation. This vegetation provides linkages between vegetation and fauna habitat types

present within the study area. In addition to this, the study area is intersected by drainage lines and associated riparian vegetation which allows for further connectivity across the Pilliga landscapes. The study area is comprised of 75% native vegetation and 10% derived native grassland all of which provide key features for ecological connectivity.

Up to 988.8 ha of remnant native vegetation and fauna habitat will be removed for development of this project. However, the area to be cleared represents only 1.29% of native vegetation within the study area. Therefore, the removal of habitat that may occur as a result of the implementation of the project is considered to not be at a scale likely to result in the isolation or fragmentation of populations between the study area and the OEH estates with ecological connectivity therefore maintained. No vegetation will be removed within OEH estate. Mitigation measures have been proposed to minimise the potential occurrence and impact of disruption to ecological connectivity.

An existing road network is present within the forested portion of the study area covering a distance of approximately 760 km. This road network contributes to potential impacts that may occur to ecological connectivity. However, it has been demonstrated that the study area continues to maintain suitable habitat for threatened flora and fauna, and for native vegetation even with connectivity reduced through the presence of the road infrastructure. Therefore, further linear clearing within the project area is expected to have minor impacts on connectivity.

Preventing access outside disturbance footprints, implementation of progressive rehabilitation, staged construction and the presence of vegetation in non-impacted areas which will continue to mature, will ensure that vegetation clearing in the areas closest to the OEH estate is not considered likely to impact upon ecological connectivity. Disturbed areas will be rehabilitated and left to regenerate where possible, which will ensure that in the long term, the connectivity of vegetation and fauna habitat will be maintained.

Given the importance of riparian corridors to maintain ecological connectivity, activities have been modified within these areas to avoid disturbance. Installation of the gas gathering system infrastructure within riparian areas of Bohena Creek will occur using under-boring methods to prevent clearing of vegetation, and no new road crossings of Bohena Creek will be constructed as part of the project.

Buffers are present around two of the OEH estates addressed within this assessment (the Brigalow Nature Reserve (180 m) and the Brigalow SCA (50 m)), and will ensure ecological connectivity within these areas. No surface disturbance will occur within 50 m of the Pilliga East SCA, which will ensure that ecological connectivity is maintained in this area.

The potential for project implementation to contribute to impacts as a result of a loss of ecological connectivity has been shown to be unlikely. This is primarily due to the small proportion of vegetation being removed relative to that retained in the wider study area; the removal of habitat not being at a scale likely to result in isolation or fragmentation; and that progressive rehabilitation of disturbed areas will be implemented as part of the project. In addition to this, the buffers and surface exclusion zones present around OEH estate will ensure that within these areas, no additional internal fragmentation will occur as a result of project implementation.

The duration of indirect impacts is discussed in **Section 4.11.2**.

7 Mitigation measures

The following section provides mitigation measures recommended for the project. These measures are recommended following the implementation of the avoidance and minimisation measures provided in **Section 6.2**. All measures and management required will be detailed in an Environmental Management Plan (EMP). It will be prepared prior to construction works commencing and would integrate ecological management procedures with construction and operation phases.

The successful application of the proposed mitigation measures requires all personnel working on the project to be aware of the mitigation measures and the reasons why they are required. To ensure this education is obtained by all personnel, an ecological induction should be prepared and undertaken prior to commencement of work. The ecological induction should be up to date with biodiversity issues and site environmental procedures specific to the project. The induction should include stop work procedures and details on key contacts for an environmental emergency of environmental notification.

7.1 General mitigation measures

General mitigation measures have been provided for each identified risk and the timing in which the mitigation measure should be applied (**Table 46**).

Table 46: Mitigation measures by impact

Impact	No.	Mitigation measure	Timing
General ecology management			
General ecology management	G1.	A Biodiversity Management Plan would be developed and would include: • Significant Species Management Plan • Management measures to minimise impacts to flora and fauna.	Pre-construction
Direct impacts			
Vegetation removal, habitat removal, removal of threatened flora individuals	D1.	Vegetation would be cleared in accordance with the clearing procedure provided in **Appendix H** to minimise impacts to fauna during vegetation removal.	Pre-construction, and construction
	D2.	The removal of large hollows (≥300 mm) will be compensated for by at least a 1:1 replacement. Specific detail regarding offset ratios, locations for hollow re-instatement and an implementation strategy is contained within the Biodiversity Offset Strategy (**Appendix L**).	Construction
	D3.	Protocols would be developed and implemented to record vegetation clearance and threatened flora	Construction

Impact	No.	Mitigation measure	Timing
		removal and ensure it is within the approved overall limits.	
	D4.	Open trenches should be inspected once daily by a suitably qualified fauna handler. Data should be collected on the species, number of individuals captured and capture locations.	Construction
	D5.	Vegetation clearing would be managed to minimise clearing during sensitive breeding periods for fauna. A hierarchical timing for clearing from most to least preferred is: March to June; February and July/August; and September to January.	Construction
	D6.	Rehabilitation of impacted areas would occur as soon as practicable in accordance with the Rehabilitation Strategy	Construction Decommissioning
Indirect site impacts			
Fragmentation	I - s 1.	Infrastructure will be co-located with existing roads wherever practicable. Well pads located no closer than 750 m to each other. Mitigation measures D1 – D6.	See D1 – D6
Noise	I - s 2.	Noise mitigation design and engineering measures as specified in Appendix M of the EIS.	Design, construction and operation
Traffic	I - s 3.	The speed limit of 60 km/h within State Forests will be enforced. This speed limit will be reduced to 40 km/h in construction areas (i.e. lease areas and service corridors constructed for the activity). Otherwise the posted speed limit will apply.	Construction, operation and rehabilitation
	I - s 4.	Driving during high fauna activity periods (that is, from dusk through to dawn) would be minimised.	Construction, operation and rehabilitation
Fencing	I - s 5.	'Fauna friendly' exclusion fencing (without barbed wire) would be installed around well sites during operation unless determined under a land access agreement.	Construction
Light	I - s 6.	Lighting would be focused on work sites during construction and on project infrastructure during operation to minimise light spill into adjoining areas.	Construction and operation
Weed invasion	I - s 7.	Prior to earthworks, weeds listed as Noxious under the NW Act that are present on the site would be	Construction

Impact	No.	Mitigation measure	Timing
		removed or treated with herbicide to prevent or reduce their spread	
	I - s 8.	Weeds would be controlled in accordance with a Pest Plant and Animal Management Plan that would be developed for the project..	Construction, operation and rehabilitation
Increased feral fauna	I - s 9.	Feral animals would be controlled in accordance with a Pest Plant and Animal Management Plan that would be developed for the project.	Construction, operation and rehabilitation
	I - s 10.	No domestic pets (including cats or dogs) will be allowed within the study area.	Construction, operation and rehabilitation
Fire	I - s 11.	Smoking should be restricted in the study area to decrease risk of a fire.	Construction, operation and rehabilitation
	I - s 12.	A bushfire hazard and risk assessment will be developed and implemented.	Construction, operation and rehabilitation
Indirect downstream or downwind impacts			
Sedimentation, erosion and dust	I - d 1.	Dust suppression within the roads and well sites should be undertaken to reduce the impacts of dust.	Construction, operation and rehabilitation
	I - d 2.	Dust suppression using water trucks should be correlated with vehicle and construction activity. Once construction is complete, water trucks should not be used to control dust at well pads.	Construction, operation and rehabilitation
	I - d 3.	Appropriate sediment and erosion control management plan should be installed and maintained. This should include the following measures: a. Specifics about activities that intersect with the riparian corridor or a waterway	Construction, operation and rehabilitation
	I - d 4.	b. Excess topsoil and subsoil generated during site preparation activities will be stockpiled onsite and used as backfill following completion of drilling.	Construction, operation and rehabilitation
	I - d 5.	c. Excavated surface and subsurface soils will be stockpiled separately to avoid profile inversion.	Construction and operation
	I - d 6.	d. Stockpiled subsoils should be covered to avoid compaction and water erosion.	Construction and operation

Impact	No.	Mitigation measure	Timing
	I - d 7.	e. Stockpiles will be managed according to best management practices such as the measures outlined in Managing Urban Stormwater: Soils and Construction (Landcom, 2004) ('the Blue Book').	Construction and operation
	I - d 8.	f. Erosion and sediment controls will be implemented where necessary during construction activities, in accordance with best management practices (such as the Blue Book or International Erosion Control Association (IECA) Guidelines). These controls will be maintained until disturbed areas of the site are stabilised.	Construction, operation and rehabilitation
	I - d 9.	g. Given the very high potential dispersibility of subsoils at the sites, exposed subsoils should be protected either with vegetation (high ground cover), appropriate matting or preferred surface protection measures during both.	Construction, operation and rehabilitation
Hydrological change	I - d 10.	Addressed in infrastructure placement and design (**Section 6.2**).	Design
	I - d 11.	A water management plan will be developed and implemented, to address issues associated with hydrological changes and water quality impacts for both surface and groundwater.	Construction and operation
Accidental spills and leaks	I - d 12.	All liquids (fuel, oil, cleaning agents, drilling liquids etc.) will be stored appropriately and disposed of at suitably licensed facilities.	Construction, operation and rehabilitation
	I - d 13.	Spill management procedures will be implemented as required.	Construction, operation and rehabilitation
	I - d 14.	A chemical management procedure will be developed to control and manage chemical use on site. This would ensure that no chemicals would enter aquatic environments through runoff or direct application.	Construction and operation
Indirect facilitated impacts			
Hunting	I - h 1.	Observations of illegal hunting or collecting of flora or fauna materials should be recorded and appropriate personnel should be notified.	Construction, operation and rehabilitation

7.2 Pre-clearing and clearing procedure

A pre-clearing and clearing procedure has been developed to minimise potential impacts or risk to fauna during vegetation removal (**Appendix H**). The purpose of the procedure is to identify fauna and flora occurrence in the subject site, encourage fauna to relocate outside of the subject site prior to habitat clearing and move fauna during clearing.

Clearing operations are supervised by an appropriately qualified ecologist following the steps listed below and described in more detail in **Appendix H**. During clearing, the number of hollow-bearing trees and threatened flora removed will be recorded so that clearing limits are not surpassed. The clearing procedure contains the following key steps.

1. Planning and walk-through
2. Slash shrub and ground layer (under scrubbing)
3. Tap hollow-bearing trees
4. Remove hollow-bearing trees

Positive communication is maintained throughout the clearing process.

7.3 Environmental management

Appropriate construction and operational controls will be developed and implemented (i.e. construction and operational management plans) to ensure that mitigation measures are successfully implemented.

7.4 Rehabilitation strategy

A rehabilitation strategy has been prepared for the project and is detailed in Appendix V of the EIS. The rehabilitation strategy has been designed to ensure an effective rehabilitation process and provide details how rehabilitation works will proceed following disturbance by the project.

The objectives of this rehabilitation strategy include:

- To ensure topsoil and subsoil is managed to conserve the seed bank, nutrients and to encourage the establishment of vegetation.
- Disturbed areas are to be rehabilitated to their pre-disturbance condition. Forested land will be rehabilitated to its former vegetation community and agricultural land will be rehabilitated to meet the former agricultural capability class.
- Ensuring rehabilitation works comply with relevant regulatory requirements.
- Establishment of a set of indicators and a rehabilitation monitoring program to ensure successful rehabilitation.
- Establishment of agreed criteria where rehabilitation is deemed successful by relevant authorities and stakeholders.

The final land use of rehabilitated areas will be consistent with previous land uses strategies and relevant planning instruments. Rehabilitation will include the re-establishment of native forest, woodland and agricultural lands where appropriate. Rehabilitation of the impacted areas will occur as soon as practicable, with timing influenced by a range of factors including safety, security and bushfire asset protection requirements. Following the construction and installation of infrastructure, approximately 55% of clearing associated with the well pads and 50% of clearing associated with the gas and water gathering systems will be rehabilitated. Following the decommissioning of infrastructure, full rehabilitation of sites will be undertaken.

Actions undertaken during the clearing of vegetation include stockpiling 'waste' timber from felled trees not suitable for forestry activities, fallen logs and bush rock for later use in habitat restoration; slashing and mulching low vegetation onsite; protection of topsoil with temporary soil protection matting or striping and stockpiling topsoil and subsoil. Rehabilitation actions include; replacing subsoil then topsoil; re-installing habitat features such as fallen timber and bush rock; followed by natural re-establishment of slashed and cleared native vegetation. Should natural regeneration not achieve the desired outcomes within a defined period, then assisted regeneration through direct seeding and/or planting will be undertaken to achieve the objectives of the rehabilitation strategy.

Rehabilitation of existing exploration and appraisal activities is currently being undertaken. These activities provide a benchmark for understanding the potential reduction in impact as a result of rehabilitation works identified for the project. The Proponent has commenced a program of rehabilitation works throughout PEL 238 and PAL 2. Rehabilitation works include:

- Reducing the size of existing well pads back to the minimum area required for operations.
- Plugging and abandoning wells that are no longer required for exploration and appraisal, according to legislative requirements, and rehabilitating associated well pads.
- Rehabilitating a number of water storage ponds that are no longer required for exploration and appraisal activities.

While floristic composition varies between rehabilitated areas and reference sites (as expected after removal of vegetation), rehabilitation monitoring has provided encouraging results for such a short time period since disturbance. Partial regeneration of well pads and gathering systems has occurred to date, with the overall site value of rehabilitation sites approximating 74% of the site value at reference sites. Rehabilitation measures undertaken have been considered using adaptive management principles with monitoring informing future modifications to works and methodology.

Preliminary rehabilitation completion criteria have been developed and will be revised in discussion with stakeholders such as the NSW Office of Coal Seam Gas (OCSG), Forestry Corporation NSW and landholders. Completion criteria provide a standard against which final rehabilitation success will be measured. The satisfactory achievement of the completion criteria (as indicated by monitoring results) will demonstrate that the rehabilitated areas can be signed off in a stable and sustainable condition.

The rehabilitation strategy includes the regular monitoring of rehabilitated areas. Monitoring will evaluate the progress of vegetation establishment, assess whether the objectives of the strategy and performance criteria are being met, and if required suggest measures to increase rehabilitation success.

7.5 Nil-tenure feral animal control strategy

The Proponent has committed to the development of a nil-tenure feral animal control strategy which will be approximately equivalent to one third of the total offset liability of the project. The feral animal control strategy will initially focus on the study area (including a 5 – 10 km buffer) and will be implemented over a 20 year period. The strategy will focus efforts heavily in the first couple of years followed by maintenance control for the remaining period.

Consultation with NSW Forestry Corporation, the NSW National Parks and Wildlife Service and private landholders will be held during the preparation of the strategy to identify ways to integrate the feral animal control strategy with other strategies across the Pilliga region.

The nil-tenure feral animal control strategy will address feral animal control at a landscape scale. Given the connectivity of habitat in the study area and Pilliga, it is considered most beneficial to approach feral animal control at this scale.

The strategy will be designed to target feral fauna identified as high risk to the survival of native flora and fauna in the Pilliga. Control measures used will be specific for the target fauna species, with a range of control techniques to be applied. The poisoning of non-target species will be addressed through the design of the control techniques. The strategy will include monitoring to detect changes to targeted feral fauna abundance from control measures applied at the landscape scale. Monitoring will also aim to detect poisoning of non-target species to ensure the program is not having adverse effects on native wildlife.

7.6 Monitoring

A monitoring program will be developed post-approval as part of a Biodiversity Management Plan for the project. The Biodiversity Management Plan will include a Significant Species Management Plan and management measures to minimise impacts to flora and fauna.

The monitoring program will specify a rigorous methodology to scientifically monitor the direct and indirect impacts of the project. This will include ensuring that the proposed mitigation measures are adequately addressing the impacts and will work to implement additional measures as required to ensure that impacts are avoided and mitigated to the highest degree possible throughout the 25 construction and operational life of the project. The monitoring program will include quantitative key performance targets to ensure that progress is being compared to measurable benchmark conditions.

Monitoring will also occur at offset properties as required to ensure that the management of the offset properties is adequate for the aims of the associated Offset Management Plan. The monitoring required will depend on the management tasks required but may include rehabilitation monitoring or revegetation monitoring.

Previous monitoring programs (e.g. by Forestry Corporation of NSW) would be reviewed to align efforts where possible with existing data sources.

8 Biodiversity offset strategy

This section provides a brief summary of the Biodiversity Offset Strategy including objectives, quantification of offset liability and the approach which will be undertaken to address the residual impacts of the project. The Biodiversity Offset Strategy is included in **Appendix L**.

The Biodiversity Offset Strategy has been prepared to ensure that the residual impacts of the project (following implementation of avoidance, minimisation and mitigation measures) are adequately compensated for and that long-term conservation outcomes are achieved in recognition of the *NSW Offsetting Principles* (OEH, 2014d) and the *NSW Biodiversity Offset Policy for Major Projects* (OEH, 2014c).

As the *NSW Biodiversity Offset Policy for Major Projects* was developed as a whole-of-government policy and includes Matters of National Environmental Significance, offsets determined under the *NSW Biodiversity Offset Policy for Major Projects* are considered likely to satisfy EPBC Act offset requirements.

This objective will be accomplished by ensuring:

- Vegetation, habitat and threatened species at offset sites have equal or greater conservation status to areas impacted by the project.
- Offsets are greater than the loss of areas impacted by the project.
- Land-based offset sites, supplementary measures and contributions to the Biodiversity Offset Fund are appropriately funded, secured and managed.
- That Aboriginal people have opportunities to increase cultural knowledge of their country and opportunities to access and manage its natural and cultural values.

The Biodiversity Offset Strategy is a framework document which considers threatened and migratory species, populations and ecological communities listed under the TSC Act and the EPBC Act and will be supported by a detailed Biodiversity Offset Management Plan detailing how the offset strategy and offset package will be implemented.

The Biodiversity Offset Strategy follows a four-step approach:

1. Quantification of the impacts of the project for informed by the Framework for Biodiversity Assessment (FBA) to guide the development of the offset strategy including direct, indirect and cumulative impacts as well as the contribution that undertaking immediate rehabilitation post construction makes to reducing the overall offset liability.
2. Undertaking ‘reasonable steps’ to locate like-for-like offset, including:
    a. Checking the biobanking public register and having an expression of interest (EOI) for credits wanted for at least six months.
    b. Liaising with the OEH Northern Plains Region office and Narrabri Council to obtain a list of potential sites that meet the requirements for offsetting.
    c. Considering properties for sale in the area.
    d. providing evidence of why offset sites are not feasible.
3. Development and contribution of funds for supplementary measures such as feral animal control, threatened species research and monitoring measures to be implemented through Planning Agreements (PAs).
4. For the remaining offset liability to be held for eventual transfer into the Biodiversity Offset Fund (once established).

8.1 Offset requirements to achieve long-term conservation outcomes

The Framework for Biodiversity Assessment (Major Projects Credit Calculator Version 4.1) was used to inform the 'quantum' of biodiversity offsets required for the project. Four key elements were considered:

- **Direct impacts** – 988.8 ha (split between direct impacts and areas subject to immediate rehabilitation) - vegetation/habitat/species clearance
- **Indirect impacts** – 181.1 ha - fragmentation, noise, light, weeds, feral animals etc.
- **Cumulative impacts** – 84.8 ha - existing impacts in the study area from infrastructure that will be utilised by the project
- **Immediate rehabilitation** – 586.6 ha - partial rehabilitation of linear and non-linear infrastructure areas immediately following construction

Quantification of impacts and offset liability for both ecosystem and species credit species was undertaken as outlined below.

Direct impacts of the project (988.8 ha) were initially calculated to require 58,813 ecosystem credits to be offset which is reduced to a total of 24,009 ecosystem credits when areas subject to immediate rehabilitation are considered separately (586.6 ha). Indirect impacts (181.1 ha) were calculated to require an additional 3,366 ecosystem credits and cumulative impacts (84.8 ha) were calculated to require an additional 5,233 ecosystem credits to be offset. Areas subject to immediate rehabilitation following construction (586.6 ha) require 23,505 ecosystem credits, which reduces the overall offset requirement for directly impacted areas by 19.2%.

A total of 53,009 ecosystem credits are required to meet the outcomes of the Framework for Biodiversity Assessment. Using the OEH credit converter which assumes an average Biobank site will generate 9.3 credits per ha, the equivalent offset area is 6,034 ha. This equates to a 6.1:1 offset ratio against a direct impact of 988.8 hectares or a 4.8:1 offset ratio against a combined direct, indirect and cumulative impact of 1,254.8 ha.

Four threatened fauna species and nine threatened flora species recorded in the study area are listed as 'species credit' species under the Framework for Biodiversity Assessment. Credits required for flora species range from 43 to 147,272 credits. Credits required for fauna species range from 20,092 to 37,792 credits. *Bertya opponens* requires the largest number of flora credits to be offset, while *Hoplocephalus bitorquatus* (Pale-headed Snake) requires the greatest number of fauna credits to be offset.

Full detail on the offset quantification methodology and results can be found in **Appendix L**.

8.2 Biodiversity Offset Package

The biodiversity offset package for the project will contain a combination of

- **Like-for-like offsets** secured via an appropriate conservation mechanism (including purchase and retirement of biodiversity credits (where available), protection under Biobanking Agreements, or reservation under the NSW *National Parks and Wildlife Act 1974*).
- **Supplementary measures** developed and funded through Planning Agreements (PAs) under the NSW *Environmental Planning and Assessment Act 1979* (EPA Act).
- **Compensatory measures** such as Koala research.
- **NSW Biodiversity Offsets Fund for Major Projects** will be used for remaining offset liability (when established).

The availability and suitability of potential offset sites in the region will be investigated post submission of the Environmental Impact Statement. This process will seek to meet the majority of the like-for-like offset liability of the project as far as practicable

A range of supplementary measures have been considered as part of the Biodiversity Offset Package including a nil-tenure feral animal control strategy, weed control and prescribed burning. The Proponent has committed to the development of a nil-tenure feral animal control strategy which will be approximately equivalent to one third of the total offset liability of the project. The feral animal control strategy will initially focus on the study area (including a 5 – 10 km buffer) and will be implemented over a 20 year period.

The Biodiversity Offset Package will also include compensatory measures, including a *Phascolarctos cinereus* (Koala) research proposal which aims to determine the precise location and sizes of remnant Koala populations in the broader Pilliga region to inform conservation efforts for the important population of this species.

Once land-based offsets and supplementary measures have been finalised, the remaining offset liability for the project will be converted into a dollar figure and held for eventual transfer into the Biodiversity Offset Fund (once established). The precise mechanism for holding the financial offset liability until the establishment of the Biodiversity Offset Fund is yet to be determined, but may include preparation of a Planning Agreement or bond.

8.3 Indigenous cultural heritage values and activities

Consideration of Aboriginal cultural heritage values is a key component of the Biodiversity Offset Strategy. Cultural heritage values will be identified and integrated into biodiversity offsets in three ways:

- Aboriginal cultural heritage values such as important sites, places of traditional or recent significance and culturally important plants and animals will be identified as part of the selection of suitable land-based biodiversity offsets.
- Community access to biodiversity offset areas will be facilitated where practicable.
- Community management of offset lands will be encouraged.

8.4 Statement of commitments

In line with the contents of the Biodiversity Offset Strategy (**Appendix L**), The Proponent will:

- Commit to delivering biodiversity offsets which meets the offset quantum determined by the Framework for Biodiversity Assessment, including the development of an offset package which includes a combination of:
    - Like-for-like offsets secured via an appropriate conservation mechanism.
    - Supplementary measures developed and funded through Planning Agreements.
    - Compensatory measures including Koala research.
    - NSW Biodiversity Offsets Fund for Major Projects will be used for remaining offset liability (when established).
- Identify cultural heritage values as part of the biodiversity offset package, including:
    - Incorporation of Aboriginal cultural heritage values in land-based offset sites.
    - Community access to biodiversity offsets.
    - Community management of land-based offsets.
- Prepare a Biodiversity Offset Management Plan that clearly outlines the responsible parties for the implementation of the plan, the works required to improve biodiversity values (including but not restricted to fire management, weed and feral animal control, erosion and sediment control,

restrictions on access, revegetation), performance criteria and a reporting and monitoring program in accordance with the Biobanking Assessment Methodology.

- Prepare a nil-tenure feral animal control strategy which will be approximately equivalent to one third of the total offset liability of the project which will address feral animal control at a landscape scale.
- Undertake reporting for land-based offsets owned and managed by the Proponent in accordance with the Biobanking Assessment Methodology.
- Undertake a periodic review of the Biodiversity Offset Management Plan every 5 years in accordance with the Biobanking Assessment Methodology.

9 Conclusion

Field surveys undertaken for this ecological assessment from 2010 to 2014 confirmed that the study area contains a high diversity of common and threatened vegetation communities, flora species and fauna species. In total, 22 Plant Community Types comprising 80,398 ha of native vegetation, 807 flora species and 289 fauna species were identified in the study area.

Four of the mapped Plant Community Types in the study area qualify as endangered ecological communities (with two of these endangered ecological communities being further divided by status under the EPBC Act and TSC Act due to condition).

Ten of the flora species in the study area are listed as threatened under the TSC Act. Of these, five are also listed as threatened under the EPBC Act. There were 116 exotic flora species recorded of which eight are declared noxious within the Narrabri Local Government Area.

A total of 17 amphibians, 186 birds, 45 mammals and 41 reptiles were recorded in the study area to species level. Of these, 16 birds, 10 mammals and one reptile are listed as threatened under the TSC Act, three mammals and one bird are listed as threatened under the EPBC Act and five birds are listed as migratory under the EPBC Act. Five birds and 12 mammals recorded in the study area are feral species.

The direct impacts of the project would result in the removal of up to 988.8 ha of native vegetation which includes 75.9 ha of derived native grassland. This equates to the removal of approximately 1.29% of native vegetation and 0.80% of derived native grassland in the study area. The indirect impacts of the project would be equivalent to an additional removal of 181.11 ha of native vegetation.

The direct and indirect impacts to vegetation would additionally impact on fauna foraging, breeding and dispersal habitat. For all threatened fauna species that potentially or are known or occur in the study area, the direct and indirect impact to habitat would account for less than 2% of the total habitat available in the study area.

The direct removal of threatened flora species has been estimated through modelling or mapping where possible. Impacts to the abundance of each threatened flora species is less than 2% of the total abundance estimated to occur in the study area.

Cumulative impacts have been calculated that consider all existing and proposed exploration and production appraisal activities associated with the Energy NSW coal seam gas exploration and appraisal program operated by the Proponent in the study region. Additionally, the direct and indirect impacts of Narrabri Coal Mine on biodiversity values relevant to the study area were included in the assessment. A total of 1,701.51 ha of native vegetation and grassland would be cumulatively impacted with the addition of the project to the study region. This would result in the removal of 2.11% of vegetation in the study area and 0.57% of vegetation in the study region. Less than 3% of fauna habitat would be cumulatively impacted. Additionally, less than 3% of the total abundance for each threatened flora species would be cumulatively impacted.

The assessments of significance concluded that the project is unlikely to have a significant impact on threatened and migratory species and ecological communities as the magnitude of direct, indirect and cumulative impacts are considered unlikely to effect the long-term survival of the species or ecological communities in the study area. This is primarily due to the small proportion of habitat being removed

relative to that retained in the study area; the removal of habitat not being at a scale likely to result in the isolation or fragmentation of populations; that the project is unlikely to result in invasive species or diseases becoming established; and that the proposed avoidance, minimisation and mitigation measures will be implemented as part of the project.

The proposed mitigation measures including the Field Development Protocol which incorporates the Ecological Scouting Framework and Pre-clearing Procedure will further reduce impacts on threatened and migratory species and ecological communities at a site scale.

Residual impacts on threatened and migratory species and ecological communities will be offset as part of a Biodiversity Offset Strategy in general accordance with the NSW Biodiversity Offset Policy for Major Projects.

References

AKF. (2012). *Review of the Native Vegetation Regulation 2005 – PNF: Submission from the Australian Koala Foundation*. Brisbane, Queensland.

Alison Hunt & Associates Pty Ltd. (2011). *Narrabri to Wellington Gas Pipeline Draft Ecological Assessment*. Prepared for Eastern Star Gas.

Austen, J. . (1999). *The management of Bertya opponens - a vulnerable shrub: a precursor to the Draft Recovery Plan for the vulnerable shrub Bertya opponens*. University of New England.

Bell, D. M., Hunter, J. T., & Montgomery, L. (2012). Ephemeral wetlands of the Pilliga Outwash, northwest NSW. *Cunninghamia*, *12*(3), 181–190. Retrieved from http://www.rbgsyd.nsw.gov.au/science/Scientific_publications/cunninghamia/contents_by_volume/volume_12#twelvethree

Benson, J. S., Richards, P. G., Waller, S., & Allen, C. B. (2010). New South Wales Vegetation classification and Assessment: Part 3 Plant communities of the NSW Brigalow Belt South, Nandewar and west New England Bioregions and update of NSW Western Plains and South-western Slopes plant communities, Version 3 of the NSWVC. *Cunninghamia*, *11*(4), 457–579. Journal Article.

Biolink Ecological Consultants. (2008). *The utility of regularized, grid-based SAT (RGB-SAT) sampling for the purposes of identifying areas being utilized by koalas (Phascolarctos cinereus) in the South-east Forests of NSW - a Pilot Study.* (Report).

Blakers, M., Davies, S., & Reilly, P. N. (1984). *The Atlas of Australian Birds*. Book, Melbourne: Melbourne University Press.

BOM. (2014). Weather station directory. Retrieved from www.bom.gov.au

Breed, B., & Ford, F. (2007). *Native Mice and Rats*. Book, Victoria: CSIRO Publishing.

Brotons, L., & Herrando, S. (2001). Reduced bird occurrence in pine forest fragments associated with road proximity in a Mediterranean agricultural area. *Landscape and Urban Planning*, *57*(2), 77–89. article.

Brown, B. T., Mills, G. S., Powels, C., Russell, W. A., Therres, G. D., & Pottie, J. J. (1999). The influence of weapons-testing noise on bald eagle behavior. *Journal of Raptor Research*, *33*(3), 227–232. Retrieved from http://ulpeis.anl.gov/documents/dpeis/references/pdfs/Brown_et_al_1999.pdf

Carlton, C., & Paull, D. (2002). *Pilliga State Forest Flora and Fauna Survey 14 to 19 November 2001* (Report). Sydney: National Parks Association of NSW.

Carter, O. (2010). *National Recovery Plan for the Spiny Peppercress Lepidium aschersonii.* Melbourne.

Cattarino, L., McAlpine, C. A., & Rhodes, J. R. (2013). The consequences of interactions between dispersal distance and resolution of habitat clustering for dispersal success. *Landscape Ecology*, *28*(7), 1321–1334. Retrieved from http://link.springer.com/10.1007/s10980-013-9881-1

Churchill, S. (2008). *Australian Bats* (Vol. Second Edi). Book, Sydney: Allen and Unwin.

Council of Heads of Australasian Herbaria. (2014). Australia's Virtual Herbarium. Retrieved from http://avh.chah.org.au

DEC. (2004). *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities (Working Draft)* (Government Document, November). Sydney: NSW Department of Environment and Conservation.

DEC. (2006). Recovery Plan for the Bush Stone-curlew Burhinus grallarius. (N. S. W. D. of E. and Conservation, Ed.). Government Document, NSW Department of Environment and Conservation.

DEC. (2009). *Permanent marking of mammals using ear notching (SOP No. 12.2)* (Government Document). WA Department of Environment and Conservation.

DECC. (2007). *Threatened species assessment guidelines: The assessment of significance*. Hurstville.

DECC. (2008a). Descriptions for NSW (Mitchell) Landscapes, Version 3. (N. S. W. D. of E. and C. Change, Ed.). Government Document, NSW Department of Environment and Climate Change.

DECC. (2008b). Recovery plan for the koala (Phascolarctos cinereus). Government Document, Sydney, NSW: NSW Department of Environment and Climate Change.

DECC. (2009). *Threatened species survey and assessment guidelines: field survey methods for fauna. Amphibians.* Sydney: NSW Department of Environment and Climate Change.

DECCW. (2010). Guidelines for developments adjoining land and water managed by the Department of Environment, Climate Change and Water. Department of Environment, Climate Change and Water. Retrieved from http://www.environment.nsw.gov.au/protectedareas/developmntadjoiningdecc.htm

Delaney, D., Grubb, T., & Beier, P. (1999). Effects of helicopter noise on Mexican Spotted Owls. *The Journal of Wildlife Management*, *63*(1), 60–76. Retrieved from http://www.jstor.org/stable/3802487

Dennis, A. J., & Johnson, P. M. (2008). Rufous Bettong. In S. Van Dyck & R. Strahan. (Eds.), *The Mammals of Australia* (p. 285–286.). Sydney: Reed New Holland.

DEWHA. (2010a). *Survey guidelines for Australia's threatened bats: Guidelines for detecting bats listed as threatened under the EPBC Act* (Government Document). Canberra: Australian Government Department of Environment, Water, Heritage and the Arts.

DEWHA. (2010b). *Survey guidelines for Australia's threatened birds: Guidelines for detecting birds listed as threatened under the EPBC Act* (Government Document). Canberra: Australian Government Department of Environment, Water, Heritage and the Arts.

DEWHA. (2010c). *Survey guidelines for Australia's threatened frogs: Guidelines for detecting frogs listed as threatened under the EPBC Act*. Canberra: Australian Government Department of Environment, Water, Heritage and the Arts.

DMR. (2002). 250,000 Geology database. (D. of M. R. NSW, Ed.). Dataset, NSW Department of Mineral Resources.

DotE. (2009). Key threatening processes under the EPBC Act. Retrieved from http://www.environment.gov.au/topics/biodiversity/threatened-species-ecological-communities/key-threatening-processes

DotE. (2013a). Census of Australian vertebrate species. Canberra: Australian Government Department of the Environment.

DotE. (2013b). *Matters of National Environmental Significance: Significant impact guidelines 1.1 Environmental Protection and Biodiversity Conservation Act 1999*. Canberra.

DotE. (2013c). *Survey guidelines for Australia's threatened orchids: guidelines for detecting orchids listed as "threatened" under the EPBC Act 1999*. Canberra.

DotE. (2014a). Atlas of living Australia. Retrieved from http://www.ala.org.au/

DotE. (2014b). *EPBC Act referral guidelines for the vulnerable koala*. Canberra, ACT.

DotE. (2014c). Register of critical habitat. Retrieved from http://www.environment.gov.au/cgi-bin/sprat/public/publicregisterofcriticalhabitat.pl

DotE. (2014d). Threat abatement plans. Retrieved from http://www.environment.gov.au/topics/biodiversity/threatened-species-ecological-communities/threat-abatement-plans

DotE. (2016a). Protected Matters Search Tool [Web Page]. Retrieved February 17, 2016, from http://www.environment.gov.au/epbc/protect/index.html

DotE. (2016b). Species Profile and Threats Database. Retrieved from Http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

DPI. (2012). Guidelines for riparian corridors on waterfront land. Government Document, NSW Department of Primary Industries (NSW DPI).

DPI. (2014a). Noxious Weed Declarations. Retrieved January 1, 2014, from www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/noxweed

DPI. (2014b). Recovery and threat abatement plans. Retrieved from http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/what/recovery

DPI. (2014c). Register of critical habitat. Retrieved from http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/what/register

DPI. (2014d). What is currently listed: Key threatening processes. Retrieved from http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/what-current#Key-threatening-processes

DSEWPaC. (2011a). Draft Referral guidelines for the nationally listed Brigalow Belt reptiles. Government Document, Canberra: Australian Government Department of Sustainability, Environment, Water, Population and Communities.

DSEWPaC. (2011b). Survey guidelines for Australia's threatened mammals: Guidelines for detecting mammals listed as threatened under the EPBC Act. Government Document, Canberra: Australian Government Department of Sustainability, Environment, Water, Population and Communities.

DSEWPaC. (2011c). Survey guidelines for Australia's threatened reptiles: Guidelines for detecting reptiles listed as threatened under the EPBC Act. Government Document, Canberra: Australian Government Department of Sustainability, Environment, Water, Population and Communities.

Duncan, A., Baker, G. B., & Montgomery, N. (1999). *The Action Plan for Australian Bats. [Online].* Canberra. Retrieved from http://www.environment.gov.au/biodiversity/threatened/publications/action/bats/index.html

Dwyer, P. D. (1981). Centrefold No.9: Common Bentwing-bat Miniopterus schreibersii. *Australian Natural History*, *20*(6), 187–190. Journal Article.

Dwyer, P. D. (1995). Common Bent-wing Bat (Miniopterus schreibersii). In R. Strahan (Ed.), *The Australian Museum Complete Book of Australian Mammals* (pp. 494–495). Book Section, Sydney: Angus and Robertson Publishers.

ELA. (2008). *Namoi Wetland Assessment and Prioritisation Project* (Report) (Vol. Draft repo).

ELA. (2011a). *Bibblewindi Pilot: Addendum to the Dewhurst and Bohena Pilots Ecological Assessment* (Report).

ELA. (2011b). *Eastern Star Gas - Ecological investigations for Tintsfield 8 and Bibblewindi 30 core holes* (Report).

ELA. (2011c). *Narrabri Coal Seam Gas Project - Dewhurst and Bohena Pilots - Ecological Assessment* (Report).

ELA. (2011d). *Narrabri Gas Project - Addendum to the Ecological Assessment: spring micro-siting survey and assessment* (Report).

ELA. (2011e). *Seismic Line Survey* (Report).

ELA. (2012a). *Narrabri Gas Project - Analysis of rehabilitation from exploratory works* (Report).

ELA. (2012b). *Narrabri Gas Project targeted threatened flora survey* (Report).

ELA. (2012c). *North-east Pilliga Forest Targeted threatened flora survey* (Report). Prepared for Santos Limited.

ELA. (2013a). A Vegetation Map for the Namoi Catchment Management Authority: Revision 2.

ELA. (2013b). *Dewhurst Gas Exploration Pilot Expansion Ecological Assessment of the expansion of operations at Dewhurst 13-18H and Dewhurst 26-31 pilots* (Report). Prepared for Santos Limited.

ELA. (2013c). *Energy NSW coal seam gas (CSG) exploration and appraisal program: Impact assessment under the EPBC Act*. Prepared for Santos Limited.

ELA. (2013d). *Narrabri Gas Development Project - TSC Act Cumulative Impact Assessment*. Prepared for Santos Limited.

ELA. (2013e). *Narrabri Gas Development Project Second year analysis of rehabilitation from exploration activities* (Report). Prepared for Santos Limited.

ELA. (2013f). *Narrabri Gas Project - Bibblewindi Water Treatment Facility - Forest Health Assessment* (Report). Prepared for Santos Limited.

ELA. (2014a). *Energy NSW Coal Seam Gas (CSG) Exploration and appraisal program - Impact Assessment under the EPBC Act* (Report). Prepared for Santos Limited.

ELA. (2014b). *ENSW Core hole and 4 Spot Pilot Environmental Assessment Ecological Impact Assessment for Bibblewindi 34 Core hole and Dewhurst 4-Spot Pilot (32, 33, 36 & 37)* (Report). Prepared for Santos Limited.

ELA. (2014c). *Leewood Phase 2 Water Processing Facilities Ecological Assessment*. Prepared for Santos Limited.

ELA. (2014d). *Narrabri Coal Mine Stage 1 and 2 Biodiversity Offset Strategy.* Prepared for Narrabri Coal Operations Pty Ltd.

ELA. (2015). *Narrabri Gas Project Vegetation Mapping* (Report). Newcastle, NSW.

Ellis, D. H., Ellis, C. H., & Mindell, D. P. (1991). Raptor responses to low-level jet aircraft and sonic booms. *Environmental Pollution*, *74*(1), 53–83. article.

Ford, F. (2008). Delicate Mouse Pseudomys delicatulus. In S. Van Dyck & R. Strahan (Eds.), *The Mammals of Australia* (3rd ed., pp. 623–624). Book Section, Sydney: Reed New Holland.

Ford, G. I., Pennay, M., Young, R. A., & Richards, G. C. (2008). Little Pied Bat Chalinolobus picatus. In S. Van Dyck & R. Strahan (Eds.), *The Mammals of Australia* (p. 537–538.). Sydney: Reed New Holland.

Forman, R. T. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C. D., Dale, V. H., … Winter, T. C. (2003). *Road ecology: science and solutions*. *Review Literature And Arts Of The Americas*. Washington: Island Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=As1yk7rRUhsC&oi=fnd&pg=PR11&dq=Road+ecology:+science+and+solutions&ots=ueJ6QNXFao&sig=q9Ng-ETWsyZ3tJn6RM_ptjaG1_8

Fox, B. J., & Briscoe, D. A. (1980). Pseudomys pilligaensis, a new species of murid rodent from the Pilliga Scrub, northern New South Wales. *Australian Mammalogy*, *3*, 109–126. Journal Article.

Garnett, S. T. (1993). *Threatened and Extinct Birds of Australia. Royal Australasian Ornithologists Union Report 82*. Book, Royal Australian Ornithology Union and Australian National Parks and Wildlife Service.

Garnett, S. T., & Crowley, G. M. (2000). *The Action Plan for Australian Birds 2000. [Online].* Canberra, ACT. Retrieved from http://www.environment.gov.au/biodiversity/threatened/publications/action/birds2000/index.html

Green, R. E., Tyler, G. A., & Bowden, C. G. R. (2000). Habitat selection, ranging behaviour and diet of the stone curlew (Burhinus oedicnemus) in southern England. *Journal of Zoology*, *250*(2), 161–183. article. http://doi.org/10.1111/j.1469-7998.2000.tb01067.x

Harden, G. . (Ed.). (1992). *Flora of New South Wales, Volume 3* (1st ed.). Sydney: University of New South Wales Press, Kensington.

Harden, G. . (Ed.). (1993). *Flora of New South Wales, Volume 4* (1st ed.). Sydney: University of New South Wales Press, Kensington.

Harden, G. . (Ed.). (2002). *Flora of New South Wales, Volume 2, Revised Edition* (2nd ed.). Sydney: University of New South Wales Press, Kensington.

Harden, G. J. (Ed.). (2000). *Flora of New South Wales, Volume One, Revised Edition*. Sydney: University of New South Wales Press, Kensington.

Higgins, P. J., & Davies, S. J. J. F. (1996). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 3: Snipe to Pigeons.* Book, Melbourne: Oxford University Press.

Holthuijzen, A. M. A., Eastland, W. G., Ansell, A. R., Kochert, M. N., Williams, R. D., & Young, L. S. (1990). Effects of blasting on behavior and productivity of nesting prairie falcons. *Wildlife Society Bulletin*, 270–281. article.

Idyll Spaces Environmental Consultants. (2005). *PEL 238 Coal Seam Gas Flora Survey* (Report).

Idyll Spaces Environmental Consultants. (2006). *Flora Survey for proposed evaporation pond, PEL 238 Coal Seam Gas Project* (Report).

Idyll Spaces Environmental Consultants. (2007). *Flora Survey for proposed gas pipeline, PEL 238 Coal Seam Gas Project* (Report).

Idyll Spaces Environmental Consultants. (2009). *Flora Assessment of Proposed Seismic Surveys EC09 & EB09* (Report).

Idyll Spaces Environmental Consultants. (2010). *Flora Assessment: Proposed Drilling of Two Exploratory Core Holes, Dewhurst 20 & 21* (Report).

Jackson, J. A., Schardien, B. J., & McDaniel, T. H. (1977). Opportunistic hunting of a marsh hawk on a bombing range. *Raptor Res*, *11*(4), 86. article.

Johnson, G., & Baker-Gabb, D. . (1994). *The Bush Thick-knee in Northern Victoria (Part 1): Conservation and Management. Arthur Rylah Institute Technical Report No 129.*

Kavanagh, R. P., & Peake, P. (1993). Distribution and habitats of nocturnal forest birds in south-eastern New South Wales. In P. Olsen (Ed.), *Proceedings of the 10th Anniversary Conference, Canberra* (pp. 86–100). Book Section, Sydney: Australian Raptor Association, Royal Ornithologists Union.

Kavanagh, R. P., & Stanton, M. (2009). Conserving Barking Owls in the Pilliga Forests. *Wingspan*, (June), 28–30. Journal Article.

Kavanagh, R. P., Stanton, M. A., & Brassil, T. E. (2007). Koalas continue to occupy their previous home-ranges after selective logging in Callitris-Eucalyptus forest. *Wildlife Research*, *34*, 94–107. Journal Article.

Kendall and Kendall Ecological Consultants. (2005). *Fauna Study - PEL 238 Coal Seam Gas* (Report).

Kendall and Kendall Ecological Consultants. (2006). *Fauna Study - Proposed Water Management Facility at Bibblewindi PEL 238 Coal Seam Gas* (Report).

Kendall and Kendall Ecological Consultants. (2007). *Proposed Gas Pipeline, PEL 238 Coal Seam Gas Project - Fauna Assessment* (Report).

Kendall and Kendall Ecological Consultants. (2009). *PEL 238 - Proposed Seismic Surveys Coal Seam Gas Project* (Report).

Kendall and Kendall Ecological Consultants. (2010). *PEL 238 Coal Seam Gas Project - Proposed Drilling of Two Exploratory Core Holes. Dewhurst 20 & 21* (Report).

Koehn, J., Clunie, P., & Rylah, A. (2010). *National Recovery Plan for the Murray Cod Maccullochella peelii peelii*. Melbourne.

Konishi, M. (2003). Coding of auditory space. *Annual Review of Neuroscience*, *26*(Knudsen 2002), 31–55. http://doi.org/10.1146/annurev.neuro.26.041002.131123

Kushlan, J. A., & Hancock, J. (2005). *Herons*. Oxford, United Kingdom: Oxford University Press.

Landcom. (2004). *Managing Urban Stormwater: Soils and Construction, 4th Edition*.

Landmark Ecological Services, & The Wilderness Society. (2012). *The Ecological Values of Pilliga East Forest and the Threats Posed by Coal Seam Gas Mining 2011-2012* (Report).

Law, B. S., Herr, A., & Phillips, W. . (2008). Eastern False Pipistrelle. In S. Van Dyck & R. Strahan. (Eds.), *The Mammals of Australia* (pp. 542–543). Sydney: Reed New Holland.

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide*. Canberra: Murray-Darling Basin Authority.

Longland, W., & Clements, C. (1995). Use of fluorescent pigments in studies of seed caching by rodents. *Journal of Mammalogy*, *76*(4), 1260–1266. Retrieved from http://www.jstor.org/stable/1382621

LPI. (2013). *Digital Topographic Database*.

Marchant, S., & Higgins, P. J. (Eds.). (1990). *Handbook of Australian, New Zealand and Antarctic Birds. Volume One - Ratites to Ducks.* Melbourne, Victoria: Oxford University Press.

Marchant, S., & Higgins, P. J. (1993). Handbook of Australian, New Zealand and Antarctic Birds. Volume 2: Raptors to Lapwings. Edited Book, Melbourne: Oxford University Press.

Mavromihalis, J. (2010). *National Recovery Plan for the Winged Peppercress Lepidium monoplocoides.* Melbourne.

McDonald, R., Isbell, R., Speight, J., Walker, J., & Hopkins, M. (1998). *Australian Soil and Land Survey Field Handbook*. Canberra: Australian Collaborative Land Evaluation Program.

McShea, W., & Gilles, A. (1992). A comparison of traps and fluorescent powder to describe foraging for mast by Peromyscus leucopus. *Journal of Mammalogy*, *73*(1). Retrieved from http://www.jstor.org/stable/1381886

Menkhorst, P. W., & Knight, F. (2004). *A Field Guide to the Mammals of Australia* (2nd ed.). Book, South Melbourne: Oxford University Press.

Menkhorst, P. W., Weavers, B. W., & Alexander, J. S. A. (1988). Distribution, Habitat and Conservation Status of the Squirrel Glider Petaurus-Norfolcensis (Petauridae, Marsupialia) in Victoria. Generic, Australian Wildlife Research 15(1) 59 - 71 .

Milledge, D. (2004). Large owl territories as a planning tool for vertebrate fauna conservation in the forests and woodlands of eastern Australia. *Conservation of Australia's Forest Fauna*, *Second edi*, 493–507. Journal Article.

Niche Environment and Heritage. (2014). *Koala refuges in the Pilliga Forests.* Prepared for Eco Logical Australia and Santos.

North West Ecological Services. (2010). *Survey of the Habitat Requirements and Review of the Conservation Status of the Five-clawed Work Skink (Anomalopus mackayi) within the Namoi River Catchment* (Report).

NPWS. (2000a). Brigalow Belt South: Regional Assessment (Stage 1)Report on Preliminary Fauna Survey of Pilliga and Goonoo Forests, November 1999 to January 2000. (N. S. W. N. P. and W. Service, Ed.). Government Document.

NPWS. (2000b). Preliminary Overview of the Brigalow Belt South Bioregion (Stage 1). NSW Western Regional Assessments. (N. S. W. N. P. and W. Service, Ed.). Government Document.

NPWS. (2002). *Bertya sp. Cobar-Coolabah (Cunningham & Milthorpe s.n., 2/8/73) Recovery Plan*. Hurstville.

NSW Scientific Committee. (2002). White box yellow box Blakely's red gum woodland - endangered ecological community listing: NSW Scientific Committee - final determination. Last updated 28 February 2011.

NSW Scientific Committee. (2008). *Tylophora linearis P.I.Forst (Apocynaceae) - Review of Current information in NSW* (Report, June).

OEH. (2011). Brigalow Belt South Bioregion. Retrieved from http://www.environment.nsw.gov.au/bioregions/BrigalowBeltSouthBioregion.htm

OEH. (2012). Vegetation types database. Hurstville: NSW Office of Environment and Heritage.

OEH. (2013a). Critical habitat register. Retrieved from http://www.environment.nsw.gov.au/criticalhabitat/CriticalHabitatProtectionByDoctype.htm

OEH. (2013b). Key threatening processes. Retrieved from http://www.environment.nsw.gov.au/threatenedspecies/keythreateningprocesses.htm

OEH. (2013c). Land and Soil Capability mapping of NSW, version 2.5.

OEH. (2014a). *BioBanking Assessment Methodology*. Sydney: NSW Office of Environment and Heritage.

OEH. (2014b). *Framework for Biodiversity Assessment. NSW Biodiversity Offsets Policy for Major Projects*. *NSW Office of Environment and Heritage (OEH)*. Sydney.

OEH. (2014c). NSW Biodiversity Offsets Policy for Major Projects.

OEH. (2014d). OEH principles for the use of biodiversity offsets in NSW. Retrieved from http://www.environment.nsw.gov.au/biodivoffsets/oehoffsetprincip.htm

OEH. (2014e). Threat abatement plans. Retrieved from http://www.environment.nsw.gov.au/threatenedspecies/ThreatAbatementPlans.htm

OEH. (2016a). NSW BioNet Altas of NSW Wildlife [Web Page]. Retrieved January 21, 2016, from http://wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas.watlas.jsp

OEH. (2016b). Threatened Species Profiles [Web Page]. Retrieved from http://threatenedspecies.environment.nsw.gov.au/tsprofile/browse_scientificname.aspx

Paull, D. C. (2002). Community Data Search and Biodiversity Survey of the Brigalow Belt South (Stage 2). NSW Western Regional Assessments. (R. and C. A. Council, Ed.). Government Document.

Paull, D. C. (2009). Habitat and post-fire selection of the Pilliga Mouse Pseudomys pilligaensis in Pilliga East State Forest. *Pacific Conservation Biology*, *15*, 254–267. Journal Article.

Quinn, D. G. (1995). Population ecology of the Squirrel Glider and the Sugar Glider at Limeburners Creek, on the Central North Coast of NSW. *Wildlife Research*, *22*, 471–505. Journal Article.

Reed, P. C., Lunney, D., & Walker, P. (1990). A 1986-7 survey of the Koala Phascolarctos cinereus in NSW and an ecological interpretation of its distribution. In *Biology of the Koala* (pp. 55–74). Book Section.

Reijnen, R., Foppen, R., Braak, C. Ter, & Thissen, J. (1995). The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. *Journal of Applied Ecology*, 187–202. article.

Royal Botanic Gardens and Domain Trust. (2016). The Plant Information Network System of The Royal Botanic Gardens and Domain Trust, Sydney, Australia. Retrieved from http://plantnet.rbgsyd.nsw.gov.au

RPS. (2012a). *Due Diligence Ecological Appraisal for a proposed CSG Exploration Site - "Kiandool", Narrabri* (Report).

RPS. (2012b). *Galathera 1 Core Hole - PEL 238, Gunnedah Basin NSW* (Report).

RPS. (2012c). *Leewood - Produced Water & Brine Management Ponds. Ecological Assessment* (Report).

RPS. (2012d). *Preliminary Ecological Assessment - Dewhurst 20 and 21 - PEL 238, Narrabri* (Report).

RPS. (2013a). *Dewhurst Northern Water and Gas Flow Lines - PEL 238 and PAL 2, Gunnedah Basin NSW* (Report).

RPS. (2013b). *Ecological Assessment - Bibblewindi 30 Core Hole, Narrabri* (Report).

RPS. (2013c). *Ecological Assessment - Dewhurst 13-18 Gathering System, Narrabri* (Report).

RPS. (2013d). *Ecological Assessment - Dewhurst 22-25 - PEL 238, Narrabri* (Report).

RPS. (2013e). *Ecological Assessment - Dewhurst 26-29 Pilot Wells - PEL 238, Narrabri* (Report).

RPS. (2013f). *Ecological Assessment - Dewhurst Southern Water and Gas Flow Lines - PEL 238 and PAL 2, Narrabri* (Report).

RPS. (2013g). *Ecological Assessment - Narrabri West Core Hole - PEL238, Gunnedah Basin NSW* (Report).

RPS. (2013h). LiDAR imagery and Canopy Height Model for Santos, Narrabri Gas Project.

RPS. (2013i). *Preliminary Ecological Assessment - Dewhurst 21 - PEL238, Narrabri* (Report).

Ruddock, M., & Whitfield, D. P. (2007). Population limitation in the northern goshawk in Europe: a review with case studies. *A Report from Natural Research (Projects) Ltd to Scottish Natural Heritage*. article.

Rutz, C. (2006). Home range size, habitat use, activity patterns and hunting behaviour of urban-breeding Northern Goshawks Accipiter gentilis. *Ardea*, *94*, 185–202. Retrieved from http://www.avibirds.com/pdf/H/Havik4.pdf

Rutz, C., Bijlsma, R. ., Marquiss, M., & Kenward, R. E. (2006). Population limitation in the northern goshawk in Europe: a review with case studies. *Studies in Avian Biology*, (31), 158–197.

Schaub, A., Ostwald, J., & Siemers, B. M. (2008). Foraging bats avoid noise. *Journal of Experimental Biology*, *211*(19), 3174–3180. Journal Article. Retrieved from http://jeb.biologists.org/

Schlencker Mapping. (2010). LiDAR Report for Eastern Star Gas, Eastern Star Gas Narrabri Project.

Siemers, B. M., & Schaub, A. (2011). Hunting at the highway: traffic noise reduces foraging efficiency in acoustic predators. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1712), 1646–1652. article.

Simpson, K., & Day, N. (2010). *Field Guide to the Birds of Australia* (8th ed.). Book, Melbourne: Viking Australia.

Specht, R. L., & Specht, A. (2002). *Australian plant communities. Dynamics of Structure, growth and biodiversity*. Melbourne: Oxford University Press.

Stalmaster, M. V, & Kaiser, J. L. (1998). Effects of recreational activity on wintering bald eagles. *Wildlife Monographs*, 3–46. article.

Stalmaster, M. V, & Newman, J. R. (1978). Behavioral responses of wintering bald eagles to human activity. *The Journal of Wildlife Management*, 506–513. article.

Stapp, P., Young, J., VandeWoude, S., & Horne, B. van. (1994). An evaluation of the pathological effects

of fluorescent powder on deer mice (Peromyscus maniculatus). *Journal of Mammalogy*, *75*(3), 704–709. Retrieved from http://www.jstor.org/stable/1382519

State Forests of NSW. (2007). Forest Types Mapping.

Strahler, A. N. (1952). Dynamic basis of geomorphology. *Geological Society of America Bulletin*, *63*, 923–938.

Threatened Species Scientific Committee. (2006). Commonwealth Listing Advice on White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Retrieved from http://www.environment.gov.au/biodiversity/threatened/communities/pubs/box-gum.pdf

Tokushima, H., Green, S., & Peter, J. (2008). Ecology of the rare but irruptive Pilliga mouse (Pseudomys pilligaensis). I. Population fluctuation and breeding season. *Australian Journal of Zoology*, *56*, 363–373. Journal Article.

Trimper, P. G., Standen, N. M., Lye, L. M., Lemon, D., Chubbs, T. E., & Humphries, G. W. (1998). Effects of low-level jet aircraft noise on the behaviour of nesting osprey. *Journal of Applied Ecology*, *35*(1), 122–130. http://doi.org/10.1046/j.1365-2664.1998.00290.x

TSSC. (2008). *Rulingia procumbens Conservation Advice*.

TSSC. (2010). *Pterostylis cobarensis (Cobar greenhood orchid) Listing Advice*.

Turner, V., & Ward, S. (1995). Eastern pygmy-possum Cercartetus nanus. In R. Strahan (Ed.), *The Mammals of Australia* (pp. 217–218). Book Section, Chatswood: Reed Books.

Warner, R. E. (1992). Nest ecology of grassland passerines on road rights-of-way in central Illinois. *Biological Conservation*, *59*(1), 1–7. article.